UK COMMISSION FOR
EMPLOYMENT AND SKILLS

Technology and Skills in the Aerospace and Automotive Industries

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Technology and Skills in the Aerospace and Automotive Industries

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UK Commission for Employment and Skills

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Foreword

The UK Commission for Employment and Skills is a social partnership, led by Commissioners from large and small employers, trade unions and the voluntary sector. Our ambition is to transform the UK's approach to investing in the skills of people as an intrinsic part of securing jobs and growth. Our strategic objectives are to:

- Maximise the **impact** of employment and skills policies and employer behaviour to support jobs and growth and secure an internationally competitive skills base;

- Work with businesses to develop the best market solutions which leverage greater investment in skills;

- Provide outstanding labour market intelligence which helps businesses and people make the best choices for them.

The third objective, relating to intelligence, reflects an increasing outward focus to the UK Commission's research activities, as it seeks to facilitate a better informed labour market, in which decisions about careers and skills are based on sound and accessible evidence. Relatedly, impartial research evidence is used to underpin compelling messages that promote a call to action to increase employers' investment in the skills of their people.

Intelligence is also integral to the two other strategic objectives. In seeking to lever greater investment in skills, the intelligence function serves to identify opportunities where our investments can bring the greatest leverage and economic return. The UK Commission's third strategic objective, to maximise the impact of policy and employer behaviour to achieve an internationally competitive skills base, is supported by the development of an evidence base on best practice: "what works?" in a policy context.

Our research programme provides a robust evidence base for our insights and actions, drawing on good practice and the most innovative thinking. The research programme is underpinned by a number of core principles including the importance of: ensuring 'relevance' to our most pressing strategic priorities; 'salience' and effectively translating and sharing the key insights we find; international benchmarking and drawing insights from good practice abroad; high quality analysis which is leading edge, robust and action orientated; being responsive to immediate needs as well as taking a longer term perspective. We also work closely with key partners to ensure a co-ordinated approach to research.

This research was carried out in conjunction with Labour Market Solutions and Semta, the Sector Skills Council for the Advanced Manufacturing and Engineering sectors. It addresses the role of technology in driving high level skills needs, a skills priority that has been identified in many recent Sector Skills Assessments. To assist employers in understanding these skill needs in more depth and to provide intelligence to the UK Commission to support investment in skills, this research provides insights into the role of three emerging technologies: Additive Manufacturing, Composites and Plastic Electronics in driving high-level skills in the aerospace and automotive industries.

Sharing the findings of our research and engaging with our audience is important to further develop the evidence on which we base our work. Evidence Reports are our chief means of reporting our detailed analytical work. All of our outputs can be accessed on the UK Commission's website at www.ukces.org.uk

But these outputs are only the beginning of the process and we are engaged in other mechanisms to share our findings, debate the issues they raise and extend their reach and impact.

We hope you find this report useful and informative. If you would like to provide any feedback or comments, or have any queries please e-mail info@ukces.org.uk, quoting the report title or series number.

Lesley Giles

Deputy Director

UK Commission for Employment and Skills

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Glossary of terms

3D	Three Dimensional
A320	Short-medium range, narrow-body, commercial jet manufactured by Airbus
A380	A double-deck, wide-body, four-engine jet airliner manufactured by Airbus
A level	Advanced level
AGP	Aerospace Growth Partnership
AM	Additive Manufacturing
AM Bureau	An organisation that provides Rapid Product Development services to the Additive Manufacturing sector
AS 9100	Quality management system for the aerospace industry
Autoclave	Pressure vessels used to process parts and materials which require exposure to elevated pressure and temperature
BIS	Department for Business Innovation and Skills
BRES	Business Register and Employment Survey
BTEC	Business Technician Education Council
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CALM	Centre for Additive Layer Manufacturing
CAM	Computer Aided Manufacturing
CATIA	Computer Aided Three-dimensional Interactive Application is a multi-platform CAD/CAM/CAE commercial software suite
CEO	Chief Executive Officer
CIKC	Cambridge Innovation and Knowledge Centre
CNC	Computer Numerical Controlled
CO2	Carbon Dioxide
COLAE	Commercialisation of Organic and Large Area Electronics
CPI	Centre for Process Innovation
CTO	Chief Technology Officer
CV	Curriculum Vitae
DT	Destructive Testing
Edexcel	An awarding body offering academic and vocational qualifications and testing to schools, colleges, employers and other places of learning in the UK
ELF	Environmental Lightweight Fan
EngD	Engineering Degree
ERP	Enterprise Resource Planning
ESS	Employer Skills Survey
FDI	Foreign Direct Investment
FE	Further Education
GCSE	General Certificate of Secondary Education
HE	Higher Education
HM	Her Majesty's
HNC	Higher National Certificate
HND	Higher National Diploma
IC	Internal Combustion
IDBR	Inter Departmental Business Register
ISO	International Organisation for Standardisation

KTN	Knowledge Transfer Network
LCA	Life-Cycle Assessment
LFS	Labour Force Survey
MCRL	Manufacturing Capability Readiness Level
MD	Managing Director
MRB	Materials Review Board
MSc	Master of Science
MTC	Manufacturing Technology Centre
N/SVQ	National/Scottish Vocational Qualifications
Nacelle	A housing, separate from the aircraft fuselage holding engines, fuel, or equipment
NCN	National Composites Network
NDT	Non Destructive Testing
OEM	Original Equipment Manufacturer is a company who assembles the final vehicle using parts sourced from the OEM’s supply chain
OND	Ordinary National Diploma
ONS	Office for National Statistics
PC	Personal Computer
PD	Product Development
PE	Plastic Electronics
PELG	Plastic Electronics Leadership Group
PhDs	Doctor of Philosophy
Pre-preg	Pre-impregnated composite fibres where a material, such as epoxy is already present
QCF	Qualifications and Credit Framework
R&D	Research and Development
RPD	Rapid Product Development
RTI	Resin Transfer Infusion
RTM	Resin Transfer Moulding
Semta	Sector Skills Council for Science Engineering and Manufacturing Technologies
SLA	Stereo Lithography
SLS	Selective Laser Sintered
SMC	Sheet Moulded Compound
SMEs	Small and Medium Enterprises
SMMT	The Society of Motor Manufacturers and Traders
SSG	Sector Strategy Group
STEM	Science, Technology, Engineering, Mathematics
Thermoset	A material that strengthen during being heated but can't be successfully re-moulded or re-heated after their initial heat-forming
Thermoplastic	A material that softens when heated and harden and strengthen after cooling. They can be re-heated, re-shaped and re-cooled as often as necessary
Tier 1	Companies that supply materials directly to the manufacturer (OEM)
TRL	Technology Readiness Level
TSB	Technology Strategy Board
UKCES	UK Commission for Employment and Skills
UKTI	UK Trade and Industry

Executive Summary

Introduction

To enable the Advanced Manufacturing sector to realise its potential, it is vital to understand how technological advances impact upon skills needs. This research aims to go beyond high-level skills data that is currently available and focuses on skills requirements of three technological areas within the aerospace and automotive sectors: Additive Manufacturing, Composites and Plastic Electronics. Addressing these skills challenges will help the sector better respond to performance challenges and opportunities.

Additive Manufacturing (AM) is a term used to describe the manufacture of products using digitally controlled machine tools and is often termed 3D printing. The approach differs from traditional manufacturing in that all Additive Manufacturing processes use a layer-by-layer approach to build up components rather than through machining from solid, moulding or casting (Materials Knowledge Transfer Network, 2012).

Composites have been defined as consisting of a bulk material (the ‘matrix’) and a reinforcement of some kind such as fibres, particles or flakes, usually added to increase strength and stiffness. This report focuses on what are termed advanced composites (Structural Fibre-reinforced Polymer Matrix Composites) used in automotive and aerospace applications and characterised as light weight higher performance materials.

Plastic Electronics has been defined as devices on flexible surfaces that make it possible to produce flexible, bendable or stretchable electronic products, which may use printing techniques, but can also be deposited onto flexible surfaces in other ways. Plastic Electronics can also refer to the use of printing techniques in relation to devices on rigid surfaces.

The UK Aerospace sector

The UK has world class capabilities in the manufacture of sophisticated parts for modern aircraft and this has led to the creation of a high-technology, high-skill industry. The UK aerospace sector is the number one aerospace industry in Europe and globally second only to the U.S. The appeal of the UK for global aerospace manufacturers stem from its highly-skilled workforce, institutional knowledge and strong science and research base.

The UK has developed a strong comparative advantage in four key, high-value, complex areas of modern aircraft; wings, engines, aero structures and advanced systems.

The adoption of new technologies such as Composites and Additive Manufacturing is starting to extend through the aerospace supply chain and Plastic Electronics has significant potential in the future. Due to the scale of investment required the industry has yet to take full advantage of these new materials and technologies.

A characteristic of the aerospace industry is its large-scale need for a broad range of high-value skills and disciplines, including engineering, science, project management, production, service, training and finance. Current skills issues are having an impact on growth within the aerospace sector, with above average levels of hard-to-fill vacancies, difficulty retaining staff and employees with technical skills gaps.

Significant commercial opportunities exist for the UK aerospace sector globally. Next generation aircraft will require radically different shapes and airframe technologies to unlock performance, cost and weight improvements demanded by the market. Development of product and process technologies and the relevant skills required to do this will be crucial to securing future market share.

The UK Automotive sector

Employment and output in the automotive sector fell rapidly during the recession. However, in recent times recovery has been quick and growth has been rapid. Global vehicle manufacturers have invested over £6 billion in the UK between 2010 and 2012. The UK is the fourth largest vehicle producer in Europe, making 1.6 million vehicles in 2012.

The attractiveness of the UK's automotive sector is underpinned by four key characteristics; economic environment, labour (costs, productivity and flexibility), skills base and R&D capabilities and support.

There are expected to be four main areas for technology development in the near future; more efficient Internal Combustion (IC) engines, energy storage, lightweight structures and powertrains and power electronics. This technology change offers the UK an opportunity to create tomorrow's vehicles, increase market share and create new supply chain companies.

At this moment in time most repetitive tasks have been automated, the product has become highly complex and manufacturing processes now require different skill sets. Skills issues have constrained the recent growth within the automotive sector with above average levels of hard-to-fill vacancies, difficulty retaining staff and technical skills gaps. The proportion of automotive establishments that trained was also below that of companies that trained across the whole economy.

The global automotive industry is forecast to grow significantly in the next few years with a strengthening trend towards premium vehicles in line with middle class income growth in developing nations. A global shift to ultra-low emission propulsion systems, low carbon technologies will present significant opportunities for UK automotive companies.

A move to new markets and increased focus on innovation will increase the demand for new higher-level technical skills, innovation in product design, the capacity to apply existing skills and the strategic management skills required to identify and capture these new markets.

Additive Manufacturing

Additive Manufacturing (AM) is a term used to describe the manufacture of products using digitally controlled machine tools and is often termed 3D printing. The approach differs from traditional manufacturing in that all Additive Manufacturing processes use a layer-by-layer approach to build up components rather than through machining from solid, moulding or casting.

Additive Manufacturing is of major strategic importance within the aerospace sector, with the UK perceived as very good at R&D but less effective than some other countries in translating this technology into production. The aerospace sector is adopting Additive Manufacturing technology at a rapid rate and is expected to be a major driver in the commercialisation of Additive Manufacturing processes over the next five years.

Within the UK automotive sector, the focus is on the manufacture of ‘live parts’ for high-end motorsport prototypes or tooling. For high volume car manufacturing, cost reduction is a key driver, so the price of Additive Manufacturing components is currently inhibiting wider adoption. Additive Manufacturing alongside improvements in technologies such as rapid CNC machining are starting to play a major role in the shift from rapid prototyping to rapid manufacturing, with major automotive OEMs all showing interest in this area.

The Additive Manufacturing workforce within aerospace is relatively small and is focussed predominantly on R&D functions, with the need for a range of highly specialist, highly qualified staff representing different aspects of the value chain.

Those employed directly in the adoption and/or development of Additive Manufacturing technologies within automotive tend to mainly be time served/recently qualified apprentices with CAD and rapid machine skills, operatives with ‘traditional’ engineering skills, assembly staff, production quality staff and a small number of highly qualified engineering staff.

Different skill requirements exist for the various parts of the Additive Manufacturing supply chain such as bureaus, powder supply, management and analysis and finishing.

There are a wide range of current recruitment problems within Additive Manufacturing companies including people with experience in Additive Manufacturing, Process Design Engineers, CAD software developers and engineers, project management staff, and apprenticed toolmakers.

It is expected that there will be an increased demand for Engineers to support the automation of Additive Manufacturing processes. Currently, highly qualified people outweigh those at technician/operative level. As Additive Manufacturing becomes more mainstream, a considerable flattening of the workforce profile is expected. Volume manufacturing will require experienced production staff, retraining of existing staff and some increase in machine operatives.

The most significant impact of Additive Manufacturing technology on future employment within both the aerospace and automotive sectors is expected to be with the supply chain rather than directly within OEMs. Within the Additive Manufacturing supply chain there is expected to be an increased demand for those responsible for making, operating and maintaining Additive Manufacturing machines, powder suppliers and finishing companies.

A lack of Additive Manufacturing training courses means that employers tend to train in house and on the job. Specific demand exists for training in design for manufacture using Additive Manufacturing technology and powder management and sampling. External training opportunities are offered by some Additive Manufacturing bureaus (mainly to their own customers), while some machine operation training is undertaken by OEMs. An increased demand for technician level training has led some employers to explore the possible development of an Additive Manufacturing apprenticeship framework. In terms of Higher Education, there are calls for greater CAD experience and Additive Manufacturing modules within degrees as well as higher level Additive Manufacturing courses.

Composites

Occupations identified as part of the aerospace and automotive composite workforce include higher level occupations/specialists including research and development, Quality and Business Management; Engineering staff including Process, Plant, Production, Product, Project, Stress, Maintenance and CAD Engineers; Technical staff including Lab Technicians, CNC machinists and Non Destructive and Destructive Testing staff; and operational staff including Fitters and Laminators

Although high growth is expected in the demand for composites within the UK aerospace and automotive sectors, there is expected to be a shortage of necessary skills at nearly all levels from operator, craft, technician, professional and management roles. Higher level technical skills will in particular be at a premium as these are the roles that are also in high demand from other sectors within Advanced Manufacturing.

The range of skill requirements within the composite workforce is also likely to change over time. The increasing use of composites will create a demand for more R&D related roles such as scientists and test engineers. The creation of new design options will lead to an increased requirement for Design Engineers and people with higher level CAD skills. The move into new products and design using composites will also require Project Engineers at all levels and new Business Development Managers. As processes become more automated it is expected that there will be a growing need for multi-skilled craft and technician level workers with both CNC and composite experience and Maintenance Engineers to keep plant running at optimum levels. Currently the skills requirements for aerospace are much clearer than for the automotive sector. The fundamental question for the automotive sector is whether the high volume automotive manufacturers will embrace the use of composites in the near future.

Training provision appears to have been driven largely by major aerospace employers, together with some other major composite supply chain players. Strong links with both FE and HE have been vital for those companies developing their own composite training programmes. For SMEs this is much harder and it is clear that major weaknesses remain in relation to access to appropriate composite provision for such employers and their respective employees.

Plastic Electronics

The multidisciplinary nature of Plastic Electronics that is required to both develop and exploit the core technologies involved is widely acknowledged, with a high proportion of highly qualified Chemists, Physicists, Material Scientists, Electronic and other Engineers employed and those with experience in the semiconductor, display or printing industries.

The Plastic Electronics workforce is typically highly qualified, at least in part linked to the high proportion of Research and Development staff, with a preponderance of those with PhDs.

When recruiting those with experience in Plastic Electronics there is a relatively small pool of key companies and academic institutions in the UK from which to potentially recruit, so it is clear that use of existing networks is very important.

A number of those companies interviewed are only able to source the skills they require by relying heavily on recruitment outside the UK.

There are a number of factors that may constrain direct employment growth in the UK within Plastic Electronic companies, including the prevalence of technology licensing business models; the propensity for Plastic Electronics companies to be bought out in the future and the location of a high proportion of production overseas.

As Plastic Electronic technologies mature and are increasingly applied within commercial production, an increase in core Research and Development staff comprising highly qualified Chemists, Physicists, Material Scientists, Electronic and other Engineers is likely, together with an increased proportion of those involved in process development and production, including Process and other Engineers and those with relevant industry experience within the semiconductor, display or printing industries and operative staff.

Training undertaken by companies interviewed tends to be mainly ‘in house’ combined with use of specialist conferences/events accessed via academic networks. There appears to be significant support for the development of an appropriate apprenticeship framework to support the Plastic Electronics sector, some support for Masters level provision, possibly on a modular level, but views on the need for specialised course provision at degree level amongst those interviewed are mixed.

Conclusions

For the aerospace sector both Additive Manufacturing and Composites have been identified as of major strategic importance while the current application of Plastic Electronics is much less clear, although it could be very significant in the future.

The use of Composites and Additive Manufacturing within the general automotive sector in the UK remains relatively limited due to the cost of investing in the technology, except in 'high end' automotive activities where cost is less of an issue. Commercialised Plastic Electronics applications within the automotive sector are expected to occur by 2020.

Although growing rapidly the scale of Additive Manufacturing activity in the UK is currently at a far lower level than Composites. Both the aerospace and to a lesser extent the automotive sector is a major contributor to both Composites annual production revenue and added value. The overall scale of Plastic Electronics activity in the UK is currently of a significantly lower order.

Growth in employment in relation to all three technologies implies a changing shape in demand for skills. However, with respect to all three technologies skill shortages pose significant threats to future UK employment growth if not tackled. Wide ranging recruitment difficulties are already reported in relation to recruitment of both Composites and Additive Manufacturing staff. In the case of Plastic Electronics companies a number of companies are only able to source the skills required by relying heavily on recruitment of non UK graduates.

Training provision within the UK remains largely fragmented in relation to all three technologies. Large Composites companies have been developing their own training programmes as they have the resources to underpin the development of this provision and the influence to drive change within local training providers. For SMEs this is not possible and this may constrain growth in the supply chain.

There is a general lack of Additive Manufacturing training available. The training that is undertaken tends to be on the job and in house, with expertise currently concentrated within those employers, such as specialist Additive Manufacturing Bureaus, certain aerospace and automotive OEMs and Tier 1 manufacturers.

Training undertaken by Plastic Electronics companies interviewed also tends to be mainly 'in house' combined with use of specialist conferences/events accessed via academic networks.

In terms of higher education, it was commented that there needs to be more initiatives that bring Composites provision closer to industry. There appears to be potential scope for Additive Manufacturing modules within relevant degree courses and higher level Additive Manufacturing courses. With respect to Plastic Electronics there is some support for Masters level provision, possibly on a modular level, but views on the need for specialised course provision at degree level amongst those interviewed was mixed.

With respect to Apprenticeships, there was some support expressed by those interviewed for the development of Additive Manufacturing and Plastic Electronics frameworks, in line with the recently launched Semta Apprenticeship Framework for the composites workforce.

At present, although some mapping of these technologies has been undertaken, very little is still known of the size and profile of these companies and the associated supply chain workforce in different localities. This means it is very difficult to assess training needs at a local level and start to address other supply chain support issues.

1. Introduction

1.1 Purpose of report

The key aims of the project were;

- To identify the current and longer-term technology driven higher-level skills needs within the aerospace and automotive sectors, focusing on three key technologies; Additive Manufacturing, Composites and Plastic Electronics;
- To bring together employers, skills specialists, academics and other stakeholders to identify the main skills issues for each technology area; and
- Through a case study approach, to understand the key issues in more detail and find potential solutions to problems identified.

It is vital to understand the skills challenges created by emerging technologies within high-value manufacturing for the sector to realise its potential. This project directly links to the UK Commission for Employment and Skills (UKCES) mission of “work with and through our partners to secure a greater commitment to invest in the skills of people to drive enterprise, jobs and growth.”

This research aims to go beyond high-level skills data that is currently available in order to help meet the demand for labour market information on skills issues relating to innovative technologies. The choice of technology areas has been influenced partly by their importance in relation to future growth of the advanced manufacturing sector and the importance attached to these areas by the Technology Strategy Board (TSB). The High Value Manufacturing Strategy 2012-2015 (TSB, 2012) highlights 22 National competencies for the UK. Additive Manufacturing is one of the 22 competency areas, Composites is a large part of the Design and Manufacture for Light Weighting competency and Plastic Electronics is mainly within the Intelligent Systems and Embedded Electronics competency.

This research focuses on the adoption of each of these three technologies on the advanced manufacturing sub sectors of aerospace and automotive and their associated supply chains - key sectors within the Department for Business Innovation and Skills Industrial Strategy (Department for Business Innovation & Skills,1 September 2012).

High Value Manufacturing ‘skills development’ is an area that TSB clearly acknowledges the importance of but can’t directly fund. This underlines the need to find appropriate ways to work with other agencies to build capability in this area. Collaborating with Semta to undertake dedicated research in these areas would therefore fulfil an important need that has been recognised.

The approach to the research has been to embed this work within the considerable body of research and on-going action to stimulate further adoption and development of these technologies, led by the Technology Strategy Board. The TSB Catapult Network is a national programme to support innovation in sectors such as automotive, aerospace, food and drink and energy. The Catapults inputting into this research include:

- The Manufacturing Technology Centre (MTC) Coventry (The lead centre for Additive Manufacturing within the Catapult Network);
- The Centre for Process Innovation’s National Printable Electronics Centre, which forms a key part of the UK Government’s first High Value Manufacturing Catapult; and
- The National Composites Centre in Bristol, also one of the key partners of the High Value Manufacturing Catapult.

1.2 Methodology

The focus of the research has been mainly qualitative in nature to enable a more detailed exploration of current and emerging higher-level skills issues faced by early adopters of Composites, Additive Manufacturing and Plastic Electronics technologies within the aerospace and automotive sectors. The study has been mainly based on a series of telephone and face to face interviews with key stakeholders, together with a series of detailed case studies of selected companies developed through face to face interviews.

In addition, to help contextualise the qualitative data collected and help derive questions for use with the survey instruments used, a number of other secondary data sources have been utilised; economy-wide quantitative data from core labour market information sources such as the Labour Force Survey 2012 and the UK Commission’s Employer Skills Survey 2011, as well as sectoral and technology specific quantitative data generated by sector bodies, Government departments and academics.

A purposive sampling approach was used to gather a range of views broadly representative of the wider population. The approach adopted towards sampling of employers for the case study interview programme has been determined largely by the nature of the sub sectors of focus:

- The particular manufacturing processes being adopted within each of the three technology areas;
- The current and projected future Technology Readiness Level (TRL) associated with each manufacturing process. TRL is a measure used to assess the maturity of evolving technologies during its development;
- The technologies of interest, particularly, Plastic Electronics and Additives are newly emerging and are therefore characterised by relatively few automotive and aerospace end users and relevant ‘technology companies’; and
- Companies within the aerospace and automotive sector that are the most advanced ‘adopters’ of these technologies.

Sourcing employers to interview was potentially difficult, as the three technology areas are not described through standard industrial classification (SIC) codes. In order to both identify and gain access to appropriate senior stakeholders within the most relevant companies, it has been essential to reach agreement with specialist centres of excellence within each sub sector to act as a conduit to senior stakeholders.

The respective specialist ‘centres of excellence’ that have been approached to fulfil this role are the TSB catapults, including the Manufacturing Technology Centre, CPI National Printable Electronics Centre and National Composites Centre.

These centres not only have credibility in the industry but each work with the key players of interest to this study. In the case of the CPI National Printable Electronics they represent the single largest concentration of Plastic Electronics activity within the UK and have developed working partnerships with key players within the automotive and aerospace industry with respect to the development and adoption of Plastic Electronics technologies.

Additionally, employers were sourced through sector groups that Semta organises or contributes to, namely Semta’s Composites Sector Strategy Group (SSG) and the Plastic Electronics Leadership Group (PELG).

Telephone interviews or face to face interviews were conducted with 18 industry experts in total; three Additive Manufacturing, five Composites and ten Plastic Electronics stakeholders. Interview data and additional secondary information relevant to the technology areas were used to produce a series of topic guides for discussion with employers. To allow some level of comparability between the different technology areas, questions were focussed on the following key areas of discussion:

- key technologies and their current and future application within the aerospace and automotive sectors;
- the current workforce profile and future change;
- changing skill needs;
- recruitment problems/skill deficiencies;
- specific job/skill requirements;
- the supply of suitably qualified labour; and
- the education and training infrastructure and gaps in provision.

In terms of the employers interviewed they cover a range of sizes (micro, SME and large). Some of these firms are relatively new, while others are firmly-established or incumbents. The firms tend to be geographically clustered although there is some geographical spread. These firms also have different relative positions within the aerospace and automotive supply chains.

Face to face interviews were mainly conducted with senior technical managers, Chief Technology Officers, Chief Executives and Managing Directors responsible for implementation of these technologies within the companies. The interviews typically lasted one hour and a case study was then written up. A total of 24 employer case studies were produced (8 employer case studies per technology area). To avoid any commercially sensitive information appearing within this report, employers had the opportunity to read through the findings to ensure the text was a fair reflection of what was discussed in the interview.

As part of a validation exercise to test findings and verify that key themes identified were relevant, three key theme papers were produced and an on-line consultation conducted with stakeholders and employers that participated in the interviews. In addition further stakeholders were approached as part of the wider consultation.

Comments from the interviews have been included as part of the analysis used within the report and additional data analysis for the validation exercise was conducted through the on-line survey software.

1.3 Report structure

Chapters 2 and 3 of this report give an overview of the aerospace and automotive sectors in terms of their economic value to the UK, the importance of innovation and new technology to develop new products, over-arching skills issues and future opportunities and challenges for these sectors.

Chapter 4 Additive Manufacturing, Chapter 5 Composites and Chapter 6 Plastic Electronics cover the application of the respective technologies within the aerospace and automotive sectors, current skill requirements, recruitment issues, future skill requirements, implications for training and conclusions.

Chapters 7 highlight the key conclusions from this research and potential implications of the findings.

2. The UK Aerospace sector

Summary

The UK has world-class capabilities in the manufacture of sophisticated and high-value parts for modern aircraft and this has led to the creation of a high-technology, high-skill industry. The UK aerospace sector is the number one aerospace industry in Europe and globally second only to the U.S. The appeal of the UK for global aerospace manufacturers stem from its highly-skilled workforce, institutional knowledge and strong science and research base.

The UK has developed a strong comparative advantage in four key, high-value, highly complex areas of modern aircraft; wings, engines, aero structures and advanced systems.

The adoption of new technologies such as Composites and Additive Manufacturing are starting to expand throughout the supply chain and Plastic Electronics has significant potential in the future. Due to the scale of investment required the industry has yet to take full advantage of these new materials and technologies.

A characteristic of the aerospace industry is its large-scale need for a broad range of high-value skills and disciplines, including engineering, science, project management, production, service, training and finance. Current skills issues are having an impact on growth within the aerospace sector, with above average levels of hard-to-fill vacancies, difficulty retaining staff and employees with technical skills gaps.

Significant commercial opportunities exist for the UK aerospace sector globally. Next generation aircraft will require radically different shapes and airframe technologies to unlock performance, cost and weight improvements demanded by the market. Development of product and process technologies and the relevant skills required to do this will be crucial to securing future market share.

2.1 Introduction

This chapter covers the aerospace sector in terms of its value to the UK economy, the importance of innovation and new technology, over-arching skills issues and future opportunities and challenges for this sector.

The UK has world class capabilities in the manufacture of sophisticated and high value parts for modern aircraft and this has led to the creation of a high-technology, high-skill industry. The UK is also one of only a handful of nations with the capability to design and manufacture advanced helicopters. The UK aerospace sector has a 17 per cent global market share, making it the number one aerospace industry in Europe and globally second only to the U.S. The sector creates annual revenues of over £24 billion, or just under one per cent of total UK Gross Value Added (GVA). The sector exports approximately 75 per cent of what it produces.

Developing a new aircraft is a complex enterprise involving an investment of billions of pounds. Aerospace is highly Research and Development (R&D) intensive with an annual R&D spend of £1.4 billion (12 per cent of total UK manufacturing R&D spend). The development of a new aircraft takes 10-15 years, so commercial and technological risks are high and the uncertain and long payback periods are unattractive to many commercial investors.

The appeal of the UK for global aerospace manufacturers stem from its highly-skilled workforce, institutional knowledge and strong science and research base. According to UK Trade and Investment (UKTI), there were 58 aerospace projects that were Foreign Direct Investments (FDI) into the UK during 2012/13, placing the aerospace sector eleventh in terms of number of investment projects by sector.

2.2 Innovation and Technology within aerospace

The UK has developed a strong comparative advantage in four key, high-value, highly complex areas of modern aircraft:

- Wings - technology and capabilities in composite wings and integrated sub-systems such as undercarriages, fuel systems and wing-mounted electronics;
- Engines - from the largest, complete new generation engines, to the provision of the smallest precision components and from project definition to support and maintenance;
- Aero structures - this encompasses the design and build of the sections that are then assembled to make up an aircraft, such as the fuselage, tail surfaces and wing elements; and
- Advanced systems – aircraft systems encompass a wide range of areas such as landing gear, actuation, avionics, fuel and power supply.

New technologies such as composites and Additive Manufacturing are starting to spread through the supply chain and Plastic Electronics has significant potential in the future. Due to the scale of investment required the industry has yet to take full advantage of these new materials and technologies to open up radical new design options and optimise manufacturing processes to allow structures to be made cheaply at high production rates.

There are important spill-over effects as new technologies and processes developed in the aerospace sector have applications in other manufacturing sectors, notably defence, marine, offshore wind and automotive.

2.3. Skills within aerospace

The aerospace sector consists of 3,000 companies distributed across the UK, directly employing 100,000 people and supporting 130,000 jobs indirectly in the supply chain. The 2012 Labour Force Survey estimates that approximately 73,000 people (73 per cent) work in direct technical occupations (engineers, scientists and technologists). Approximately 32,000 people (44 per cent) of those working in technical occupations are employed in higher-level technical occupations (managers, professionals and technicians).

A characteristic of the aerospace industry is its large-scale need for a broad range of high-value skills and disciplines, including engineering, science, project management, production, service, training and finance.

Skills issues are having an impact on growth within the aerospace sector. Analysis of data from the Employer Skills Survey 2011 shows that 14 per cent of all aerospace establishments had hard-to-fill vacancies. Around 10 per cent of all aerospace establishments had difficulty retaining staff compared to five per cent of all establishments across the UK. Around 28 per cent of all aerospace employers had employees with skills gaps and 17 per cent of all aerospace establishments had employees with technical skills gaps. Over 80 per cent of all aerospace establishments had trained in the last 12 months compared to an average of only 61 per cent of all establishments training across the Advanced Manufacturing sector as a whole.

Estimates from the Labour Force Survey 2012 show that currently 40 per cent of the aerospace sector workforce is qualified to N/SVQ level 4 plus; however, the sector's target is to raise this to 50 per cent by 2022. This target will not be achieved through employment of graduates alone, but could be reached through an increase in higher apprenticeships to raise the skills of existing workers. The demand for high skill levels within the aerospace sector can be shown by the fact that 70 per cent of managers within the aerospace sector are qualified at N/SVQ Level 4 plus, compared to 56 per cent of managers within the Advanced Manufacturing sector as a whole.

2.4 Future opportunities and challenges

The Aerospace Growth Partnership (AGP) 2013 report 'Lifting off' highlights that significant commercial opportunities exist for the UK aerospace sector globally, with a forecast demand for 27,000 new passenger aircraft, 24,000 business jets and 40,000 commercial helicopters by 2031. Next generation aircraft will require radically different shapes and airframe technologies to unlock performance, cost and weight improvements demanded by the market.

The AGP report highlights that the UK aerospace industry can differentiate itself from competing nations by developing product and process technologies now that secure market share in the short and medium term, while focussing on the high-technology innovation and skills required to deliver competitive, next generation products for future platforms.

A number of aerospace companies that contributed to the case studies in this report are actively increasing their investment in R&D and technology such as Additive Manufacturing and composites to enable them to maintain competitiveness in current markets or enter new markets as part of their growth strategy. The boundaries between research, design, development and manufacturing are becoming increasingly blurred as companies seek added value from integrating these activities rather than just concentrating on a single element of the supply chain. Ensuring that key capabilities are developed and anchored in the UK is critical to the long-term future of the aerospace sector. The ability of UK industry to develop and apply new technologies and manufacturing processes, develop new skills and a flexible and adaptable supply chain will be critical to future success within the UK aerospace sector.

2.5 Conclusions

The UK has world class capabilities in the manufacture of aerospace components and this has led to the creation of a high-technology, high-skill industry with a strong science and research base which contributes significantly to UK GVA and exports.

New technologies such as composites and Additive Manufacturing are starting to spread through the supply chain and Plastic Electronics has significant potential in the future. Due to the scale of investment required the industry has yet to take full advantage of these new materials and technologies to enable more efficient, cost effective design options and manufacturing processes. Technical skills gaps within the current aerospace workforce are already having an impact on growth within the sector.

3. The UK Automotive sector

Summary

Employment and output in the automotive sector fell rapidly during the recession. However, in recent times, recovery has been quick and growth has been rapid. Global vehicle manufacturers have invested over £6 billion in the UK between 2010 to 2012. The UK is the fourth largest vehicle producer in Europe, making 1.6 million vehicles in 2012, (Automotive Council, 2013).

The attractiveness of the UK's automotive sector is underpinned by four key characteristics; economic environment, labour (costs, productivity and flexibility), skills base and R&D capabilities and support.

There are expected to be four main areas for technology development in the near future; more efficient Internal Combustion (IC) engines, energy storage, lightweight structures and powertrains and power electronics. This technology change offers the UK an opportunity to create tomorrow's vehicles, increase market share and create new supply chain companies.

At this moment in time most repetitive tasks have been automated, the product has become highly complex and manufacturing processes now require different skill sets. Skills issues have constrained the recent growth within the automotive sector with above-average levels of hard-to-fill vacancies, difficulty retaining staff and technical skills gaps. The proportion of automotive establishments that trained was also below that of companies that trained across the whole economy.

The global automotive industry is forecast to grow significantly in the next few years with a strengthening trend towards premium vehicles in line with middle class income growth in developing nations. A global shift to ultra-low emission propulsion systems, low carbon technologies will present significant opportunities for UK automotive companies.

A move to new markets and increased focus on innovation will increase the demand for new higher-level technical skills, innovation in product design, the capacity to apply existing skills and the strategic management skills required to identify and capture these new markets.

3.1 Introduction

This chapter covers the automotive sector in terms of its value to the UK economy, the importance of innovation and new technology, over-arching skills issues and future opportunities and challenges for this sector.

Data from the recent report “Driving success,” (Automotive Council, 2013) shows that in 2009, the sector produced just over one million vehicles – the lowest level since 1956. Employment had fallen to 158,000 from 177,000 in 2008, reflecting the impact on demand from the recession, with EU demand continuing to be weak as a result of on-going economic challenges in the euro zone. However, UK recovery has been quick and growth has been rapid with sector turnover growing by 17 per cent between 2010 and 2011. Over the same period gross value added grew by 11 per cent. Global vehicle manufacturers have invested over £6 billion in the UK between 2010 and 2012.

Data from the Society of Motor Manufacturers and Traders (SMMT) also shows that there are more than 40 companies manufacturing vehicles in the UK, ranging from global volume car, van, truck and bus builders to specialist niche makers. The UK is the fourth largest vehicle producer in Europe, making 1.6 million vehicles in 2012 (expected to rise to over two million vehicles by 2017). The sector generates around £54 billion of turnover, just under two per cent of total UK Gross Value Added (GVA). Over 80 per cent of current production is exported to more than 100 countries.

According to the SMMT the attractiveness of the UK’s automotive sector is underpinned by four key characteristics:

- Economic environment – the UK has not suffered from the global recession as much as other key automotive manufacturing countries;

- Labour costs, productivity and flexibility – global manufacturers such as Nissan, BMW and Jaguar Land Rover have increased production of existing models and launched new models for production in the UK due to the increased productivity and cost effectiveness of their operations;

- Skills base – overseas global manufacturers have invested heavily in training workers within their UK operations to improve quality and drive productivity;

- R&D capabilities and support – the UK has a strong science and research base and automotive companies tend to be clustered around these.

The recently published strategy document "Driving success," (Automotive Council, 2013) focuses on a number of key challenges and opportunities for the UK automotive sector, including innovation and technology, supply chains and skills. We discuss each of these in turn in this next section.

3.2 Innovation and Technology within automotive

There are expected to be four main areas for technology development in the near future:

- More efficient Internal Combustion (IC) engines - integration of combustion engines and electric machines, downsizing, sophisticated charge air/boost systems, fuel injection and variable valve & actuation systems, waste heat recovery to shaft power or electricity production and low carbon liquid fuels;

- Energy storage - electrolytes, catalysts, additives, surface modification and coatings, scale up technologies to move from laboratory to prototype cells for in-field development, innovative storage technologies that offer improved cost, energy density & packaging;

- Lightweight structures and powertrains - migration of motorsport/aerospace technologies into the premium sector and ultimately into high volume vehicle manufacture, advances in manufacturing/joining technologies for advanced low weight materials to achieve automotive scale and cost requirements, next generation multi-physics computer aided engineering for weight optimisation and new vehicle topologies enabled by advanced materials; and

- Power electronics - advanced lower cost control electronics, conductivity in windings, topology & innovative configurations, thermal management & conduction.

This technology change offers the UK an opportunity to create tomorrow's vehicles, increase market share and create new supply chain companies. The introduction of new technologies such as composites, Additive Manufacturing and Plastic Electronics in products and processes will in turn give rise to new skill needs. By 2040 no new cars manufactured in Europe will be powered solely by traditional petrol or diesel engines.

3.3 Supply chains

To meet the challenges of innovation and new technology, the UK needs not only an increase in R&D investment, but also to capitalise on this by securing production in the UK. This requires innovative Small and Medium-Sized Enterprises (SMEs) to be nurtured and invested in by multinational companies. The current domestic supply chain is relatively weak in that on average only a third of the parts that go into vehicles manufactured in the UK are sourced here. The Automotive Council have identified £3 billion of opportunities for UK suppliers with the right skills.

3.4 Skills within automotive

Inward investment into the UK automotive sector by overseas owned Original Equipment Manufacturers (OEMs i.e. those companies assembling the final vehicle), introduced more effective and integrated production techniques and skills development, supported by high levels of investment in advanced manufacturing technologies. At this moment in time most repetitive tasks have been automated, the product has become highly complex and manufacturing processes now require different skill sets.

Over 127,000 people are employed by 3,000 automotive establishments within the UK. Semta estimates from the Labour Force Survey 2012 that approximately 53,000 people (42 per cent) work in direct technical occupations (engineers, scientists and technologists). Approximately a third of those working in technical occupations, some 17,000 people, are employed in higher-level occupations (managers, professionals and technicians).

Skills issues have constrained the recent growth within the automotive sector. Analysis of data from the Employer Skills Survey 2011 shows that seven per cent of all automotive establishments had hard-to-fill vacancies. Of all automotive establishments, around six per cent had difficulty retaining staff, 17 per cent had employees with skills gaps and nine per cent had employees with technical skills gaps, all these figures being roughly twice the rate compared to the corresponding figures for the economy as a whole. Only 55 per cent of all automotive establishments trained their employees in the last 12 months compared to 59 per cent of companies across the whole economy.

3.5 Future opportunities and challenges

According to the Global Auto Forecast (R.L. Polk & Co, 2012), the global automotive industry is forecast to grow from 77.7 million cars, light trucks and commercial vehicles manufactured in 2012 to 96.3 million in 2016. In addition, there is a strengthening trend towards premium vehicles in line with middle class income growth in developing nations. A global shift to ultra-low emission propulsion systems with some leading low carbon technologies developing in the UK will present significant opportunities for UK automotive companies.

A move to new markets and increased focus on innovation will increase the demand for new higher-level technical skills, innovation in product design, the capacity to apply existing skills and the strategic management skills required to identify and capture these new markets.

The scale of future opportunities and increasing production demand has highlighted a shortage of engineers and other skilled workers. The Automotive Council (2013) highlight that the UK needs a comprehensive talent pipeline, including in the supply chains, starting in schools and encouraging a career path to apprenticeships, graduates and post graduates. Early outcomes from the Automotive Council's work include improving the quality and quantity of those in intermediate and higher-level occupations within the automotive industry. Industry members expect to take on more than 7,600 apprentices and 1,700 graduates over the next five years. Failure to do this will make the UK less attractive as a place to invest and will restrict supply chain growth.

3.6 Conclusions

The UK automotive sector has seen significant investment in the last two years from global vehicle manufacturers. The attractiveness of the UK to global automotive manufacturers is underpinned by the UK's relatively stable economic environment, productivity increases, skills base and R&D capabilities.

Currently most repetitive tasks have been automated, the product has become highly complex and manufacturing processes now require different skill sets. The focus on innovative technology developments related to internal combustion engines, energy storage, lightweight structures, powertrains and power electronics will potentially enable the UK automotive sector to increase global market share and create new supply chain companies.

The scale of future opportunities and increasing production demand has highlighted a shortage of engineers and other skilled workers. The move to new markets will increase the demand for new higher-level technical skills, innovation in product design and the capacity to apply existing skills together with the strategic management skills required to identify and capture these new markets.

The introduction of new technologies such as composites, Additive Manufacturing and Plastic Electronics in products and processes will in turn give rise to new skill needs and training requirements.

4. Additive Manufacturing and skills in aerospace and automotive

Summary

Additive Manufacturing (AM) is a term used to describe the manufacture of products using digitally controlled machine tools and is often termed 3D printing. The approach differs from traditional manufacturing in that all Additive Manufacturing processes use a layer-by-layer approach to build up components rather than through machining from solid, moulding or casting.

Additive Manufacturing is of major strategic importance within the aerospace sector, with the UK perceived as very good at R&D but less effective than other countries in translating this technology into production. The aerospace sector is adopting Additive Manufacturing technology at a rapid rate and is expected to be a major driver in the commercialisation of Additive Manufacturing processes over the next five years.

Within the UK automotive sector, focus is on the manufacture of 'live parts' for high end motorsport prototypes or tooling. For high-volume car manufacturing, cost reduction is a key driver, so the price of Additive Manufacturing components is currently inhibiting wider adoption. Additive Manufacturing alongside improvements in technologies such as rapid CNC machining are starting to play a major role in the shift from rapid prototyping to rapid manufacturing, with major automotive OEMs all showing interest in this area.

The Additive Manufacturing workforce within aerospace is relatively small and is focussed predominantly on R&D functions, with the need for a range of highly specialist, highly qualified staff representing different aspects of the value chain.

Those employed directly in the adoption and/or development of Additive Manufacturing technologies within automotive tend to mainly be time served/recently qualified apprentices with CAD and rapid machine skills, operatives with 'traditional' engineering skills, assembly staff, production quality staff and a small number of highly qualified engineering staff.

Different skill requirements exist for the various parts of the Additive Manufacturing supply chain such as bureaus, powder supply, management and analysis and finishing.

There are a wide range of current recruitment problems within Additive Manufacturing companies including people with experience in Additive Manufacturing, Process Design

Engineers, CAD software developers and engineers, project management staff, and apprenticed toolmakers.

It is expected that there will be an increased demand for Engineers to support the automation of Additive Manufacturing processes. Currently, highly qualified people outweigh those at technician/operative level. As Additive Manufacturing becomes more mainstream, a considerable flattening of the workforce profile is expected. Volume manufacturing will require experienced production staff, retraining of existing staff and some increase in machine operatives.

The most significant impact of Additive Manufacturing technology on future employment within both the aerospace and automotive sectors is expected to be with the supply chain rather than directly within OEMs. Within the Additive Manufacturing supply chain there is expected to be an increased demand for those responsible for making, operating and maintaining Additive Manufacturing machines, powder suppliers and finishing companies.

A lack of Additive Manufacturing training courses means that employers tend to train in-house and on the job. Specific demand exists for training in design for manufacture using Additive Manufacturing technology and powder management and sampling. External training opportunities are offered by some Additive Manufacturing bureaus (mainly to their own customers); while some machine operation training is undertaken by OEMs. An increased demand for technician-level training has led some employers to explore the possible development of an Additive Manufacturing apprenticeship framework. In terms of Higher Education, there are calls for greater CAD experience and Additive Manufacturing modules within degrees as well as higher level Additive Manufacturing courses.

4.1 Introduction

This chapter covers the use of Additive Manufacturing (AM) technologies within the aerospace and automotive sector in terms of its value to the UK economy, current skills requirements, workforce profile, recruitment issues, skills requirements and future opportunities and challenges for use of this technology.

Additive Manufacturing is a term used to describe the manufacture of products using digitally controlled machine tools and is often termed 3D printing. The approach differs from traditional manufacturing in that all Additive Manufacturing processes use a layer-by-layer approach to build up components rather than through machining from solid, moulding or casting (Materials Knowledge Transfer Network, 2012).

Adoption of this approach can enable components with extremely complex geometries and in built moving parts to be constructed with very little waste by only using the amount of material required.

Available evidence suggests the global Additive Manufacturing industry is expected to continue to grow quickly and strongly with sales estimated at $1.7 billion in 2011 and predicted to be worth $3.7 billion worldwide by 2015. It is estimated there are approximately 30,000 plastics Additive Manufacturing machines in operation worldwide and about 500 metal Additive Manufacturing machines (AM Platform, 2013).

In order to try and understand the current and potential future skill requirements resulting from the use of Additive Manufacturing technologies within the aerospace and automotive sectors, different employers representing both Original Equipment Manufacturers (OEMs) that assemble the final products and Tier 1 suppliers (direct suppliers to OEMs) in automotive and aerospace sectors were interviewed together with an Additive Manufacturing Bureau (a company that specialises in providing plastic and metal Additive Manufacturing services) a company supplying powder for Additive Manufacturing and related services, a company providing automated finishing services for Additive Manufacturing parts and a company developing bespoke software for application in Additive Manufacturing processes.

A brief outline of each case study company is included in Appendix A.

4.2 Additive Manufacturing in the aerospace sector

Additive Manufacturing is of major strategic importance within the aerospace sector, with the UK perceived as very good at R&D but less effective than other countries in translating this technology into production. The aerospace sector is adopting Additive Manufacturing technology at a rapid rate and is expected to be a major driver in the commercialisation of Additive Manufacturing processes over the next five years.

Available evidence suggests Additive Manufacturing growth within the aerospace sector worldwide increased by 12 per cent in 2012 and investment in Additive Manufacturing research in the UK now totals £13 million (AM Platform, 2013).

A key driver of technological change within the aerospace industry is what is termed the ‘Buy to Fly’ ratio which describes the cost associated with the amount of raw materials required to produce a finished part. With ever-increasing performance being required of modern aircraft, designers are using more high performance alloys, such as titanium and nickel, to meet these demands. There has been a move over the last 20 years towards complex, thin walled metal components, driven by parts integration and also the need to reduce weight. Unfortunately, this means that the traditional approach of machining parts from billet is costly and extremely wasteful in terms of material. Parts can have a ‘Buy to Fly’ ratio of perhaps 20:1 which means that only five per cent of the original billet is used in the final part. AM is identified as an important technology to produce complex parts more efficiently and thus has been identified as of major strategic importance within the aerospace sector. Millions of pounds worth of savings in fuel efficiency can be made through using Additive Manufacturing techniques to reduce the weight of aerospace components.

One industry expert indicated that the aerospace sector now regards Additive Manufacturing as always within the top 5 manufacturing processes in terms of importance and it is rare if it is not considered one of the top two in terms of importance.

The buyout by GE Aviation of the US Additive Manufacturing Bureau Morris Technologies in November 2012 is commonly understood to have been a key trigger for increased investment in Additive Manufacturing by the aerospace industry. This was identified as a major endorsement of Additive Manufacturing technology by a key aerospace employer in the global market:

“The sale of Morris Technology to GE aviation has really stirred things up globally with regards to AM. The fact that GE took out possibly a quarter of the total capacity of AM in a

single go and they were by far the most advanced of the bureaus, really shook up the people working towards using Additive Manufacturing...I would say from observation that has been a critical event for AM," (3T RPD).

The importance attached to Additive Manufacturing technology by major aerospace companies is illustrated by EADS, a major aerospace OEM and GKN Aerospace, a major Tier 1 aerospace manufacturer:

- EADS has established a dedicated Additive Manufacturing team working in the Metallic Technologies research area at Innovation Works (IW), Filton, Bristol.
- GKN is undertaking a major programme of investment and recruitment in Additive Manufacturing in the UK and globally:

  "As a business we see Additive Manufacturing as one of the most significant technologies for the future," (GKN Aerospace).

Feedback from companies interviewed points to the conclusion that the aerospace sector is likely to be a major driver of future change in relation to the commercialisation of Additive Manufacturing processes over the next five years, as highlighted by the case study below.

3T RPD: The stated goal of 3T RPD is to be the first choice production supplier of metal and plastic Additive Manufacturing parts in Europe. Although 3T RPD recognise that future growth in numbers employed by the company is extremely hard to predict it was commented:

"I would be surprised if we are not round about 100 employees within 5 years."

The stated aspiration of 3T RPD is to more than double company turnover from just over £4m currently to more than £10m within four years. The company indicated that this expected growth trajectory is heavily based on an expected increase in aerospace orders. Currently it is estimated that between 20-30% of turnover across the whole company is accounted for by aerospace orders, but it was commented that:

"If you come back in four years and we are a £10 million turnover company I would guess that at least 60% if not more will be aerospace."

In relation to future trends, aerospace is expected to account for an increasing share of First Surface work, based on recent experience in the USA:

"For me I would suggest aerospace is the future of my business...I would expect in the next 3 years aerospace to be 80% of my business," (First Surface).

Additive Manufacturing in the UK aerospace sector is still not used widely for the production of flight components and is considered to still be very much at the research and development stage.

The UK is identified as 'behind the curve' in relation to the adoption of Additive Manufacturing technology within the aerospace sector by comparison with a number of other countries. Overall, the UK is perceived as very good in relation to R&D, but hasn't been as effective in relation to the translation of this into production. Part of the challenge the UK faces is identified as a lack of new UK product platforms in aerospace for insertion of Additive Manufacturing technology.

The main Additive Manufacturing technology focus within the aerospace sector at present is in relation to Powder Bed technologies. Powder Bed Additive Manufacturing uses fine powders (5-50µm) to build parts layer by layer. The machine comprises a powder supply, a build platform, a powder spreader, a laser, and a pointing and focusing system. The powder spreader spreads a thin layer of powder on the build platform. The laser melts the powder in locations where the part is to be. When the layer is complete, the build platform is moved downward by the thickness of one layer and a new layer is spread on the previous layer.

With the Powder Bed technologies a wide range of potential applications are identified in relation to space craft, on satellites and launchers and within application areas such as propulsion and communications systems.

It is clear that there is an extremely rapid rate of change within the aerospace sector in relation to the adoption of Additive Manufacturing technology. One industry expert pointed out that the innovation process that usually takes four to five years is being compressed into 18 months to two years in the case of Additive Manufacturing developments within the aerospace industry.

4.3 Additive Manufacturing in the automotive sector

Substantial investment in Additive Manufacturing research is being undertaken within the automotive sector. It is reported that the sector has contributed £3.5 million research funding to lever Additive Manufacturing research activities of £6.5 million (Materials KTN 2012).

Within the automotive sector in the UK, Additive Manufacturing tends to be focussed on high-end motorsport and parts that will be used for the final product or ‘live parts”, rather than prototypes.

Cost reduction is a key driver in high-volume car manufacturing. Currently, the relatively high piece price of Additive Manufacturing components is a major inhibitor of wider adoption in the sector.

Additive Manufacturing is starting to play a major role within the mainstream automotive sector in the UK, progressing beyond rapid prototyping of scale models to what is termed rapid manufacturing, whereby finished components are directly manufactured using additive technologies. Rapid Manufacturing has eliminated the need for conventional tooling techniques using a model or mould, hence dramatically cutting production times.

Companies including Jaguar Land Rover (JLR), Bentley and Ford are all identified as interested in this. It was pointed out that the trend in the car industry is towards much more rapid changes in models and thus lower production volumes, with the consequence that conventional tooling techniques are relatively expensive:

“The car industry is now subject to rapid changes in models, but still using the same tooling – We are scrapping our tooling before it is worn out. This is very expensive, so there is a need for low volume production techniques for making tooling, but using rapid technology to make that happen,” (Ford).

Additive Manufacturing technology is identified as playing a vital part in this continued growth, but alongside improvements in other technologies such as more rapid CNC machining:

“This is a part of industry where there is huge potential...Normally if you want to make an engine block you go to a foundry – The foundry will design a pattern making equipment which is then CNC milled and manually lathed – What we do here is we print sand moulds which completely eliminates the tooling,” (Ford).

More traditional production methods are then used for mass production. Effectively the printed sand moulds are traditional sand moulds using Additive Manufacturing technology, but using this technique enables far more complex and accurate moulds.

4.4 Current skill requirements

The current workforce profile of those directly involved in the adoption and/or development of Additive Manufacturing technologies differ significantly between aerospace and automotive firms, reflecting the different foci within the two sectors with respect to Additive Manufacturing. Within the automotive sector there is a primary focus on rapid manufacture and prototyping, while in aerospace the primary focus is on the testing and validation of different Additive Manufacturing procedures in preparation for full volume production.

4.4.1 The aerospace Additive Manufacturing workforce

Currently the aerospace Additive Manufacturing workforce is relatively small and is focussed predominantly on research and development functions, with the need for a range of highly specialist, highly qualified staff, the majority of which have PhDs. Typically, R&D staff include Material Engineers specialising in Additive Manufacturing technologies, Design Engineers with optimised design and process solutions skills, Process Engineers who have a particular understanding of the Additive Manufacturing process and Post Process Engineers.

GKN Aerospace – Current workforce profile

Currently GKN aerospace employs about 8 people at the Additive Manufacturing Centre at Filton, but is rapidly expanding, with numbers expected to reach 20 over the next few years.

The workforce will be made up of the complete engineering skillset from apprenticeships to degree-level and above qualified, with a large proportion of staff having PhDs and experience working in an Additive Manufacturing environment.

The company stress that as Additive Manufacturing is not one process but multiple processes, and in addition you need to have people and skills across the whole Additive Manufacturing value chain, not just the process, in order to successfully deliver AM parts within an appropriate time frame.

Current Additive Manufacturing Centre R&D staff includes Material Engineers specialising in Additive Manufacturing technologies, Design Engineers with optimised design and process solutions skills, Process Engineers who have a particular understanding of the Additive Manufacturing process and Post Process Engineers.

It was stressed that the skills required are not just about the Additive Manufacturing process but include the raw materials suppliers, the post production process (Finishing), but particularly around the design to get the full benefit and understanding of the application of Additive Manufacturing technologies.

"So you need to have people and skills in each one of those areas in order to successfully deliver AM parts within an appropriate time frame."

4.4.2 The automotive Additive Manufacturing workforce

The workforce profile of employers adopting Additive Manufacturing technologies within the automotive sector is characterised by:

- A high proportion of time served staff;
- Recently qualified apprentices with CAD and rapid machine skills;
- Operatives with 'traditional' engineering skills;
- Assembly staff;
- Quality staff associated with production quality issues, and
- A small number of highly qualified engineering staff.

Ford- Current workforce profile

A total of 35 people are employed in the Ford Rapid Product Development. The workforce comprises:

- The Head of the Unit, who has many years engineering experience, originally starting as a pattern maker and is currently undertaking a PhD, the Business Manager who has an Engineering MSc and a Senior Manager with an Engineering degree.

- There are three CAD staff mainly qualified to degree level.

The remainder are hourly staff, of which:

- Two thirds have CAD and rapid machine skills and are a mixture of time served engineering apprentices and those that have undertaken Ford's own 'Rapid Apprenticeship'.

- One third with 'traditional' engineering skills who undertake a wide range of tasks including material handling, topping up machines and bench work.

Overall, skills are identified as more important than the actual technology utilised:

"I always say it is 70 per cent people only 30 per cent machines. That is the rapid side of things - It doesn't have to be about technology. That is why the training and thought process is so important."

In terms of the overall skill set required for rapid product development the importance of a diverse range of skills was emphasised:

"There are not many people out there with rapid experience, so I would say the vast majority of people in here come from a background of high end traditional skills; pattern makers, model makers, tool makers, sheet metal workers."

The workforce profiles of different companies interviewed as part of this research provide an insight into the different skill requirements of the main parts of the Additive Manufacturing supply chain, in particular, in relation to Additive Manufacturing bureaus, powder supply, management and analysis and finishing.

3T RPD a major Additive Manufacturing bureau currently employing 46 people employs a blend of management, research and development, specialist sales, quality, CAD, traditional engineering, finishing, production engineering, IT and support staff.

LPW Technology offer a full range of services for industrial users of Additive Manufacturing, from application development through to machine maintenance and supply of high quality powders. The company have a blend of experienced mechanical engineering and materials engineering staff together with PhD students, with these disciplines combined with technician level, sales and support staff.

A strong crossover between the skills required for manual finishing of Additive Manufacturing components and automated finishing is identified by **First Surface** (which provides automated finishing services in relation to the use of both Additive Manufacturing and other technologies), with experienced time served engineering apprentices being the main source of recruits for these positions.

In addition to the above there are other more specialist elements of the Additive Manufacturing supply chain such as software development for Additive Manufacturing. For example **Delcam** have a team of ten software developers working on the development of Additive Manufacturing related products. The role of these staff is described as essentially a usual software development role, although because a number of the projects these staff are involved in are collaborative activities involving meetings and presentations with outside companies, the role of these staff members is described as slightly more outward facing than the general profile of developers.

CAD skills: CAD skills are fundamental to both the design and production of Additive Manufacturing components. In addition to high level knowledge of CAD, having a methodical approach and the ability to solve problems was emphasised as important amongst those using CAD software, with a crossover between these skill requirements needed for Additive Manufacturing and for other technologies such as 5 axis CNC machining. This enables modification utilising two further axes aside from the x, y, and z planes, such as a circular axis and diagonal axis.

Process skills: Additive Manufacturing process skills required include an excellent knowledge about the materials that are going into it, the stresses that are built up during the manufacture, what impact that will have on the part and knowing a lot about the statistical probability that those things will fail or succeed.

Practical engineering experience: The need for people with practical engineering experience was emphasised by a number of companies. One company commented:

"Experience and work ethic is more important to me than the actual qualifications," (LPW Technology).

Additionally, companies were looking for people who were multi-skilled to enable them to take on a number of different tasks, people who had good problem solving skills and could think independently together with staff who generally had a 'good attitude'.

4.5 Recruitment Issues

A wide range of current recruitment problems were identified by Additive Manufacturing companies interviewed. These included:

Process Design Engineers: One of the biggest current bottlenecks in terms of recruitment is identified as Process Design Engineers:

"I couldn't name one person in the UK at the moment who can design an Additive Manufacturing process...We are getting a lot of pressure from customers saying we need someone to do our design for Additive Manufacturing processes; who do you recommend – can't recommend anyone," (Industry expert).

People with experience in* Additive Manufacturing*: Given the stage of development of Additive Manufacturing in the UK it is reported as very difficult to find people at all levels with experience of Additive Manufacturing. The Additive Manufacturing community in the UK is identified as very small:

"At the moment you are only talking about a handful of people that really know about the technology," (Industry expert).

One stakeholder indicated that in relation to recruitment of staff at a project leader level they would be very surprised if they got many applicants with Additive Manufacturing experience, with some likely not even to know what Additive Manufacturing was.

It was pointed out by another industry expert that the reason GE recently acquired two major Additive Manufacturing bureaus was not because of the machines but because of the respective skill sets within the two companies. The two Additive Manufacturing bureaus bought by GE operate 21-22 additive machines and employ 350 people with direct experience in using Additive Manufacturing techniques. This type of knowledge is tacit, in that it is embedded within the technological processes and cannot be taught using textbooks or manuals:

"GE could have bought the new equipment out of their pin money, the reason they recruited the company is for the people and their skills, not the machines. They recognise the skills are in very short supply," (Industry expert).

This underlines the importance of building hands-on, practical experience into any training or course options on Additive Manufacturing technologies.

Project Management staff: A shortage of skilled people to manage big research/evaluation projects in relation to Additive Manufacturing is also identified.

CAD staff: CAD staff with a level of knowledge required for Additive Manufacturing is also identified as a recruitment issue.

Other recruitment problems: Other examples of recruitment problems highlighted included apprenticed toolmakers and Additive Manufacturing CAD software developers:

Delcam – Recruitment Problems – Additive Manufacturing CAD software developers

Delcam who describe themselves as the world's leading developer and supplier of CADCAM software for 3 dimensional design, manufacture and inspection of complex shapes, recently recruited 14 graduates on to their graduate recruitment programme, but processed 1,400 applications to in order to select these 14. The company indicated that they would have recruited more graduates had suitable candidates been available. It was commented:

"The point is I would have hired more than 14 – there is no limit on the graduate recruitment programme, but we couldn't find any more suitable candidates. We only found 14 that Delcam thought were appropriate. Despite unemployment the people with the right kind of skills are like hens teeth."

4.6 Future higher level and other skill requirements

Although it is difficult to predict the precise trajectory of workforce change in relation to those involved in the development and application of Additive Manufacturing technology the following section sets out what has emerged from consultations in relation to the most likely key components of these changes relating to emerging skills needs.

4.6.1 Future skill requirements in relation to Additive Manufacturing within the aerospace sector

The greatest impact in relation to skill requirements within both aerospace OEM and Tier 1 suppliers is expected to be in relation to a major increase in demand for design and optimisation skills, with a with a major impact on the demand for Design Engineers with Additive Manufacturing skills, particularly within the aerospace sector:

"Additive Manufacturing is such a fundamental shift in design, we call it revolutionary, not evolutionary," (Industry expert).

With transition to full commercialisation a short-term increase is expected in numbers of R&D staff but little change in the overall composition of the workforce within OEM and Tier 1 suppliers. For example:

The need for an increased number of Research Engineers who understand Additive Manufacturing is expected within aerospace, which is identified as a current need.

A major programme of up skilling is expected throughout the aerospace supply chain in preparation for the use of Additive Manufacturing in production.

In order to undertake aerospace production, the need to have the appropriate competencies in place, the technical capability, the quality systems and the delivery capability, coupled with the necessary customer interface were identified as critical pre-requisites before achieving production orders. It was commented by one company:

"So we have to have all of those competencies robustly in place before we get the chance to bid for a production order and then hopefully win it," (3T RPD).

EADS - The need for increased design and optimisation skills

The main drivers of technology change within EADS are identified as lead time, cost and weight performance. Weight is identified as a particularly important driver because of fuel cost increases. EADS is therefore always looking for improvements in efficiency on engines, aero dynamics and reducing weight. Additive Manufacturing technology has the potential to reduce significant amounts of weight, but this is reliant upon being able to optimise the parts. Currently the focus is on structural optimisation of large parts, but over time this is expected to extend to other parts, with the implication for an increase in staff with these skills - something identified as a future skill bottleneck.

As Additive Manufacturing technology becomes fully commercialised every part will have to be designed and prepared for manufacture in CAD. It was commented:

“It is the design side in our organisation where we need to be able to exploit... Without the design improvement we don’t get the weight savings. So it is design and optimisation skills.” Responsibility for the design element sits with EADS and ‘risk sharing partners’ (typically certain first-tier suppliers), implying a collective increase in demand for these skill sets. Specifically in relation to the powder bed process the skill is identified as in the CAD design and in the design for manufacture (orienting a part best for manufacture, supporting it in the process), but these skills are identified as currently in very short supply:

“These are very specialised skills which today, maybe only a handful of people have – there may be 20 people in the UK who can do it well but we need thousands in the future at some point.”

One industry expert commented that currently for every hour spent on an Additive Manufacturing machine ten hours are being spent testing the materials/parts. Given this, a particular demand is expected for powder material scientists and those with metallurgy Non Destructive Testing (NDT) skills. This is likely to go hand in hand with advances in NDT techniques for Additive Manufacturing which is still being developed. This requirement is expected to increase rapidly over the next couple of years but then level off to be roughly proportional to volume increases, or even a somewhat lower rate of increase as the requirement becomes less labour intensive.

The following case study highlights the extent of quality related preparation that one Additive Manufacturing bureau has undertaken and is expecting to take place:

3T RPD:

In order to ensure 3T RPD meet rigorous quality requirements, particularly within the aerospace industry, the company have devoted significant resource to attainment of relevant quality standards and have achieved ISO 9001, ISO312405 (Medical production) and about a year ago AS 9100 Rev C for the production of aerospace metal parts using Additive Manufacturing. 3T RPD was the first Additive Manufacturing company to achieve all three standards.

Coupled with the need for rigorous quality standards the company identified a requirement for a different mix of skill sets in the workforce with a much higher proportion of those trained to follow strict processes, rather than develop processes. As a result of this critical focus on quality, the Quality Team at 3T RPD is expected to triple in size over the next year.

3T RPD identify a number of aspects to changing skill requirements as a result of these trends. In particular, an increase in:

- People that are good at working with customers to determine quality requirements and related skills sets;
- Trained auditors to audit the process and identify what needs adjusting;
- Inspectors to undertake final inspections; and
- Staff responsible for ensuring tight process control.

In line with the above trends is an increased focus on the automation of Additive Manufacturing processes, with a consequent increase in demand for Process, Manufacturing and other Engineers that can support the automation of Additive Manufacturing processes. A shortfall in numbers of those with these skills is predicted as currently these people are typically qualified to PhD/good degree/MSc level and have worked in industry, often within the automotive industry. Although a considerable flattening of the workforce profile is expected, the absolute increase in machine operatives is expected to be limited by increased automation.

It has been estimated that automation of Additive Manufacturing machines in the aerospace sector in a reasonably sized facility turning over about £10m a year will only require about 20 employees, whereas using other technologies you might expect 20 employees per £1m turnover.

4.6.2 Future skill requirements in relation to the use of Additive Manufacturing within the Automotive sector

It is expected that the large scale adoption of Additive Manufacturing across the general automotive sector has a somewhat longer trajectory than is the case with aerospace. Although the same overall approach is involved within both sectors, the prices are identified as generally far lower within the consumer automotive sector, with little scope for expensive components. Within high-end motorsport prototypes or tooling the focus is on the manufacture of parts where cost is less of a consideration. For high-volume car manufacturing, cost reduction is a key driver, so the price of Additive Manufacturing components is currently inhibiting wider adoption.

In terms of how the skills profile of one Additive Manufacturing company will evolve it was described as essentially comprising two parts; production and design:

"So we will develop our competencies to include product design for AM *processes we use. We currently advise people how to design their parts for AM manufacture. However, we will increasingly have a design function that feeds [into] our production function,"* (3T RPD).

At Ford, the move from rapid prototyping to rapid manufacture has implications for the future shape of the workforce, with a growing divide between higher-skilled technical jobs and lower-skilled manual jobs. It is envisaged that the net result of this trend over time is likely to be a reduction in demand for manual labour and an increase in demand for higher-skilled technical staff:

"What we are seeing is a divide, where the technical jobs are becoming more technical and the manual jobs are becoming less skilled - Some of our skilled workforce have agonised because they have seen the skills disappear....Our rapid machines make the parts – those parts need cleaning up...There is a skill there but not a high end skill," (Ford).

Moving from prototyping to any form of production requires a different set of skills. While those associated with prototyping are still required:

"What everybody has learnt is that when you move from pure prototype to any form of production it is a really different skill set as far as control goes. You have to have schedules, planning, quality checks and a lot of formal processes. The prototype groups struggle with that – our people are quite innovative, quite dynamic.... Five years ago we had all our skills

in place. We have had another five years of morphing into another low volume supplier," (Ford).

The most significant impact on future employment as a result of the use of Additive Manufacturing technology within both the aerospace and automotive sectors is expected in relation to growth of its use in the supply chain rather than directly with the large aerospace or automotive manufacturers (OEMs). The main employment impacts on Additive Manufacturing supply chain are expected in relation to the manufacture and maintenance of Additive Manufacturing machines. This includes making Additive Manufacturing machines, their operation, powder suppliers and the finishing process.

The workforce profile of those currently working in the Additive Manufacturing industry is described as an 'inverted pyramid' with too many highly qualified people and too few at technician/operative level. There will need to be an increase in the proportion of technician level employees as Additive Manufacturing moves from its current R&D focus to becoming more widely used.

One of the industry experts interviewed indicated that currently the Machine Operator at their facility has a PhD and the Mechanical Operator has a degree. It was commented that the organisation has only just started to take on people at HND/OND level to run Additive Manufacturing machines, but it is expected that in one or two years they will be recruiting machine operators who can come in with very limited skills and be trained. The current position was described as unsustainable:

"You can't build the industry using this level of skilled persons, because it is not a viable business case," (Industry expert).

By 2020, it is expected that there will be a significant increase in Designers with Additive Manufacturing skills, as well as more Material Scientists, more Quality related employees, particularly with NDT skills, an increase in Health and Safety employees, an increase in Machine Operators, Technicians and those with automated techniques for finishing.

4.7 Implications for Training

Additive Manufacturing technology is evolving constantly, with much knowledge of the practical application of Additive Manufacturing held within Additive Manufacturing bureaus, academic institutions, key employers and other institutions directly involved in the application of this technology. At the time of writing there are no training manuals generally available in relation to the use of Additive Manufacturing.

4.7.1 Training needs in Additive Manufacturing

A number of different issues relating to the current adequacy and extent of Additive Manufacturing related training and the need for additional training were identified through the research which are summarised below. Feedback from interviews indicates that currently there is very little Additive Manufacturing training available to companies:

"There are a number of different areas and they all need to be addressed. Educating people in additive is the only way we are really going to exploit it," (Industry expert).

As a result much of the workforce training that does take place is undertaken 'in-house'. While courses relating to basic programming, project management and more generic skills are identified as readily available, more specific skills are identified as being acquired by working with people:

"A lot is on the job training, learning by doing and by talking to other people. This does not always feel very satisfactory, but much of what we have sent people on externally has not proved very useful. It is very difficult because we are very specialised. I have got no illusions that the education system will turn out people profiled to work at Delcam. It would be pretty startling if it did, which is why we recruit for aptitude and willingness to learn," (Delcam).

Training Additive Manufacturing customers

As a result of the lack of external training providers serving the Additive Manufacturing industry, 3T RPD are providing training and knowledge transfer for their own customers:

"The other side of the training for 3D print process is that we actually need to provide training for our customers to be able to design for manufacture. This is a tool in their toolkit they have never had before," (3T RPD).

There appears to be a need for introductory workshops for businesses introducing them to Additive Manufacturing technology, together with slightly more advanced provision for those companies already involved in Additive Manufacturing technology.

Machine operation

Additionally, machine manufacturers (OEMs) provide training in relation to the operation of Additive Manufacturing machines. Currently there are very few Additive Manufacturing machine manufacturers. The view on the adequacy of training provided by these OEMs is mixed.

Although some feedback on this training was positive one interviewee commented that currently, if you buy a system you are reliant on the manufacturer for up to 2-3 days' worth of training:

"You don't get the intensive training to operate the machine, so often you will find that you may not be able to operate it yourself straight away. We are fortunate to have members of staff who have worked with these machines for years, however, if I was a company looking to bring in this technology I would imagine you would struggle to get this machine up and running in any short space of time. Unless a member of staff had previous experience of operating the system, you are reliant on the manufacturer giving you that training," (Industry expert).

Design for manufacture

The need for both major programmes of re-training in Additive Manufacturing techniques for existing Design Engineers and substantial numbers of new Design Engineers trained in Additive Manufacturing techniques was identified. For example, EADS identified a future need for thousands of engineers able to design for manufacture utilising Additive Manufacturing technology, with the need for appropriate training for both new and existing Engineers.

Powder management and sampling

There is perceived to be a growing need for training associated with powder sampling and management of powders. Due to a lack of industry-wide standards and processes, training specifically related to powder management and sampling is not generally available. Individual companies are therefore setting their own standards.

CAD training

A number of companies have identified the need for an increase in the level of CAD training undertaken as part of engineering degree courses that enables full exploitation of design for Additive Manufacturing. It was perceived by EADS that the overall level of CAD training needs to be higher than is currently the case to provide designers with the skills required to design the types of complex parts enabled by the technology.

The need for technician level training

The workforce profile within Additive Manufacturing at present has been described by one firm as an 'inverted pyramid' with too many people at PhD level and too few at S/NVQ Level 2 and 3:

"You can't have machine operators at PhD level, it is not very practical. This is why there needs to be more apprentice style/ non university courses in additive. That means you then get people who are educated at the right level to be operators," (Additive Manufacturing employer).

This is at least in part linked to the stage of development of the technology. As the focus of Additive Manufacturing moves from R&D to full product commercialisation, the processes involved will need to become more fully specified as well as more automated. This in turn brings much more scope for Level 2 and 3 staff and less need for higher level skills.

The current engineering apprenticeship frameworks do not address Additive Manufacturing technology and there appears to be at least some support for exploring the development of an Additive Manufacturing apprenticeship framework:

"Coming in with some base level knowledge of powder, some CAD, handling and the machine operation would be very useful. I brought in a technician 12 months ago who had a general engineering A Level qualification and he has all the skills to be an Additive Manufacturing *technician, but he had no knowledge of the process and even the CAD level he had done was not enough for him to go straight onto a CAD PC; we have had to invest a*

lot of time in him to get the skill level up. As more machines become available there will be more demand for the general technician level role," (Industry expert).

If a wide range of Additive Manufacturing machines start to be utilised it is perceived that it might also be appropriate to establish an apprenticeship programme relating to maintenance.

4.7.2 Qualification needs

The level of awareness of Additive Manufacturing among engineering graduates appears to vary considerably from University to University. There was some employer support expressed for more structured embedding of Additive Manufacturing techniques into relevant degree and Masters courses, although one company commented that as long as the courses incorporate some form of hands-on-experience:

"There is always a risk with academia is it gradually becomes detached from reality. So the training has got to be practical; hands on – people have got to be allowed to fail as well as succeed with what they are trying to build. The training has to be both demanding and interesting," (3T RPD).

4.7.3 Tackling Additive Manufacturing training needs

There are a number of examples of initiatives to try and tackle emerging Additive Manufacturing related training needs. The Manufacturing Technology Centre in Coventry (MTC) is currently writing a guide to Additive Manufacturing design in one of their research programmes. EADS is also focussed on how best to ensure an adequate supply of appropriate skills as outlined in the following case study.

EADS identified a future need for thousands of engineers able to design for manufacture utilising Additive Manufacturing technology.

In order to tackle this EADS are talking with universities about the possibility of introducing a course with some EADS knowledge embedded to try and support this. It is envisaged this would cover issues such as the limitations of the technologies, how to design a part that is well suited to the process and how to do the build set up. It is envisaged this provision is also likely to be useful for Product Designers that need to understand the limitations of Additive Manufacturing, or others who might need to use the technology:

"For me the biggest training issue is awareness of the capabilities and limitations of Additive Manufacturing *technology and the implications for design – that is the biggest gap. There are a lot of people out there who could design very good things using the process but don't understand the limitations, therefore design things that aren't suited, or don't take full advantage. If the UK wants to be sitting on the top with the Design Engineers really exploiting the capabilities of the technology then we need more people who are able to do that."*

EADS are also looking at integrating Additive Manufacturing technology into their Apprenticeship programme by offering Airbus apprentices 3-month placements with EADS IW in order to gain some Additive Manufacturing experience:

"At the moment for whoever we recruit we have to pay for the training to get them up to speed. There aren't people out there we can just pick up off the street who have already been trained (in Additive Manufacturing techniques). It would be nice in the future if there was a real pool of people to choose from."

4.8 Conclusions

The use of Additive Manufacturing technology will be of major strategic importance within the aerospace sector. Currently, the UK's strength in Additive Manufacturing R&D is perceived as being very strong, however the UK is seen as less effective than some other countries in using Additive Manufacturing technology in full production. The use of Additive Manufacturing technology within the aerospace sector is increasing rapidly and will be a key driver of the use of this technology across the wider Advanced Manufacturing sector in the next five years.

Additive Manufacturing within the UK automotive sector currently focuses on the manufacture of parts for high end motorsport prototypes or tooling, where performance rather than cost is the main issue. Within high volume car manufacturing, cost is a major factor, so the adoption of Additive technology will only become more mainstream when the cost of the technology is reduced significantly. Major automotive OEMs are showing interest in this area when combined with improvements in other technologies to help make the shift from rapid prototyping to rapid manufacturing.

In terms of skills, the Additive Manufacturing workforce within aerospace is relatively small and focussed on highly qualified, specialist staff in R&D functions. In the automotive sector the focus is on production staff with ‘traditional’ engineering skills and a much smaller number of highly-qualified engineering staff. There are different skill requirements within the various parts of the Additive Manufacturing supply chain such as bureaus, powder supply, management and analysis and finishing.

Currently there are a wide range of current recruitment problems within Additive Manufacturing companies, particularly in terms of those with higher-level skills such as Process Design Engineers, CAD Software Developers, Engineers and Project Management staff. All of these types of roles are in high demand across the whole of the wider Advanced Manufacturing sector.

As Additive Manufacturing becomes more mainstream and automated, there will be less concentration on higher-level jobs. Volume manufacturing will require experienced production staff, retraining of existing staff and some increase in Machine Operatives to support the manufacturing process.

Development of skills and employment related to Additive Manufacturing technology within SMEs in the supply chain of both the aerospace and automotive sectors will be key to full adoption of this technology, particularly in terms of those responsible for making, operating and maintaining Additive Manufacturing machines, powder suppliers and finishing.

There is currently a lack of Additive Manufacturing training courses, particularly in design for manufacture, using Additive Manufacturing technology and powder management and sampling. The development of an Additive Manufacturing apprenticeship framework would help to ease the demand for technician level training. In terms of Higher Education, the integration of greater CAD experience and Additive Manufacturing modules within degrees as well as higher level Additive Manufacturing courses would be welcomed by employers utilising Additive Manufacturing technologies.

5. Composites and skills within aerospace and automotive

Summary

Occupations identified as part of the aerospace and automotive composite workforce include higher level occupations/specialists including Research and Development, Quality and Business Management; Engineering staff including Process, Plant, Production, Product, Project, Stress, Maintenance and CAD Engineers; Technical staff including Lab Technicians, CNC machinists and Non Destructive and Destructive Testing staff; and operational staff including Fitters and Laminators

Although growth is expected in the demand for composites within the UK aerospace and automotive sectors, there is expected to be a shortage of necessary skills at nearly all levels from operator, craft, technician, professional and management roles. Higher level technical skills will in particular be at a premium as these are the roles that are also in high demand from other sectors within Advanced Manufacturing.

The range of skill requirements within the composite workforce is also likely to change over time. The increasing use of composites will create a demand for more R&D-related roles such as scientists and test engineers. The creation of new design options will lead to an increased requirement for Design Engineers and people with higher-level CAD skills. The move into new products and design using composites will also require Project Engineers at all levels and new Business Development Managers. As processes become more automated it is expected that there will be a growing need for multi-skilled craft and technician level workers with both CNC and composite experience and Maintenance Engineers to keep the plant running at optimum levels. Currently the skills requirements for aerospace are much clearer than for the automotive sector. The fundamental question for the automotive sector is whether the high volume automotive manufacturers will embrace the use of composites in the near future.

Training provision appears to have been driven largely by major aerospace employers, together with some other major composite supply chain players. Strong links with both FE and HE have been vital for those companies developing their own composite training programmes. For SMEs this is much harder and it is clear that major weaknesses remain in relation to access to appropriate composite provision for such employers and their respective employees.

5.1 Introduction

The Department for Business Innovation and Skills UK Composites Strategy (Department of Business Innovation and Skills, 2009) defines most composites as consisting of a bulk material (the 'matrix') and a reinforcement of some kind such as fibres, particles or flakes, usually added to increase strength and stiffness. This report focuses on what are termed advanced composites (Structural Fibre-reinforced Polymer Matrix Composites) used in automotive and aerospace applications and characterised as light weight higher performance materials.

This chapter examines the role of composites in both the aerospace and automotive sectors; current composite skill requirements within both aerospace and automotive OEMs and within the composite supply chain; recruitment issues faced and measures taken to tackle these issues; likely future levels of demand for composite-related skills within both the aerospace and automotive sectors and the implications for training.

The UK Composites Strategy identifies particular benefits for the aerospace and automotive industries of using composites as reductions in weight can deliver significant savings in running costs and a reduction in carbon emissions.

The UK Composites Supply Chain Scoping Study (Ernst and Young, 2010) indicates there are about 1,500 companies involved in the UK composites sector with annual production revenue of £1.6 billion and added value of £1.1 billion. The report Best of British (HM Government, 2009) estimates that approximately 40,000 people are employed within the composites sector. It is noted that composites activity is undertaken in all parts of the UK with a notable cluster of activity in the aerospace composites corridor in the South West of England.

There is strong demand for highly skilled people within the UK composites sector. In 2012, there were nearly 800 jobs posted within the UK which had the word 'composites' in the job specification (Labour Insight, Burning Glass Technologies, 2013). Of these jobs, over half were in higher-level occupations such as technicians, professionals and managers. Of these higher-level occupations, approximately half were in the area of design, with the rest falling into general production and R&D roles.

The UK Composites scoping study (Ernst and Young, 2010) also indicates that carbon fibre and glass fibre materials currently constitute the greatest value in UK demand and supply of composite components and structures for both the aerospace and automotive sectors.

However, it should be noted, the application of new metal matrix and ceramic matrix composite materials are currently being researched in the UK aerospace industry.

A total of eight companies with a significant composite capability within the aerospace or automotive sectors or their supply chain were interviewed as part of this research (See Appendix B).

5.2 Composites in the aerospace sector

The UK Composites Supply Chain Scoping Study (Ernst and Young, 2010) identified an expected growth in demand for composites within the UK aerospace sector of 9 per cent per annum over the period 2010-2015.

In aerospace the industry performance requirements placed upon materials can be far greater than in other sectors and this is why composites are becoming widely used as a direct substitute for metal components. Key advantages of composites over traditional metals include light weight, high strength, high stiffness and good fatigue and corrosion resistance. The use of composites within the aerospace industry is long standing. Major employers such as Rolls-Royce have been flying composite parts in aerospace engines for over 30 years. Bombardier (Belfast) has been using composites in aircraft manufacture for over 40 years and now has three dedicated composite manufacturing facilities.

The Airbus 320 uses a whole range of components made from composites, including the fin and tailplane. This has allowed a weight-saving of 800 kg over its equivalent in aluminium alloy. Composite materials comprise more than 20 per cent of the A380's airframe. Carbon-fibre reinforced plastic, glass-fibre reinforced plastic and quartz-fibre reinforced plastic are used extensively in wings, fuselage sections (such as the undercarriage and rear end of fuselage), tail surfaces and doors.

It is clear that composites are a critical technology in driving change within the aerospace industry, although the focus in terms of specific uses and approach varies quite significantly across the industry. For example, the primary focus of Rolls-Royce in relation to composites is on aero engines, particularly fan systems, wings in the case of Bombardier and engine casings with respect to Aircelle.

Large-scale research investments are required to fully exploit composite technologies in the aerospace sector. For example, Bombardier have invested £520 million in a composite wing development programme for the CSeries aircraft, which is the largest ever investment in Northern Ireland. The CSeries is a totally new aircraft involving a new concept in aircraft design, which has been designed to compete with the Airbus 320 and the Boeing 737 (150/160 seater).

Collaboration and strategic partnerships

Collaboration with industry networks, academic organisations and in some cases strategic partnerships with other selected manufacturers has been critical to the development and implementation of strategies to exploit composites by major aerospace OEM/Tier 1 suppliers, as the case of Rolls-Royce highlights.

Rolls-Royce - Composites Strategy

Initial work on the strategy reinforced the need to strengthen the Rolls-Royce infrastructure and capability in relation to composites which included:

- the need for Rolls-Royce to expand and reinforce its interface with academia specifically in relation to composites.
- Rolls-Royce involvement in the development in what became the National Composites Centre.
- the further development of Rolls-Royce's own programmes of activity, particularly work around the composite fan system expanded.
- a joint venture with GKN Aerospace called Composites Technologies and applications Ltd (CTAL) to develop composite fan blades and also composite fan cases.
- engagement with the global composite supply chain.
- the need for new skills. Whilst there was already composite skills and knowledge within the company it was considered that additional capability was needed to translate the composite vision and strategy into reality.

5.3 Composites in the automotive sector

The UK Composites Supply Chain Scoping Study (Ernst and Young 2010) identified an expected annual growth rate of 10 per cent in relation to carbon fibre composite demand within the UK automotive sector over the period 2010-2020, although from a relatively small base.

In automotive, composites are extensively used in high-end small-volume car production such as Formula 1, Aston Martin, Ferrari and Porsche.

The manufacturing operations are much less capital intensive and so the resistance to change in material is somewhat less. Currently, composites are mostly likely to be used by Formula 1 car manufacturers and other high-end, low-volume performance car makers. The primary use of carbon fibre composite components is for cosmetic parts such as spoilers, trim accents and wheels, while Sheet Moulded Compound (SMC) technology is used for parts like tailgates. Other composite applications include under-trays using stamp or flow moulded thermo plastic composites. Carbon composites are also starting to become widely adopted in alternative vehicles such as electric/hybrid and fuel cell vehicles.

The main advantages composites offer the automotive applications are in cost reduction, weight reduction and recyclability. Composites offer many structural and weight advantages over traditional steel and injection moulded automotive parts. Compared to thermoset based composites, thermoplastic materials offer the automotive industry key advantages: zero solvent emissions, reduced material scrap, improved work safety conditions, elimination of painting steps (through use of high-molecular weight polymer surface films), elimination of tedious production steps via automation, and finally greatly improved recyclability. Thermoplastic composites also offer excellent crash performance compared with traditional steels.

By comparison with the aerospace sector the use of composites within the general automotive sector in the UK remains relatively limited, a large percentage of the cost is in the capital plant needed for manufacture, so once equipment has been procured and commissioned it is very costly to change the design of a component. This naturally makes the industry very conservative and therefore less likely to invest in new materials such as composites, as the example of Jaguar Land Rover (JLR) highlights.

No structural composite components are currently used by Jaguar Land Rover (JLR) in car manufacturing with the main application of composites being in relation to:

- Cosmetic parts – spoilers, trim accents, wheels, etc. The primary reason for the use of these composite components is as design/ styling cue, where they are used on limited edition, sports “R” derivatives.
- Sheet Moulded Compound (SMC) technology is used for parts like tailgates (e.g. on the new Evoque and the new Land Rover), but this technology has been around a long time and established in automotive body/ closure applications; and
- Other composite applications include under-trays using stamp or flow moulded thermo plastic composites using long glass fibre mat in a thermoplastic matrix.

In relation to the general automotive sector in the UK, the future use of composites is not clear, given that at present the cost base is considered too high for large volume production.

Jaguar Land Rover - Future use and application of composites

JLR consider that the composites arena currently lies in niche super cars (e.g. Lamborghini) and Motorsport/ Formula 1. However, JLR has produced a concept car, the CX75, which is an all composite vehicle, with only a small number of these vehicles manufactured to prove out the design and technology by using made carbon pre-preg (pre-impregnated) carbon fibre and hand laying techniques, and consequently low volume/ high cost production techniques.

The CX75 was developed in conjunction with a relatively small number of partners coming from the Formula 1 arena (Williams was one of the key partners). Indeed, the process involved in building the CX75 was very similar in nature to the building of a super car. This approach would not translate to mainstream automotive production because it is simply too slow and expensive in relation to the volumes required (the Range Rover Evoque has a 100,000+ production volume).

"Clearly for it (a wholly composite car) to be part of our world of volume production something needs to change to bring that cost base down. That's what we are working on now to understand what options and technologies are required."

It is understood that BMW has undertaken a programme of investment in the development and production of a composite hybrid car all in-house. Very little has therefore emerged on how BMW has achieved this and the automotive industry is keen to understand how BMW has done this and will make it work from a cost perspective. What is clear is that BMW will invest $100m in a carbon fibre manufacturing facility in partnership with producer SGL at Moses Lake in the USA. This site was chosen by BMW because of the availability of hydro-electric power to carbon offset the energy intensive carbon fibre production process with the aim of yielding lower cost, lower carbon footprint raw materials.

"The buzz in the industry is that everybody is working on it. We are working on it and BMW are going to be launching, I think at the end of this year, a hybrid electric car (made wholly out of composites)," (Jaguar Land Rover).

5.4 Current skill requirements

5.4.1 Overview of current composite workforce skill requirements

Occupations identified as part of the aerospace and automotive composite workforce include:

- Higher level occupations/specialists including research and development staff (such as Material Scientists and Engineers with specialist composite experience), Quality, Plant and Site Managers/Directors, Resource Planners and Business Directors;
- Engineering staff including Process, Plant, Production, Product, Project, Stress, Maintenance and CAD Engineers;
- Technical staff including Lab Technicians, CNC machinists, Non Destructive and Destructive Testing staff; and
- Operational staff including Fitters and Laminators.

A number of factors influence the profile of the workforce within the composite supply chain including:

- Market focus – Those organisations specialising in the ‘high end’ automotive sector are likely to have a somewhat different workforce profile than those serving the aerospace OEMs for example;
- Position in the supply chain – The workforce profile of companies developing and supplying composite materials (pre-preg material, resins etc) will differ from those producing composite components for example; and
- Size of the organisation.

5.4.2 Aerospace composite skill requirements

Case study examples (Rolls Royce, Bombardier, Aircelle) underline considerable growth in the aerospace composite workforce over the last decade. For example, within Rolls-Royce there are currently up to 100 people involved in work on composites which is a significant increase compared to recent years. In relation to Aircelle in Burnley there are currently about 130 shop floor workers in the composites area, an increase from about 55 in 2008.

The aerospace OEM composite workforce tends to be highly qualified engineers and scientists.

Rolls-Royce - Aerospace OEM Skills profile

Most of the people engaged in the composite programme within Rolls-Royce are graduates. Quite a lot have master's degrees and doctorates. It is a professionally qualified workforce consisting of engineers and scientists from a range of relevant disciplines.

A significant proportion of the current Rolls-Royce composites workforce has been recruited externally by the company.

Aspects that Rolls-Royce considers when recruiting skills in relation to composites include:

- Knowledge of the composite supply chain;
- Knowledge of advances in technology; and
- Design, manufacturing and materials knowledge, experience and skills.

The aerospace supply chain composite workforce tends to be more diverse, including significant numbers of operational staff (Fitters, Laminators), technical and engineering staff.

The stringent quality requirements of the aerospace sector is reflected in the relatively high proportion of quality-related roles, including Destructive Testing (DT), Non Destructive Testing (NDT), stress and quality assurance.

Aircelle - Composite workforce

The composites workforce in Burnley comprise about a fifth of the total 1,000 employees. Shopfloor workers are mainly semi-skilled operatives involved in laying up composites, but also skilled fitters. In addition to management, the composite workforce at Aircelle currently includes:

- 7 people in a laboratory undertaking Destructive Testing (DT) with some additional people undertaking Non Destructive Testing (NDT) (mostly trained internally by Aircelle);
- 9 people working on autoclaves at any one time;
- 12 people working 5-axis and 3-axis CNC machines and perforation drilling; and
- A qualified engineering workforce of about 11 engineers involved in control, stress and quality assurance, and a further 5 manufacturing/process engineers.

5.4.3 Automotive composite skill requirements

The case study interviews underline the upward growth trend within the automotive composite workforce, although with respect to OEM volume car manufacturers, this workforce remains very small, specialist, highly qualified and focussed on research and development.

Jaguar Land Rover - Automotive OEM composite skill requirements

JLR currently employ 8 people whose roles and responsibilities relate exclusively to the composites area. Employment is concentrated in the Research/ Product Development departments, looking at different aspects of composites development within JLR. It was commented:

"Relative to the size of PD (Product Development) it is still a relatively small arena that we are talking about."

The composites resource within JLR has gone from virtually nothing two years ago, to JLR now having a team with a set of core competencies associated with composite manufacturing, including high level skills, knowledge and experience in the following areas:

- Design skills and the development of design guidelines- especially the ability to translate material properties and manufacturing influences through to design guidelines;
- Crash simulation and durability modelling;
- Composite fatigue characterisation; and
- Materials supply base.

In relation to 'high-end' low volume car manufacture a more diverse workforce is evident comprising mainly engineers and operative staff.

Gurit Ltd specialises in the development and manufacture of advanced composite materials, tooling systems, structural engineering solutions, and select finished parts. A total of 500 people are employed on site on the Isle of Wight, which includes 150 people in the Automotive Department. The Automotive Department has about ten Engineers including both Process and Plant Engineers, some with previous industry experience before joining Gurit and others going through the Gurit Graduate Programme. Most of the Automotive workforce comprises operatives, many of whom have been recruited directly from school at both GCSE and A level.

5.5 Recruitment Issues

5.5.1 Overview of recruitment issues

A number of recruitment difficulties in relation to the composites workforce have been widely acknowledged within the industry for a number of years. For example The Polymer Composites Sector report (National Composites Network, 2009) identified the following skill shortages among the UK composite workforce: Leaders and managers with commercial awareness and business skills to exploit new products, markets and technologies; material scientists; qualified engineers, technicians and supervisors that understand composite materials and associated design and manufacturing processes and skilled operatives (such as laminators).

Recruitment difficulties reported by case study employers included higher-level occupations/specialists such as Operational and Site Managers, Resource Planners and R&D staff with relevant industry experience; Engineering staff were also noted as being in short supply, including those with experience in precision engineering and CAD Designers; technical staff including Quality-related staff and CNC Machinists; and Operators.

Jaguar Land Rover faced considerable challenges in recruiting R&D staff with the required skills and experience in composites.

"You can get university researchers and university graduates in composites, but we want people who have had their hands dirty, know what it's like and can translate it into our thinking," (Jaguar Land Rover).

The specialist nature of composites has meant that a number of growing firms face wide-ranging challenges hiring staff. One company reported that they recently used a local paper to advertise for seven jobs. This resulted in 238 applicants but out of all these, only three CVs received by the company had 'A' grades, irrespective of age.

Recruitment is always considered a major challenge for the Gurit Ltd with particular difficulties experienced in relation to:

- 'High end' recruits such as Operational Directors, Plant Managers and Site Mangers;
- Quality related recruits with the necessary quality skills/accreditation;
- Planners: Gurit require Planners to have Enterprise Resource Planning (ERP) system skills such as SAP software and an understanding of how materials are planned within the system; and
- Certain Operatives.

Aircelle in Burnley has also experienced difficulty in recruiting engineers, notably Stress Engineers and Composite Manufacturing Engineers:

"Composite Manufacturing Engineers with any knowledge are very few and far between," (Aircelle).

5.5.2 Tackling recruitment challenges

In relation to the aerospace sector, particular examples were cited of steps taken to ensure an adequate supply of appropriate skills. In particular the development of appropriate internal training and other structures for developing and retaining skills, together with the importance of structured academic links were stressed as a common way for aerospace firms to tap into sources of talent.

Rolls-Royce indicated that they have always had a very strong relationship with the academic network, not only in commissioning research, but also in relation to the student infrastructure such as sponsoring post graduate qualifications – EngD or PhDs across a whole range of subject areas, including composites. The composites aspect is more recent but as with other areas of materials technology, Rolls-Royce sees this as a very rich ground for recruitment.

The benefit of strong academic links in order to address recruitment needs was also underlined by Bombardier (Belfast). In relation to the recruitment of engineers:

"In the first instance I think that we would bring in local people. We have Queen's University here; they provide aeronautical engineering degrees here, Master's degrees and so on... We actually sponsored a Chair at Queen's, so there are strong linkages between ourselves and Queen's University and the University of Ulster as well," (Bombardier).

The company also grow their own Engineers and are currently looking to develop a level 4 apprenticeship in conjunction with Semta.

"Chief Engineers have told me in the past that a third, and certainly a fourth year technical apprentice, is much better equipped or adding more value to the organisation than bringing in a graduate," (Bombardier).

Many examples of industry-university and FE collaboration were found among large companies who are able to recruit from a global pool for specialist skills and are of sufficient size to be able to have direct relationships with HE and FE institutions in order to ensure a supply of suitably trained graduates, technicians and operatives. SMEs do not have these resources and influence and therefore face much greater recruitment challenges. EPM Technology, for example have had mixed experiences with FE/HE collaboration in terms of meeting their requirements in relation to training such as CAD.

*"The challenge for FE and HE coming to EPM is that they need to be commercial," (*EPM Technology).

5.6 Future higher level and other skill requirements

5.6.1 Overall expectations of growing skill requirements within the composites workforce

The UK Composites Supply Chain Scoping Study (Ernst and Young, 2010) identified an expected growth in demand for composites within the UK aerospace sector of nine per cent per annum over the period 2010-2015 and an annual growth rate of ten per cent in relation to carbon fibre composite demand within the UK automotive sector over the period 2010-2020, although from a relatively small base.

The Department for Business Innovation and Skills UK Composites Strategy (Department of Business Innovation and Skills, 2009) identified the aerospace sector together with wind energy as the two sectors likely to drive future global growth in composites. The report also identified a shortage of necessary skills at nearly all levels.

Case study interviews underlined the expectation of considerable future growth in the composites sector and the recruitment challenges likely to be associated with this. One company interviewed stated that there is a recognition that the whole composites industry, not just in the UK, but around the world, is expanding as people now are starting to realise the potential. In this regard it was commented:

"There is a finite size of skill pool (in relation to composites), and it's starting to move around. That skill pool has to be supplemented, so that the movement of that talent pool is not subject to the highest bidder. That's in no one's best interests," (Managing Director, Composites SME).

This expectation of significant future growth throughout the composites supply chain is underlined by the example of EPM Technology overleaf.

EPM Technology- Future skill needs

"We are actually quite strong about our ability to grow, it's not particularly worrying because the hard bit was getting from 10 to 50 (employees). Getting from 50 to 100, the systems are already in place, we just have capacity issues."

The company is somewhat tied to current capacity by virtue of the existing facility, but EPM are investing £6 million in a new building in order to expand productive capacity (£3.5 million investment in a new building and a £2.5 million investment in equipment and technology). A recruitment drive is currently underway to meet EPM's current and future skill needs:

"We have got 42 vacancies today, so we are trying to get the job numbers up to well beyond a hundred, perhaps even to 130, once we have moved in and we are settled in our new environment."

Vacancies at the time of writing included:

- Senior and Junior Fitters (multiple roles);
- Senior and Junior Laminators (multiple roles);
- Project Engineer and Junior Project Engineer (EPM triangulate project engineering with senior, intermediate and junior project engineers);
- Business Development Managers (2 roles); and
- CAD Engineer (with V5 Catia know how – the aim is to triangulate skills in this area with senior, intermediate and junior CAD engineers).

The range of skill requirements within the composite workforce is also likely to change over time. For example as processes become more automated it is expected that there will be a growing need for those with both CNC experience as well as composite experience. One company interviewed that serves both the aerospace and automotive sectors is making use of 'pure' CNC apprenticeships to grow their own skills in this area.

5.6.2 Future higher level and other requirements - Aerospace

Evidence from case study interviews and industry forecasts (Ernst and Young, 2010) underline the expectation of significant future growth in demand for composites within the aerospace sector.

The £520 million investment in a composite wing development programme, including a new 600,000 square foot factory that will enable Bombardier (Belfast) to take its composite capabilities to a new level has already been highlighted earlier.

In relation to Aircelle the next 18 months is going to constitute the next stage in the company's plans to increase productive capacity within the company.

This implies the need for significant increased demand for qualified engineering staff, quality related staff and operational staff.

The current and planned expansion of manufacturing operations in Burnley has meant that Aircelle is currently seeking to recruit a range of:

- Skilled Engineers including a Manufacturing Process Engineer, MRB Engineer, Stress Engineer, Manufacturing Operations Engineer and Maintenance Engineer;
- Specialist quality related staff including a Programme Quality Assurance Engineer, NDT Level 3 (Ultrasonic's) and NDT Level 2 (Process Engineer), Quality Excellence Manager and Programme Quality Manager; and
- Other staff including an Industrial Strategic Planner and Process Manager.

Increasing automation of processes is likely to alter the profile of staff required. For example Aircelle is trying to grow knowledge skills and experience in relation to automation, particularly in relation to Manufacturing /Process Engineers who also have composite experience. The company particularly value experience and knowledge gained from working in a shop floor environment, dealing with issues and problems on the assembly line. Increasingly therefore, the company is seeking this dual knowledge and expertise from future employees.

Although Aircelle are moving towards an automated manufacturing process, it is felt that there will still be a significant requirement for semi and skilled 'hands-on' work in the production process (laying up carbon fibre).

5.6.3 Future higher level and other skill requirements - Automotive

Evidence from case study interviews and other sources (Ernst and Young, 2010) underline the expectation of significant future growth in demand for composites within the automotive sector. However, expectations vary by particular market segment, with strong future growth in skill requirements expected within the 'high end' small volume automotive sector as the example of Gurit Ltd illustrates.

Gurit Ltd - Future growth

The UK workforce has grown from about 350 five or six years ago to the current figure of about 500. This growth has taken place at the same time as a very strong focus on automation. The biggest future challenge facing the company is identified as meeting the recruitment needs of the company over the next two years in relation to the automotive section:

"We have the technology, we have the materials, we have the expertise from a skills point of view; its recruiting people from the local community to come in and learn the Gurit way. There are some huge challenges for us, but where we are today, we never thought we would be here five or six years ago...Effectively the sales go off the Richter scale, so it's a very steep growth."

This expected growth implies an increase in demand for operative staff including Fitters and Laminators together with a range of engineering staff including Process, Plant, Mechanical, Project, CAD and Design Engineers.

However, likely skill requirements for the general automotive sector in the UK are much less clear. The wide ranging adoption of composites within the volume car manufacturing sector would require major capital investment and a considerable reduction in the current composite cost base. Currently it is not clear how such cost reduction will be achieved.

Composites research, development and planning within JLR are likely to continue to develop over the next few years in conjunction with the Technology Strategy Board (TSB) with the "VARCITY" project, which will address many fundamental questions around manufacturing, design feasibility and materials developments and provide an important focus for the project work over the next 2 ½ years. JLR are therefore only at a high level conceptual / planning phase in relation to both the TSB project and their own thinking on the manufacture of composite cars and some way off having the results of tests on parts, processes, etc. The question of investment in a facility and a factory to actually manufacture a composite car is even further away on the horizon.

In this context the company consider that it is too early for JLR to be even thinking about the skill needs of a future composite workforce:

"We haven't even got to that stage yet...It's far far too early. As I say, it might not even happen," (Jaguar Land Rover).

5.6.4 Supply chain issues

The extent to which growth in composites within aerospace and automotive will impact on UK employment will depend to a great extent on the ability of the UK composites supply chain to capitalise on growing opportunities. Evidence suggests the need for support to enable this to happen, both in relation to workforce up-skilling and measures to ensure UK suppliers are aware of procurement opportunities with aerospace and automotive OEMs.

The UK Composites Supply Chain Scoping Study (Ernst and Young, 2010) indicates that 85 per cent of composite activity in the UK is undertaken by the 38 largest companies, but outside of these companies the UK supply chain comprises much smaller companies with annual revenues of less than £5 million. It notes that these companies could benefit significantly from regional and national support including in relation to up-skilling to diversify their production techniques and product range to exploit a wider range of applications.

EPM Technology indicated that one of the difficulties for an SME is obtaining information on the requirements of UK based OEMs, so that there is an opportunity for the company to meet specified requirements, even if this meant further investment in capital equipment.

Keeping up with the changes and developments that take place within an OEM, particularly changes in personnel and structure is considered a challenge for a small company.

What is a particular concern for EPM Technology is that an OEM was looking for help in the UK in relation to a component that EPM Technology could make, but EPM Technology were not visible to that OEM. The component was purchased through a supplier outside the UK.

"I still think that UK plc has to engage much better within its supply chain," (EPM Technology).

EPM Technology believes that the UK composite supply chain needs to be developed and that support is needed to enable this development.

5.7 Implications for Training

5.7.1 Overview

The UK Composites Strategy (Department for Business Innovation and Skills, 2009) identified training in relation to composites as difficult to identify and access with qualifications addressing industry sectors rather than the composites industry alone.

The research undertaken for this report indicates that within the automotive and aerospace sectors, to date, training provision in relation to composites appears to have been driven largely by major aerospace OEMs and Tier 1 suppliers, together with some other major composite supply chain players.

In other words, those employers with the resources and influence to develop appropriate training rather than SMEs that face much greater challenges in sourcing appropriate training and do not have the resources to develop their own tailored provision.

These issues are highlighted in more detail in the following sections.

5.7.2 Tackling training needs

A number of major employers within aerospace and the composite supply chain have successfully developed their own training provision. These examples include Aircelle who were the first company in the UK to develop and implement a structure of accredited training purely on composites; Bombardier opened a new Skills Centre in Belfast in January 2013 and Gurit Ltd that developed a programme that was launched four years ago called ‘Training for Success’, aimed at every level of individual in the business.

Bombardier (Belfast) - Skills training and development

The new Bombardier Skills Centre was opened in January 2013 within a newly refurbished factory, providing ‘state of the art’ training facilities. Bombardier is a company that is committed to the development and promotion of people from within the business. The Skills Centre plays an important role in meeting Bombardiers needs for skills and because of the development programme in place within the company people can be brought on quite quickly to address any skills shortages. The Skills Centre covers the following areas:

- Apprenticeships
- Upskill training – taking semi-skilled people and upskill them to skilled. The upskill programme also involves a full apprenticeship
- Training skilled people from outside the company and the aerospace industry – these skilled workers are being put through a bespoke programme. There is not an academic side to this training; it’s purely about the application of existing skills and on-the-job training. It was commented: *“There just aren’t the skills out there, so we’re bringing in skilled people from the motor trade, for example, and they are being upskilled”.* Senior executives within Bombardier started off as skilled tradesmen within the automotive sector, came over to Bombardier and worked their way through the organisation.

The importance of collaborative links with FE and HE

Strong links with both FE and HE have been vital for those companies developing their own composite training programmes. This is underlined by the examples of:

- The Airbus academy in partnership with Deeside College (now Coleg Cambria) and Glyndŵr University
- Aircelle’s links with Burnley College
- Links within Belfast Metropolitan College and Queen’s University, Belfast and the University of Ulster in the case of Bombardier.
- Rolls-Royce which has always had a very strong relationship with the academic network, not only in commissioning research, but also in relation to the student infrastructure.

These examples are all characterised by a systematic examination of specific training requirements and in a number of cases major programmes of investment in facilities and associated training infrastructure.

Aircelle's links with Burnley College

Aircelle has worked closely with Burnley College to develop a relevant composites qualifications framework. Aircelle consider that Burnley College has been very responsive in seeking to meet the company's training needs. The College has recently expanded its engineering offer and invested in new training facilities (e.g. the college has purchased a mini autoclave for training purposes). Burnley College is Aircelle's preferred partner on composite apprenticeships and is now also likely to be Aircelle's preferred partner in relation to all apprenticeships, including those for fitters and CNC machinists (who are increasingly involved in the composites area as the company moves towards automation).

The college is now the main training partner for the company's manufacturing excellence programme. All the Fitters (over 200) that were started with the Trent programme have been sent to the college for two days to update skills. The company are also looking at things like refresher training on composites, to update staff on different initiatives.

Aircelle has also sought to develop good relations with local schools in Burnley, involving the 50 STEM ambassadors that have been recruited from within Aircelle.

Bombardier

Composite training is undertaken by Belfast Metropolitan College, who are now seen as Bombardiers main external education provider. This training takes place in a brand new facility recently opened by the college (containing an autoclave and other relevant equipment involved in the manufacture of composites). Bombardier has a large number of people that use the college for various qualifications, from basic skills training through to degrees.

Airbus Academy Case study

Airbus located its first fully composite wing manufacturing facility at Broughton within the Deeside Enterprise Zone in Wales. The 46,000 sq metre factory was officially opened in October 2011. The site employs about 6,600 people

In order to ensure appropriate composite related training was developed to meet the needs of the Airbus workforce the Advanced Composite Training and Development Centre was launched in October 2010 and was the result of a partnership between Deeside College (now Coleg Cambria), Glyndŵr University, Airbus and the Welsh Government.

Provision through Coleg Cambria in relation to composites is predominantly linked to assembly rather than manufacture. The college supported Airbus in setting up a series of qualifications linked to appropriate modules predominantly at Level 3.

To date the College have trained about 500 Airbus employees over the last two years and envisage about 250 employees a year continuing to be trained. Employees are awarded a City and Guild Aerospace Studies Certificate which has a composites pathway. The training also provides a pathway to higher level studies such as Foundation Degrees or HNC's for those interested.

Higher level composite provision including Foundation Degrees, Degrees and NVQ level 4 provision is provided predominantly by Coleg Cambria and Glyndwr University, including provision relating to Design Engineers, Quality Engineers and Manufacturing Engineers.

Composite Apprenticeship programmes

In the absence of a structured composite industry apprenticeship framework until 2013, a number of major employers have put in place their own apprenticeship frameworks, including Gurit Ltd, as highlighted below.

Gurit Ltd – The Gurit Apprenticeship programme

Gurit run an apprenticeship programme and currently have six apprentices in their final year, all on HND's. The apprenticeship is described as following a basic framework developed with the local college and in line with the national framework but also adapted so as to be 'challenging to our apprentices'. It was commented:

"The one thing that we found with the framework that we were given was that the apprentices outgrew it very quickly and it wasn't challenging enough...Although now they should be on NVQ Level 3 Tech Cert through EAL, they are all on HNDs and have left that level behind...What we found was the national framework wasn't challenging enough; it was far too basic...we found that it just wasn't what we required, although it was a good foundation they soon left it behind."

Apprentices spend time in planning, quality, engineering, maintenance and production functions and the course is described as a very diverse programme which exposes them to everything, but also enables them to specialise within a given area. It was commented:

"Wherever they show their strengths we try and force them gently into that area and say you have shown a huge amount of potential...we endeavour to try and get them where their strengths are because it's a win, win situation for the learner and management."

Semta, announced the launch of a new Composite Engineering Apprenticeship Framework in May 2013. The development of the framework was overseen by Semta's employer-led Composite Sector Strategy Group and was developed through working groups of employers and stakeholders. The Framework combines a Level 2 pathway aimed at semi-skilled operator occupations where UK manufacturing is identified as currently experiencing serious and persistent skill shortages, with a Level 3 pathway for developing craft skilled and technician occupations, identified by Semta as critical if UK manufacturing is to maintain its competitive advantage in world markets. This is identified by the Composite Sector Strategy Group as a critical step in putting in place mechanisms to underpin the supply of composite skills.

At a higher level there are a number of examples of initiatives, such as Bristol University with strong links to the National Composites Centre and the Centre for Innovative Manufacture, which is collaboration between Bristol, Nottingham, Cranfield and Manchester Universities, also linking into the National Composites Centre. However, overall it was commented that this was often not the case with provision within other Universities.

Despite the above examples of industry wide and specific employer initiatives, training provision within the UK remains fragmented. In particular, it is clear that those companies that have successfully developed their own training programmes have the critical mass and resources to underpin the development of this provision and the influence to drive change within local training providers.

For SMEs this is not possible and it is clear that major weaknesses remain in relation to access to appropriate composite provision for such employers and their respective employees. The example of Custom Carbon highlights some of these challenges.

Custom Carbon - The lack of appropriate composite training locally

The owner-manager of Custom Carbon has no formal qualifications relating to composites and has not attended any training relating to composites over the past 10 years, having largely self-taught in the use of new techniques and materials.

Part of the difficulty is the lack of available training. In the North Yorkshire area there is very little, if anything, available on courses/qualifications in relation to composites. The nearest college offering qualifications/modules relating to composites is Burnley College, some 85 miles away. The owner-manager also experienced some difficulty in arranging for an appropriate apprenticeship.

The lack of composite training available locally has prompted Custom Carbon to examine the possibility of providing composites training to local companies.

"I know there are a few companies trying to break into composites, just from having to try and sell my business, and they are all lacking the training side of things."

The company believes that there is market potential for a local introductory training course in composites that could include Carbon fibre – its qualities, handling, etc; resins; pre-preg; mould-making and polishing the moulds; wet lay; and finishing the products.

5.8 Conclusions

Composites have been defined as consisting of a bulk material (the 'matrix') and a reinforcement of some kind such as fibres, particles or flakes, usually added to increase strength and stiffness. This report focuses on what are termed advanced composites (Structural Fibre-reinforced Polymer Matrix Composites) used in automotive and aerospace applications and characterised as light weight higher performance materials.

The use of composites within the aerospace industry is both prevalent and long standing. It is also clear that composites are a critical technology in driving change within the aerospace industry.

Within aerospace collaboration with both industry networks and selected academic organisations is identified as extremely important for the development and implementation of strategies to fully exploit composite technologies. It is also clear that in some cases strategic partnerships with other selected manufacturers is essential for the full exploitation of composites in the production process.

The development of an integrated international supply chain is also identified as vital for the successful exploitation of composites by OEMs.

Currently the use of composites in relation to high volume car manufacturing in the UK remains relatively limited. This contrasts with the 'high end' low volume automotive sector, where extensive use of composites occurs.

In relation to the general automotive sector in the UK, the future adoption of composite technology is not clear. However, BMW have undertaken a major programme of investment in composites which could have significant ramifications for the future of automotive manufacturing.

Current skill requirements

Significant growth in the composite workforce within both the aerospace and automotive workforce has occurred over the last 5 years.

The profile of the composite workforce tends to vary according to market focus, position in the supply chain and size of organisation. Occupations identified as part of the aerospace and automotive composites workforce include:

- Higher level occupations/specialists including research and development staff (such as Material Scientists and Engineers with specialist composite experience), Quality, Plant and Site Managers/Directors, Resource Planners and Business Directors;
- Engineering staff including Process, Plant, Production, Product, Project, Stress, Maintenance and CAD Engineers;
- Technical staff including Lab Technicians, CNC machinists and Non Destructive and Destructive Testing staff; and
- Operational staff including Fitters and Laminators.

The composite workforce within automotive OEMs is characterised by a relatively small core of very specialist, highly qualified engineers and scientists focussed predominantly on research and development, while the workforce within aerospace OEMs tends to be somewhat more diverse.

Recruitment issues

The case study interviews reinforced evidence from elsewhere of the wide-ranging recruitment challenges faced by some firms in relation to the composite workforce.

Recruitment difficulties reported by case study employers (EPM Technology, Gurit Ltd, Jaguar Land Rover), included higher level occupations/specialists such as Operational and Site Managers, Resource Planners and Research and Development staff with relevant industry experience; Engineering staff including those with experience in precision engineering and CAD Designers; technical staff including Quality related staff and CNC Machinists; and Operative level positions.

A range of steps have been taken by OEMs (particularly in the aerospace sector) and larger composite employers to ensure an adequate supply of appropriate skills. In particular the development of appropriate internal structures for developing and retaining skills, together with the importance of structured academic links was stressed as beneficial in this respect.

Future higher level and other skill requirements

High growth is expected in the demand for composites within the UK aerospace and automotive sectors, with an expected shortage of necessary skills at nearly all levels from operator, craft, technician to professional and management roles. Higher level technical skills will in particular be at a premium as these are the roles that are also in high demand from other sectors within Advanced Manufacturing.

The range of skill requirements within the composite workforce is also likely to change over time. The increasing use of composites will create a demand for more R&D related roles such as Scientists and Test Engineers. The creation of new design options using composites will lead to an increased requirement for Design Engineers and people with higher level CAD skills. The move into new products and design using composites will also require Project Engineers at all levels and new Business Development Managers. As processes become more automated it is expected that there will be a growing need for multi-skilled craft and technician level workers with both CNC and composite experience and Maintenance Engineers to keep plant running at optimum levels.

Currently the skills requirements for aerospace are much clearer than for the automotive sector. The fundamental question for the automotive sector is whether the high-volume car manufacturers will seek to embrace the widespread use of composites in the near future.

Implications for Training

Training provision in relation to composite technologies appears to have been driven largely by major aerospace employers, together with some major composite supply chain firms.

Establishing strong links with both FE and HE have been vital for those companies developing their own composite training programmes and for bringing composite provision closer to industry needs. Those firms that have successfully developed their own training programmes have the critical mass and resources to drive change within local training providers. A number of major employers have put in place their own apprenticeship frameworks and a new Composite Engineering Apprenticeship Framework was launched in May by Semta. This is identified by the Composite Sector Strategy Group as a critical step in putting in place mechanisms to underpin the supply of composite skills.

Despite the above examples of industry wide and specific employer initiatives, training provision within the UK remains largely fragmented. Smaller firms have experienced greater difficulty in achieving FE and HE collaboration.

For many SMEs who lack sufficient resources and networks, collaboration is hard to achieve and many SMEs experience difficulties in accessing composite provision in line with their needs.

6. Plastic Electronic technologies and skills in advanced manufacturing

Summary

The multidisciplinary nature of Plastic Electronics that is required to both develop and exploit the core technologies involved is widely acknowledged, with a high proportion of highly qualified Chemists, Physicists, Material Scientists, Electronic and other Engineers employed and those with experience in the semiconductor, display or printing industries.

The Plastic Electronics workforce is typically highly qualified, linked to the high proportion of Research and Development staff, with a preponderance of those with PhDs.

When recruiting those with experience in Plastic Electronics there is a relatively small pool of key companies and academic institutions in the UK from which to potentially recruit, so it is clear that use of existing networks is very important.

A number of those companies interviewed are only able to source the skills they require by relying heavily on recruitment outside the UK.

There are a number of factors that may constrain direct employment growth in the UK within Plastic Electronic companies, including the prevalence of technology licensing business models; the propensity for Plastic Electronics companies to be bought out in the future and the location of a high proportion of production overseas.

As Plastic Electronic technologies mature and are increasingly applied within commercial production, an increase in core Research and Development staff comprising highly qualified Chemists, Physicists, Material Scientists, Electronic and other Engineers is likely, together with an increased proportion of those involved in process development and production, including Process and other Engineers and those with relevant industry experience within the semiconductor, display or printing industries and operative staff.

Training undertaken by companies interviewed tends to be mainly ‘in-house’ combined with use of specialist conferences/events accessed via academic networks. There appears to be significant support for the development of an appropriate apprenticeship framework to support the Plastic Electronics sector, some support for Masters level provision, possibly on a modular level, but views on the need for specialised course provision at degree level amongst those interviewed are mixed.

6.1 Introduction

Plastic Electronics has been defined as devices on flexible surfaces that make it possible to produce flexible, bendable or stretchable electronic products, which may use printing techniques but can also be deposited onto flexible surfaces in other ways. Plastic Electronics can also refer to the use of printing techniques related to devices on rigid surfaces.

The application of Plastic Electronics technology opens up the possibility of new applications and markets not accessible using rigid electronics technology. The report Best of British (HM Government, 2009) estimates that the global Plastic Electronics industry is worth around $2 billion annually. The UK currently employs around 3,000 people in the Plastics Electronics sector but it has been estimated this could increase to over 50,000 jobs by 2027. It has been estimated that the global market value of Plastic Electronics devices could be $335 billion by 2029 (King, 2009).

There is generally a lot of confusion over what constitutes Plastic Electronics:

*"Most people don't understand it because it has so many different names; it certainly isn't clear to people yet…Some people like calling it plastic electronics, some people like calling it organic electronics; so it is based on carbon rather than silicone and other people talk about flexible electronics; in other words any electronic circuits that include things like displays which are printed or deposited on flexible substrates. We have agonised a lot over this, I think what we mean by Plastic Electronics is where electronics are printed or deposited on a whole range of sub straights; it is electronics that is not conventional silicone," (*Member of the Plastic Electronics Leadership Group).

Although there are examples of UK Plastic Electronics companies with fully commercialised products, such as Plastic Logic, many companies remain at the R&D stage.

By comparison with the scale of use of Additive Manufacturing and particularly composite technology in the UK, Plastic Electronics activity remains relatively low-level. Most companies are quite small, with typically less than 20 employees. The diversity of companies which can be termed Plastic Electronics companies is illustrated by the case study companies interviewed as part of this study. A brief summary of each company is set out in Appendix C.

6.2 Potential applications in the automotive and aerospace sectors

In relation to fully commercialised applications within the automotive and aerospace sector this is still some way off, although some of those interviewed expected commercial applications by 2020, particularly in the automotive sector.

The range of future potential applications identified within the automotive sector that were identified by those consulted as part of the research, included use of flexible displays around the dash and console area, embedding of controls in textiles and interiors, seat sensor applications and exterior safety applications.

Potential aerospace applications using plastic electronic technologies include flexible, lightweight passenger displays, embedding passenger controls in seat/cabin textiles, other weight saving applications and the use of embedded sensors.

Embedding of electronic functionality within components by combining Plastic Electronic technology with Additive Manufacturing techniques was identified as having potential within both sectors.

6.3 Current skill requirements

The mix of disciplines required

The multi-disciplinary nature of occupations involving Plastic Electronics to develop and exploit the technology is widely acknowledged. For example, Plastic Electronics; A UK Strategy for Success (Department of Business Innovation and Skills, 2009) identified the need for Material Scientists and Chemists who understand electronics; Print/Process Engineers who understand materials science; and Electronics Engineers who understand chemistry.

One company interviewed as part of this research commented that academic disciplines are intentionally a broad mix of material science, chemistry, electronics, physics, engineering and mathematics, together with nano technology.

The need to integrate a range of different disciplines was underlined by one industry expert:

"Basically you need Material Scientists and Chemists when it comes to the base materials; you need Electronic Engineers and Electrical Engineers which is where a lot of people have been coming who previously worked on silicone when we had such an industry and you have another area of people with the printing and processing expertise and that's where the UK has got enormous strengths. Again, it is bringing all of those things together," (Member of PELG).

The most common areas of expertise required that were identified by case study companies interviewed were:

- Material Scientists, Physicists and Chemists;
- Electronic, Electrical, Process and Mechanical Engineers;
- Business Development and Sales staff with relevant technical knowledge; and
- Those with experience in the semiconductor, display and print industries.

Although difficult to generalise across companies given the diversity of the Plastic Electronics sector, there appears to be a broad split between those engaged in:

- Research and Development activities, with a workforce comprising a high proportion of highly qualified Chemists, Physicists, Material Scientists, Electronic and other Engineers,
- Process Development and pilot production activities where there tends to be a higher proportion of those with an engineering background together with industry experience often from the semiconductor, display or printing industries.

The case study of PragmatIC Printing overleaf provides an example of this broad split.

PragmatIC Printing - Workforce profile

PragmatIC have developed printed logic circuits that are applicable to any product requiring low cost, non-invasive electronic functionality. Electronics can be integrated on plastic, paper, card or metal surfaces, which may be curved or flexible.

The workforce is split fairly evenly between Cambridge and Sedgefield. Cambridge is the business headquarters and focus of design and applications development, while Sedgefield is the location of process and pilot production activities.

The majority of those working for the company have been recruited from industry backgrounds rather than academia, including those with experience working in electronics, semiconductors, telecoms, plastic electronics and optical disk manufacturing. People have been recruited from a range of roles including sales and marketing, engineering, design and production.

In relation to activities in Sedgefield the company have recruited staff from the semiconductor manufacturing industry that between them have 30 years of experience working within fabrication and fully understand how this process works. Activities in Sedgefield are also used as a process development platform, so the company have in place people with an engineering background that understand production design processes.

In relation to research and development activities at Cambridge it was commented:

"There are people looking at the design of devices and circuits and integrating different technologies, which may give an unusual, hopefully useful property for a device."

A highly qualified workforce

The Plastic Electronics workforce is typically highly qualified, at least in part linked to the high proportion of research and development staff. Smartkem, for example, employs a total of fourteen people at present all of whom have PhDs with the exception of the Chief Executive Officer, who is an international business professional with over twenty years' experience specialising in technology ventures and a background in print based technologies.

Skills-mix sought linked to technology focus

The mix of skills required tends to be closely linked to the technologies used or being developed, which means there is significant variation in the occupational make up of different Plastic Electronics companies. For example, Smartkem produce organic semi-conductors that require a core expertise based on chemistry:

Smartkem

Smartkem produce high-performance organic semiconductors enabling flexible, lightweight electronics. Smartkem's organic semiconductors can be processed at room temperature and can be easily formulated into electronic 'inks' for the printing of organic transistors used in displays, sensors and logic circuits.

Although Smartkem employs people from a range of disciplines, the core expertise of the company is founded on Chemistry. It was commented:

"We are a chemical company – Highly specific, highly focussed on one particular product. A lot of companies are making more physical, mechanical, electrical products. We are all about chemistry."

This contrasts with **Peratech** who have developed a composite material (QTC™ Material) which exhibits significantly different electrical properties when compared with any other electrically conductive material. While the company draws on the expertise of Chemists located at Durham University, the seven scientists currently employed directly by Peratech are predominantly Physicists.

PragmatIC Printing on the other hand employs a broad mix of staff but stress the importance of core materials engineering skills. In this respect it was commented:

"In our case we don't use inks but instead we use vacuum deposition. We need a materials engineer who understands that and how to test and characterise materials. There is a requirement to understand the physics of the material, how do the processes change the material properties and how does that relate to how it works in a device?" (ParagmatIC Printing).

The particular technology focus of **Novalia** is also reflected in the specific mix of core skills assembled by the company.

Novalia focus on the integration of creative design, traditional print and silicon microelectronics for use in products incorporating a mixture of sensors, displays, lights, speakers, printed batteries and communication devices, with the active device produced using a conventional printing press.

Novalia employ nine people, including the Chief Executive Officer who is a semiconductor physicist with a PhD and described as a ‘creative scientist’, a graduate Graphic Designer, a graduate Electronic Engineer, two Software Developers and a print technician with significant printing/packaging production industry experience.

The workforce profile was described as *“very different from every single plastic electronics company I have met so far.”*

Both the academic discipline and level of qualifications of staff tend to be linked to the type of roles undertaken, as the example of Plastic Logic indicates.

Plastic Logic - Employment and skills profile

Plastic Logic develops and manufactures ultra-thin, ultra-lightweight and high-quality plastic displays of various sizes and in both colour and monochrome based on the development by Plastic Logic of plastic transistor technology that enables electronics to be manufactured on flexible or plastic sheets.

There is a significant workforce of scientists and engineers employed by Plastic Logic in Cambridge, with a manufacturing plant located in Dresden, Germany, and a small sales presence in Russia.

The workforce based at Cambridge comprises three core teams, these being Research and Development, Control Systems and Process Development. It was commented *"we have people that can make the display, people that can drive the display and then people that can design the display."*

- Research and Development: The team comprises a mixture of Physicists, Chemists and Material Scientists. All have at least an MSc with about 70 per cent having PhDs. Some of this group have undertaken specific studies relating to Plastic Electronics. The group is described as a mixture of "*those with specific Plastics Electronics backgrounds and others that are just talented scientists that can contribute."*
- Control Systems: This team comprises a mixture of those with Electronic Engineering and Software Development backgrounds. About 30 per cent have PhDs;
- Process Development: This team is the largest of the three and is somewhat more varied with a mixture of those with A levels, degrees and those with experience in the semiconductor or printing industries. About 20 per cent have PhDs. The Team includes Process Engineers, Micro Electronics Engineers, Manufacturing Engineers and Physicists. The focus is on designing, managing and operating the prototyping process.

The company states it has "*assembled the world's leading team of Plastic Electronics experts."*

The manufacturing plant in Dresden is identified as highly automated with many tasks undertaken by robots. The overall profile of the manufacturing workforce is described as similar in relation to equipment and process roles to that of the rest of the display industry but, with a lower proportion of operative roles.

However, given the larger size of Plastic Logic compared with most other companies in the sector and the fact that the company has a fully commercialised manufacturing plant; the roles undertaken with Plastic Logic are more structured than is the case with a number of other companies interviewed as part of the research.

Specific characteristics sought

A number of specific characteristics of staff were underlined as useful including:

The ability to work across different academic disciplines

Plastic Electronics involves the integration of different disciplines and the solving of problems that cross academic boundaries, or in some cases the advantages of a broader based academic discipline alongside the ability to link with colleagues from other disciplines:

"You need people who can operate across disciplines, so the broader scientific disciplines tend to be better. So we are looking at more natural science degrees and less pure chemistry degrees," (MFLEX).

The need to think 'out the box'

The innovative nature of Plastic Electronics means there is a need to go beyond the application of known solutions and think about different ways of approaching problems. One company commented:

"Skills sets for us include electronics. Speaking with conventional electronic designers can be difficult because they have been taught conventional methodologies. We need people to think out of the box, so you have to look for people who are not in a box, which is why we employ people straight from universities. It is called electronics but apart from that word, everything else is different," (Printed Electronics Ltd).

The need to undertake multiple roles

Given the small size of many Plastic Electronics companies and the need to work across different disciplines, the employees are often expected to take on multiple roles.

One company pointed out that people need to be pliable and nobody taken on is doing what they were doing in their previous job, but are using aspects of previous experience. It was commented:

"We have got the only Graphic Designer in the world that designs circuitry quite frequently...You don't learn that at graphic design college. Similarly the Engineers that are

designing electronic boards are now designing them to take into account attaching them to a piece of print and using different methods to attach different types of substrates. The Software Engineers we have got on board...who write the software to link plastic circuitry to a smart phone had not done anything like this before," (Novalia).

Another company commented:

"We are a small company so everyone has more than one job and to some extent you have to fill the gaps when someone doesn't know how to do something else. Our physicist is the IT manager; one of the engineers is the Operations Manager and one of the chemists is the Quality Manager; we spread around the usual tasks by utilising people's dispositions and interests," (Epigem).

Problem solving

Disciplined, methodical problem solving was highlighted as a critical skill by a number of Plastic Electronics companies and in some cases more important than a specific understanding of any particular technology area. One company commented:

"First and foremost it is important to have people with the right analytical mind set, knowing how to break problems down and solve them and that range of disciplines gives us a good amount of knowledge, so we know where to seek answers," (PragmatIC Printing).

Another company pointed out that while the relevant academic disciplines were considered as an essential pre requisite, the ability to solve problems was considered fundamental. In this context it was commented: *"what is of paramount importance is high quality problem solving,"* (MFLEX).

Attitude

Having the right attitude was considered extremely important at all levels. In relation to Technician level staff one company commented: *"If people are enthusiastic and have curiosity about them then there is potential and I don't care about their educational background,"* (Printed Electronics Ltd).

6.4 Recruitment issues

A range of specific recruitment difficulties were identified by Plastic Electronics companies in relation to the following; Electronic Engineers, Vacuum Process Engineers, Software Developers, Chemists, Multi-disciplined graduates and Clean room skills (skills needed to operate in an environment where the level of environmental pollutants such as airborne microbes, aerosol particles and chemical vapours are strictly controlled).

It was stressed by some of those interviewed that while it was possible to recruit particular disciplines sought, the real challenge was to get those of the calibre sought in relation to these disciplines.

"It is not that you can't find people who could do a job it is if you can find people who can do the job to the highest standard in the time required, working the long hours that are required and be self-starting," (MFLEX).

In a number of cases companies have been dependent upon particular geographical 'clusters' of expertise that in some cases have influenced location decisions.

Problems recruiting multi-disciplined graduates

Recruiting graduates with skills across multiple disciplines were highlighted as an issue by a number of employers. One company indicated that they specifically wanted someone with a broader based scientific and engineering academic training (not usually offered in the UK) in order to be able to work across different disciplines in relation to 'formulations'. Although the company was successful eventually, recruitment proved particularly problematic. It was commented:

"We searched long and hard for our formulations guy. And he came from Ireland. We were quite specific about what we wanted," (Smartkem).

Problems recruiting UK graduates

A number of those companies interviewed are only able to source the skills they require by relying heavily on recruitment outside the UK. One company indicated that although it manages to recruit suitably qualified staff, many of the applicants are not from the UK, with only 30 per cent of research staff within the company being from the UK. In this respect it was commented:

“Maybe that is the biggest story – We are finding the people, but not necessarily from the UK,” (Plastic Logic).

Unless these issues are addressed this may place a significant constraint on the future expansion of Plastic Electronics activities in the UK, with an increased incentive to locate such activities outside the UK.

A dependence upon geographical clusters of expertise

In some other cases the location of the company or particular company functions has been determined by the availability of geographical clusters of specialist expertise, as illustrated with the example below.

Smartkem - Recruitment Issues

Smartkem has managed to recruit the appropriate calibre of staff to the company, but has only managed this by being flexible about the location of particular company functions.

In particular, the company would have preferred to locate all activities at their head office location in North Wales but recognised they would not be able to recruit the appropriate calibre of Organic Chemists required by the company:

"Ideally we would like everybody to be based in Wales, but everybody who we wanted to employ was based in Manchester. There is a good organic chemistry base in north Manchester due to the ICI heritage. So we had to open an office there. It just so happened that Avecia (a privately owned group of biotechnology companies) *was acquired, which provided the opportunity to recruit a number of organic chemists. But in an ideal world we would have invested heavily in the North Wales area. We just could not get the workforce...So for organic chemists we got lucky with Avecia – Merck bought them and a lot didn't want to relocate."*

A reliance on academic and industry networks

When recruiting those with experience in Plastic Electronics there is relatively small pool of key companies and academic institutions in the UK from which to potentially recruit, so it is clear that use of existing networks is very important.

"In the past we have tended to go through recruitment agencies. Now there are more efficient and smarter ways of finding the right candidates such as LinkedIn," (Smartkem).

A common way of recruiting people cited by a number of those companies interviewed is the use of PhD placements. This provides organisations with a cost effective way of enhancing research and development capacity and introduces potential employees to career opportunities within the host employer at the same time as enabling the employer to test out individuals over an extended period.

Peratech indicated it relies heavily on using PhD placements within the company as a way of finding suitable future employees. A number of current employees have come to the company through this route. Currently the company has four PhD students with the company from Durham and Leeds Universities, together with the London College of Fashion:

"Our future input will come from there unless we expand suddenly, but we are not planning that," (Peratech).

6.5 Future higher level and other skill requirements

Although very difficult to predict future employment patterns what does seem clear is that significant employment growth will need to relate to actual production activities rather than just research and development. In a number of cases this production may actually be located overseas, so not impact very much on employment opportunities in the UK.

Companies interviewed expect some growth in employment over the period up to 2015 and beyond to 2020, although some are quite cautious about the likely rate of growth. A number of factors could place a limit on direct employment growth in the UK within Plastic Electronic companies. In particular:

- It is common to adopt a technology licensing model;
- Some Plastic Electronics companies expect to be bought out in the future;
- Amongst those Plastics Electronics companies undertaking or planning to undertake full volume production, some of this is likely to be located abroad
- The unpredictable nature of technological innovation.

Each of these issues is considered below:

A technology licensing model

The business model adopted by many Plastic Electronic companies is one of licensing the technology. For example Novalia indicate that future expansion is likely to be shaped by their particular business approach which is to avoid owning direct production whilst controlling the production specification through product licensing. Specifically Novalia are developing printing technologies, printing inks, processes and designs for application within existing print companies.

This model may lead to significant growth within licensee companies in the UK or elsewhere.

Buy out the most likely future scenario

One of the companies interviewed indicated that the most likely future trajectory through to 2015 was a buy-out by one of the ‘big players’, such as a large chemical or display company that considers the technology too valuable not to control:

“The chances are one of the big players will say this is too valuable for us now. We can’t allow other people to get access,” (Plastic Electronics Company).

The potential for buy-out by a larger company was also identified by other companies.

Use of overseas production arrangements

Amongst those Plastics Electronics companies undertaking or planning to undertake full volume production some of this activity is, or is likely to be located abroad. For example:

Peratech have indicated that if there is a need to move rapidly to full production, some of this is likely to take place in Singapore.

The rationale for establishing a Singapore office is primarily linked to the rapid availability of a pool of broad based scientists if required:

“That is the reason we have a Singapore office. We are going to build an ink generator out there so that we have a second base….First of all there are people there willing to work on this type of thing. We have a couple of scientists which are a lot less defined in Singapore. I think that is because they are taught in a broader fashion,” (Peratech).

Plastic Logic, one of the few examples in the UK of a Plastic Electronics company that has developed a full volume manufacturing capability has located production at a manufacturing plant in Dresden, Germany.

MFLEX Europe has developed low cost, flexible printed display material using roll to roll screen printed techniques. The display is emissive – it shines light out – but also reflects light. The company has developed a pilot production line in Cambridge, but full production will be transferred to China.

The extent to which this trend will act as a constraint on the growth of Plastic Electronics employment growth in the UK will depend upon the extent to which the reasons for this, such as accessing an appropriately skilled workforce, are addressed in the UK.

The unpredictable nature of technological innovation

The development of products through to full production using Plastic Electronic technologies is a very unpredictable process which can act as a constraint on both levels of investment in these activities and workforce recruitment. One company currently with 10 employees commented in relation to the future strategy of the company:

"It will be based on actual not on potential development and growth. I have been in R&D for 40 years and when orders are in and money is in the bank that is when it is real. It is very easy to get carried away in this industry; I won't take anyone on unless they are needed," (Printed Electronics Ltd).

The profile of workforce changes as companies move towards full commercialisation

As Plastics Electronics companies move to full commercialisation, the particular changes in skill requirements will depend heavily on the particular business model adopted, but two areas of increased skill demand are identified in particular:

- Business development staff with experience in those industries relevant to the particular company (Typically, the semiconductor industry, displays or the print industry);
- Staff able to support technology transfer to customers.

Research and Development (R&D) activity is considered as critical to future of companies

All companies interviewed expect R&D to remain a core component of the workforce, typically comprising a mixture of highly qualified material scientists, physicists and/or chemists, together with other disciplines depending upon the technology focus.

One company interviewed envisaged that the R&D Team would never comprise less than 50 per cent of the company including a mix of material scientists, software developers and graphic and product designers. It is envisaged that software development will become increasingly important in order to meet client requirements, that design will always be important and material scientists will be essential to apply 'pure' research skills in relation to material behaviour to printing and production processes.

Those organisations adopting a business growth model that retains production in house will require a considerable increase in skills relating to the design and implementation of the production process, such as:

- A mix of Process Engineers, Micro Electronics Engineers, Manufacturing Engineers together with those with the required scientific backgrounds; and
- Operative and Technician level employees on the production line.

Two particular scenarios for employment growth relating to different production models that were raised by companies are explored below. These are the potential employment implications of the commercialisation of Plastic Electronics:

- For the UK print industry;
- As a stimulus for new manufacturing approaches in the UK by combining the use of Plastic Electronics technologies with Additive Manufacturing and or composite technologies

Each of these scenarios is considered below.

Implications for the UK Print Industry

Views are mixed on the potential implications of Plastic Electronics for the UK print industry. Novalia envisage utilising existing commercial print companies for the production of a range of Plastic Electronics products under a licensing arrangement. They perceive that the approach taken by a number of Plastic Electronics companies of establishing bespoke in house print production lines is very constrained and see much more potential in working with the existing print industry. It was commented *"this is a very limiting message compared with our approach to say to potential customers we can put this technology into your products – can create it on a printing line – We can work with your existing print/packaging company suppliers to develop your manufacturing line,"* (Novalia).

Although it was acknowledged that a slightly different skills set would be required by printers to ensure effective production, it would be within the existing commercial print sector in the UK where the greatest impact in relation to employment generation is identified as likely to occur. This view was also supported by Peratech, as illustrated in the case study overleaf.

Peratech - Implications for the UK Print Industry

The Chief Technology Officer at Peratech thinks that the inks produced by Peratech have major implications for the UK printing industry. Peratech is currently involved in a £0.5M Government project in conjunction with the CPI, the objective of which is to make inks in a form that can be used by standard printing machinery. It was commented:

"I realised early on through talking with the CPI that the future for printing really lies with the present printing industry, which to some extent has been overtaken by the computer."

The project is looking specifically at how to apply Peratech inks using flexographic printing techniques. Two main implications for future skill requirements within the UK are identified if this proves successful. Firstly, there will be some new skill requirements for those working within the existing UK print industry; although it is perceived that much of the quality testing will be automated. In this respect, it was commented:

"You could see an argument for saying that the printer has to have new skills. The saving grace in all this is that it will be done in black boxes. The printer will be capable of printing down electronics in a number of forms. There are electronics inks which will have other qualities. Testing the end result of that will be necessary on the print line, however, I suspect that will be done by a black box rather than a person."

The potential for the creation of a 'new industry' developing appropriate inks, with associated skill requirements is also identified. It was commented:

"There is a whole new industry being created which is creating all new kinds of inks."

It is envisaged this will be undertaken both by industry and within Universities.

However, others have expressed considerable scepticism as to the viability of transferring the production of Plastic Electronics products to the UK commercial printing sector:

"People have talked about taking people with experience in the traditional printing industries; that's all they have, experience but no knowledge. There is an absence of qualifications and skilled people...You are not going to get an ordinary printer to run the press well enough to print electronics," (Industry expert).

Plastic Electronics - The stimulant for new manufacturing approaches in the UK?

Plastic Logic identify two broad scenarios for expansion; the first would not have a major impact on future employment in the UK, while the second, based on a potential move into new areas of manufacturing could potentially have a much more significant impact on future employment. These two scenarios are set out below.

Plastic Logic - Future skill requirements:

Plastic Logic identifies two broad scenarios for expansion:

- Firstly, expansion driven by market demand that will require a broadly similar profile of skills to the current profile located within Cambridge. This scenario will depend upon how successfully the company markets the evolving product portfolio, with all manufacturing still based outside the UK;
- A second scenario relates to the ‘next generation’ of plastic electronics, which will require different fabrication techniques. At the moment the company cannot be explicit about what these new techniques will be, but that this is likely to happen over the next 2-3 years. This may involve new paradigms in terms of manufacturing, such as use of Additive Manufacturing technologies. It was pointed out that to date the company has developed a process for displays and an associated manufacturing process, but as the company diversifies outside of displays, this may or may not utilise that same process. In this case, there will be an opportunity to manufacture in a different way that could provide a manufacturing opportunity for the UK. It was commented:

“*What really could change is if we start looking at alternative applications and start deviating away from the specific display space, then we would rapidly need to start employing people with different sorts of skills. You would potentially be manufacturing in different ways and different end products. That could have a more dramatic impact on the type of company and the type of resources employed in Cambridge and the UK.”*

With this scenario, although the workforce implications are not clear at present, the need for a higher proportion of those at technician/operative level, working in a clean room environment, is identified. The profile of higher level staff is also likely to change with this scenario. For example, within Control Systems there may be a need to supplement embedded software engineers, focussed on driving and optimising displays, to those with broader systems skills for this new era.

The potential of combining Additive Manufacturing with Plastic Electronics and composites was highlighted by Printed Electronics Limited (PEL) which identified considerable interest in PEL technology within the aerospace sector, particularly in relation to the integration of composite, Additive Manufacturing and Plastic Electronics as part of an integrated manufacturing process:

“Composites, electronics and 3D: these all work together for us,” (Printed Electronics Ltd).

Collaboration

It is clear that collaborative links forged with Universities and specialist industry networks/forums such as those relating to the Centre for Process Innovation (CPI) in Sedgefield, Cambridge Innovation and Knowledge Centre (CIKC) and Plastic Electronics Leadership Group (PELG) are considered very important as a way of accessing information, networking and even identifying potential recruits. In some cases academic links have been forged over a number of years, particularly in the case of those companies that were originally University spin outs.

PragmatIC Printing - The benefits of academic and industry collaboration

PragmatIC Printing emphasise the importance of collaboration with both industry and academia. It was commented:

"What we have done successfully is collaborate both with academia and industry where we have found complementary expertise."

The company have worked with Cambridge University in relation to electrical engineering, nano science and material science and also worked with a number of other Universities drawing on specialist expertise in order to try out new ideas or to solve particular problems.

PragmatIC Printing have also utilised the industrial Plastic Electronics expertise of the Holst Centre, and considers this collaboration to be a key aspect of the development of the company. The Holst Centre is based in Eindhoven and is an independent open-innovation R&D centre that develops generic technologies for Wireless Autonomous Sensor Technologies and Flexible Electronics. A key feature of Holst Centre is its partnership model with industry and academia based around shared roadmaps and programmes.

The company have also worked with a range of UK based SMEs, particularly from the Plastic Electronics industry and is also collaborating with the Centre for Process Innovation in Sedgefield. CPI's National Centre for Printable Electronics has been crucial in supporting PragmatIC's move to pilot production:

"We have built networks from a technology perspective and used that to add to our core expertise."

6.6 Implications for training

Training undertaken by companies interviewed tends to be mainly 'in house' combined with use of specialist conferences/events accessed via academic networks. This is linked to the relatively small size of the Plastic Electronics sector currently and the specialist nature of many activities.

There appears to be significant support for the development of an appropriate apprenticeship framework to support the Plastic Electronics sector. For example the Centre for Process Innovation (CPI's) Printable Electronics Centre have been looking at the potential for apprenticeships to underpin the work they undertake and have concluded that currently there are no apprenticeship schemes available that suit their specific requirements.

The Centre for Process Innovation (CPI) is a UK-based technology innovation centre and part of the Government funded High Value Manufacturing Catapult. The CPI's Printable Electronics Centre which is based in Sedgefield focuses on design, development and prototyping for the emerging printable electronics industry.

In relation to improvements to current training opportunities the potential benefits of developing an apprenticeship framework tailored to the needs of the Plastic Electronics industry were identified:

"I would say that one of the most positive outcomes that could come out of this (research study) is the development of an apprenticeship framework," (Plastic Logic).

At a higher level there is some support for Masters-level provision, possibly on a modular level:

"There is a need for Master's courses or modules that people can dip into. You need people with core skills in electronics and physics but they need more specific training and up skilling on Plastic Electronics, so you may have a range of Master's modules available tackling different areas. I can certainly see a need for that," (Member of PELG).

Views on the need for specialised course provision at degree level amongst those interviewed are mixed. Unpublished findings from a recent survey undertaken by COLAE provide an insight as to the perceived gaps in Plastic Electronics related training at a European level. Commercialisation of Organic and Large Area Electronics (COLAE) is a European project designed to simplify and speed up the commercialisation and adoption of organic electronics technology through the creation of industry clusters. The survey findings pointed to:

- A lack of hands on training;
- A need for more courses targeted at current employees and particularly technicians, rather than students;
- A requirement for more training at advanced and intermediate level rather than introductory; and
- A preference for more of the training to be offered in short workshops.

The Centre for Printing and Coating in Swansea are currently developing a Master's Course in Printing that would suitable for those involved in high end graphics printing, printed electronics and print bio materials, with the option of more specialised elements linking to this. It is envisaged that key elements would cover printing technologies, materials, the process and production and include practical hands on workshops.

One of the barriers to the development of appropriate training at present seems to be the small size of many companies operating in the sector, which lack both the resources and influence with potential providers.

One industry expert underlined the difficulties of accessing appropriate training for many Plastic Electronics companies in the following way:

"In my previous experience the organisation works with the local college, tweaks the academic course and adds modules to make the course relevant and give them day release. I have seen that happen, but usually that requires such an investment and effort that you usually have to have your organisation at a critical size before you do that. The Plastic Electronics sector doesn't have large enough companies to invest heavily," (Stakeholder interviewee).

6.7 Conclusions

Current skill requirements

The Plastics Electronics workforce is typically highly qualified, linked to the high proportion of Research and Development Staff and comprises predominantly qualified Chemists, Physicists, Material Scientists, Electronic and other Engineers.

The main industries from which experienced recruits are drawn from are the semiconductor, display or printing industries.

Specific characteristics sought from staff include the ability to work across different academic disciplines; think 'out the box'; undertake multiple roles and solve problems.

Recruitment issues

Academic networks are an important channel for recruitment with the use of PhD placements common given the relatively small pool of key companies within the UK.

However, many companies can only fulfil their high level scientific and engineering recruitment needs by relying heavily on overseas graduates.

Future higher level and other skill requirements

It has been estimated that the UK currently employs around 3,000 people in the Plastics Electronics sector, but that this might increase to over 50,000 jobs by 2027.

However, this research indicates that there are a number of factors that may place a limit on direct employment growth within Plastic Electronic companies, linked to their particular business models. In particular it is common to adopt a technology licensing model; some Plastic Electronics companies expect to be bought out in the future; amongst those Plastics Electronics companies undertaking or planning to undertake full volume production some of this activity is or is likely to be located abroad, based on current UK conditions.

These business strategy considerations, together with the unpredictable nature of innovation make it difficult to estimate the likely scale of Plastic Electronics employment growth in the UK.

Two particular factors that may influence the scale of future Plastics Electronics employment growth within the UK are the extent to which the commercialisation of Plastic Electronics products will impact on employment within the UK print industry and the extent to which new approaches to manufacturing in the UK are stimulated by combining the use of Plastic Electronics technologies with other technologies such as Additive Manufacturing and composites.

Implications for training

Given the small size of the current Plastic Electronics sector and predominance of small employers, training is not well developed and tends to be mainly ‘in-house’, combined with use of specialist conferences/events accessed via academic networks.

There appears to be significant support for the development of an appropriate apprenticeship framework to support the Plastic Electronics sector.

At a higher level there is some support for Masters level provision, possibly on a modular level, but views on the need for specialised course provision at degree level amongst those interviewed are mixed.

7. Conclusion and implications

Summary

For the aerospace sector both Additive Manufacturing and Composites have been identified as of major strategic importance while the current application of Plastic Electronics is much less clear, although it could be very significant in the future.

The use of Composites and Additive Manufacturing within the general automotive sector in the UK remains relatively limited due to the cost of investing in the technology, except in 'high end' automotive activities. Commercialised Plastic Electronics applications within the automotive sector are expected to occur by 2020.

Although growing rapidly, the scale of Additive Manufacturing activity in the UK is currently at a far lower level than Composites. Both the aerospace and to a lesser extent the automotive sector are a major contributor to both Composites annual production revenue and added value. The overall scale of UK Plastic Electronics activity is of a significantly lower order.

Growth in employment in relation to all three technologies implies a changing shape in demand for skills. However, with respect to all three technologies skill shortages pose significant threats to future UK employment growth if not tackled. Wide-ranging recruitment difficulties are already reported in relation to recruitment of both Composites and Additive Manufacturing staff. In the case of Plastic Electronics companies a number of companies are only able to source the skills required by relying heavily on recruitment of non UK graduates.

Training provision within the UK also remains largely fragmented in relation to all three technologies. Large Composites companies have been developing their own training programmes as they have the resources to underpin the development of this provision and the influence to drive change within local training providers. For SMEs this is not possible and this may constrain growth in the supply chain.

There is a general lack of Additive Manufacturing training available. The training that is undertaken tends to be on the job and in-house, with expertise currently 'locked up' with those employers, such as specialist Additive Manufacturing Bureaus, certain aerospace and automotive OEMs and Tier 1 manufacturers.

Training undertaken by Plastic Electronics companies interviewed also tends to be mainly 'in house' combined with use of specialist conferences/events accessed via academic networks.

In terms of higher education, it was commented that there needs to be more initiatives that bring Composites provision closer to industry. There appears to be potential scope for Additive Manufacturing modules within relevant degree courses and higher level Additive Manufacturing courses. With respect to Plastic Electronics there is some support for Masters level provision, possibly on a modular level, but views on the need for specialised course provision at degree level amongst those interviewed was mixed.

With respect to Apprenticeships, there was some support expressed by those interviewed for the development of Additive Manufacturing and Plastic Electronics frameworks, in line with the recently launched Semta Apprenticeship Framework for the composites workforce.

At present, although some mapping of these technologies has been undertaken, very little is still known of the size and profile of these companies and the associated supply chain workforce in different localities. This means it is very difficult to assess training needs at a local level and start to address other supply chain support issues.

7.1 The use and scale of technology

7.1.1The use of technology within the Aerospace sector

Additive Manufacturing is identified as an important technology to produce complex parts more efficiently. Both Additive Manufacturing and composites can enable parts to be made lighter, which can deliver millions of pounds of savings in fuel efficiency. Both technologies have been identified as of major strategic importance within the aerospace sector. Plastic Electronics by contrast is identified as potentially playing an important role in achieving these objectives, but future applications within the aerospace sector are much less clear.

While Additive Manufacturing in the UK aerospace sector is still not used widely for the production of flight components and is considered still very much at the research and development stage, the use of composites in the UK aerospace sector is widespread and longstanding.

It is also clear that composites is already a critical technology in driving change within the aerospace industry, while the aerospace sector is likely to be a major driver of future change in relation to the commercialisation of Additive Manufacturing processes over the next five years.

Potential Plastic Electronics applications identified within aerospace include flexible/lightweight passenger displays, embedding passenger controls in seat/cabin textiles and other weight saving applications and the use of embedded sensors, but it is not clear when any of these will be in full commercial use within the aerospace sector.

7.1.2 The use of technology within the Automotive sector

By comparison with the aerospace sector the use of composites within the general automotive sector in the UK remains relatively limited. This contrasts with what can be termed 'high end' automotive, where extensive use of composites occurs.

Similarly, within the automotive sector in the UK, the focus of Additive Manufacturing technologies is in relation to the manufacture of 'live parts' rather than prototypes or tooling associated with high-end motorsport, including Formula 1.

In relation to high-volume car manufacturing in the UK cost reduction is a key driver. Currently, the relatively high piece-price of Additive Manufacturing components is a major inhibitor of wider adoption in the sector, while in the case of composites, although the technology can provide cost reductions, the relatively high manufacturing capital plant costs act as a disincentive to wider adoption at the current time.

However, BMW have undertaken a major programme of investment in composites which could have significant ramifications for the future of automotive manufacturing.

Within the mainstream automotive sector in the UK, Additive Manufacturing is starting to play a major role in relation to a move from rapid prototyping to what is termed rapid manufacturing. Companies including Jaguar Land Rover (JLR), Bentley and Ford are all identified as interested in this. Additive Manufacturing technology is identified as playing a vital part in this continued growth, but alongside improvements in other technologies such as more rapid CNC machining.

Fully commercialised Plastic Electronics applications within the automotive sector is still some way off, although some of those interviewed expected commercial applications by 2020. The range of potential applications within the automotive sector that were identified by those consulted as part of the research, included use of flexible displays around the dash and console area, embedding of controls in textiles and interiors, seat sensor applications and exterior safety applications.

7.1.3 Scale of Additive Manufacturing, Composites and Plastic Electronics activity in the UK

Although growing rapidly, the scale of Additive Manufacturing activity in the UK is currently at a far lower level than composites. No reliable figures are available in relation to annual production revenue but it has been estimated that Additive Manufacturing research in the UK aerospace sector now totals about £13 million and within the automotive sector about £10 million.

The recent UK Composites Supply Chain Scoping Study indicates there are about 1,500 companies involved in the UK composites sector with annual production revenue of £1.6 billion and added value of £1.1 billion. Both the aerospace and to a lesser extent the automotive sector is a major contributor to both composite annual production revenue and added value.

The overall scale of Plastic Electronics activity in the UK is currently of a significantly lower order.

7.2 Workforce skill requirements

Occupations identified as being in demand within aerospace and automotive composite workforce include:

- Higher-level occupations/specialists including research and development staff (including Material Scientists and Engineers with specialist composite experience), Quality, Plant and Site Managers/Directors, Resource Planners and Business Directors;
- Engineering staff including Process, Plant, Production, Product, Project, Stress, Maintenance and CAD Engineers;
- Technical staff including Lab Technicians, CNC machinists and Non Destructive and Destructive Testing staff; and
- Operational staff including Fitters and Laminators.

The composite workforce within automotive OEMs is characterised by a relatively small core of very specialist and highly-qualified people, focussed predominantly on research and development.

Some aerospace OEMs by contrast have a much wider composite workforce base depending upon their business model and supply chain arrangements.

The workforce profile of those directly involved in the adoption and/or development of Additive Manufacturing technologies also differ significantly between aerospace and automotive firms.

Currently the Additive Manufacturing workforce within aerospace is relatively small and is focussed predominantly on research and development functions, with the need for a range of highly specialist, highly qualified staff representing different aspects of the value chain.

By contrast, the profile of those directly involved in the adoption and/or development of Additive Manufacturing technologies within the automotive sector is characterised by a high proportion of time served/recently qualified apprentices with CAD and rapid machine skills, operatives with ‘traditional’ engineering skills, assembly staff, quality staff associated with production quality issues and a small number of highly qualified engineering staff.

Although difficult to generalise across companies given the diversity of the Plastic Electronics sector, there appears to be a broad split between those engaged in:

- Research and Development activities, with a workforce comprising a substantial proportion of highly qualified Chemists, Physicists, Material Scientists, Electronic and other Engineers; and
- Process Development and pilot production activities where there tends to be a greater proportion of those with an engineering background together with industry experience often from the semiconductor, display or printing industries.

The Plastic Electronics workforce is typically highly qualified, at least in part linked to the large share of research and development staff, with a preponderance of those with PhDs.

All three sectors, composites, Additive Manufacturing and Plastic Electronics have certain common skill requirements, including a relatively high proportion of those with Material Science and Engineering backgrounds.

CAD and quality-related staff is also particularly prevalent in relation to both the Additive Manufacturing and composites workforce.

The Plastic Electronics, Aerospace Additive Manufacturing and Automotive composites workforce are also characterised by a very highly qualified workforce. This is not the case to the same extent within the Automotive Additive Manufacturing and Aerospace composites workforce.

7.3 Opportunities and threats

The aerospace sector is expected to be a major driver of higher-level and other skills demand in relation to both composites and Additive Manufacturing up to 2020.

Significant future growth in Additive Manufacturing and composites skill requirements is also expected in the 'high end' automotive sector, although this sector is relatively small compared with the general automotive sector.

With respect to the general automotive sector in the UK, the rate of adoption of composites is much less clear, with many fundamental questions around the feasibility for high-volume automotive manufacture unanswered at the current time.

The opportunities for significant employment growth through the adoption of Plastic Electronics technologies within the aerospace and automotive sectors up to 2020 is less certain, particularly with respect to aerospace.

Growth in employment in relation to all three technologies implies a changing shape in demand for skills. As Additive Manufacturing moves from prototyping and research and development through to full volume manufacturing there will be a need for more experienced production staff, Engineers that can support the automation of Additive Manufacturing processes and a major increase in demand for Design Engineers with Additive Manufacturing skills.

The increasing use of composites will create a demand for more R&D-related roles such as scientists and test engineers. The creation of new design options using composites will lead to an increased requirement for Design Engineers and people with higher level CAD skills. The move into new products and design using composites will also require Project Engineers at all levels and new business development managers. As processes become more automated it is expected that there will be a growing need for multi-skilled craft and technician level workers with both CNC and composite experience and Maintenance Engineers to keep plant running at optimum levels.

As Plastic Electronic technologies mature and are increasingly applied within commercial production, an increase in core Research and Development staff comprising highly qualified Chemists, Physicists, Material Scientists, Electronic and other Engineers is likely, but together with an increased proportion of those involved in process development and production, including Process and other Engineers, those with relevant industry experience within the semiconductor, display or printing industries and operative staff.

However, with respect to all three technologies skill shortages pose significant threats to future UK employment growth if not tackled

Wide-ranging recruitment difficulties are already reported in relation to recruitment of both composites and Additive Manufacturing staff.

In the case of composites, reported recruitment problems include higher level occupations/specialists such as Operational and Site Managers, Resource Planners and Research and Development staff with relevant industry experience; Engineering staff including those with experience in precision engineering and CAD Designers; technical staff including Quality related staff and CNC Machinists; and Operative level positions.

Recruitment issues within Additive Manufacturing include people with experience in Additive Manufacturing, Process Design Engineers, Project Management staff and CAD staff.

A number of Plastic Electronics companies are only able to source the skills required by relying heavily on recruitment of non UK graduates. Unless this issue is tackled more UK Plastic Electronics companies may decide to locate production overseas in order to undertake full volume production.

7.4 Training

Linked to differences in both the relative scale of composites, Additive Manufacturing and Plastic Electronics in the UK and the stage of development of each technology, the current education and training infrastructure serving the respective workforces relating to each technology differs widely.

- The research undertaken for this report indicates that composite training provision appears to have been driven largely by major aerospace OEMs and Tier 1 suppliers, together with some other major composite supply chain players. Notwithstanding this, there are a number of examples of major training initiatives serving the workforces of these employers. Despite these examples, however, training provision within the UK remains largely fragmented with respect to composites. In particular, it is clear that those companies that have successfully developed their own training programmes have the critical mass and resources to underpin the development of this provision and the influence to drive change within local training providers. For SMEs this is not possible and it is clear that major weaknesses remain in relation to access to appropriate composite provision for such employers and their respective employees.

- With a few notable exceptions there is a general lack of Additive Manufacturing training available. The training that is undertaken tends to be on the job and in house, with expertise currently 'locked up' with those employers, such as specialist Additive Manufacturing Bureaus, certain aerospace and automotive OEMs and Tier 1 manufacturers which have developed a significant expertise with this technology.
- Training undertaken by Plastic Electronics companies interviewed also tends to be mainly 'in house' combined with use of specialist conferences/events accessed via academic networks.

At a higher education level:

- A number of examples of initiatives that bring composite provision closer to industry needs were cited. However, overall it was commented that this was often not the case with provision within Universities;
- There appears to be potential scope for Additive Manufacturing modules within relevant degree courses and higher level Additive Manufacturing courses; and
- With respect to Plastic Electronics there is some support for Masters level provision, possibly on a modular level, but views on the need for specialised course provision at degree level amongst those interviewed was mixed.

With respect to Apprenticeships, Semta recently launched an Apprenticeship Framework for the composites workforce. Such frameworks do not currently exist with respect to both Additive Manufacturing and Plastic Electronics but there was some support expressed by those interviewed for the development of such frameworks.

7.5 Practical implications

The findings of the research imply a number of implications for practical action in relation to Additive Manufacturing, Composites and Plastic Electronics as set out below:

7.5.1 Additive Manufacturing

There was some support expressed for the development of an appropriate apprenticeship framework to support the Additive Manufacturing workforce. The feasibility and potential content of such a framework should be explored in detail.

A wide range of potential training needs were identified by those interviewed as part of this research. More work needs to be undertaken to test these training needs more rigorously, together with identification of the most appropriate delivery mechanisms.

Much of the development and expertise relating to training appears to be concentrated in specialist Additive Manufacturing Bureaus, selected OEMs and Tier 1 suppliers that have devoted significant resources to Additive Manufacturing research, certain academic institutions and centres of Additive Manufacturing expertise such as the Manufacturing Technology Centre in Coventry, TWI Technology Centre (Yorkshire) and Centre for additive Layer Manufacturing (CALM), Exeter. Appropriate mechanisms need to be established to try and share some of this knowledge more effectively to support the development of a more effective Additive Manufacturing training infrastructure in the UK.

7.5.2 Composites

There is a need to identify how best to address the barriers composite supply chain SMEs currently face in obtaining information on the requirements of UK based automotive and aerospace OEMs, in order to fully capitalise on procurement opportunities. This information would provide a useful basis for addressing any workforce up-skilling, further investment in capital equipment and other steps that might be required.

At present, although some mapping of the sector has been undertaken, very little is still known of the size and profile of the composite companies and the associated supply chain workforce in different localities. This means it is very difficult to assess training needs at a local level and start to address other supply chain support issues. This implies the need to map:

- Current composite workforce size and skills profile in different localities/regions;
- Composite supply chain skills capabilities in different localities/regions; and

- Existing composite training provision in different localities/regions.

This would provide a much sounder basis to identify gaps and weaknesses in provision at different levels together with strengths and weaknesses in relation to skills throughout the supply chain. By undertaking a systematic assessment of provision by geography linked to a workforce profiling exercise by geography, identification of clusters of provision and potential areas of consolidation would be possible, together with weaknesses in relation to geographical reach of current provision.

This research identified a number of approaches employers have taken to identify and address training requirements, tackle recruitment issues, up-skill and help retain existing employees. These responses appear to be quite isolated and in response to individual employer needs. Currently there does not appear to be an easy way that others can learn from these experiences of what has worked well in order to help them tackle their own particular training, recruitment and other workforce related issues. Mechanisms for enabling this to happen need to be put in place.

It is clear that while a number of major OEMs and other large employers within the composite supply chain have the resources and influence with local providers to ensure adequate workforce provision that meets their own needs is addressed, this is not the case for SMEs. Ways of enabling SMEs to collaborate in order to be in a position to influence the shape and access to local/regional composite training provision therefore need to be explored.

7.5.3 Plastic Electronics

There appears to be significant support for the development of an appropriate apprenticeship framework to support the Plastic Electronics sector. The feasibility and potential content of such a framework should be explored in detail.

It would be useful to build on existing evidence of international and UK Plastic Electronics training needs in order to develop a much clearer understanding of these needs across the UK. However, the limited size of the Plastic Electronics workforce at present might limit the scope for the development of bespoke provision, unless it cuts across other technology areas.

7.5.4 Cross cutting implications

At present very little is known of the size and profile of both the Additive Manufacturing and Plastic Electronics workforce in different localities, implying the need for a more systematic mapping of the this workforce in different regions.

Given the level of uncertainty of future workforce trends in relation to both the UK Plastic Electronics and Additive Manufacturing workforce the establishment of structured mechanisms to track workforce trends over time would provide a much clearer basis to try and identify emerging workforce related needs and potential areas of useful support.

In order to enhance the ongoing intelligence on the Additive Manufacturing, composites and Plastic Electronics workforce to inform practical intervention it would also be useful to:

- Set up procedures to monitor Additive Manufacturing, composites and Plastic Electronics related vacancies over time by role, skills and qualifications required and locality; and
- Establish intelligence to track trends in the Additive Manufacturing, composites and Plastic Electronics workforce over time.

This would provide a much clearer basis to try and identify emerging workforce related needs and potential areas of useful support.

Appendix A

Employers contributing to the Additive Manufacturing Case Studies

- **EADS** is a global leader in aerospace, defence and related services. In 2012, the Group – comprising Airbus, Astrium, Cassidian and Eurocopter – generated revenues of EUR 56.5 billion and employed a workforce of over 140,000. EADS has established a dedicated Additive Manufacturing team working in the Metallic Technologies research area at Innovation Works (IW), Filton, Bristol.
- **GKN Aerospace** is the leading Tier 1 manufacturer serving the aerospace industry globally in both aero engines and aero structures. The site at Filton, Bristol is a key facility in the company's global aero structures manufacturing and assembly operations. 1,200 of the total GKN Aerospace workforce of 12,000 globally are employed at the site making it one of the company's largest single manufacturing facilities. GKN is undertaking a major programme of investment and recruitment in AM in the UK and globally.
- **Ford UK** have utilised Additive Manufacturing to develop a range of parts including brake rotors, oil pan, differential carrier, exhaust manifolds and cast aluminium oil filtration adaptors and employ about 35 people within Rapid Product Development.
- **WCM** uses the latest manufacturing technologies (including Additive Manufacturing) combined with traditional engineering skills to provide a Rapid Manufacturing Service for Product Development including; Design, Rapid Prototyping, Metal Casting, Tooling and Low Volume Production, for metal and plastic products.
- **3TRPD** Ltd was established in 1999 and has become a leading provider of both plastic and metal Additive Manufacturing (AM) services throughout the UK and Europe.
- **LPW** offer a full range of services for industrial users of Additive Manufacturing, from application development through to machine maintenance. The company supplies high quality powders including Aluminium, Cobalt, Nickel, Steel, Titanium and Tungsten Carbide alloys.
- **First Surface** was formed in 2008 and opened for business in the UK in 2009. The company has licensed a unique deburring & super finishing technology called MMP Technology from the Swiss company BESTinCLASS and provides automated finishing services in relation to the use of both AM and other technologies.
- **Delcam UK** is a division of Delcam Plc, which state they are the world's leading developer and supplier of CADCAM software for 3 dimensional design, manufacture and inspection of complex shapes. Delcam products are used in a wide range of sectors including aerospace and automotive.

Appendix B

Employers contributing to the Composites Case Studies

- **Rolls-Royce** has been flying composite parts in aero engines for over 30 years. The composite workforce has grown significantly over the past decade. At the present time there are up to 100 people who are involved in work on composites
- **Bombardier Aerospace**, Belfast (Bombardier) is the largest manufacturing company in Ireland and with about 6,000 employees is one of the largest aerospace companies in the UK. Bombardier is also a recognised leader in the design, manufacture and certification of advanced composite components and Belfast has been developed as Bombardier's centre of excellence for composite technologies.
- **Aircelle Ltd** In Burnley is the U.K. operation of Aircelle, which is a subsidiary of the Safran high technology group that has activities in aerospace, defence and security. Aircelle is a part of Safran aircraft equipment branch, and is a global leader in the manufacture of engine nacelles and components. The company is a Tier 1 aerospace supplier and has a composite workforce of about 200 employees.
- **Jaguar Land Rover (JLR)** is a business that is built around two British car brands that are designed, engineered and manufactured in the UK. JLR employs over 16,000 people, predominantly in the UK. JLR currently employ 8 people whose roles and responsibilities relate exclusively to the composites area.
- **Gurit UK** is based on the Isle of Wight and is part of Gurit Holding AG, Wattwil/Switzerland, which specialises in the development and manufacture of advanced composite materials, tooling systems, structural engineering solutions, and select finished parts. Wind energy, marine and automotive are the key markets for Gurit in the UK:
  - Prepreg is one of Gurit's primary products for the Wind Energy sector that is an engineered material combining fibres and resin matrices in an easy-to-apply material. The materials used are aerospace-qualified suitable for a range of interior and structural applications;
  - Gurit's automotive composite parts production facility has been supplying leading OEMs with carbon fibre based Class-A composite panels since 2007. Gurit's award winning SPRINT™ CBS materials technology enables the production of Class-A carbon body panels directly from the tool, whilst utilising an out of auto-clave moulding process.

- **EPM Technology** was launched in 1996 as a high performance engineering business, typically undertaking Formula 1 assemblies, jigs and fixtures for a leading OEM, the design of impact structures and a developmental car project. A significant proportion of the company's activities relate to the manufacture of specialist composite components.
- **Custom Carbon** services the motorsport market, producing bike parts for both World and British superbikes. The company has also developed its own range of products and now also provides a product development service, which includes all stages of pattern, mould and prototype manufacture.
- Deeside College (now Coleg Cambria) in relation to the **Airbus Academy**

Appendix C

Employers contributing to the Plastic Electronics Case Studies

- **Plastic Logic** develops and manufactures ultra-thin, ultra-lightweight and high-quality plastic displays of various sizes and in both colour and monochrome. These are based on the development by Plastic Logic of plastic transistor technology that enables electronics to be manufactured on flexible or plastic sheets.
- **Printed Electronics Limited** (PEL) is focussed on integration, development and commercialisation of processes and systems for fabrication of electronic circuits, structures and devices using digital, additive and inkjet methods.
- **Epigem** is a polymer micro engineering company specialising in the development and manufacture of micro fluidic devices, micro optical components and printed electronics.
- **MFLEX Europe** has developed low cost, flexible printed display material using roll to roll screen printed techniques. The display is emissive – it shines light out – but also reflects light. One of the features is it is visible clearly in sunlight.
- **Smartkem** produce high-performance organic semiconductors enabling flexible, lightweight electronics.
- **Novalia** focus on the integration of creative design, traditional print and silicon microelectronics for use in products incorporating a mixture of sensors, displays, lights, speakers, printed batteries and communication devices, with the active device produced using a conventional printing press.
- **PragmatIC** have developed printed logic circuits that are applicable to any product requiring low cost, non-invasive electronic functionality. Electronics can be integrated on plastic, paper, card or metal surfaces, which may be curved or flexible.
- **Peratech** have developed a unique composite material, QTC™ Material, which exhibits significantly different electrical properties when compared with any other electrically conductive material and has applications across a wide range of sectors.

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