# Composites

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# 1 DEFINITIONS OF THE INDUSTRIAL TECHNOLOGY

## 1.1 Core and range of technologies

This paper is concerned with **Composite materials**, which represent a crosscutting technology, rather than a sector in itself. Composite materials (or composites for short) are engineering materials made from two or more components. One component (known as the 'reinforcement material') is often a strong fibre, such as fibreglass, quartz, kevlar or carbon fibre that gives the material its tensile strength. The other component (called a 'matrix') binds the fibres together.[1] Most commercially produced composites use a polymer matrix (e.g. polyester, vinyl ester, epoxy, phenolic, polyimide, polyamide, polypropylene, etc.)

The two or more constituent materials that make up a composite have significantly different physical or chemical **properties**, which remain separate and distinct on a macroscopic level within the finished structure. However, the synergies when combined produce material properties unavailable from the individual constituent materials and the designer can choose an optimum combination of materials for their particular needs. Often, the materials have excellent strength to weight properties that enable lightweight, durable, low maintenance, strong structures.[2] Carbon composites, for example, are up to 3 times stronger and 4 times lighter than steel and therefore have widespread applications in many sectors as alternatives to metallics, concrete and lower tech composite materials. [3]

The Composite Materials Report currently being drafted by the Task and Finish Group (consisting of representatives of the RDAs, BIS and the TSB)[4] focuses on *advanced* carbon and carbon-metallic composite materials, rather than older, lower technology, less dynamic materials, such as Glass Reinforced Plastic (GRP) or reinforced concrete. This paper similarly focuses predominantly on advanced 'engineered' composite materials.

**Engineered composites** are combined, compacted and processed, before undergoing a melding event. Depending upon the nature of the matrix material, this melding event can occur in various ways, such as:

- A curing reaction, using additional heat or chemical reactivity (e.g. for thermoset polymeric matrix material)
- Solidification from a melted state (e.g. for thermoplastic polymeric matrix material)
- Fusing at high pressure and temperature (e.g. for metal matrix material)

A variety of **molding techniques** can then be used to set the shape of the composite material, depending on the requirements of the end-use material and the matrix and reinforcement materials being used. The technology used can impact upon the final ratio of matrix to reinforcement material, which in turn can affect the strength and other properties of the final product. Molding methods include:

- Vacuum bag molding (using a vacuum on one half of the mold)
- Pressure bag molding (using inflation pressure on one half of the mold)
- Autoclave molding (using vacuum and an autoclave)
- Resin transfer molding (reinforcement material is added after the mold is closed)

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[1] BERR composites website

[2] BIS Advanced manufacturing website

[3] Task and Finish Group Report: Composite Materials (September 2009)

[4] Task and Finish Group Report: Composite Materials (September 2009)

- Other techniques (including press, transfer and pultrusion moldings, filament winding, casting, etc.)

The gross quantity of material to be produced is also an important factor in the technology used. Large quantity production can often justify the high capital expenditures required for rapid automated manufacturing technologies, whilst small quantities will result in lower capital expenditures, but higher labour/tooling costs and a slower rate of production.

Composites can be ‘structural’ or ‘non-structural’. Structural composites are load bearing, whereas non-structural composites (and to a large extent semi-structural composites) are not intended to carry a load in use (and are therefore used in such products as doors, windows, furniture and automotive interior parts). Both types of composites use similar materials and production technologies, however non-structural composites are often lower in cost than structural composites.

## 1.2 Applications

Typical **applications for engineered composites** are characterised by two requirements:

1. The need for minimum material usage, because of high material costs and weight constraints, and
2. The need for safe predictable performance within a demanding service environment[5]

Composites are increasingly being used in applications where there is a demand for materials that are low-weight and high-strength[6] with a need for resistance against corrosion. For example, composite materials have gained popularity in high-performance products such as aerospace components (tails, wings, fuselages, propellers), boat and scull hulls, bicycle frames and racing car bodies. Other uses for composite materials include fishing rods and storage tanks, plus launch vehicles and spacecraft (solar panel substrates, antenna reflectors and yokes of spacecraft, plus payload adapters, inter-stage structures and heat shields of launch vehicles). They are also increasingly used in the construction, oil and gas, sporting goods and medical sectors.[7]

It is also important to note that developments in lightweight structural materials will also help to meet the objectives of a low carbon economy and environmental legislation through the production and use of energy efficient and environmentally friendly materials and components[8]. Environmental considerations are likely to increasingly sit alongside weight / performance issues as drivers for the use of composite materials. Composite materials also come in different ‘grades’ of quality, with different attributes and slightly different costs for these different grades. The safety / tolerance requirements on composites used in the manufacture of planes, for example, are likely to be higher than those for wind turbine blades.

The National Composites Network identifies a number of **broad sectors of the economy** where composites technology is most relevant (in terms of end-use / application). It’s 2007 Foresight Report[9] focused on the following generic sectors, which it considers to be the major industrial sectors that together comprise the composites industry (in the UK):

[5] MERL composites website

[6] BERR composites website

[7] BIS Advanced Manufacturing website

[8] Succeeding through innovation, Second Call of the Technology Programme - Advanced Composite Materials and Structures (DTI, 2004)

[9] Foresight Report 2007 - National Composites Network, IOM3/NCN Foresighting Working Group

- Defence and aerospace
- Rail
- Automotive
- Chemical and process plant
- Construction
- Marine

Composite materials are expensive and largely restricted (at present) to the more advanced applications within these sectors[10]. As such, the composite industry is very much focused on niche products, high added value components, and one-off structures and not on volume production of stock parts (perhaps with the exception of pipes and pultrusions).[11]

Some other sectors that could claim to be major components of the composite industry worldwide were not included explicitly within the foresight report, as they were assumed to be included within those areas already covered (e.g. off-shore uses within the marine sector and wind energy applications within the construction sector). Nevertheless, the renewable energy sector, and in particular wind turbines are an important current and future market for composite technology.

[10] Task and Finish Group Report: Composite Materials (September 2009)

[11] Foresight Report 2007 - National Composites Network, IOM3/NCN Foresighting Working Group

# 2 UK CENTRES OF EXPERTISE AND EXCELLENCE

## 2.1 Science and technologies

A significant amount of composites R&D is being funded within UK universities.

Total **UK University research funding** for the broad area of *materials* research (which includes composites research) is over £95 million per annum. This includes approximately £60 million from EPSRC, £7 million from other UK Research Councils and the remainder from other sources (industry, the EU, etc.)[12]. Materials research projects are funded across all UK HEIs. However, in practice most research grants are held in a relatively small number of institutions. For example, between 2002 and 2007, five institutions each received in excess of £30 million of research grants from the EPSRC Materials Programme (the Universities of Cambridge, Oxford, Sheffield and Manchester, plus Imperial College London) and together accounted for half of total funding during this period.[13]

The EPSRC 'structural polymers, composites and polymers' sub-programme of the EPSRC Materials Programme accounts for approximately £12 million of funding per annum[14] and EPSRC have identified £29.6 million of specifically *composites*-related research funding that it has awarded over the last five years (plus a recent award of £7 million for a composites Doctoral Training Centre at the University of Bristol) [15]. In addition, the TSB allocated around £10m to fund research and development in the area of Sustainable Materials and Products, including composites, in its November 2008 competition for funding[16].

The NCN has undertaken work to identify UK Universities that have currently / recently been engaged specifically in composites research funded by either the EPSRC or the TSB[17] and has identified 38 Universities involved in relevant projects, accounting for approximately £54 million in funding. A full list of these universities is shown in Annex 1, along with funding details. As with materials research funding overall, *composites* research grants are given to a large number of universities, yet most of the funds are held within a relatively small number of institutions. The table below lists the major recipients during this period (those in receipt of at least £2 million of composite research funding) with relevant departments and total funding indicated. Cranfield University heads the table, with £17.4 million in project funding, which includes a £9.8m grant for the Cranfield Innovative Manufacturing Centre. The University of Sheffield figure (the second largest) includes a £6.4m grant for the Advanced Ceramics, Polymers and Composites Project.

[12] Advanced Materials – Key Technology Area 2008-20011 (Technology Strategy Board, 2008)

[13] Advanced Materials – Key Technology Area 2008-20011 (Technology Strategy Board, 2008)

[14] Advanced Materials – Key Technology Area 2008-20011 (Technology Strategy Board, 2008)

[15] Task and Finish Group Report: Composite Materials (September 2009)

[16] Sustainable Materials and Products - Competition for Funding (TSB, Nov 2008)

[17] NCN website – research in the UK

**Table 2.1 Recent EPSRC/TSB Funding for Composites Research**

| Funding | University | Department / School |
|---|---|---|
| £17.4m | Cranfield University | Applied sciences / engineering / defence college of management and technology |
| £7.4m | University of Sheffield | Civil and structural engineering / engineering materials |
| £4.7m | University of Nottingham | Electrical and electronic engineering / civil engineering / mechanics, materials, manufacture engineering & management |
| £3.3m | Imperial College London | Composites centre / aeronautics / chemical engineering & chemical technology / chemistry / civil and environmental engineering / materials / mechanical engineering |
| £3.2m | University of Manchester | Composites centre / materials / mechanical aerospace and civil engineering / physics and astronomy |
| £2.6m | University of Bristol | Aerospace engineering / chemistry |
| £2.0m | University of Cambridge | Engineering / materials science and metallurgy / surgery |

*Constructed using data available from the NCN website*

The NCN investigation into recent public funding also identifies 72 **non-academic organisations** engaged in current / recent EPSRC/TSB-funded composite research in the UK (with each involved in 1 or 2 projects). These organisations are listed separately within Annex 2, by region and a summary of the business-university collaborations undertaken within TSB-funded composites research is given in the table in Annex 3.

Industry also conducts a significant amount of R&D without public support. Big businesses have been investing in composites for some time and there has been considerable technological advancement in companies such as BAE, Boeing and Airbus, among others relating to composite materials. As a recent example, **Rolls-Royce** announced in 2008 that it was establishing a joint venture company with **GKN Aerospace** to carry out research and development into the use of composite materials in aero engine fan blades, building on the development of composite blade applications undertaken during the EU-funded VITAL programme. Funding for research and development was expected to be approximately £11 million, split between Rolls Royce and GKN.

The T&FG report identifies *private* sector investment in composites totalling £856 million over the past 5 years[18], with the majority of this investment identified in the North West and South West of England (£300+ million in each case). Some of the main areas of industry investment are highlighted in the following section on commercialisation.

## 2.2 Commercialisation

There are a number of existing and developing partnerships between academia and industrial players and the recently established National Composites Network (NCN) Centres of Excellence are taking further steps in bringing together Universities and Businesses to provide resources to the wider composite industry.

The National Composites Network (NCN) is a unique Knowledge Transfer Network jointly funded by government and industry that embraces the entire UK Composites industry and its supply chain. It has recently established five **Regional Centres of Excellence**, where the composite industry can access technical resources, obtain hands-on support and expert advice. To complement their own specialised resources, each Centre also has strong links with key research facilities at universities and with leading research and technology

[18] In addition to £1,966 million match funding for UK Government loans for the design, development and build of composite wings for civil aerospace

organisations and industry. The intention is to grow this cluster of centres from existing UK capabilities and focus future infrastructure investment on capability gaps defined by industry[19]. Each of the Centres is described briefly below:

**Table 2.2 NCN Centres of Excellence**

| Centre | Overview |
|---|---|
| **Airbus** Composite Structures Development Centre (CSDC)<br><br>(Filton, Bristol – South West) | A 6,000 square metre facility based at Airbus and the **University of Bristol** that forms the hub of a regional alliance of companies, universities and colleges in the South West. The Centre provides world-class capability in the field of composites technology and focuses its activity around technology development, including low-cost technologies for wider structural applications of composite materials (e.g. large aerostructures). The facilities are available for 3rd party use and have been used by marine, automotive and other aerospace companies.[20]<br><br>SWRDA is investing over £3.3m in equipment within the Centre with the aim of forging links between industry and academia and build on the strengths in composites across a number of Universities and HE colleges across the region, including Bristol, Bath, Exeter, Plymouth and UWE, as well as City of Bristol, Filton and Yeovil Colleges.<br><br>This group of Universities are also part of the **Coral Reef** (the Composites Research Alliance Regional Engineering Facilities) project, which was established to provide state of the art facilities to support research on manufacturing and development of composite structures. Their main facilities are at the Airbus CSDC, with additional equipment at the University of Bristol. |
| **GKN Aerospace** Composites Research Centre<br><br>(Cowes, Isle of Wight – South East) | The focus of the Centre's activity is technology development in automated manufacture of complex composite parts for high performance sub-assemblies. At the heart of the Centre lies an MTorres automated tape layer for high speed deposition of 300mm wide tape, capable of producing carbon fibre composite components up to 14m long x 1.5m wide. The research facility has the very latest testing and analysis equipment to support development of innovative composite materials and structures, along with high efficiency manufacturing techniques. |
| NDT Validation Centre<br><br>(Port Talbot, South Wales) | An independent organisation that assesses the accuracy and consistency of non-destructive testing (NDT) methods used in the manufacturing and construction industries. There is a focus on composite materials, but the validation process is equally applicable to all other engineering materials, and the Centre has considerable knowledge and experience of the inspection of many materials and components. The NDT Validation Centre is run by **TWI Ltd** with academic partners - the Faculty of Applied Design and Engineering at Swansea Institute of Higher Education, and University of Wales Swansea. |

[19] NCN website

[20] Task and Finish Group Report: Composite Materials (September 2009)

| Centre | Overview |
|---|---|
| Northwest Composites Centre (NWCC) (University of Manchester – North West) | A joint venture between the **Universities of Bolton, Lancaster, Liverpool and Manchester**. The Centre draws together and enhances the region's scientific expertise, supporting, evaluating and introducing innovation in composites manufacture and design to the benefit of industry. One key focus of the Centre is 3-D fibre structures and its activities include applied research for the development of new, cost-effective, low energy, low cycle time composite processing routes and establishing their effect on composite structure and performance to optimise fitness-for-purpose. The Centre also has capabilities in validation and certification. |
| The **University of Sheffield** Advanced Manufacturing Research Centre (AMRC) with **Boeing** Composite Centre (Rotherham, Yorkshire & Humberside) | Formed in 2006 (with £2.1m NWDA funding[21]), this is a successful collaboration between the University of Sheffield and Boeing. The Composite Centre is a research, design, manufacturing and technology transfer facility for composites with applications in advanced manufacturing, hybrid structures and aerospace. It is a state-of-the-art research organisation for advanced composite manufacturing and development of hybrid structures. The Composite Centre manages development contracts with partner organisations, focusing on market-facing, application specific research that can be transferred into industry with maximum impact.<br><br>The T&FG Report[22] states that the AMRC Composites Centre is "probably the largest non-private composites technology facility of its kind in the country. The centre has access to the latest in composite manufacturing technology as well as industrial-sized processing equipment capable of producing large scale aerospace components."<br><br>The AMRC has grown considerably since it was established and now has partners developing new manufacturing technologies that enhance the competitiveness of British industry across a broad spectrum of sectors – not only aerospace, but also marine, automotive and medical. [23] The AMRC opened both the new Factory of the Future building (AMRC2) and its new Composites Centre building (AMRC1) in the autumn of 2008. A new 'AMRC3' building is currently being planned, which will eventually house an enlarged Composites Centre plus focus on Teaching Factory efforts. The current AMRC1 building will then focus entirely on structural testing.<br><br>The AMRC is located within the Advanced Manufacturing Park, which is also home to a number of other high technology manufacturing and research companies, including **Rolls-Royce, Cti, TWI and Dormer Tools** (including it's Composite Competence Centre). |

The Airbus CSDC Centre of Excellence (discussed in the table above) forms part of the **Advanced Composite Centre for Innovation and Sciences (ACCIS),** based at the University of Bristol. This is an important regional and national centre for composites R&D, and it is worth examining in more detail briefly.

ACCIS was established in 2007 and brings together composites research (and 40 academic staff) from across the university (engineering, science, medicine, etc). It also acts as a focus for collaboration between academia and industry. **Airbus** is one of the main industrial sponsors of research work at ACCIS, both through the CSDC and through other initiatives, such as the Bristol-Bath Collaboration on Composites (B2C2), where it supports eight joint PhD studentships. However, other organisations are also involved in the Centre, for example:

[21] Task and Finish Group Report: Composite Materials (September 2009)

[22] Task and Finish Group Report: Composite Materials (September 2009)

[23] Boeing Website

- In 2007 **Rolls Royce** opened a new University Technology Centre (UTC) in Composites at the University of Bristol to further develop composites technology for future products across its aerospace, marine and energy markets. The research at UTC aims to provide a validated analysis capability for the mechanical response of composites that can be used in the design of these components. It forms part of the University's ACCIS and acts as a focus point for composites research activity
- The Systems division of **GE Aviation** established SMARTCOMP, a University Technology Strategic Partnership, with the Universities of Bristol and Oxford, with ACCIS providing the academic lead. Set up with an investment of £1.25 million, SMARTCOMP focuses on low cost and 3D composites for propellers and aerostructures (3-5 year horizon) and self-actuating composites (5-10 year horizon)
- In July 2009, ACCIS also announced a partnership with **Vestas Wind Systems** (international provider of wind power and services) to develop composites technology for future products. The partnership will expand Bristol's expertise beyond aerospace, to renewables. The Composites Centre is now part of the Vestas Innovation Network (a worldwide network of research partnerships including partners in the US, Singapore, China and Denmark). The Bristol-based partnership will act as a focus for composites research activities and will focus on three areas (manufacturing of blades, smart materials and lightweight structures).

Building work has started on a £5.4m extension for ACCIS (increasing laboratory and office space) – due to be completed in 2010. Bristol University was also recently awarded a £7m EPSRC grant for a composites Doctoral Training Centre[24].

In addition to the Centres of Excellence, the NCN identifies four **commercial research and technology centres/organisations** (MERL, NPL, QinetiQ and TWI) that are engaged in composite research and development in the UK. Each has strong links to industry and plays a key role in the commercialisation of composites research and development. A brief description of each centre/organisation is provided below.

MERL (Hitchin, Hertfordshire) - is an independent UK company founded in 1986 by a group of polymer scientists and engineers, providing R&D, laboratory testing and consultancy services on polymer materials for engineering systems and structures. It currently employs 27 staff (of whom approximately two thirds have degrees or higher degrees) and has a client base of several hundred companies worldwide covering all industry sectors. The company's expertise is in engineering polymers (including polymer composites) and various materials research programmes are performed using these materials. Materials knowledge combined with engineering know-how is used to solve problems through the supply chain from materials selection to design and manufacture to recycling and end-of-life considerations. Materials research facilities are available for composites conditioning, exposure, mechanical testing, chemical analysis, modelling and failure analysis, and an integrated approach is offered whereby detailed knowledge of the materials, process methods and design analysis can be brought together. MERL has also been developing methods for the life prediction of composite materials for engineering applications.

The National Physical Laboratory (Teddington, Middlesex) - is a science and research facility and the UK's National Measurement Institute. Its composites research is primarily aimed at increasing confidence in the use of composites by industry by improving the understanding of the material behaviour and performance through the full life cycle. NPL offers expertise in adhesives, polymers and composites, from design and materials characterisation to performance testing and failure analysis. It also offers tailored polymer and composite testing and measurement solutions, plus technical advice on national and international standards. Its composite design analysis software is also used in aerospace, automotive and construction industries to assist in preliminary design of material synthesis.

[24] Task and Finish Group Report: Composite Materials (September 2009)

QinetiQ (Farnborough, Hampshire) - is an international provider of technology-based services and solutions to the defence, security and related markets. It develops and delivers services for government organisations, predominantly in the UK and US, including defence departments, intelligence services and security agencies. It also provides technology insertion and consultancy services to commercial and industrial customers. QinetiQ has a fully automated facility for production of through-thickness reinforced dry fibre preforms using robotic stitching and tufting techniques. The facility is based around industry standard equipment making it equally suitable for both development and production. It is just one of a handful of such facilities in the world.

TWI (Cambridge, Cambridgeshire) - TWI is an independent research and technology organisation, with several offices around the world (including South Wales, where it runs the NDT Validation Centre of Excellence). The company works across all industry sectors and has expertise in all aspects of materials joining and related technologies. TWI's Composites Team has the knowledge and facilities to provide technical support at all stages of manufacture: from design, materials selection, production and quality assurance, to in-service performance and repair. It is "one of the largest RTOs with expertise in polymer science and other composite disciplines"[25] and its expertise extends to: polymer science, surface modification, curing techniques; mechanical & environmental testing; joining & lifetime assessments; and structural integrity & failure analysis.

## 2.3 International and national standing

The UK has a world-class science base in advanced materials, which is ranked fourth in the world behind the USA, Japan and Germany, in terms of total numbers of papers and citations[26].

Specific information on the international standing of Universities in *composites* research is not available. However, the Research Assessment Exercise (RAE) 2008 results for the 38 Universities in receipt of EPSRC/TSB composite funding (identified above) suggest high, international quality research activity across a large number of Universities in the areas most likely to include composites research activity.

The quality of the 38 Universities identified by NCN as in receipt of EPSRC/TSB composite research funding have been specifically looked at in more detail using RAE 2008 results for the three most relevant UoA:

- Civil Engineering (CE)
- Mechanical, Aeronautical and Manufacturing Engineering (MAME)
- Metallurgy and Materials (MM)

The proportion of submissions where quality is judged as 3* (internationally excellent) or 4* (world-leading) have been calculated and institutions ranked according to the percentages.

Full details of the results of this analysis are provided in the table in Annex 1, however it is worth noting that in ten of the *English* Universities, at least three-quarters (75%) of submissions to one of the three relevant UoA were classed as internationally excellent or world-leading. These 'high-scoring' Universities are shown in the table below, with their scores and rankings shown. It is worth noting that the three English Universities centrally involved in the NCN Centres of Excellence (Bristol – CSDC, Manchester – NWCC, and Sheffield – AMRC) all appear within the table.

[25] Task and Finish Group Report: Composite Materials (September 2009)

[26] Advanced Materials – Key Technology Area 2008-20011 (Technology Strategy Board, 2008)

**Table 2.3 RAE 2008 Assessments and Rankings for 'High-Scoring' English Universities**

| Institution | Civil Engineering | | Mechanical, Aeronautical & Manu Engineering | | Metallurgy & Materials | |
|---|---|---|---|---|---|---|
| | % | Rank (of 23) | % | Rank (of 33) | % | Rank (of 20) |
| Imperial College London | 95 | 1 | 80 | 1 | 55 | 9 |
| University of Birmingham | 65 | 12 | 70 | 7 | 75 | 5 |
| University of Bristol | 80 | 8 | 80 | 1 | - | - |
| University of Cambridge | - | - | - | - | 95 | 1 |
| University of Manchester | - | - | - | - | 80 | 2 |
| University of Newcastle | 90 | 3 | 65 | 11 | - | - |
| University of Nottingham | 85 | 5 | 75 | 4 | - | - |
| University of Oxford | - | - | - | - | 80 | 2 |
| University of Sheffield | 85 | 5 | 75 | 4 | 65 | 7 |
| University of Southampton | 80 | 8 | 60 | 14 | - | - |

*Constructed using data available from the NCN website and RAE 2008 results. Blank fields indicate where universities were not assessed against one of the three UoA.*

# 3 THE VALUE CHAIN

## 3.1 Application, products and markets

The **global composites market** has been growing steadily over the past decade. Estimates of the current size of the industry vary considerably, but suggest that the current market size is somewhere between £12 billion [27] and £53 billion[28] (or an average estimate of £33 billion). Composites have important applications in a range of sectors, particularly in transport (aerospace, rail, automotive, marine), but also in areas of construction and renewable energy production.

An overview of each of the main sectors associated with composite material products is provided below. Some of the main products and applications within each sector are discussed, along with any available information on current market size. Much of the material in this section is based on the analysis undertaken for the NCN Foresight Report[29], along with other sources of information.

<u>The Defence and Aerospace sector</u> - Defence and Aerospace represents a broad and important sector of the composite market, which may be simplistically differentiated from other sectors in that performance has traditionally been a higher priority than cost. Certainly this has been true in the defence sector (more so for aerospace than ground and naval defence sectors), while civil aerospace has always maintained a greater interest in costs for commercial reasons. The type of composites used by aerospace and land / sea defence military users also differs. Aerospace applications make lightweight a priority and carbon fibre based materials predominate, whereas in land / sea applications glass fibre composites are more prevalent. The pressures on the military and civil aerospace composite sector are similar, although not identical, with the scale of the structures involved being one major difference. Manufacturing processes that are utilised for military applications may become uneconomic or simply unfeasible when considered for civil use.

The use of composites within the Aerospace industry has already seen steady increases and composite technology has become a key feature of modern aircraft design (structures, engines and other components). Airbus for example has increased the composite content of its airliners from less than 5% in the A300-600 20 years ago, to 15% in the A320 in the 1990s, while its next generation aircraft, the A380, has nearer 25% composite material.[30] The advent of the A380 has also increased demand and demonstrated a number of new structural applications. The aerospace composites market was valued at £4.09 billion in 2006[31], therefore accounting for 13% of the global composites market (based on the average estimate above) and it is estimated to have consumed 21% of global carbon fibre production in 2007, making it by far the largest user of the highest specification fibre.[32]

<u>The Rail Transport sector</u> - The rail vehicle manufacturing industry is dominated by a number of large, multinational systems integrators who operate manufacturing / assembly facilities in a number of countries (who may in turn subcontract elements of the manufacturing to other suppliers). Currently no single primary material dominates rail vehicle construction, although aluminium steel and stainless steel are prevalent. A given manufacturing plant will normally specialise in just one material, with the choice of which

[27] Global Composites Market 2009-2014: Opportunities, Markets and Technologies (Lucintel, July 2009)

[28] Advanced Manufacturing Package (BIS, July 2009)

[29] Foresight Report 2007 - National Composites Network, IOM3/NCN Foresighting Working Group

[30] A strategy for materials (Materials Innovation and Growth Team, DTI, March 2006)

[31] UKTI website

[32] Task and Finish Group Report: Composite Materials (September 2009)

country to select for a specialisation being based on availability of staff, strong local support network (suppliers, testing facilities, research and technology organisations and universities with relevant expertise) and possibly cost. There is not a known 'composites specialist' currently.

Beyond rail vehicles, composite materials have a range of applications relating to the rail industry. For example, composites are currently being used to strengthen the lining of tunnels of the London Underground and for replacing large steel structures.

The Automotive sector - From the standpoint of composite materials, the automotive industry is not a single sector, but consists of mass production vehicles, niche vehicles, trucks and buses, all of which have different characteristics and needs:

1. The *mass production industry* is a big user of composite materials, but these tend to be short glass fibre reinforced thermoplastics for non- or semi-structural parts (dashboards, covers, radiator parts etc.), which are compatible with the production volumes required by this sector. Currently, the only structural form of composite that is compatible in materials properties, cost and manufacturing speed, with volume production is sheet moulding compound (SMC), which has a long history with the industry and is well established. Resin transfer moulding is another process that is beginning to feature strongly in the automotive sector for the production of medium volume parts, often being used in combination with SMC.

2. The *niche vehicles sector* is more likely to utilise larger volumes of composites (per unit) as the production volumes are more compatible with composite processing methods and there is a greater benefit to be gained from exploiting the properties of composites (styling, weight, corrosion resistance, stiffness, crash worthiness, etc). As the value of the vehicle increases, the likelihood of increased usage of carbon fibre as opposed to glass also increases, while applications are also more likely to include fully integrated composite structures reaching the complete carbon fibre chassis adopted by all Formula 1 teams. In the motorsport sector, which as a whole is worth £5 billion[33], all cars use some carbon fibre.

3. *Trucks* are larger and produced in smaller volumes than passenger cars, resulting in a significant uptake of composites for large panel components (e.g. truck cabs and radiator grills made from glass fibre RTM or SMC), although the choice of materials selected is dependent on the relative costs of steel and composites at the time of design. Given the size of vehicles in this category, the total quantity of composites in any one vehicle can be quite high. For example, the Ford Aeromax 9500 truck cab contains a total of 240kg of composites in its door panels, bonnet, roof and bumper. Trailers for large trucks also represent an emerging large market for composites with resin infusion of glass fibre thermoset now being seriously considered for the trailer beds and the wall panels.

4. In the *bus sector*, composites are widely used for interior panels. The large size of buses means that when chassis and bodywork are being produced from composites, then a variant of vacuum infusion is the most common manufacturing process.

The Process Plant sector - Process plant composites technology can be considered in three categories: *(i) Tanks and silos* – An alternative approach to "clean" processing may be achieved by adopting thermoplastic composites for tank and pipe manufacture. These are extensibly used where the structural requirements are minimal, and have a good service record for resisting aggressive environments; (ii) *Pipes* – Already constitute a large Fibre Reinforced Plastic (FRP) market, but the penetration of composite materials within the pipe sector as a whole still remains very low (est. 2%); and (iii) *Pumps, filters and other ancillary items* – This is a diverse category with many different requirements. However, the

[33] Task and Finish Group Report: Composite Materials (September 2009)

majority of needs are considered to be adequately catered for with existing materials and technologies (as such, the sector was not considered further by the foresight report).

The Construction sector - Applications range from structural to non-structural components for everything from new dwellings to bridges, towers, office blocks, railway and airport infrastructure and general urban furniture. Composites provide some obvious advantages to the construction sector. Load bearing structures can be relatively lightweight, the materials do not suffer from electrochemical corrosion, and manufacturing processes are sufficiently flexible to allow novel architectural features to be developed and traditional materials to be simulated. Another major attraction of composite materials in the current industrial climate is that they enable architects and engineers the ability to incorporate energy saving ideas, novel sensing technology and recycled materials while facilitating off-site prefabrication and reducing transportation costs and build times.

As such, the construction industry is already a major market for composite materials. Figures presented in 2001 by NPL / Netcomposites estimated that the sector represented 11% of the total UK composite market. More recent 2004 figures put the percentage of thermoset glass fibre composites used in the construction industry at 25% of the total European market. The current European market for composites in the construction industry is estimated to be approximately £1.6 billion.[34]

The Marine sector - The Marine industry covers a number of different diverse businesses (leisure industry, performance boats, work boats, military, oil and gas, etc.), but all use (to a greater or lesser extent) the same materials and processes used across all other industrial sectors. In the majority of cases, the volume of finished goods restricts the use of automated "mass production" processes. In the majority of the businesses, the sold product also includes the installation of equipment etc. The higher up the scale of product in terms of size, performance and complexity, the less becomes the percentage value of the composite element. Within the UK, there are a number of recognised 'large' users of composites, but there are also a considerable number of small companies. In some cases, the smaller companies offer a moulding service, which is not specific to the marine industry. This results in a broad range of companies, which apart from their common use of composite materials, is not a recognised 'body'. The marine defence industry (covered in defence and aerospace above) is increasingly making use of composites for such things as panels on submarines, frigates, warships etc.

According to 2004 market data (from NCN), the marine sector represents about 6.5% of the total tonnage of composite products, equivalent to some 400,000 tonnes of materials. Figures are not available for the UK, but it is thought that this would equate to a total tonnage of around 20,000 tonnes per annum. The leisure marine sector currently produces some £2.8 billion worth of composite structures, albeit the vast majority is GRP/lower technology materials. However, higher-tech carbon composites are increasingly being used in naval and specialist applications and for components such as masts.[35]

It is also worth specifically noting the 'renewable energy' sector (although it may be considered a part of marine or construction technology), where composite materials have a key role to play, especially with innovations in the technology driving the wind turbine industry. In 2008, Vestas alone produced 7,500 blades and used 50,000 tonnes of composite material (of all descriptions). The sector has seen a growth in installed capacity of 25% per annum since 1996, which is predicted to increase in the future.[36] Marine power also offers potential applications for composites in order to meet the strength and corrosion

[34] Based on expectation from Task and Finish Group Report: Composite Materials (September 2009) that the European construction market for composites is expected to reach £2 billion by 2013, having seen average annual growth of 6%.

[35] Task and Finish Group Report: Composite Materials (September 2009)

[36] Task and Finish Group Report: Composite Materials (September 2009)

requirements needed to deal with under-water conditions. The renewable energy sector is likely to be an important growth area for composites use in the future.

## 3.2 Drivers of demand

Asia emerged as the largest regional market in terms of composites shipment in 2008 replacing North America and is expected to maintain its leadership in the future, helped by the growing economies of China and India. However, the industry presently finds itself caught in the middle of the global economic crisis with recent dramatic changes in the market as a result. The global liquidity crunch, low consumer spending and low business confidence continues to affect economies across the world and a recent decline in the composites industry reflects that wider decline.

Construction, automotive and marine markets were particularly badly hit in 2008 due to recession in industrialised nations and the decline in several market segments is expected to have continued into 2009. However, composites shipments in wind energy, and pipe and tank continued to grow at a healthy rate and holds strong promise, albeit at lower rates, during 2009-2014. The economic situation will improve towards the end of 2009 but will take effect in 2010 as stimulus packages in major economies such as the US and China are expected to put the global economy once again into a growth trajectory. [37]

Despite the global economic downturn, new developments in the various key sectors mentioned above mean that the global composites market is expected to experience further substantial growth in the near future. Although at present composite materials are expensive and restricted to more advanced applications, as the cost falls (as some predict) their usage will increase significantly which will have a disruptive impact in all sectors and in all regions.[38] The shift from metal to composite materials will provide vast commercial opportunities and will have important applications in the automotive, marine, aerospace, wind and wave, construction, oil and gas, and medical equipment sectors. [39]

Composite materials, in particular those based on carbon fibres, are expected to be a key part of the next generation of aircraft, high performance boats, cars and larger wind turbine blades.[40] There is also clear evidence that the use of composites in transport applications and in renewable energy devices, particularly large wind turbines, is about to increase dramatically. [41] One available estimate suggests an annual growth rate in the global composites industry of 15% between 2010 and 2015[42], which - based on average 2009 global market estimates of £33 billion - would result in a global composites market of £75 billion by 2015. An alternative estimate by BIS suggests a broadly similar figure for the global composites market of £74 billion by 2013[43].

Specific drivers of demand within the main economic sectors of relevance to the composites industry are discussed individually below:

The Defence and Aerospace sector – In future applications for defence and aerospace there will be a move towards lighter and smaller systems for certain applications. Here advanced materials, including composites, can offer potential robust, weight efficient solutions.[44] The potential of composites to reduce the weight of aircraft and other defence

[37] Global Composites Market 2009-2014: Opportunities, Markets and Technologies (Lucintel, July 2009)

[38] Task and Finish Group Report: Composite Materials (September 2009)

[39] Building Britain's Future: New Industry, New Jobs (HM Government, April 2009)

[40] BIS Advanced manufacturing website

[41] Task and Finish Group Report: Composite Materials (September 2009)

[42] NINJ Strengths Document (Draft) (Yorkshire Forward, 2009)

[43] Advanced Manufacturing Package (BIS, July 2009)

[44] A strategy for materials (Materials Innovation and Growth Team, DTI, March 2006)

vehicles implies that these sectors will be a large and growing market for composite materials over coming years.[45]

The *Aerospace sector* in particular is set to increase its use of composites dramatically over the next few years. Higher fuel prices and tighter emission standards requiring weight reduction in new aircraft in particular are likely to further increase the demands for composites within the aerospace sector,[46] and we are likely to see an increasing shift from defence to civil aerospace applications.

There is continual investment in composites within the Aerospace sector and the industry will shortly see the fruits of the £4 billion of UK public and private sector investment (over the past 5 years) in composites when a new range of aircraft enter service with wings made almost entirely of composites.[47] The biggest boost will come from the Boeing B787 Dreamliner, which is now due to enter service at the end of 2010 and its rival the Airbus A350 which is scheduled for 2012, both of which will feature extensive use of composites (carbon fibre) in the wings and fuselage and will be the first major airliners to use composite materials for their construction.[48] The 787 'Dreamliner' is due to be the first commercial jet aircraft in which composite materials will make up most of the primary structure[49] and the A350 is expected to be close to 50% composites by weight.

The aerospace sector's consumption of global carbon fibre production is likely to grow quickly as the Boeing 787, Airbus 350 and Bombardier C-Series enter service,[50] and the demand for composites in the aerospace market could grow by more than 10% in the next five years with the introduction of several of these new aircraft containing high percentages of composites. Based on a projected global market for large civil aircraft over 100 seats, over the next 20 years of £1.6 trillion, Airbus and Rolls Royce have suggested that the export potential for wings and engines from the UK could be worth £80 billion and £380 billion respectively during that period. Similarly, the market for rotorcraft over the next decade is estimated to be 9,500 commercial craft, worth £29 billion and 6,500 military rotorcraft worth £85 billion.[51]

The UK has the world's 2nd largest aerospace industry, with sales of over £20 billion per annum (of which over half is exported). It accounts for 27% of the global engine market, 16% of the global wing market and 8% of the global outsourced aero-structures market.[52] The UK is also global leader in the development and production of advanced composite structures for aerospace applications.[53] The ability of the UK to excel in composites and move from metal to composite material will have a significant bearing on the future viability of UK aerospace and other industries[54]. As the use of composites in aerospace components and power systems increases, so a better understanding of physical behaviour and more advanced design and manufacturing methods will be required.

In relation to *land and sea defence*, the needs are complicated due to the very broad range of applications, from body armour to ship hulls, and the fact that composite attributes (low

[45] A strategy for materials (Materials Innovation and Growth Team, DTI, March 2006)

[46] UKTI website

[47] Task and Finish Group Report: Composite Materials (September 2009)

[48] Foresight Report 2007 - National Composites Network, IOM3/NCN Foresighting Working Group

[49] A strategy for materials (Materials Innovation and Growth Team, DTI, March 2006)

[50] Task and Finish Group Report: Composite Materials (September 2009)

[51] Task and Finish Group Report: Composite Materials (September 2009)

[52] Task and Finish Group Report: Composite Materials (September 2009)

[53] UKTI website

[54] BIS Advanced Manufacturing website

radar signature, blast resistance, lightweight, corrosion resistance, thermal insulation, fire protection, etc.) have different degrees of value in different contexts. The importance of the materials and the most relevant properties will depend to some extent on the profiles of the armed forces that emerge in the future. Composites may have a role to play in reducing total vehicle costs by facilitating integrated manufacture using low cost moulding processes. Improved reliability and reduced maintenance costs may have an increased importance in an era where defence budgets are under pressure and the capability is stretched.[55]

The Renewable energy sector - Renewable energy is set to play a major role in UK (and global) energy supply over the next 20 years, with the wind sector in particular an area of particularly rapid development. BTM Consult expect a 15% annual growth in installed wind turbines up to 2013, with larger blades increasingly using carbon composite materials[56]. It is estimated that the UK market for composite wind turbine blades alone will be worth in excess of £5bn. Vestas have been awarded TSB funding to look into the rapid manufacturing of turbine blades, which will be necessary if use of composites within this industry is to significantly increase.

The Rail Sector - The potential of composites to reduce weight, drive performance and reduce fuel requirements (plus produce significant reductions in CO2 emissions) means that transport will be a large and growing market for composite materials.[57] [58] To a certain extent this will include the rail sector. According to the NCN Foresight Report, UK interests in rail composites would be best served by creating the conditions in which the UK was the logical place to site a manufacturing / assembly plant specialised in composites. Given labour costs, the best advantage that the UK could offer is likely to come from the quality of the workforce and the quality of the design expertise. If the UK developed a capability for large scale textile performing, this might be an additional factor. This would suggest that education and training are critical as well as technology advances.[59]

The Automotive sector - The potential of composites to reduce weight, drive performance and reduce fuel requirements (plus produce significant reductions in CO2 emissions) means that the automotive sector will also be a large and growing market for composite materials[60] [61]. The New Automotive Innovation and Growth Team notes that the climate change agenda is accelerating technological change at an unprecedented rate, and the industry in Europe and the UK has embraced the CO2 challenge and is investing heavily in people and technology to provide innovative solutions.[62]

The niche and specialist vehicle arena is where there is the possibility of more extensive use of structural composites in the short term and where there is ample scope for innovations in materials, processing and design concepts. [63] However, the use of composites in the non-motorsport automotive sector is also set to grow significantly, driven

[55] Foresight Report 2007 - National Composites Network, IOM3/NCN Foresighting Working Group

[56] Task and Finish Group Report: Composite Materials (September 2009)

[57] A strategy for materials (Materials Innovation and Growth Team, DTI, March 2006)

[58] BIS Advanced Manufacturing website

[59] Foresight Report 2007 - National Composites Network, IOM3/NCN Foresighting Working Group

[60] A strategy for materials (Materials Innovation and Growth Team, DTI, March 2006)

[61] BIS Advanced Manufacturing website

[62] An independent report on the future of the automotive industry in the UK (NAIGT, May 2009)

[63] Foresight Report 2007 - National Composites Network, IOM3/NCN Foresighting Working Group

by the need for weight reduction[64]. Some estimates put the future composites market value at £10 billion. [65]

The need to reduce emissions and fuel consumption through a step change reduction in weight may mean a sudden shift from steel to light-weight manufacturing of vehicles in the future. However the relatively slow and labour intensive nature of current composites technologies prevents this sector from rapidly expanding its use of composite materials at the current time. Greater use of structural composites requires lower cost and / or greater manufacturing speed in order to be compatible with the production volumes required by the sector. If rapid manufacturing technologies for composites can be developed, the automotive sector offers considerable market potential for composites.

None of the large volume automotive producers currently operating within the UK are UK owned. Decisions on the selection and sourcing of composite parts will not necessarily be taken in the UK. The most relevant factors determining the health of the composites automotive component supply industry as far as the UK is concerned is to nurture strong component design capabilities, either within the laboratories of the prime auto companies based in the UK, or at supporting universities or RTO's and to link these design centres with UK component suppliers who are in a position to implement innovations quickly. The sector of the market where UK investment in research and innovation is likely to pay most dividends is in the niche and specialist vehicle arena.[66] The UK is already a global leader in the development and production of advanced composite structures for automotive applications.[67]

<u>The Chemical and process plant sector</u> - So far, only PP, PA, PET and high performance, aerospace-type thermoplastic composites, are in commercial use for tanks and silos, and development would be needed to extend the range to other potentially interesting materials, such as PVC and HDPE. Steel and concrete dominate the pipes sector, while the scope for thermoplastic pipes is limited by their performance under pressure and practical manufacturing constraints. Continuous filament winding of thermoplastic composite pipe, optionally with a co-extruded thermoplastic linter and / or outer covering, would enable larger diameter and higher rated pressure pipes to be manufactured economically, and so enable thermoplastics to challenge new sectors of the market. [68]

<u>The Construction sector</u> - The major obstacles for the continued expansion of the use of composites in this sector are the lack of design data coupled with inexperience and unfamiliarity with the materials from the construction sector as a whole. The construction industry is also notoriously conservative, extremely price sensitive and safety critical. In addition, the industry is very large, which could present logistical problems for the composite industry (i.e. demands exceeding supply). [69] However, the use of composites is likely to increase gradually within the industry. For example, the corrosion-resistant properties of composites are likely to result in the use of carbon fibre for suspension cables on bridges moving forward in order to extend the life of these structures.

The Network Group has identified a lack of data on the market for composites in the construction industry in the UK as an issue. However, in Europe, the market is expected to

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[64] Task and Finish Group Report: Composite Materials (September 2009)

[65] Foresight Report 2007 - National Composites Network, IOM3/NCN Foresighting Working Group

[66] Foresight Report 2007 - National Composites Network, IOM3/NCN Foresighting Working Group

[67] UKTI website

[68] Foresight Report 2007 - National Composites Network, IOM3/NCN Foresighting Working Group

[69] Foresight Report 2007 - National Composites Network, IOM3/NCN Foresighting Working Group

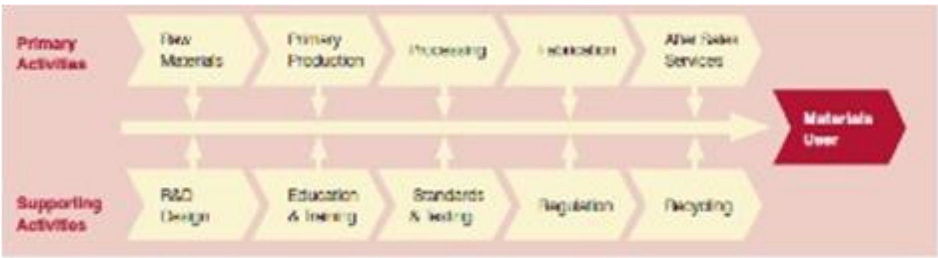
reach £1.9 billion by 2013, with an average annual growth of 6% - a picture that corresponds to global trends. [70]

The Marine sector - Composites are established in the traditional marine industries and, as with other transport sectors, the qualities of composites can drive performance and reduce fuel requirements, helping produce significant reductions in CO2 emissions.[71] However, areas of offshore use (ships, oil and gas, etc.) tend to use more traditional materials and, whilst the composite technology exists, the willingness from the project office to take on the risk is often less and hence stifles the use of the material. It is difficult to promote the use of composite against traditional materials unless there is a defined need to use them.[72] A consortium (Babcock Marine, Frazer Nash Consulting and Bristol University) are currently seeking funding for research into the use of carbon hulls on boats and improvements to their resistance to 'slamming' (i.e. during planning). The use of composites within marine-defence is likely to continue to increase and there is also the potential for composite materials to play an important role in the development of marine-based renewable energy.

### 3.3 The chain of inputs and outputs

The following figure shows a simplified value chain for the wider advanced materials sector.

**Figure 3.1 Advanced Materials Value Chain**




*Source: Technology Strategy Board*

Activity within the Composite industry is spread throughout the supply chain, as follows:

- **Inputs**: Reinforcement materials (fibreglass, quartz, Kevlar, carbon fibre, etc.) and Matrix materials (polyester, epoxy, polyamide, etc.). The chemicals and materials industries are important downstream providers of products for composite material production
- **Primary Production**: Melding (curing, solidification, fusing, etc.), requiring, for example, textile expertise to 'weave' composite materials
- **Intermediate output**: Composite materials (carbon composites, carbon-metallic composites, GRP, reinforced-concrete, metal-matrix composite, etc)
- **Processing and Fabrication**: Molding (Vacuum bag, Pressure bag, Autoclave, Resin transfer, etc.) and advanced manufacturing and engineering
- **Final products**: Defence and aerospace (tails, wings, fuselages, propellers, spacecraft), Rail (panels), Automotive (niche vehicle car bodies and chassis, mass market dashboards, covers and radiator parts, truck cabs, radiator grills, trailer beds and wall panels, bus interior panels, chassis and bodywork), Chemical and process plant (tanks, pipes, pumps, filters), Construction (dwellings, bridges, towers, office blocks, railway/airport infrastructure and urban furniture), and Marine (boat and scull hulls).

[70] Task and Finish Group Report: Composite Materials (September 2009)

[71] BIS Advanced Manufacturing website

[72] Foresight Report 2007 - National Composites Network, IOM3/NCN Foresighting Working Group

### 3.4 The position of UK producers

The UK does have a strong materials research base, which has led to breakthroughs in many areas. It therefore has strengths in high-end composites.[73] The NCN Foresight report notes, however, that while at the present time the UK has manufacturing capacity for glass fibres, thermosetting resins, intermediate products such as prepregs and fabrics, it does not have a significant capacity to manufacture carbon fibres. There are currently no UK suppliers of aerospace-quality raw materials, for example. Recent problems in the supply of carbon fibre have highlighted that this can pose problems with the country reliant on supply from external countries whose priorities are not always the same. [74] The Strategy for Materials similarly highlights that there is a growing demand for composite materials and in the UK there can be supply problems (e.g. there are limited supplies of materials such as carbon fibre).[75] Resin system development, fibre weaving expertise and machine tool expertise are all also outside of the UK.

Whilst there are many thousands of companies in the UK producing metallic or GRP products, there are thought to be only 100 or so companies across the UK currently of any significant size using carbon / high technology composites.[76]

**Key companies** operating in the UK composites sector are discussed below, with information (where available) on their market size, activities in relation to the composites value chain and applications relating to composites, wider supply chains and impact on the UK economy.

Boeing[77] - Boeing is a leading aerospace company and the largest manufacturer of commercial jetliners and military aircraft, with capabilities in rotorcraft, electronic and defence systems, missiles, satellites, launch vehicles and advanced information and communication systems.

The company has a long-standing relationship with British industry, the armed forces and the air transport industry dating back over 70 years and it currently employs some 650 people across the UK at numerous sites, from Almondbank near Perth to Gosport. Today the UK remains a critically important market, supplier base and a source of inventive technology partners, and its annual spend in the aerospace industry supports up to 40,000 jobs according to an Oxford Economic Forecasting report, in the process generating intellectual property, enhancing skills and facilitating exports.

In addition to its own local presence, Boeing has an extensive network of industrial and academic partners and suppliers across the UK. Through these relationships, Boeing is helping to create and sustain thousands of high-grade, high value jobs in the British aerospace industry and wider economy. Boeing's expenditure also stimulates new capital investment in the UK industrial base, which helps companies maintain their competitive edge. In 2005 Boeing (and its subsidiaries) spent £600 million in the UK (40% in the East Midlands) across more than 250 supplier sites. Boeing is ranked 32$^{nd}$ in the world in terms of R&D expenditure, with investment of £1.9 billion in 2007/8[78].

Boeing has used composites since the 1960s, but its 787 ‘Dreamliner’ (expected in 2010) is due to be the first commercial jet aircraft in which composite materials will make up most of

[73] UKTI website

[74] Foresight Report 2007 - National Composites Network, IOM3/NCN Foresighting Working Group

[75] A strategy for materials (Materials Innovation and Growth Team, DTI, March 2006)

[76] Task and Finish Group Report: Composite Materials (September 2009)

[77] Boeing Website

[78] The 2008 R&D Scoreboard (DIUS, January 2009)

the primary structure[79] The new Boeing 787 structure, including the wings and fuselage, is composed largely of composites.[80]

Since 2006, Boeing has been collaborating with the University of Sheffield AMRC in the Boeing Composite Centre, providing a research, design, manufacturing and technology transfer facility for composites with applications in advanced manufacturing, hybrid structures and aerospace. Boeing is working with the AMRC to develop advanced manufacturing technologies that will help reduce the cycle time and cost of producing aerospace products while improving their quality and performance.

Airbus[81] - Airbus is one of the world's leading aircraft manufacturers, and it consistently captures approximately half or more of all orders for airliners with more than 100 seats. The company has had a leading role in driving the aerospace industry's use of composites and its products are the largest end user of carbon composites in the UK[82]. It has increased the composite content of its airliners from less than 5% in the A300-600 20 years ago, to 15% in the A320 in the 1990s.

Its next generation aircraft will have nearer 50% composite material (by weight)[83] and for the first time in aircraft manufacture, the centre wing box – a crucial element of the primary structure connecting the wings to the fuselage – is also a primarily composite structure. The A350 XWB will also be a faster, more efficient and quieter aircraft as a result of its advanced wing design – which combines aerodynamic enhancements that have already been validated on the A380 with further improvements developed by Airbus engineers.[84]

Today, the Airbus sites at Filton, near Bristol, and Broughton, North Wales, are part of the Airbus Centre of Excellence 'Wing/Pylon' and around 140,000 jobs are generated in the UK by Airbus wing work, directly as well as indirectly through supplier contracts. The Filton site manages the design of all wings for the whole Airbus family of aircraft and the facility at Broughton assembles the wings for all Airbus aircraft. Wings are one of the UK's largest exports and Airbus designed and now assembles the A400M all-composite wing at Filton.

Airbus is ranked 8th in the UK in terms of R&D expenditure, with investment of £397 million in 2007/8[85]. It is one of the main industrial sponsors of research work at ACCIS, both through its involvement in the composite structures development centre (centre of excellence) and through other initiatives. The CSDC facility, based at Airbus and the University of Bristol forms a central hub for a wider regional alliance of companies, universities and colleges in the region active in composites technology development, particularly for large aerostructure applications.

GKN Aerospace - GKN Aerospace is a supplier to the global (civil and military) aviation industry. Its headquarters are in Redditch (West Midlands) in the UK, but it has 10,000 employees across 31 global centres, including in its Aerostructures sites in Filton and Somerset. It has acquired the Airbus Wing Division at Filton, enhancing its aerostructure expertise with additional wing component manufacturing and assembly capabilities. It has started work on the creation of a new £200 million composites manufacturing facility in Bristol ('Filton-West') that will house automated composites manufacturing operations.

[79] A strategy for materials (Materials Innovation and Growth Team, DTI, March 2006)

[80] BIS Advanced Manufacturing website

[81] Airbus website

[82] Information from SWRDA

[83] A strategy for materials (Materials Innovation and Growth Team, DTI, March 2006)

[84] UK – Your springboard for global growth: UK Inward Investment 2008/9 (UKTI, June 2009)

[85] The 2008 R&D Scoreboard (DIUS, January 2009)

From January 2010 the plant will manufacture composite wing spars and trailing ends assemblies for the Airbus A350 XWB aircraft.

The company is an independent supplier of composite structures to the aerospace industry and supports customers in developing new applications for lightweight composite materials to help reduce emissions and advance efficiency and performance. It is focused on refining conventional production techniques and defining new automated and repeatable manufacturing processes to deliver high-quality composite components, which achieve rigorous consistency levels, while reducing the time and costs in the manufacturing cycle.

It has applied these state-of-the-art production technologies to the manufacturing of composite structures, including the first large engine composite fan containment case for the GEnx engine and the wing spar of the A400M military transporter. The A400M wingspar is the first application of carbon composites for a primary structure on a large transport aircraft wing and is manufactured using state-of-the-art automated manufacturing processes. GKN is now evolving and reapplying these skills for use in the manufacture of the A350 XWB wing spar at Filton. [86]

Today, GKN Aerospace is supporting the industry in defining new applications for composites to meet the requirements of advanced aerostructures and engines. Its capabilities in composite wing applications are developed through its innovation program and collaboration with customers, materials and equipment providers, and universities and research institutes. It also runs the Composites Research Centre (NCN Centre of Excellence) in the Isle of Wight. GKN is ranked 40th in the UK in terms of R&D expenditure, with investment of £83 million in 2007/8[87].

BAE systems[88] – BAE Systems is a global company engaged in the development, delivery and support of advanced defence, security and aerospace systems in the air, on land, and at sea. It is the second largest global defence company, with approximately 105,000 employees worldwide and sales exceeding £18 billion. It is also the UK's biggest engineering company, with 60+ sites across the country and a direct GVA contribution to the UK of £2.4 billion. BAE is ranked 18th in the UK in terms of R&D expenditure, with investment of £176 million in 2007/8[89].

The demands of the BAE Systems aerospace and defence businesses and the close connections that exist between the company and Airbus have led to a world-class capability in materials and manufacturing, and it is one of the key UK players in the design and manufacture of composites. For example, it has continued to develop carbon fibre composite fighting vehicles, which are able to be easily and rapidly transported by air. The development of such compounds holds great potential for use within civilian transport (i.e. cars, trucks and buses), offering the possibility of savings in fuel costs and more environmentally friendly vehicles. BAE systems also manufactured the Typhoon fighter (with Alenia Aeronautica and EADS), which involved the use of advanced techniques including complex composite structures.[90]

BAE Systems Composite Structures division is a leading supplier of advanced composite components and assemblies for military and aerospace applications. It specialises in the design and manufacture of highly engineered components that utilise composite materials in their construction and it designs and / or fabricates a wide range of composite assemblies for defence and commercial applications. Its products include:

[86] UK – Your springboard for global growth: UK Inward Investment 2008/9 (UKTI, June 2009)

[87] The 2008 R&D Scoreboard (DIUS, January 2009)

[88] BAE Systems website

[89] The 2008 R&D Scoreboard (DIUS, January 2009)

[90] Economic contribution of BAE Systems to the UK (Oxford Economics, April 2008)

- V-22 Osprey Engine Nacelles and Wing Fences for Bell Helicopter
- MH-47 IR Suppressor Duct for Rolls Royce
- H-1 Turned Exhaust System Bell Helicopter
- Boeing 737 Thrust Reverser Hinge Kits and Fairings for Boeing and Spirit Aerospace
- Airbus APU Exhaust Ducting for Honeywell
- Engine Bypass Duct for Honeywell
- Model 20 Airborne Camera Body for Wescam
- Internal Magazine Panels for Non-Line-of-Sight Cannon for BAE Systems
- Composite Missile Canisters for BAE Systems
- Compression Molded Parts for 737,747, 777 and 787 for Spirit Aerospace
- Aircraft Seat Panels for B/E Aerospace

Other key business in the UK - Other businesses mentioned in the literature as significant players in the composites industry include (amongst others):

- Formula One[91] - Composite material is superior to others for racing car construction because it is very lightweight, strong and stiff, and can be easily molded into different shapes. In the early 1980's Formula One began using carbon composite materials to build chassis and today most of the racing car chassis (suspension, wings, engine cover, monocoque, etc.) are built with carbon fibre. There are currently ten Formula 1 teams, six of which are based in the UK:
  - Brawn GP (Brackley)
  - Red Bull (Milton Keynes)
  - McLaren (Woking) - McLaren Group includes McLaren Composites (advanced composite structures)
  - Williams (Grove)
  - Renault (Ennstone)
  - Force India (Silverstone)
- Rolls Royce - Rolls Royce is a global business providing integrated power systems for use on land, at sea and in the air, with strong connections to the composites industry. It opened a new University Technology Centre in Composites at the University of Bristol in 2007 to further develop composites technology for future products across its aerospace, marine and energy markets. It announced in 2008 that it was establishing a joint venture company with GKN Aerospace to carry out research and development into the use of composite materials in aero engine fan blades. The company is ranked 7th in the UK in terms of R&D expenditure, with investment of £454 million in 2007/8[92].
- Vestas wind systems - a Danish wind turbine company, but with operations in the UK: Vestas Blade (production) and Vestas Technology R&D (Research). The company already uses 20% of the global production of a particular grade of carbon fibre and is expected to significantly increase its production over the coming years. The company has recently established new links with the University of Bristol and ACCIS to undertake research activities relating to the manufacturing of blades, smart

[91] Formula 1 website

[92] The 2008 R&D Scoreboard (DIUS, January 2009)

materials and lightweight structures, and will shortly open a 100-person office in Bristol.

- Hexcel – an important composite material supplier and the main worldwide provider of aerospace-quality composite raw materials, which undertakes R&D into textiles and resin systems.  Although it has a presence in the UK, much of the materials it sells to the UK market are imported from abroad.
- Advanced Composite Group - manufacturers of composite components and tooling for aerospace, automotive and motorsport applications.
- Bentley – which is developing a number of novel processes which can enhance the appearance and mechanical properties of composites and the speed at which they are produced[93].
- Agusta Westland – an Anglo-Italian helicopter company that makes extensive use of composite materials, especially within rotorblades.
- Various composite consultancy companies (e.g. W.S Atkins – which employs 900 people in Bristol and undertakes work relating to the design and stress analysis of composite materials – Halcrow and Frazer-Nash), who are important players in the UK and significant exporters.

[93] Task and Finish Group Report: Composite Materials (September 2009)

# 4 DEVELOPING UK ASSETS IN COMPOSITE MATERIALS

The UK Government is in the process of developing a cross sector UK composite strategy to be published in Autumn 2009, which will explore in detail the key challenges for the sectors involved in the exploitation of composites and the most appropriate Government intervention. Issues to be explored through this strategy include ways to increase the availability of skilled composite engineers, ways to raise the awareness of the capabilities of composite materials, and what steps are necessary to help improve the UK's capacity to produce composite structures cost effectively at the speed and volume required by key markets crucial to the UK's economic future[94].

## 4.1 The interface between science, R&D and business

Aerospace companies (Airbus, BAE Systems, Rolls Royce, etc. discussed above) have traditionally led the way in composites manufacturing capability in the UK, but they have been joined by a long list of small (yet world-leading) composites supply chain companies. The application of composites is now cross-sector, from aerospace to automotive, from healthcare devices to energy, from high performance sports equipment to marine.[95]

As the aerospace primes (in particular) to switch to new materials there is concern many smaller companies are ill prepared for the change. The challenge is therefore to provide support to those companies already using composites, and ensure there is communication and support for those who aren't[96].

The 2008 DIUS/BERR Manufacturing Strategy[97] notes that "the costs of demonstrating that a new technology or production process is viable can be a significant barrier to investment in the development of new products, especially for smaller manufacturers. To help overcome this, the UK has a number of leading technology bodies and Knowledge Transfer Networks", including the National Composites Network. These enable manufacturers and their supply chains to work with academic institutions to prove concept, demonstrate and exploit new products.

Current major regional supply-chain activities that address composites issues include:

- NWDA – Aerospace Supplier Excellence Programmes: The first ASCE £8.2m programme was launched in 2006 and has increased supplier performance through a range of coaching, mentoring, training and support activities. ASCE 2 is an £11m 5-year programme that will build on the success of ASCE 1
- A number of regions have funded the Supply Chain 21st Century initiative which covers four themes (1) performance, (2) accreditation, (3) supply chain relationships, and (4) innovative supply chains. A number of companies engaged in these programmes are composites related. There is anecdotal evidence of this programme's impact but this has not been formally evaluated at present

The T&FG report[98] highlights that, whilst there are some high quality initiatives underway, there is a desire to explore the possibility of developing a national Composites supply chain initiative (similar to the successful DTI Automotive Supply Chain programme) to address the myriad of issues identified in its report.

[94] Advanced Manufacturing Package *(BIS, July 2009)*

[95] TSB Blog: Advanced Composite Materials – Investing for the future (Iain Gray, September 2009)

[96] Task and Finish Group Report: Composite Materials (September 2009)

[97] Manufacturing: New Challenges, New Opportunities (DIUS/BERR, September 2008)

[98] Task and Finish Group Report: Composite Materials (September 2009)

## 4.2 Industrial capacity

The UK has an impressive global reputation for innovation and research in composite materials and recognised high skills and quality based manufacturing, which is heavily led by implementation of new technologies.[99] In principle, the UK has the potential to become a global leader in composite technology and manufacturing. It has advanced composite expertise in automotive (Formula 1 and fast cars), boats, aerospace, and other sectors and has an outstanding international reputation in engineering and design. There is a deep pool of intellectual expertise in the UK composites research community and the UK has traditionally been very efficient in prototyping and debugging new processes.[100]

However other countries have been quicker than the UK to exploit advanced composite materials. In particular, the US, EU and Japan have invested heavily, often with significant Government support. Asia also emerged as the largest regional market in terms of composites shipment in 2008, replacing North America, and is expected to maintain its leadership.[101]

Nevertheless, it is estimated that the UK composites market is currently worth ~£800 million (~3% of global market), with key sectors including aerospace and defence, motorsport, marine and construction[102]. Based on work within BIS, and using external estimates based on composite use in construction and automotive sectors, a conservative estimate of the future value of the UK composite market is at least £20bn (this figure ignores the potential of the medical, oil and gas sectors), with composite wind turbine blades alone worth £5+ billion[103]. However, timeframes for these predictions are not clear.

## 4.3 Framework conditions

The T&FG report identifies **skills** as one of the main issues arising from the T&FG exercise. It states that "all regions reported a shortage of composite technicians, engineers and material scientists. This has been highlighted as a priority at national level through activities such as the Aerospace Skills Roadmap being undertaken by SBAC. It is clear there is an urgent need for skills conversion for the transition from metallics to composites at manufacturing and design engineering levels." [104]

Across the regions, there are a wide range of skills activities focused on the needs of business, many of them making use of the Regional Skills Partnerships. A number specifically relate to composites including:

- The Aerospace Training South West and Composites Gateway. A group of six of the UK's largest aerospace and aviation companies and SME representation linked to four universities and five FE colleges to focus on composite skills. The detailed skills demand signal developed has been used to develop/ acquire course content. The Gateway has signed a licence for modular training content with Advanced Composites Group in the East Midlands, which can be built into a single award. Links with colleges in the East Midlands, North West and South East are currently developing. The work has attracted a £0.5m LSC grant and £750k of Agency and ERDF funding is anticipated later this month.
- SEEDA has funded the development of a Composite Programme with COGENT which offers a series of modules including Composite Materials & Processes,

[99] NCN website

[100] BIS Advanced Manufacturing website

[101] Global Composites Market 2009-2014: Opportunities, Markets and Technologies (Lucintel, July 2009)

[102] National Composites Network – Presentation by Marcus Warwick of TWI (December 2007)

[103] BIS Advanced Manufacturing website

[104] Task and Finish Group Report: Composite Materials (September 2009)

Composite Manufacturing & Processes, Product & Tooling Design for Manufacture, Composite Repair & Refurbishment, Quality, Inspection & Testing, and Recycling. The South East and South West are continuing to explore the SEEDA-funded composites Blueprint which looks at skills issues in the wider context of industrial structure, market presence, resource and capital requirements, supply chain arrangements and the role of academia with the involvement of the universities of Southampton, Oxford, Cranfield and Imperial.

- In Yorkshire, NAMTEC is delivering higher-level skills in advanced engineering and materials to improve the supply, quality and capability of graduates. The programme comprises three areas:
- Education Intervention (insight into engineering for young people/ attract into sector)
- Graduate Intervention (high quality, structured extracurricular study programme alongside the experience of working for an engineering business)
- Employee Development Programme (structured professional development for engineering technical staff).

In terms of **finance,** the T&FG Report[105] states that "the UK has invested/committed at least £4 billion into composites research, development and manufacturing over the past 5 years… and composites have attracted significant investment from a number of public and private sector sources over the past five years." For instance, it states that "the UK Government has recognised that the costs of developing a new civil aircraft are beyond the means of any company or any one country. As such, loans have been made to support the design, development and build of composite wings".

The report shows £983m of loans, which include £530m for the Airbus A380 (2005), £113m for the Bombardier C-series (2009) and £340m for the Airbus A350XWB (2009). The minimum private sector match funding for these loans was £1,966m [note that it does not state what proportion of this might relate to composites]. In addition, it details other investments relating to composites [again these do not necessarily relate entirely to composites]. These 'other composite investment estimates are detailed in the table below:

**Table 4.1 Composite Investments**

| Source | Amount |
|---|---|
| Central Government refundable loans | £983m |
| Private sector match funding (min) | £1,966m |
| **Total government loans + match funding** | **£2,949m** |
| | |
| Other private sector funding | £856.32m |
| EPSRC | £29.6m |
| TSB (a proportion of which is composites related) | ~£85m |
| NCN | £2.5m |
| RDAs | £94.66m |
| LSCs | £0.5m |
| EU: FP5, 6, 7 | £33.1m |
| Other (incl. BIS support to GKN, HEI investment, etc) | £117.44m |
| **Total Other Investments** | **£1,219.12m** |
| **Grand total** | **£4,168.12m** |

[105] Task and Finish Group Report: Composite Materials (September 2009)

The T&FG Report[106] also notes a number of significant RDA investments relating to composites, which are “in the pipeline” (current bids and secured funding). These include:

- Manufacturing Technology Centre (MTC) - £133m (RDAs: AWM and EMDA)
- ADCOMP Thermoplastics Composites Centre - £10m (RDA: AWM)
- Computational Modelling for Advanced Materials (COMSTAR) - £10m (RDA: AWM)
- The Aerospace Supply Chain Excellence 2 Programme (RDA: NWDA)
- Expansion of the AMRC (RDA: YF)
- Coral Reef 2 (RDA: SWRDA)
- Centre for Fluid Mechanic Simulation (CFMS) (RDA: SWRDA)
- Business Technology Centres (RDA: SWRDA)

In relation to **infrastructure**, current methods of manufacture of composite structures are relatively slow, labour intensive and costly, and so there is a need to identify cost effective rapid production methods that can be used in industry. The challenge is to develop an integrated manufacturing system that can be taken up by existing industries that have become expert in the use of metallic materials.[107]

Another major problem for continued growth is likely to be the availability of materials at an economic cost. Capacity for carbon fibres has to grow to meet demand, but the cost of the materials must also be addressed. A long-term goal for aerospace (and other sectors) could well be the search for an alternative low cost fibre to carbon or alternative methods of producing the fibres. A major drive for lower manufacturing costs will be pointless if the materials are either not available or are too expensive. Current predictions suggest that the cost of titanium metal is likely to be halved within ten years if the new FFC process replaces the Kroll methods of winning the metal from its ore. This could seriously affect the market share of composite materials unless the cost issues are tackled.[108]

[106] Task and Finish Group Report: Composite Materials (September 2009)

[107] BIS Advanced Manufacturing Website

[108] Foresight Report 2007 (National Composites Network, IOM3/NCN Foresighting Working Group, 2007)

# 5 SPATIAL DISTRIBUTION

## 5.1 Technology by Region

There are thousands of companies in the UK producing metallic / GRP composite products (i.e. low value/low tech). However, there are thought to be only 100 or so companies across the UK currently using high technology composites[109]. These 100 companies and the ~40 HEI and research organisations active in composites research are dispersed across the UK, with few strong patterns of concentration. However, the five Centres of Excellence, each of which is located at leading composites-research Universities and / or key industrial players, do now act as focal points for the UK composites industry. These 'hubs' are in Bristol (SW), Isle of Wight (SE), Manchester (NW), Rotherham (Y&H) and South Wales.

The T&FG Report[110] considers the strengths in relation to the composites industry for each region of the UK in turn. The findings are summarised below:

**Figure 5.1 West Midlands**

- Economy – a diverse manufacturing-based economy with strengths in automotive, aerospace, rail, construction and energy sectors. Structural composites are one area of focus
- Composite Centres – AWM and EMDA are investing in the Manufacturing Technology Centre at Ansty, which will be a large, world-class manufacturing research, development and demonstration organisation, which will focus on advanced tooling, intelligent autonomation and fixturing

**Figure 5.2 East of England**

- Economy - has a number of F1 / motor racing companies which have pioneered the use of composites. The marine industry is also significant (although this is predominantly GRP and lower tech materials). The region has construction composite interests
- Composite Centres – TWI, one of the largest RTOs with expertise in polymer science and other composite disciplines
- Specific composite companies - Hexcel, one of the world's leading composite material suppliers and undertakes R&D into textiles and resin systems
- Academic expertise in composites - HEI expertise at Universities of Cambridge, Cranfield, East Anglia and Hertfordshire

**Figure 5.3 East Midlands**

- Composite Centres – partner in the Manufacturing Technology Centre (MTC) project, supported by Rolls Royce.
- Specific composite companies – the Advanced Composite Group, one of the UK's leading manufacturers of composite components and tooling for aerospace, automotive and motorsport applications
- Academic expertise in composites – MTC project involves Universities of Nottingham and Loughborough
- Skills - Composites Gateway in the South West, which seeks to address industry's needs for short technical courses

[109] Task and Finish Group Report: Composite Materials (September 2009)

[110] Task and Finish Group Report: Composite Materials (September 2009)

**Figure 5.4 North West**

- Composite Centres – The NCN Centre of Excellence 'Northwest Composites Centre' (Manchester), which includes the £8 million Composites Certification and Evaluation Facility (providing support to the composites industry in testing, certification and evaluation)
- Specific composite companies - BAE systems has a strong presence in the region, where – as part of the Typhoon and Joint Strike Fighter consortium – it develops and manufactures aircraft with high composites content. There are other companies in the supply chain which have developed advanced weaving, tooling and composite processing technologies, many of them proprietary. Although the Airbus wing assembly plant is in Wales, it is a key part of the aerospace economy of the region. Bentley is developing a number of novel processes which can enhance the appearance and mechanical properties of composites and the speed at which they are produced
- Academic expertise in composites – The NorthWest Composites Centre links the Universities of Manchester, Bolton, Lancaster and Liverpool

**Figure 5.5 North East**

- Economy – dominated by the process industries, but has identified a number of initiatives in the emerging industries that have composite applications. The region has a strong defence industry (which has need for composite armour) and a cluster of automotive businesses (Caterpillar, Komatsu, Nissan) and suppliers (Magna Kansei)
- Composite Centres – There are a number of Agency investments around the New and Renewable Energy Centre (NaREC) which seeks to accelerate the deployment of wind, wave, tidal and other renewable technologies, some of which may relate to composites
- Academic expertise in composites – The Interdisciplinary Research Centre in Polymer Science and Technology (Polymer IRC) is a consortium of research groups from Universities including Durham. There are other composite-related activities at a range of other universities in the region, including Newcastle, Sunderland and Northumbria

**Figure 5.6 South East**

- Economy – has strengths in aerospace, marine, renewables and materials technologies
- Composite Centres – The NCN Centre of Excellence 'GKN Aerospace Composites Research Centre' (Isle of Wight). VT group operates the VT Composites Technology centre, which has extensive capabilities
- Specific composite companies - Major companies include QinetiQ and GKN
- Academic expertise in composites – Leading composite universities are Southampton, Oxford, Cranfield and London's Imperial College, all of whom are involved in the composites Gateway project

**Figure 5.7 South West**

- Economy – has a strong aerospace and marine sector and an emerging renewables sector. The region also has a significant marine sector (though many companies are using GRP materials).
- Composite Centres – The NCN Centre of Excellence 'Airbus Composite Structures Development Centre' (Bristol)
- Specific composite companies – Bristol is home to Airbus UK and a significant part of its supply chain, including GKN. Other aerospace companies engaged in composites in the South West include AgustaWestland (rotorcraft), GE Aviation (power and fuel systems), Cobham and Dowty Propellers. EADS, Rolls Royce and important composites consultancy companies are also present in the region
- Academic expertise in composites – Bristol University were appointed by Vestas as its composites research partner (as have Rolls-Royce, GE Aviation, Airbus and Agusta Westland). Four other HEIs are engaged in composites

**Figure 5.8 Yorkshire and Humber**

- Economy – the advanced composites industry in the region is relatively small but growing sub-sector. Regional industry performs well in niche products and niche markets and there are some companies with a world-wide reputation in the automotive, leisure, aviation and marine sectors
- Composite Centres – The NCN Centre of Excellence 'University of Sheffield AMRC with Boeing Composite Centre' (Rotherham)
- Specific composite companies – include Slingsby Advanced Composites (design and manufacture of advanced composites products, primarily for the defence and transport sectors) and Linear Composites (manufacture of textile reinforced plastic composites)
- Academic expertise in composites – Expertise in composites has been identified in 5 of the 8 universities in the region. In particular, Leeds University has expertise in 3-D weaving and spread-tow technology for textile pre-forms and Sheffield University have established the AMRC Composites Centre. Also, the Interdisciplinary Research Centre in Polymer Science and Technology (Polymer IRC) is a consortium of research groups from Universities including Leeds, Sheffield and Bradford.

# ANNEX 1: EPSRC/TSB FUNDING FOR COMPOSITES RESEARCH (UNIVERSITIES)

The summary table below lists Universities currently / recently in receipt of EPSRC/TSB funding for composites research. The table details the amount of EPSRC / TSB funding provided to each institution.

Research Assessment Exercise (RAE) 2008 results and rankings for the 38 identified universities have also been analysed using the three most relevant Units of Assessment within the RAE: Civil Engineering; Mechanical, Aeronautical and Manufacturing Engineering; and Metallurgy and Materials. The table below provides full details of relevant scores and rankings in these fields. The RAE % columns show the proportion of submissions where quality was judged as 3* (internationally excellent) or 4* (world-leading). The rank columns show the ranking of institutions scores across the UK out of the number assessed (shown in the header).

**Universities Currently/Recently in Receipt of EPSRC/TSB Funding for Composites Research**

| Institution | EPSRC Grants | TSB Funding* | RAE 2008 - UoA: Civil Engineering | | RAE 2008 - UoA: Mechanical, Aeronautical & Manu Engineering | | RAE 2008 - UoA: Metallurgy & Materials | |
|---|---|---|---|---|---|---|---|---|
| | | | % | Rank (of 23) | % | Rank (of 33) | % | Rank (of 20) |
| Cranfield University | £ 16,977,102 | £ 438,596 | - | - | 60 | 14 | - | - |
| University of Sheffield | £ 7,430,348 | | 85 | 5 | 75 | 4 | 65 | 7 |
| University of Nottingham | £ 3,895,319 | £ 782,767 | 85 | 5 | 75 | 4 | - | - |
| Imperial College London | £ 3,263,144 | | 95 | 1 | 80 | 1 | 55 | 9 |
| University of Manchester | £ 3,153,770 | | - | - | - | - | 80 | 2 |
| University of Bristol | £ 2,268,962 | £ 330,692 | 80 | 8 | 80 | 1 | - | - |
| University of Cambridge | £ 2,037,223 | | - | - | - | - | 95 | 1 |
| Queen's University Belfast | £ 1,146,632 | | 75 | 10 | 65 | 11 | - | - |
| University of Birmingham | £ 968,307 | £ 234,174 | 65 | 12 | 70 | 7 | 75 | 5 |
| University of Oxford | £ 828,875 | | - | - | - | - | 80 | 2 |
| University College London | £ 815,722 | | 55 | 14 | 55 | 17 | - | - |
| University of Strathclyde | £ 811,564 | | 40 | 21 | 50 | 20 | - | - |
| University of Bradford | £ 766,972 | | 55 | 14 | 40 | 27 | - | - |
| Queen Mary, University of London | £ 667,765 | £ 111,734 | - | - | - | - | 55 | 9 |
| University of Bath | £ 660,124 | | - | - | 55 | 17 | - | - |
| University of Leeds | £ 569,242 | | 55 | 14 | 75 | 4 | - | - |
| University of Southampton | £ 513,821 | £ 87,850 | 80 | 8 | 60 | 14 | - | - |
| University of Ulster | £ 407,683 | £ 220,939 | - | - | - | - | 50 | 11 |

| Institution | EPSRC Grants | TSB Funding* | RAE 2008 - UoA: Civil Engineering | | RAE 2008 - UoA: Mechanical, Aeronautical & Manu Engineering | | RAE 2008 - UoA: Metallurgy & Materials | |
|---|---|---|---|---|---|---|---|---|
| | | | % | Rank (of 23) | % | Rank (of 33) | % | Rank (of 20) |
| Bangor University | £ 335,718 | | - | - | - | - | - | - |
| University of Glasgow | £ 322,202 | | 55 | 14 | 45 (Aero) / 55 (Naval) | 23 (Aero) / 17 (Naval) | - | - |
| Brunel University | £ 306,266 | £ 97,640 | - | - | 50 | 20 | - | - |
| University of Durham | £ 301,646 | | - | - | - | - | - | - |
| University of Aberdeen | £ 296,984 | | - | - | - | - | - | - |
| Nottingham Trent University | £ 268,248 | | - | - | - | - | - | - |
| University of Liverpool | £ 237,281 | | 50 | 19 | 60 | 14 | 70 | 6 |
| University of Newcastle upon Tyne | £ 223,179 | | 90 | 3 | 65 | 11 | - | - |
| University of Surrey | £ 204,424 | | - | - | - | - | - | - |
| University of Bolton | £ 189,851 | £ 109,753 | - | - | - | - | - | - |
| University of Warwick | £ 163,457 | | - | - | - | - | - | - |
| University of Exeter | £ 138,919 | £ 207,394 | - | - | - | - | - | - |
| Aberystwyth University | £ 120,924 | | - | - | - | - | - | - |
| Cardiff University | £ 113,983 | | 90 | 3 | 65 | 11 | - | - |
| Manchester Metropolitan University | £ 105,716 | | - | - | - | - | 30 | 17 |
| University of Reading | £ 37,106 | | - | - | - | - | - | - |
| Swansea University | £ 29,717 | | 95 | 1 | 45 | 23 | 60 | 8 |
| University of Edinburgh | £ 28,858 | | - | - | - | - | - | - |
| Loughborough University | | £ 213,270 | 65 | 12 | 70 | 7 | - | - |
| University of Plymouth | | £ 236,530 | 45 | 20 | 25 | 29 | - | - |

*Constructed using data available from the NCN website and RAE 2008 results. TSB funding has been assumed to divide evenly between project partners. RAE % column shows the proportion of submissions where quality was judged as 3* (internationally excellent) or 4* (world-leading).*

# ANNEX 2: EPSRC/TSB FUNDING FOR COMPOSITES RESEARCH (ORGANISATIONS)

The table below lists all organisations currently / recently in receipt of EPSRC/TSB funding for composites research. Universities and research and technology organisations are not included.

**Organisations Currently/Recently in Receipt of EPSRC/TSB Funding for Composites Research, by Region**

| **North East** | **East of England** |
|---|---|
| Cytec Engineered Materials | TWI |
| ICI plc | Highways Agency |
| **North West** | IMT |
| Auxetic Technologies Ltd | Insys |
| Federal-Mogul Friction Products Ltd | MERL Ltd |
| Fibreforce | Wichita Company Ltd. |
| HSE | **South East** |
| Inoes Chlor | Auxetic Technologies Ltd |
| Mitras | BMT Renewables |
| Network Rail | BOC |
| Rolls Royce | Deepsea Engineering |
| Shakespeare Monofilament UK Ltd | EMC |
| Sigmatex | ESR Technology |
| Surface Transforms plc | FYS |
| Testsure | HME |
| **Yorkshire and Humberside** | Insensys |
| E&F Composites | MCA |
| Ecocats | NPL |
| Fairline Boats | Pultrex |
| John Brierley Ltd | Qinetiz |
| Lightweight Medical | Smart Fibres |
| NetComposites Ltd | SP Technologies |
| Sam Weller and Sons Ltd | VT Halmatic |
| Springdale Crop Synergies | **South West** |
| **East Midlands** | BAE Systems |
| Rolls Royce | Devonport RD |
| Advanced Composites | Dowty Propellers |
| EPM | European Friction |
| Euro Projects | Menzolit |
| NDT Solutions | Parson Brinckerhoff |
| Scott Bader | RNLI |
| **West Midlands** | Supacat |
| AP Racing Ltd. | ***Outside the English Regions*** |
| BF Entron | St Gobain Vetrotex |
| Curon Ltd | MBEL |
| Dunlop Aerospace Braking Systems | BPF |
| Lister Petter After-Market Ltd | Lloyds Register |
| Milled Carbon Ltd | SMMT |
| Morgan | |
| Oscar | |

| |
|---|
| People Seating Ltd |
| SIMS |
| WS Atkins |

# ANNEX 3: TSB FUNDED COMPOSITES RESEARCH

The table below lists all current/recent TSB-funded Composites research identified by the NCN, along with the academic institutions and industry partners involved.

**TSB-funded Composites Research Involving Universities and Businesses**

| |
|---|
| **ACLAIM - Advanced Composite Life Assessment and Integrity Management (£1,820,577)**<br>Academic Institutions: Cranfield Univ<br>Industry: ESR Technology, Network Rail, MBEL, Devonport RD, Parson Brinckerhoff, Deepsea, HSE, Euro Projects, Insensys, NPL, Insys, Highways Agency, Inoes Chlor, ESR Technology |
| **Continuous Production of Off-axis Thermoplastic Prepregs (£496,819)**<br>Academic Institutions: Univ of Plymouth<br>Industry: IMT, EPM, Pultrex, Qinetiq, St Gobain Vetrotex |
| **LIFECar (£1,903,345)**<br>Academic Institutions: Univ of Oxford, Cranfield University<br>Industry: Morgan, Oscar, BOC, Qinetiq, Oscar, BOC, Qinetiq |
| **Lightweight Thermoplastic Composites for Made-to-order Structural Assemblies (£702,796)**<br>Academic Institutions: Univ of Southampton<br>Industry: Lloyds Register, St Gobain, RNLI, VT Halmatic, Supacat, TWI, BF Entron |
| **Materials Technologies for Remanufacturing Automotive & Engineering Components (£468,348)**<br>Academic Institutions: The University of Birmingham<br>Industry: Lister Petter After-Market Ltd |
| **Reactive Structural Materials with Auxetic Inclusions 'Reactics' (£987,781)**<br>Academic Institutions: University of Exeter, University of Bristol, University of Bolton<br>Industry: Auxetic Technologies Ltd, Auxetix Ltd, Shakespeare Monofilament UK Ltd, ICI plc, Cytec Engineered Materials, Rolls-Royce plc |
| **Simulation and Modelling of 3D Woven Fabrics for Structural Composites (£1,988,447)**<br>Academic Institutions: Univ of Bristol, Univ of Nottingham, Univ of Ulster (Northern Ireland)<br>Industry: Rolls Royce, Advanced Composites, BAE Systems, Deepsea Engineering, Dowty Propellers, Sigmatex |
| **RECCOMP (Recycling composites) (£878,764)**<br>Academic Institutions: Exeter Univ, Brunel Univ<br>Industry: SIMS, Menzolit, BPF, SMMT, Mitras, European Friction, SP Ltd |
| **Extended Life and Innovative Recycling of Carbon Waste for Friction Applications (£1,492,887)**<br>Academic Institutions: Loughborough University<br>Industry: Surface Transforms plc, Milled Carbon Ltd, AP Racing Ltd., Dunlop Aerospace Braking Systems, Wichita Company Ltd., Federal-Mogul Friction Products Ltd |
| **Commingled Biomaterials from Nature (COMBINE) (£1,005,605)**<br>Academic Institutions: Queen Mary, University of London<br>Industry: Sam Weller and Sons Ltd, Ecocats, Lightweight Medical, NetComposites Ltd, Springdale Crop Synergies, Fairline Boats, John Brierley Ltd, E&F Composites |

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  http://www.baesystems.com/AboutUs/index.htm

- BERR Composites

  http://www.berr.gov.uk/whatwedo/sectors/materialsengineering/materials/composites/page38761.html

- BIS Advanced Manufacturing Website:

  http://interactive.bis.gov.uk/advancedmanufacturing/annex-case-studies/composite-materials/

- NCN website

  http://www.ncn-uk.co.uk/DesktopDefault.aspx?tabindex=105&tabid=451

- NCN website – Research in the UK

  http://www.ncn-uk.co.uk/DesktopDefault.aspx?tabindex=0&tabid=15

- UKTI website

  https://www.uktradeinvest.gov.uk/

- Airbus website

  http://www.airbus.com/en/

- Boeing Website

  http://www.boeing.co.uk/Home.do

- Formula 1 website

  http://www.formula1.com/

- National Composites Network Presentation (Marcus Warwick. TWI. December 2007):

  http://www.gla.ac.uk/ads/newsevents/composite_materials_presentations/ncn%20intro.pdf

# ANNEX 5: LIST OF CONSULTEES

- Graham Harrison, SWRDA and Composite Materials T&FG Chair
- Mike Palin, NWDA