FLYING HIGH?

A STUDY OF TECHNICIAN DUTIES, SKILLS, AND TRAINING IN THE UK AEROSPACE INDUSTRY

PAUL LEWIS
DEPARTMENT OF POLITICAL ECONOMY, KING'S COLLEGE LONDON
paul.lewis@kcl.ac.uk

GATSBY

GATSBY IS A FOUNDATION SET UP
BY DAVID SAINSBURY
TO REALISE HIS CHARITABLE OBJECTIVES.
WE FOCUS OUR SUPPORT ON A LIMITED
NUMBER OF AREAS:

PLANT SCIENCE RESEARCH
NEUROSCIENCE RESEARCH
SCIENCE AND ENGINEERING EDUCATION
ECONOMIC DEVELOPMENT IN AFRICA
PUBLIC POLICY RESEARCH AND ADVICE
THE ARTS

WE ARE PROACTIVE IN DEVISING PROJECTS TO ACHIEVE OUR AIMS. WE ARE ENTHUSIASTIC ABOUT SUPPORTING INNOVATION. WE ARE ANALYTICAL AS WE BELIEVE IT IS IMPORTANT TO UNDERSTAND THE OPPORTUNITIES AND PROBLEMS WE TACKLE. WE TAKE A LONG-TERM VIEW AS WE DO NOT THINK MUCH CAN BE ACHIEVED BY SHORT, ONE OFF PROJECTS. WE ARE ALWAYS EAGER TO FORM PARTNERSHIPS WITH ORGANISATIONS WHO SHARE OUR GOALS.

The Gatsby Charitable Foundation
The Peak, 5 Wilton Road, London SW1V 1AP
T +44 (0)20 7410 0330 F +44 (0)20 7410 0332
www.gatsby.org.uk

CONTENTS

EXECUTIVE SUMMARY

1. The Coalition Government has set itself the goal of creating 'a modern class of technicians.' Technicians are highly productive people who apply proven techniques and procedures to the solution of practical problems. They carry supervisory or technical responsibility and competently deliver their skills and creativity in the fields of science, engineering and technology. As the term 'technician' is currently used by policy-makers in the UK, it denotes people occupying technical roles that require either level 3 or level 4/5 skills. Consequently, the class of 'technicians' encompasses both 'skilled trades' and also 'associate professional/technical' roles.

2. There are currently concerns both about skills shortages at the technician level and also about the age of the technician workforce. The government is attempting to address these concerns through policies designed to increase both the status and also the numbers of technicians in the UK economy.

3. This report investigates the role played by technicians in one of the most important industries in the British economy, namely aerospace. The UK aerospace industry – whose member firms contribute to the design and manufacture of civil and military aircraft, as well to their maintenance, repair and overhaul - is the second largest in the world, with a turnover of £24 billion and around 96,000 employees.

4. The goal of the research described in this report is to inform policy by examining how the UK aerospace industry uses technicians and how it acquires and/or develops those it needs. The project forms part of a wider programme of research into technician duties, skills and training in various strategically important sectors of the economy, including – in addition to aerospace – the composites, chemicals, nuclear, and space sectors.

5. More specifically, the research reported here focused on six sets of questions.
    - First, what roles do the technicians employed in the aerospace industry in the UK occupy, and what are their main duties?
    - Second, what qualifications do those technicians typically possess?
    - Third, how do aerospace employers acquire the technicians they need?
    - Fourth, do aerospace companies suffer from any skill shortages at the technician level?
    - Fifth, what provision do employers make for the ongoing training and career development of their technicians?
    - Sixth, and finally, what – if anything – should government do to help aerospace employers in their efforts to acquire skilled technicians?

6. Data was collected via interviews with 17 sector-level organisations, including government departments, learned societies, trade bodies, and sector skills councils, and through case studies of 21 employers. The case study organisations included manufacturers of major aircraft structures, manufacturers of aircraft components and sub-systems/systems, and organisations that maintain, repair and overhaul civil and military aircraft (MROs).

7. The roles filled by the technicians who work in the aerospace industry include those of machinist, aircraft fitter, aircraft mechanic, and category 'A' licensed engineer, in the case of 'skilled trades' roles, and those of draughtsman/junior design engineer, production/manufacturing engineer, quality engineer, and category 'B' licensed aircraft engineer in the case of 'associate professional/technical' roles. The occupants of 'skilled trades' roles tend to possess a level 3 qualification in some form of engineering, most commonly aeronautical or aerospace engineering. The occupations of 'associate professional/technical' roles tend to be qualified at least to level 4/5, possessing at a minimum HNCs, HNDs or Foundation Degrees in engineering. In addition, those people who fill the role of licensed aircraft engineers must also possess the relevant category of licence.

8. Technicians typically account for a substantial share of the workforce at the various types of case study organisation, averaging somewhere in the region of 45-55% of total employment in the case of most of the manufacturers and maintenance organisations visited for this study. The main exceptions are to be found in the case of some MROs, where the share of the total workforce accounted for by technicians is driven down either by the presence of large numbers of non-technical staff (in the case of those MROs that form part of airlines) or by the employment of semi-skilled composites laminators (in the case of those MROs that also fabricate composite parts).

9. The manufacturers of aircraft components and sub-systems/systems, along with the manufacturers of large aircraft structures, who were able to supply data indicated in the past they have relied principally on in-house training programmes to acquire their technicians, estimating that apprenticeship training or the upgrade training of semi-skilled employees has provided them with over half of their current technician workforce. Practice varies between the MROs visited for this study: around half, including most of smaller firms, have tended in the past to recruit most of their technicians ready-made from the external labour market; the other MROs estimate that 40-60% of the technicians they currently employ have been trained internally.

10. The workforce planning strategies currently being used by the aerospace companies in the UK, with a view to satisfying their future need for technicians, see an increased reliance on in-house training. There are two main aspects to this. First, the increasing difficulty of recruiting experienced technicians (especially those experienced in working with composite materials), coupled with employers' desire to deal with the problems posed by an ageing technician workforce, is leading them to place (even) more emphasis on apprenticeship training than they have in the past. In particular, several employers that had discontinued their apprenticeship schemes in the 1990s or early 2000s have restarted them within the past five years, both as succession planning tool and as a means of dealing with the increasing difficulty of acquiring experienced technicians from the external labour market (see points 11-13 below). Second, some manufacturers of aircraft structures, components and sub-systems are changing their approach to filling associate professional/technical occupations; their frustration with graduates' lack of practical skills, combined with their appreciation of the skills and loyalty of vocationally educated workers, is encouraging them to rely less on hiring recent university graduates to fill such roles and to turn instead to training people in-house using Higher Apprenticeships (see point 14 below).

11. The vast majority of the firms involved in aerospace manufacturing typically differentiate explicitly between those apprentices who are destined for skilled trades roles and those who will occupy associate professional/technical occupations upon completing their training, offering separate training programmes with different entry requirements for the two groups of trainees. 'Craft apprentices', as those apprentices who are in training for skilled trades roles are often known, usually aim to achieve qualifications at level 3 in subjects such as aeronautical engineering (for aircraft fitters), mechanical engineering (for machinists), and electrical/electronic or mechanical engineering for those fitters who make mechanical and/or electronic/electronics components. 'Technical apprentices' – as those in training for associate professional/technical occupations are often known – aim to achieve qualifications at level 4 (e.g. HNC) or level 5 (Foundation Degree, often as part of a Higher Apprenticeship) in subjects such as aerospace/aeronautical engineering, manufacturing engineering, mechanical engineering, or electrical/electronics engineering, with a view to filling roles such as draughtsman, junior design engineer, manufacturing engineer, production engineering, and quality engineer.

12. The most common form of apprentice training offered by MROs sees trainees take level 3 qualifications in aeronautical engineering or aerospace engineering and maintenance. The young people who complete their apprenticeship are ready to work as unlicensed aircraft mechanics. Those who wish to become licensed engineers will spend a fourth year, if they aspire to a category 'A' licence, and a fifth year, if they wish to acquire a category 'B' licence, taking the relevant examinations and acquiring the requisite practical experience. It is widely thought that the apprenticeship-based route provides a much better way of becoming a licensed aircraft engineer than university-based approaches. The latter involve young people attending university for two years in order to acquire a Foundation Degree in aerospace engineering. The problem, however, is that while the graduates of such programmes acquire the theoretical knowledge required to become a licensed engineer, they lack the practical maintenance experience required to obtain their licence, the reason being that, unlike apprentices, they are not accumulating time working in the maintenance hangar from the outset of their course. It is not always easy for the graduates to persuade an MRO to give them the opportunity to gain the necessary practical experience, because MROs often understandably prefer to restrict opportunities for on-the-job training to their own apprentices. Moreover, even if they do gain the relevant practical experience, the overall length of time before they can achieve licensed status is typically longer than for those trainees who come up via the apprentice-based route.

13. The organisations that train apprentices usually mentioned one or more of the following four reasons for doing so. First, as already noted, apprenticeship enables employers to acquire specialist technician skills in a context where there is a limited availability of the relevant kind of worker on the external labour market. Perhaps the most striking example of this involves those firms that make composite components and structures, where expanding firms are finding it extremely difficult to hire experienced workers with the relevant skills and as a result have little option but to train workers in-house. Second, apprenticeship helps organisations in their efforts to plan for the orderly succession of an ageing technician workforce. Third, apprenticeship training affords employers an opportunity to introduce young people to the organisation's culture and to instil in them the values, standards and norms of behaviour - such as teamwork, attention to detail, leadership, and the ability to take responsibility and act in a trustworthy fashion - desired by the employers. Fourth, and relatedly, the provision of apprentice training can signal to young people that they are valued by their employer, who will support them and give them the opportunity to develop their career within that organisation, thereby helping to build apprentices' loyalty and commitment to the employer that initially trained them.

14. Manufacturers of major aircraft structures, components and sub-systems/systems are making more and more use of Higher Apprenticeships, usually in Aeronautical Engineering. This is motivated by a number of considerations. First, employers believe that Higher Apprentices offer a combination of theoretical and practical training that enables people to apply their skills and knowledge in the workplace more effectively than can many new university graduates, who are often said to lack the requisite practical skills. Second, having received more in-house training and practical experience from their employer than most graduates, the Higher Apprentices often have more realistic expectations of what their job involves, and greater loyalty to the firm that invested in them. Third, employers believe that the Higher Apprenticeship affords them the opportunity to appeal to talented and ambitious young people who might in the past have gone straight from school to university but who now, after the rise in university fees, are attracted by the prospect of obtaining a degree whilst gaining practical experience and without accumulating large debts. In this way, it is thought, the use of Higher Apprenticeships will enable firms to increase the supply of talented individuals entering their organisations.

15. Employers face a number of impediments to their efforts to offer high-quality apprenticeship training. Several, in particular those involved in aircraft maintenance and those looking for training in techniques for working with composites materials, expressed dissatisfaction with the quality of the training offered by local colleges of further education. A majority of the employers who are SFA contract-holders are highly critical of what they see as the excessive bureaucracy involved in managing the apprentice training contract. The employers that train Higher Apprentices also expressed concerns about the additional difficulties caused by the split in funding between HEFCE (which funds the Foundation Degree) and the SFA (which funds the other parts of the training). Several employers expressed concerns about the attitudes towards vocational education and training displayed by schools, arguing that – perhaps because of the influence of league tables - schools seemed to be biased towards encouraging young people to go to university rather than encouraging them to consider apprenticeships. These employers believed that, all too often, schools viewed apprenticeships as suitable only for less able pupils, rather than as an option that could be valuable for more able young people (including those who ultimately might want to go to university).

16. So far as ongoing training for more established technicians is concerned, the vast majority of the non-MROs sponsor suitable vocationally-educated people to HNCs (if they are not already the target outcome of the firm's apprenticeship programme), HNDs, Foundation Degrees and full honours degrees. Significant proportions of the managers in several of these organisations have risen to their current position via the vocational route, testifying to the organisations' commitment to establishing and sustaining robust career paths for technicians. MROs typically support ex-apprentices through the additional training required to become licensed aircraft engineers. In addition, the licensing regime under which MROs operate demands that licensed engineers receive continuing training to ensure that they are aware of new developments in technology and the lessons to be learned incidents.

17. Several of the aerospace manufacturers visited for this study have had their apprenticeship schemes accredited either by one of the professional engineering bodies, so that apprentices in these firms will be eligible to register as an Engineering Technician upon completion of their training. Higher Apprenticeship programmes have typically been mapped onto the requirements for Incorporated Engineer, so that their Higher Apprentices can register for IEng. status once they have completed their training. In contrast, only a small minority of the MROs that take apprentices have had their schemes accredited by one of the professional engineering bodies. The reason is that there already exists a well-defined, well-known and oft-followed vocational route that takes people from an apprenticeship to higher levels of professional recognition, namely those associated with being a category 'A' or a category 'B' licensed aircraft engineer.

18. A number of recommendations for policy emerge from the findings presented above, connected primarily with the need to help firms offer high-quality apprenticeship training and thereby deal with the problems posed by an ageing workforce and the increasing difficulty of recruiting experienced technicians.

- At times, aerospace employers' efforts to offer high-quality apprentice training are hampered by the poor quality of support they receive from colleges. Determining the right response requires the collection of additional evidence, but possible solutions include (i) sharpening the incentives that encourage further education colleges to invest in their workshops and to offer high-quality practical training; and (ii) providing college lecturers with secondments in industry, so that they can learn more about current industry best practice.
- Another potentially helpful initiative would involve small and medium-sized firms that wish to take apprentices 'piggy backing' on the established training schemes offered by larger employers. Such 'over-training', as it is known, can take a variety of forms, that may for example involve the larger organisation (i) simply assuring the quality of the provision offered by local colleges, so that the

other firms could be confident that their apprentices would be well trained, or (ii) taking a more direct role, for instance – in the case of those firms that have their own training school – by providing the hand skills training for other firms' apprentices during the latter's period of block release.

- In the case of large employers that hold SFA contracts, two beneficial reforms would be (i) to reduce the burden of bureaucracy involved in running an apprenticeship scheme, and (ii) to simply the funding regime by creating a single funding source for apprenticeships at level 3 and levels 4-5.
- Finally, the careers advice provided to young people should also be improved. Young people need to be made aware that the vocational route can lead to high quality training, that following it does not preclude going to university at some point, and that it offers the prospect of swift progress along a well-defined career path. In the case of aircraft maintenance in particular, young people need better advice about precisely which career goals are best pursued via a university-based Foundation Degree route and those, such as licensed aircraft engineer, which are arguably better followed from the foundation provided by a traditional apprenticeship.

1. INTRODUCTION[1]

The current UK Coalition Government has set itself the goal of increasing both the status and also the numbers of technicians in the UK economy. Technicians are 'highly productive people who apply proven techniques and procedures to the solution of practical problems. They carry supervisory or technical responsibility and competently deliver their skills and creativity in the fields of science, engineering and technology' (Technician Council 2012). As it is currently used by policy-makers in the UK, the term 'technician' denotes people occupying technical roles that require either level 3 or level 4/5 skills. Consequently, the category encompasses both 'skilled trades' and also 'associate professional/technical' roles (BIS 2010a: 7; Jagger et al. 2010; Technician Council 2012).

There is currently widespread concern about skills shortages at the technician level in the UK economy (UKCES 2010a, 2010b; HM Treasury and Department of Business, Innovation and Skills 2011: 85; Spilsbury and Garrett 2011). The policy response to this problem centres on the creation of a 'modern class of technicians' and ambitious targets have been set for the number of apprentice technicians (BIS 2009a: 18, 2010a: 7, 15, 18; HM Treasury and Department of Business, Innovation and Skills 2010: 18-19; House of Commons Library 2011: 4-6). A Technician Council has been established, its main goals being: to ensure that the contribution made by technicians to the organisations in which they work, and thence to society at large, is properly recognised, thereby raising the status and the esteem in which technicians are held; to increase (awareness of) the opportunities for career advancement open to technicians, in particular by helping to develop a common framework for professional registration for technicians working across science, technology, engineering and mathematics; and, ultimately, by increasing the attractiveness of the technician jobs and careers in the ways just described, to increase the number of technicians being trained in the UK (BIS 2009a, 2010a: 18; HM Treasury and Department of Business, Innovation and Skills 2011: 89; Technician Council 2012: 2, 5).

The policy goals of increased numbers of technicians and enhanced status will be achieved only if the nature of technician work, and the demand for and supply of technician skills, are well understood. The research reported in this paper helps to achieve such an understanding by investigating the duties, skills, and training of the technicians employed in one of the most important industries in the UK economy, namely aerospace. The UK aerospace (civil and defence) industry is one of the success stories of British manufacturing. It is the second largest aerospace industry in the world, after the USA. In 2011, the sector had a turnover of £24 billion, of which around 75% was exported. It has particular expertise in the design and manufacture of aircraft wings and engines. British firms account for 25% of all aircraft engines sold in the world and make the wings for 50% of all large aircraft. UK firms also have a 17% share of the £28 billion world market in the maintenance, repair and overhaul (MRO) of aircraft.[2] To

1 The funding for the research that informs this report was provided by the Gatsby Foundation. I am grateful to the Foundation and, in particular, Daniel Sandford Smith, for that support. A considerable debt of gratitude is owed to all of the interviewees, who were very generous with their time. Matthew Harrison, Daniel Sandford Smith and Richard Smith provided very useful feedback on an earlier version of this report. Geoff Mason also provided helpful comments on various issues. Any errors that remain are solely my responsibility.

2 More specifically, MROs carry out both line maintenance and base maintenance. Line maintenance is relatively light maintenance that can be completed without the aircraft being taken out of service. It consists of (i) minor, scheduled maintenance activities of the kind required to ensure that aircraft are fit to fly and to prepare them for their next flight – including checking the level of oil and hydraulic fluids, replacing batteries and wiper blades, and checking wheels and tire pressures - along with (ii) minor repairs and modifications that do not require extensive disassembly of the aircraft and can be accomplished through relatively simple procedures. Base maintenance is heavy maintenance that involves the aircraft being taken out of service. It may, for example, involve the entire aircraft being taken apart for inspection, overhaul, and the implementation of complex structural repairs, modifications and upgrades (see EASA 2010: AMC 145.A.10).

achieve all this, the sector directly employs in the region of 96,000 people, around 2500 of them apprentices (ADS 2011; Aerospace Growth Partnership 2012: 3).

As one of the jewels in the crown of advanced manufacturing in the UK, aerospace is naturally of interest to those policy-makers who, like the current government, are seeking to increase the number of apprentices in training and thereby promote the fortunes of UK manufacturing and catalyse export-led growth (BIS 2010b; SEMTA 2009: 11-19; Aerospace Growth Partnership 2012). As a recent report on technicians has put it, 'the level and type of skills that technicians have are vital to emerging markets in the UK, such as [the] advanced manufacturing and engineering industries. Becoming more production and export-led means becoming more technician led' (Skills Commission 2011: 16).

The goal of the research described in this report is to inform policy by examining how the UK aerospace industry uses technicians and how it acquires and/or develops those it needs. More specifically, the paper seeks to answer six sets of questions:

- First, what roles do the technicians employed in the aerospace industry in the UK occupy, and what are their main duties?
- Second, what qualifications do those technicians typically possess?
- Third, how do aerospace employers acquire the technicians they need? In particular, what balance do employers strike between hiring experienced technicians from the external labour market, on the one hand, and training them in house, on the other, and - if they rely on in-house training - what form does it take?
- Fourth, do aerospace companies suffer from any skill shortages at the technician level?
- Fifth, what provision do employers make for the ongoing training and career development of their technicians?
- Sixth, and finally, what – if anything – should government do to help aerospace employers in their efforts to acquire skilled technicians?

The structure of the report is as follows. Section 2 outlines the research methodology used in this study. Section 3 begins the presentation of the study's findings, examining the current technician workforce with respect to three main sets of issues: the kind of roles that technicians fill; the skills – and, as a proxy for skills, the qualifications - they need to fill those roles successfully; and whether they were acquired by their current employer via the external labour market and/or through some form of in-house training. Section 4 continues with the presentation of the results, but shifts attention towards the workforce planning strategies that aerospace employers are currently using in their efforts to ensure that they can satisfy their need for technicians in the medium to long term. Accordingly, the section examines both the balance that employers seek to strike between recruitment and different forms of in-house training, and also to consider the ongoing training that employers provide for their more established technicians. Section 5 summarises the discussion and offers recommendations for policy.

2. RESEARCH METHODOLOGY

In the absence of a large data set concerning the skills and training of technicians in the aerospace industry, a case study method was adopted. This has the benefit of making it possible to explore employers decisions how about to obtain and use technicians in considerable contextualised detail.

The process of data collection had two main stages. The first involved a series of 17 interviews with various sector-level organisations, such as the Department of Business, Innovation and Skills, the Royal Aeronautical Society, national skills academies, trade associations, learned societies, and sector skills councils. These interviews, along with secondary sources such as reports and policy documents concerning the UK aerospace industry, were used both to acquire information about key issues associated with the industry's use of technicians and also to inform the choice of case study organisations.

The second stage of the project involved the collection of data about technician duties, skills, recruitment, and training from a total of 21 employers. Information was collected via 22 semi-structured interviews with a total of 29 interviewees, whose ranks included HR, training, apprenticeship, and production managers, managing directors, training instructors, heads of technology, directors of engineering, and MRO base managers, using a schedule piloted in the early cases. The interviews were carried out between July 2011 and June 2012 and averaged a little over 60 minutes in length. Notes were written up and, where gaps were revealed, these were filled by email follow-ups. Primary and secondary documentation was also collected where available.

The case study organisations were drawn from several parts of the industry and included: manufacturers of major aircraft structures (two cases); manufacturers of aircraft components and sub-systems (five cases); the MROs that carry out the maintenance, repair and overhaul of civil aircraft, some of which do so as their sole line of business (five cases), others of which carry out their MRO work either as part of a commercial line (four cases) or in conjunction with the manufacture of various kinds of aircraft components (two cases); and organisations involved in the manufacture, maintenance, repair and modification of military aircraft and (in one instance) associated components and sub-systems/systems (three cases). The cases are summarised in Table 1:

Table 1: Summaries of Case study organisations, by type of organisation

Type of organisation	Number	Average total workforce	Average share of technicians in the total workforce (%)
MROs	5	595	45
MROs / airlines	4	13,200	11
MROs / component manufacture	2	150	25
Manufacture/maintain/modify military aircraft, and components/ sub-systems/systems[a]	3	1,400	44
Manufacturers of large aircraft structures	2	5,000	53
Component/sub-system manufacturers	5	4,300	51

a: one military-related aerospace company did not supply complete data on technician numbers

3. RESULTS I: THE CURRENT TECHNICIAN WORKFORCE: SIZE, ROLES, QUALIFICATIONS, AND ORIGINS

This section of the report outlines the research project's findings concerning issues such as: the duties and qualifications associated with typical technician roles; the size of the technician workforce; and how organisations in the aerospace industry have hitherto gone about satisfying their need for technicians.

3.1 TYPES OF TECHNICIAN AND THE NATURE OF TECHNICAL SUPPORT

A variety of different types of technician are employed in the aerospace industry. A selection of common technician roles, including both 'Skilled Trades' and 'Associate Professional/Technical Occupations', will be described below in order to give a flavour of the kinds of jobs that are filled by technicians in the sector. Brief summaries of the roles in question, along with the section of the report in which they are discussed, can be found in Table 2.

Table 2: Typical Technician Roles in the Aerospace Industry

Section of report	Role	Duties	Skill level
3.1.1	Aircraft fitter	Manufactures and assembles aircraft components, structures and systems	3, 4
3.1.2	Machinist	Produces aircraft parts and structures	3
3.1.3	Composites laminator	Fabricates composite parts and structures	2 (for non-automated methods of production) 3-4 (for automated production techniques)
3.1.4	Non-destructive testing (NDT) technician	Tests for defects in aircraft components and structures	3, 4
3.1.5	Draughtsman/junior design engineer	Helps to design aircraft components and systems	4, 5
3.1.6	Production/ manufacturing engineer	Develops and optimises production processes	4, 5
3.1.7	Quality engineer	Develops and implements quality assurance systems	4, 5
3.1.8	Aircraft mechanic	Inspects, services, maintains and repairs aircraft components and systems	3
3.1.8	Licensed aircraft engineers	Carries out and certifies the maintenance, repair and overhaul of aircraft	3 (Category A), 4/5 (Category B)

Four points should be kept in mind whilst considering the descriptions that follow. First, the selection of roles provided below is by no means comprehensive, and many important – and common – roles have been excluded. Second, few if any organisations will employ each and every one of the different kinds of technician described below. For example, licensed aircraft engineers are found only in MROs, while composite laminators will not be found in organisations making only metallic or electronic components. An attempt will be made in what follows to give a sense of the types of organisation that employ particular kinds of technician. Third, the technicians employed by one particular firm may be assigned duties that combine elements of more than one of the roles outlined below. For example, the licensed aircraft engineers who work in MROs will undertake non-destructive testing (NDT) that might in some organisations be carried out by specialist NDT technicians. Fourth, there may well also be instances where the boundaries between the roles occupied by more experienced technicians and those occupied by less experienced and/or more practically inclined graduates become blurred (as in the case of roles such as production/manufacturing engineer, quality engineer, and junior design engineer). These caveats notwithstanding, the following should provide a faithful introduction to the type of roles occupied by technicians in the aerospace industry.[3]

3.1.1 Aircraft Fitters (mechanical and electrical)

Aircraft fitters are production workers who are involved both in the manufacture and assembly of aircraft structures and also in the task of fitting out those structures with the electrical and electronic equipment required to build a flightworthy aircraft. This category of worker is found in the two case study organisations that manufacture large aircraft structures. Mechanical fitters need to be able to: read engineering drawings, interpret technical specifications, and use measuring tools in order to be able to mark out materials such as aluminium panels and composite wing spars and ribs in preparation for assembly; use hand and machine tools in order to carry out any drilling, turning, and milling required to prepare those materials for assembly; fit the prepared parts into jigs or fixtures and then assemble them in order to form the relevant aircraft structure (wing, fuselage, nacelle, etc). Mechanical fitters will also be involved in installing various mechanical components and systems – such as fuel tanks, pipes and pumps, mechanical flying controls, landing gear, and hydraulic and pneumatic systems – to the airframe. The successful completion of these tasks will typically require fitters to be expert in rigging and slinging and in the use of cranes.[4] Electrical/avionics fitters must also be able to interpret engineering drawings and technical data so that they can carry out the electrical wiring and cabling, and install the electrical/electronic instruments and avionics systems (e.g., engine and flight control instruments, electrical actuators and motors, navigational equipment, radar and radios), required to build an aircraft. Fitters of both kinds will also be involved in inspecting and testing the sub-systems and systems they have assembled using a variety of manual and electrical/electronic instruments. They may well also be required to collect and record data for use in quality-improvement projects. Aircraft fitters will typically have done an apprenticeship and will possess level 3 qualifications in aeronautical engineering.

3 For older accounts of technician roles, see Liepmann (1960: 20-21, 67), Evan (1963) and EITB (1970, 1980).

4 Some assembly tasks – e.g. the riveting of structural parts – are typically carried out by semi-skilled (level 2) operators.

Fitters similar to those described above are also employed by five of the case study companies that manufacture some of the mechanical and electrical/electronic components and sub-systems/systems used on aircraft. These fitters will work in accordance with engineering drawings and use technical data in order to fabricate and/or assemble a variety of items, ranging from small components such as fairings and machined rings to larger systems such as jet engines. Depending on the precise nature of the object being manufactured, they will be skilled in tasks such as, to name but a few possibilities: the use of hand-operated tools and CNC machines in order to mill, turn, grind, and drill sheet metal and other materials, most notably composites; welding; the assembly of mechanical components; and the cutting, bending, joining, sealing and installation of pipework. In addition, fitters will typically inspect components and be involved in testing sub-systems/systems once they are assembled (e.g. checking pipe systems for leaks or testing engines to make sure that they run properly). Some fitters will also be trained in rigging, slinging and lifting. The duties of electrical/electronics fitters will include the construction and fitting of electrical and fibre optic looms and cable harnesses, involving such tasks as crimping, termination, earth bonding, and - in the case of electronics technicians in particular – soldering and surface mount assembly. Electrical/electronics fitters will also be involved in testing the components and systems in question both visually and also using appropriately calibrated instruments. Both mechanical and electrical/electronics fitters are usually required to maintain paperwork documenting the procedures that have been carried out and recording test results, and also to collect data that can be used to facilitate their employer's attempts continuously to improve its manufacturing processes. Fitters of this kind will be apprentice-trained and will typically possess level 3 or (less commonly) level 4 qualifications in mechanical and/or electrical/electronic engineering. The qualifications at level 3 typically include both an NVQ and also a technical certificate, such as a BTEC or City and Guilds qualification in aeronautical engineering, while the level 4 qualifications are usually only technical certificates (e.g. HNC).

3.1.2 Machinists

Six of the organisations visited for this study employ specialist machinists who use manual and CNC milling, turning and drilling machines in order to produce a variety of aircraft parts, in both metals and composite materials. The operators of CNC machines usually work from 3-D CAD files and engineering drawings provided by junior design engineers or draughtsmen (see Section 3.1.5 below), but will programme, set and operate the CNC machines themselves. Machinists may also be involved in making the mould tools, jigs and fixtures required for the manufacture and assembly of novel metal and composite parts. They will often be trained in the use of precision measuring instruments so that they can work to high degrees of accuracy. Machinists will typically be qualified to level 3 in mechanical engineering, possessing both technical certificates and NVQs in that discipline.

It is important to note that machining composites is different from machining metals, not only because different cutters and drills are used but also because rather different techniques are needed. For instance, in machining composites, different feed rates and spindle speeds, different ways of placing the drill on the part being machined, etc., are required compared to metals. Machinists therefore require specific training in machining composite parts, as indeed do the aircraft fitters who assemble parts of aircraft (who need to be trained in the appropriate techniques for drilling, reaming and fastening together composite components). This is usually provided via (usually uncertificated, though sometimes certificated) in-house training in the case of experienced workers but is increasingly being incorporated into formal, certificated training programmes in the case of apprentices.

3.1.3 Composite laminators

The skills that laminators need varies according to the particular methods being used to make composite aircraft parts. Consequently, a short account of the nature of composite materials, and of some of the main techniques used in the manufacture of composite components and structures, provides background information that is helpful in understanding the level of skills that laminators are required to possess.

Increasingly, large parts of aircraft wings and fuselages are made of composite materials, in particular carbon fibre. For many purposes, composites have notable advantages over their metallic counterparts such as aluminium. Very crudely speaking, if carbon fibre material is impregnated with resin, shaped by being laid in a mould, and cured/hardened by being exposed to heat and pressure, then - thanks to the resulting alignment of the carbon fibres within the material – the composite parts that are produced are lighter, stronger, and more resistant to corrosion and fatigue than those fashioned from metal. Moreover, aircraft structures can be made with fewer physically separate components when they are made out of composites rather than metal – in the jargon, the part count is lower - so that there is less need for labour-intensive assembly work, making the manufacturing process quicker and cheaper (BIS 2009b: 6-7, 16; SEMTA 2009: 45-46; SEMTA and NSAPI 2011: 19; Aerospace Growth Partnership 2012: 15).[5]

Five of the organisations visited for this study are engaged in the manufacture of a variety of composite parts for the aerospace industry, including wings, nacelles, radomes, flying control surfaces and doors. In 4 of those cases, the laminators who make the parts in question use either carbon pre-preg techniques or resin infusion methods. Carbon pre-preg involves the laminator taking pieces of carbon-fibre material, which have already been impregnated with resin, and placing them in a mould, which is then vacuum-bagged and placed under pressure, before being cured (baked) in an oven or autoclave to ensure that the layers of carbon-fibre material consolidate properly in order to form a component that has the appropriate structural properties. Resin infusion is a little different, because – rather than it being the case that the carbon fibre has already been impregnated with resin, as is the case in pre-preg laminating - dry carbon fibre is placed in a mould and vacuum-bagged, with resin then being drawn into the mould under pressure, before autoclaving to form the finished part.[6]

The vast majority of the workers who fabricate composite parts using either of these two techniques are semi-skilled, possessing no more than level 2 skills – sometimes certificated via the award of an NVQ2, but also often uncertificated - in laminating. Consequently, they do not count as 'technicians', as that term is currently used. (None of the case study employers referred to their pre-preg

5 For a very useful overview of the UK composites industry, including aerospace, see UKTI (2010).
6 For a helpful introductory guide to composites, including descriptions of the relevant manufacturing techniques, see Gurit (2012).

laminators as 'technicians'.)[7] The small number of workers who are qualified to level 3 (usually NVQ only) typically amount to no more than 10% of the composites workforce and tend to occupy roles such as supervisor, production unit manager and team leader. Accordingly, their duties tend to involve less hands-on work than those of the semi-skilled laminators and instead see them carry out tasks that require a slightly higher level of skills, such as trouble-shooting, monitoring the quality of work, identifying opportunities to improve the production process, and the on-the-job training of new laminators. It is worth noting, however, that while currently most laminators are semi-skilled, two of the organisations visited for this study are considering raising the level of skills their laminators are expected to possess from level 2 to level 3, in an attempt to improve the quality of work being carried out and so reduce the incidence of defective parts (each of which may in some cases be worth up to £100,000) and the volume and value of scrappage and re-working that is required in their manufacturing operations.

While many composite parts, in particular those with geometrically complex shapes, are still made by hand along the lines described above, the use of automated production technologies such as Automated Tape Laying (ATL) and Automated Fibre Placement (AFP) is becoming more common as manufacturers attempt to increase the speed, consistency, repeatability and reliability of their production processes so as to enhance quality and reduce costs. Interviewees reported that the operators of machines involved in AFP/ATL need to be skilled to at least level 3 and possibly to level 4, both in terms of competence (as certificated by an NVQ) and underpinning knowledge (as certificated by a qualification such as a BTEC or an HNC). (The uncertainty over the precise level of skills arises because of the novelty of this technology.) While graduate–level engineers will write the programmes that govern how the machine will deposit the carbon fibre in order to make the composite part, the operators still have a key role to play. As one interviewee put it, 'they don't just look at a screen and press a green button'. This is not because the operators need good hand skills. On the contrary, one of the principal benefits of using automated manufacturing processes is precisely that it leads to a reduced reliance on the dexterity and hand skills of individual workers, thereby increasing not only the speed but also the consistency of the production process. Or, as one source put it, the use of automated processes is designed 'to increase throughput and reduce errors by minimising human involvement in the production process.' However, human involvement is not entirely eliminated. In particular, in order to ensure that the automated processes works smoothly and efficiently, the operators must have a well-developed understanding of how the machines work, so that they can monitor the production process, assess accurately whether it is going well (e.g. whether the bundles of fibres being deposited are of the right thickness, whether the gaps between them are the right size, whether they are oriented in the right way around the mould, etc.), and tweak the operation of their machine to optimise its performance. The operators must also have sufficient knowledge to be able to make sound judgements about whether any problems that arise are routine ones that they themselves can solve - something that it is important for them to do wherever possible, given that pre-preg carbon fibre degrades very quickly once it is removed from the freezer, so that stoppages in the production

7 Additional evidence that the workers in question are semi-skilled is provided by the fact that they are paid typically a lower wage (sometimes explicitly referred to as 'the semi-skilled rate') than the occupants of skilled trades roles (e.g. aircraft fitters).

processes can be very costly in terms of lost materials - or whether the difficulties are sufficiently complex to justify halting production and calling a supervisor or engineer for assistance. The machine-operators need to have level 3 or 4 qualifications – interviewees differed in their opinion of the precise level of skills required - in mechanical engineering, with a large dose of composites engineering in particular, so that they have the requisite understanding of how the automated process is supposed to be working, of when and how to adjust the operation of the machine, and of when to call for help (cf. SEMTA and NSAPI 2011: 15). The qualifications at level 3 typically include an NVQ and a technical certificate, such as a BTEC qualification in aerospace engineering, while the level 4 qualification is a technical certificate only (usually an HNC).

3.1.4 Non-destructive testing technicians

Specialist non-destructive testing (NDT) technicians are found in a majority of the organisations visited for this study, including component and sub-systems/systems manufacturers, the manufacturers of large aircraft structures, and the different kinds of organisation involved in aircraft maintenance, repair and overhaul. The testing will be carried out by specialist NDT technicians in the case of some MROs, subsequently being signed off by licensed engineers, and by the licensed engineers themselves in others.

Such workers use a variety of techniques – including x-ray methods, dye-penetrants testing, woodpecker tap-testing, and eddy-current, magnetic particle and ultra-sonic inspection (A-, B- and C-scan) – to test for defects in both newly made and repaired/modified composite and metallic components and structures. They must also prepare the paperwork required to certify the integrity of components and structures that pass the tests. The occupants of these roles will typically be apprentice-trained in mechanical engineering to level 3 (BTEC/C&G) or - a little less often – to level 4/5 (HNC/FD). They will also typically possess specialist NDT qualifications, most commonly being certified to NDT level 2 or – slightly less often – to level 3.

3.1.5 Draughtsman/Junior design engineer

One role occupied by workers with level 4/5 vocational qualifications is that of a junior design engineer or draughtsman. As those job titles suggest, such workers will be involved in the design of various kinds of hardware. Chartered and other highly qualified engineers will produce a broad schematic overview of a particular structure or system, specifying the functional parameters it must satisfy. But junior design engineers or draughtsmen will flesh out that broad outline by developing more detailed designs of the individual components, structures, and cabling and piping layouts required to complete the overall design. Notably, while the junior engineers and draughtsmen operate within the broad parameters set out by the chartered engineering designers, they exercise discretion and bring their own expertise to bear in deciding how precisely the engineer's broad schematic designs are to be realised. Junior design engineers may also be involved in helping to design the tooling that is used in the production process (e.g. the mould tools that are used in the fabrication of composite parts, and the jigs and fixtures that are used to hold parts securely in place during manufacture and assembly). In all these ways, the technicians in question make an important contribution to turning the chartered engineers' general schematic ideas into concrete reality.

In making this contribution, vocationally educated technicians may well be able to advise the professional engineers who occupy more senior positions within the organisation about the ease with which the components and structures can actually be built, or – in the case of MROs – the ease with which particular kinds of repair/modification can be effected. The technicians' experience of how work is actually carried out on the shop floor – and, in particular, their awareness of the difficulties that can arise in implementing certain kinds of design, repair or modification - can enable them to provide advice and feedback to ostensibly better qualified, but in terms of hands-on manufacturing often less knowledgeable, chartered engineers about how to design components, structures and repairs/modifications in ways that will make them as easy to make/carry out as possible. For example, one interviewee described how vocationally-educated technicians, who had considerable experience of working on aircraft, pointed out to a chartered design engineer that the repair he had designed for an aircraft structure would not in fact be feasible, because in practice the pipes and wiring looms on the aircraft precluded the kind of access needed to effect it. This was a problem that, because of his limited experience of hands-on repair work, the chartered engineer had not anticipated.[8]

The role of junior design engineer/draughtsman tends to be occupied by people with qualifications pitched at level 4/5, most notably HNCs and HNDs, as befits a role that falls under the heading of 'Associate Professional/Technical Occupations'.

3.1.6 Production/manufacturing engineers

In addition to contributing to the design of the final product, technicians with level 4/5 skills will also be intimately involved in developing, implementing and optimising the production processes and systems through which that product is made. In particular, technicians occupying associate professional/technical roles such as those of a manufacturing or production engineer will define the processes through which production workers manufacture outputs, translating the design engineers' plans into a set of the work instructions that specify for the benefit of production workers the procedures that should be followed in order to build a particular component or sub-assembly. For example, in the case of a composite component that is made through carbon pre-preg laminating, manufacturing engineers will write the 'job card' or 'ply-book' that specifies key aspects of the production process such as: the dimensions of the pieces of carbon fibre material or 'plys' that are to be used to make the part in question; the order in which the plys are to be laid into the relevant mould; how different plys are to be oriented towards each other; the extent to which the plys should overlap; and the pressures, temperatures, and periods of time for which the part has to be vacuum-bagged and cured. Manufacturing/production engineers must also ensure that the procedures and systems they create comply with any requirements set by customers or external regulatory bodies.

Manufacturing/production engineers may also be involved in helping to design the jigs, tools, and fixtures used in the production process. They will typically also oversee the day-to-day activities of the production workers in their team, responding to queries and dealing with relatively straightforward problems. Another common duty is that of continually reviewing procedures, especially in

8 Draughtsmen and junior design engineers thus exemplify the point made by Evan (1963: 7) who, in characterising the difference between engineering technicians and chartered engineers comments that, 'The technician possesses skills that the professional [chartered engineer] does not have … The hallmark of the technician, especially at the higher levels, is his unique blend of some professional knowledge and manual or instrumental skill.'

the light of apparent failures in procedures and processes, in order to identify opportunities to reduce waste, eliminate the causes of defects, and enhance the speed with which operations are carried out, thereby improving the efficiency of the production process.

People working as production/manufacturing engineers tend to be qualified to at least level 4/5, possessing HNCs, HNDs or Foundation Degrees. They may also have qualifications in Business Improvement Techniques (e.g. NVQ2) and/or the 6 Sigma approach to quality improvements (e.g. green belt). As is also true of the role of junior design engineers/draughtsmen, there may in this case be a blurring of the boundary between technician-level roles and graduate-level roles; the position of manufacturing engineering may be occupied either by technicians of the kind just described or by more practically-oriented graduates.

3.1.7 Quality engineer

As their job title suggests, quality engineers are responsible for various aspects of the quality of the work carried out in a particular part of a business. For instance, they will conduct inspections of manufacturing operations, and of samples of the output of those operations, to make sure that the appropriate procedures are being adhered to and that products conform to the desired specifications. They will also be responsible for developing quality procedures, deciding how often work will be sampled, specifying how data will be recorded and analysed, and defining suitable performance indicators, and they will train personnel in carrying out these procedures. Their duties will also include ensuring that procedures are adequately documented so as to demonstrate compliance with relevant external standards (e.g. aerospace quality assurance systems such as AS9010 and AS9102, and/or specific customer requirements). They will investigate, diagnose and remedy the underlying causes of sub-standard work, where products do not comply with the requisite standards and specifications, and of late delivery to customers, and they will propose measures designed to improve the quality of the outputs being produced and to reduce the costs thereof.

The role of quality engineer may be occupied either by people with upper-level vocational qualifications, such as HNCs and HNDs, plus relevant experience or by graduates.

3.1.8 Aircraft mechanics and licensed aircraft engineers

We move on now to examine some of the main technical roles found in organisations involved in the maintenance, repair and overhaul of aircraft (MROs). In order to understand what follows, it is important to appreciate that, in its attempt to ensure the safety of air travel, the European Commission, via the European Aviation Safety Agency (EASA), has established a regulatory framework governing the approval of organisations and personnel involved in maintaining the airworthiness of commercial aircraft. The rules that implement the framework are described in Commission Regulation (EC) No. 2042/2003 (see European Commission 2003). These rules specify the criteria that must be satisfied both by organisations that are involved in the maintenance of large aircraft and aircraft involved in commercial air transport, known as Part-145 approved maintenance organisations, and also by the Part-147 approved organisations that are entitled to provide the training required for someone to become a licensed aircraft engineer.

One important regulation concerns the need for aircraft to be certified as airworthy and fit-to-fly by suitably qualified personnel. More specifically, while – as we shall explain below – some of the simpler work carried out on aircraft can be undertaken by unlicensed aircraft mechanics, more complex and safety critical work will typically be carried out by licensed aircraft engineers, while all work must be certified or signed off by an appropriately licensed aircraft engineer. In certifying a piece of work, the licensed engineer is stating that it has been properly carried out, that the component or sub-systems/systems is fit-for-service, and that the aircraft is ready to fly. (In the official language, the licensed engineer issues a 'certificate of release' for the aircraft.) We shall first look at the kinds of tasks that are carried out by mechanics and licensed engineers, before going on to discuss how those task are divided between the different categories of worker.

3.1.8.1 Duties of aircraft mechanics and licensed aircraft engineers

Mechanics and licensed engineers carry out maintenance and repair work on aircraft, inspecting, testing, servicing and – where necessary – replacing – aircraft components and modules, either in situ or after removal from the aircraft, and carrying out fault diagnostics and repairs where required. More specifically, mechanics and licensed engineers working on the aircraft's mechanical systems, such as its fuselage and wings, engines, landing gear, flight controls, breaks, air conditioning and anti-icing systems, etc., will carry out tasks such as the following:

- performing functional checks on electrical, hydraulic, pneumatic and mechanical components and systems (e.g. by inspecting and, if necessary, repairing or replacing the valves, filters, pipes and pumps that form part of the aircraft's fuel system, or by servicing and maintaining the hydraulic systems that operate the aircraft's breaks);
- adjusting, aligning and calibrating systems, using hand tools, gauges, and test equipment (in particular, non-destructive testing of aircraft parts and structures);
- using hoists to remove engines from aircraft, before stripping the engines and using various instruments such as boroscopes and x-ray equipment to inspect their constituent parts for wear, corrosion, cracks, and other faults, repairing or replacing any defective parts, and then reassembling and testing the operation of the engine before finally reinstalling it on the aircraft;
- maintaining the aircraft's electrical generation and distribution systems;
- servicing the aircraft by, for example, greasing moving parts, checking the level of oil and hydraulic fluids, replacing batteries and wiper blades, cleaning screens, and checking wheels and tire pressures;
- using engineering drawing and drawings and technical publications to modify aircraft components, systems and structures following; and
- carrying out inspections of the aircraft's structure, either repairing any defects to the airframe or replacing the defective structural part if problems are found.

In performing these and other duties, the mechanics and licensed engineers may be required to use hand and machine tools in order to manufacture the parts required to carry out the repair in question (e.g. by fabricating sheet metal or composite patches for repairs to an aircraft's wings or fuselage, or by making pipes that can be used to fix problems with parts of an aircraft's fuel system). On the avionics side, mechanics and licensed engineers will inspect, calibrate, test, maintain and, where necessary, repair or replace, electrical, electronic and electro-mechanical components and modules such as those concerning the following aircraft systems: cockpit instrumentation; wiring; radio communications, navigation, and radar; automatic pilot systems; flight management computers; and, in the case of military aircraft, weapons-aiming and delivery systems. For all of this work, whether it be on the avionics or mechanical side, mechanics and licensed engineers must be able to read and interpret the relevant aircraft maintenance manuals and technical specifications in order to be able to interpret test results and determine the need, feasibility and method of repairing or replacing damaged or malfunctioning components and systems.

Given the increasing importance of composites in aircraft manufacture, it is worth discussing explicitly, if only briefly, the capacity of the MROs visited for this study to undertake composites testing and repairs (cf. BIS 2009b: 27). Interviewees reported that, while some Part-145 licensed organisations have extensive capabilities in composites, many prefer to outsource all but the most straightforward composites repairs by sending the relevant parts either back to the manufacturer or to an MRO that specialises in composites work. The sample of 145-licensed organisations visited for this study lends support to that description. Five of the case study organisations have invested in both the physical and human capital required to develop a significant composites capability, up to and in some cases including the autoclaving composite parts. Consequently, they have both the equipment, and the appropriately trained mechanics and licensed engineers, required to test and repair a wide range of composite components, including airframe structures (e.g. wings, fuselage), nacelles, radomes, side panels from jet engines, flying controls, and thrust reversers. The other six MROs have thus far chosen not to invest to the same extent, and are as a result restricted to carrying out relatively simple repairs (e.g., interior components like overhead luggage bins, and door and floor panels, or small-scale repairs to external components such as fairings).

3.1.8.2 The Qualifications possessed by aircraft mechanics and licensed aircraft engineers

Mechanics are usually time-served apprentices with level 3 qualifications (NVQs and BTECs/City and Guilds) in aerospace/aeronautical engineering. Especially in larger organisations, where a more extensive division of labour can be sustained, mechanics may specialise in either the mechanical or the avionics side of maintenance work. While mechanics will be involved in carrying out much of the work involved in servicing, testing, maintaining, modifying and repairing aircraft, the fact that they are unlicensed implies that they must at all times be supervised by a licensed engineer and cannot certify any of the work they do, which must instead be inspected and signed off by an appropriately-licensed engineer.[9]

9 Licensure is one of three main forms of occupational regulation, the other two being registration and certification (Kleiner and Krueger 2010: 676-77 Sandford Smith et al. 2011). Registration involves an agency registering the names and other relevant details of the individuals who practise a particular occupation. Possession of a particular type/level of qualification may be a prerequisite for joining a particular register. Those who do not register remain free to practise the occupation in question. Certification schemes arise in cases where individuals must possess a particular level of skill in order to use a title of some kind. While workers who are not certified can still engage in that kind of work, they are not permitted to use the title in question. The most stringent form of occupational regulation is licensing, in which case only people who are registered and certificated have the legal right to practise a certain trade and/or to perform out certain activities. In the case of licensed aircraft engineers, as we shall see, only people who have passed certain examinations, acquired a certain amount of practical maintenance experience, and who also maintain their competence by engaging in continuing personal development and training, are entitled to issue certificates of release for aircraft.

Two categories of licensed engineer concern us here. In both cases, the licences are recognised across all European Union states. A category 'A' licence holder is known as a Certifying Mechanic and is permitted 'to issue certificates of release to service following minor scheduled line maintenance and simple defect rectification … that the licence holder has personally performed' (European Commission 2003: 74). Hence, while Category 'A' licensed engineers are allowed to carry out a very broad range of tasks, their certification privileges are relatively limited, so that they will be authorised to certify only some of the work they carry out. Specifically, holders of a category 'A' licence are authorized to certify the satisfactory completion of only certain relatively simple inspections and routine tasks, such as the lubrication of aircraft systems, the replenishment of fluids and gases, repairs to internal (non-pressurised) cabin doors, overhead lockers, seat belts and cabin furnishings, and the replacement of batteries, wheel assemblies and break units (European Commission 2003: 74; CAA 2007: 76). A category 'A' licence does not entitle its bearer to certify more complex tasks. Nor does it permit its holder to certify any work that has been carried out by other people. For that, one needs a category 'B' licence, which is the mainstay qualification for aircraft maintenance engineers.

There are two varieties of category 'B' licence: engineers who hold a B1 licence bear the title of Maintenance Certifying Technician (Mechanical) and – as that name suggests - are authorized to certify work that is carried out on an aircraft's mechanical systems, including the 'aircraft structure, powerplant [including engines], and mechanical and electrical systems'. A B2 licence-holder is referred to as a Maintenance Certifying Technician (Avionic) and is entitled to certify maintenance, repairs and modifications to an aircraft's 'avionic and electrical systems' (European Commission 2003: 74). B1 licence-holders cannot sign for B2 work and vice versa. The 'B'-licensed certifying technicians play a more significant role in the functional testing of systems, in detailed system inspections, and the assessment, diagnosis and rectification of defects, than do the A-licensed certifying mechanics. Holders of a category 'B' licence are also entitled to certify a broader range of (more complex) work than those who hold only a category 'A' licence and, unlike the A-licensed mechanics, are also allowed to certify work that has been undertaken by other people (European Commission 2003: 74; CAA 2007: 13).[10]

The work of category 'B' licensed aircraft engineers in particular exemplifies the attributes that technicians are expected to possess. Recall that a technician is someone who can apply proven techniques and procedures to the solution of practical problems, often in ways that require considerable ingenuity and creativity. Then consider, in the light of that definition, the following description provided by an interviewee of the kind of work undertaken by a licensed aircraft engineer working on an aircraft, where some corrosion has been discovered in an aircraft structure:

> The [B-licensed] engineer will analyse and diagnose the nature of the problem, measuring its extent, understanding the materials in question and the stresses that are imposed on them by the operation of the aircraft. He

10 There is a third category of licensed engineer, namely those who hold a category 'C' licence. 'C' licence holders have an overview of the work being done on each aircraft, checking that all relevant maintenance and tests have been completed before signing off on all the work and finally releasing the aircraft back into service .Given that the licence in question is primarily concerned with the management of maintenance activities, rather than with those activities themselves, it will not be considered further here. For more details, see European Commission (2003: 74) and CAA (2007: 13, 57-59).

> will determine from that evidence, along with the information provided in the aircraft manufacturer's manuals, whether the relevant component can be repaired or whether it needs to be replaced entirely, and will then specify the relevant part and/or treatment required, before carrying it out … [In short], he will design the work, working through the problem to find the solution.

These remarks vividly illustrate how the duties of category 'B' licensed aircraft engineers require them to carry out the kind of creative, but disciplined, problem-solving that is the hallmark of good technician-type work.

To summarise, then, in a Part-145 approved maintenance organisation, unlicensed mechanics and category 'A' licensed engineers will do much of the actual work involved in maintaining, overhauling, repairing and modifying aircraft. More difficult work – in particular, the diagnosis of faults and the assessment of defects, along with complex system inspections - tends to be carried out by category 'B' licensed engineers. All the work, whoever carried it out, must be certified by an appropriately-qualified licensed engineer, with certifying mechanics who hold a category 'A' licence being allowed to sign off relatively straightforward tasks that they themselves have carried out, while category 'B' licensed certifying technicians certify more complex tasks, including those carried out by other people.

3.1.8.3 Routes to becoming a licensed aircraft engineer

The more extensive certifying privileges enjoyed by those engineers who hold a category 'B' licence reflects the fact that achieving a category 'B' license requires more knowledge, and greater experience, than is needed for a category 'A' licence. This brings us to the requirements for becoming a licensed aircraft engineer, which are set out in Part-66 of Appendix III of European Commission Regulation No. 2042/2003. In order to obtain a basic licence, prospective licensed engineers must demonstrate that they have the knowledge and practical skills and experience required competently to maintain, overhaul and repair aircraft. To that end, they must undergo a minimum number of hours of instruction, designed to teach them the practical skills and underpinning knowledge required successfully to discharge the duties associated with their role (800 hours for category 'A' licence, 2400 hours for a category 'B' licence). They must also pass the set of EASA examinations associated with the particular category of licence for which they are applying. The examinations cover subjects such as mathematics, physics, aircraft structures and engines, electrical principles, maintenance practices, materials, and electronic instrument systems, and are mainly assessed via multiple choice questions, save for one examination where an essay format is used to ensure that prospective licensed engineers have an adequate mastery of written English. Finally, in order to obtain a basic licence, candidates must also accumulate a minimum amount of practical maintenance experience on operating aircraft at a Part-147 approved facility, the requisite period being three years in the case of a category 'A' licence and five years for people wishing to obtain a category 'B' licence (European Commission 2003: 74-137; CAA 2007: 13, 41-56, 95-105). In practice, what this all means is that a young person who starts as an apprentice mechanic or fitter can gain his apprenticeship qualifications at level 3 after three years of training and can then – depending on his or her goal – spend the next one or two years passing the relevant EASA exams and accumulating sufficient experience to gain a category 'A' basic licence (after a total of four years of training) or a category 'B' basic licence (after a total of five years of training).[11]

Finally, before being able to certify work on an aircraft, someone who has acquired a basic licence also has to obtain what is known as a *type licence* (that is, a licence to certify work carried out on a particular type of aircraft). The requisite type-training, as it is known, involves both classroom training and also a requirement for a prescribed period of experience, typically 4-6 months, working on aircraft of the relevant type in a Part-147 approved organisation. Type-training ensures that the licensed engineer is acquainted with the structure and major systems of a particular type of aircraft, along with the associated inspection and maintenance practices, tooling and test equipment (European Commission 2003: 138-43; CAA 2007: 72, 77-81).[12]

While, as noted above, the most common way for young people to become licensed aircraft engineers is via an apprenticeship, there do exist alternative routes, one of which is worth discussing on account of the widespread criticism it received from interviewees. This route involves the young person attending university for two years in order to acquire a Foundation Degree in aerospace engineering, the syllabus for which covers the EASA examinations required for the category B1 licence. The problem, however, is that while the young people who pass such a degree acquire the theoretical knowledge required to become a licensed engineer, they do not acquire sufficient practical maintenance experience required to obtain their licence because, unlike apprentices, they are not accumulating time in the maintenance hangar from the outset of their course. Even if graduates from such courses are able to persuade an MRO to provide them with the opportunity to gain the relevant experience, which is not easy because the MROs typically prefer to restrict opportunities for on-the-job training to their own apprentices, they still face the prospect of an additional 4-5 years of on-the-job training until they have accumulated enough practical experience to apply for their licence. Therefore, while someone taking the apprenticeship route can become a licensed engineer in around 5 years, the university-based, Foundation degree option typically takes a total of 6-7 years. Moreover, even when students taking the Foundation Degree route are provided with opportunities to gain experience at a Part-145 licensed organisation as part of their programme, as was the case with two of the organisations visited here that were involved in 4-year courses in aircraft maintenance that attempted to combine a Foundation Degree with practical training, interviewees reported that the young people had inadequate practical skills at the end of the programme compared to apprentices, so that they were unable to do the jobs expected of them in the hangar.[13]

11 Individuals do not have to apply for a category 'A' licence and can go straight on to apply for a 'B' licence if they wish to do so, though this will still take a minimum of 5 years of training.

12 In order to hold a licence, a person must be at least 18 years of age, while the minimum age for someone to certify work is 21 (CAA 1007: 12).

13 This point has also been made by ADS, the trade body for the aerospace, defence and security industries, who commented in written evidence presented to the House of Commons that, 'Within the Maintenance, Repair and Overhaul (MRO) sector, there are concerns that young people are being steered into Higher Education and degree courses in aircraft maintenance that do not deliver the required hand skills, but which then make graduates ineligible for apprenticeship funding. The regulations require that Licensed Aircraft Engineers have recent work experience on the particular aircraft for which they are licensed and graduates can find it difficult to acquire this' (ADS 2012: paragraph 5.3). Similar concerns have been expressed by the Royal Aeronautical Society, which in written evidence submitted to the House of Commons reported that airlines 'are particularly concerned about the numbers being steered into Higher Education for degrees in aircraft maintenance which do not provide the appropriate practical hand skills required for aircraft maintenance and make graduates ineligible for apprenticeship funding. Many graduates often struggle to get appropriate work experience for the regulatory requirements' (2012: point 5).

3.2. THE SIZE OF THE TECHNICIAN WORKFORCE

Nineteen of the 21 case study organisations provided usable data on the size of their technician workforce (see Table 1).

Consider first the five organisations that are MROs 'pure and simple', in the sense that they neither form part of an airline nor manufacture components for the aerospace industry. These are amongst the smallest of the case study organisations, employing just under 600 people on average. In these cases, the percentage of the total workforce that is comprised of technicians varies from a low of around 30% to a high of about 60%, averaging around 45%. On average, some 40-45% of the technicians are category 'B' licensed engineers, the remainder being unlicensed aircraft fitters. On average, about 75% of the category 'B' licensed engineers hold a category 'B1' (mechanical) licence, with only around 25% holding a B2 (avionics) licence. This reflects the fact that, in the words of one interviewee, more of the avionics equipment on an aircraft is 'plug and play' and will therefore be sent off to the manufacturers to be repaired or replaced rather than being fixed in-house, whereas the mechanical maintenance tends to lend itself more to in-house repair and modification.

Four of the case study MROs form part of airlines. These are the largest organisations in the sample studied here, with an average total workforce of just over 13,000 people. Out of all the MROs in the sample, these four cases employ the largest number of technicians in absolute terms, with one employing over one thousand licensed engineers, but – thanks to the very large number of non-engineering staff that, as airlines, they employ – the technician workforce actually constitutes a rather small percentage of their total workforce, averaging only about 11% across the four cases.

Finally, we look at the MROs that, in addition to maintaining and repairing aircraft, also manufacture components. Data supplied by the two organisations that fall into this category indicate that they are the smallest employers in the study, with an average total workforce of 150 people. On average, about 25% of their workforces were qualified to technician level. The fact that technicians account for a smaller fraction of the workforce in these two organisations, compared to the organisations that are simply MROs, reflects the fact that both of these organisations are involved in the manufacture of composite parts using techniques – such as carbon pre-preg laminating – that require workers to have no more than level 2 skills. Such semi-skilled workers form a large percentage of workforces of the organisations in question. Only 10-15% of the technicians employed in these organisations are category B licensed aircraft engineers, reflecting the fact that MRO-work forms only a relatively small part of their business.

Three organisations in the sample were involved in the maintenance, modification, overhaul and repair of military aircraft. One of these organisations also manufactures some of the components and electronic systems used in those aircraft. A little under half (44%) of the total workforce of the two organisations in this group that provided usable data are technicians. This is very close to the figure for the share of technicians in the total workforce employed by the five specialist MROs discussed above (45%). The similarity is unsurprising, given close resemblance in the work carried out by the two types of organisation.

In the case of the two organisations that manufacture major civil aircraft structures, both of which employ somewhere in the region of 5000 people, technicians account for a little over half the workforce on average (53%). The same is also true of the five manufacturers of components and sub-systems/ systems for the aerospace industry; on average, around half of the workers in those organisations are technicians (51%), out of an average total workforce of around 4300 people. On average, around two thirds of the technicians employed in these seven manufacturing organisations were qualified to level 3, the remaining third having level 4/5 qualifications.

3.3 QUALIFICATIONS

This section draws out and summarises the findings concerning the qualifications typically possessed by technicians working in the aerospace industry. The evidence presented above indicates that there is a reasonably clear distinction between roles - such as machinists, aircraft fitters, and unlicensed aircraft mechanics – for which a level 3 qualification is the norm, and which therefore fall into the category of 'skilled trades', and roles like production/manufacturing engineer, quality engineer, draughtsman, and licensed aircraft engineer, for which qualifications such as an HNC, HND or Foundation Degree are required, and which therefore fall under the heading of 'Associate Professional/ Technical Occupations'.

Of course, the distinction between the two occupational classifications is not perfect: in some component and sub-systems/systems manufacturers, mechanical and electrical/electronic fitters are typically qualified to level 4 (HNC); NDT technicians are qualified to level 3 in some organisations, and to level 4 in others; and in the case of companies that use automated methods for fabricating composites parts, the qualification level – and, more specifically, the underpinning knowledge - required of the technicians who operate the (rather novel) automated type-laying or fibre placement machines lies somewhere around level 3-4, while the level of hand skills required of such technicians is typically said to be no more than level 2.[14]

Overall, though, the evidence indicates that one can answer the question posed by Mason (2012: 4) – about whether the distinction between 'Skilled Trades' and 'Associate Professional/Technical Occupations' remains relevant in industry today - by saying that it does indeed still capture an important distinction between the qualifications and duties associated with the occupants of different sets of roles in the aerospace industry. The continued relevance of the distinction is only reinforced by the fact that many of the organisations visited for this study offer separate training programmes – with different entry requirements, content and exit qualifications – for those apprentices who are destined for 'Skilled Trades' and 'Associate Professional/ Technical Occupation' roles (see Section 4.2.1.1 below).

14 In the case of composites fabrication, there is also some uncertainty about the status of the workers who use non-automated production methods such as carbon pre-pre laminating to make composite parts. While the occupants of such roles currently tend only to have level 2 skills, some organisations are – as we have seen – considering the possibility of training their laminators to level 3 in order to improve the quality of their work. If that were the case, then the role of carbon pre-preg laminator would count as a 'Skilled Trade' rather than, as it does at present, a semi-skilled occupation.

3.4 SOURCES OF TECHNICIANS

How did the technicians who currently work for the aerospace companies visited for this project come to work for their current employer and acquire the skills required to carry out their current role? Three alternative possibilities may be distinguished. The first is external recruitment, which involves the employer recruiting the technician 'ready-made' from the external labour market. Second, and in sharp contrast, the employer might obtain its technicians by training them in-house, via its own apprenticeship scheme. An apprenticeship can be defined as a contract between an employer and a (traditionally, young) person that combines a structured programme of on-the-job training and productive work with part-time, formal technical education (Steedman et al. 1998: 11; Ryan et al. 2007: 129). Apprenticeship training, which is usually formally certificated, equips people with intermediate-level skills of the kind required to fill roles that fall under the heading of 'Skilled Trades' or 'Associate Professional and Technical Occupations' in the UK's Standard Occupational Classification system. A third possibility also involves the employer playing a role in training workers, but in a rather different fashion to what is involved in apprenticeship. This third approach, which will be referred to here as 'upgrade training', involves the employer taking people who have already undergone some post-compulsory education and training, and who have worked for some time in a semi-skilled role, often with the employer in question, and then providing them with the additional training required to fill a higher-level role – for example, one that would be classified as a 'skilled trade' - within their organisation. In contrast to apprenticeship training, therefore, upgrade training: is typically offered to adults, who have received some training and possibly obtained a formal qualification in the past; who have acquired considerable work experience, upon which foundation the upgrade training then builds; is usually closely tailored to the requirements of a specific role; is often provided informally, on-the-job; and is equally often uncertificated (Ryan et al. 2007: 130, 137; Lewis et al. 2008: 7).

What balance was struck by the firms visited for this study between these three different ways of obtaining technicians? Of the 11 MROs in the sample, nine were able to provide rough estimates of the origins of their technicians: in three cases, amongst which were numbered three of the four smallest MROs in the sample as measured by total employment, interviewees reported that the vast majority of their technicians were recruited, with fewer than 10% being trained in-house; one larger MRO also relied heavily on recruitment, with 70-80% of its technicians being hired from the external labour market. Matters were somewhat different in the case of five other MROs, however. One estimated that about 40% of its licensed engineers had been trained via its own apprenticeship scheme, while the other four indicated that between a half and two thirds of their technicians were developed internally.

All five of the manufacturers of aircraft components and sub-systems that supplied data suggested that over half of their technicians were home-grown. The need to train workers in-house was felt especially acutely by those organisations that were involved in the manufacture of composite components because, as we shall see in Section 4.1 below, the availability of workers with good skills in composite manufacture is extremely limited. Finally, the two manufacturers of major aircraft structures offered some indication of the source of their current technician workforce. In one case, it was estimated that around 30% of the technicians had been trained in-house, mostly via the company's long-standing apprenticeship scheme but with some contribution being made by the upgrade training of some of the firm's semi-skilled workers. In the second case, the organisation suggested that the majority of its technicians were trained in-house, again either via an apprenticeship scheme or via the upgrade training either of its own semi-skilled workers or of skilled tradesmen from a non-aerospace background.

4. RESULTS II: THE FUTURE TECHNICIAN WORKFORCE

The previous section of the report focused on various attributes of the current technician workforce in aerospace firms, including: the kinds of duties carried out by technicians; their qualifications; and the routes by which the case study organisations acquired the technicians they employ at present. In this section, we shift our attention towards the future in order to examine how the organisations in question propose to satisfy their future need for technicians. In other words, in what follows we shall investigate the workforce planning strategies currently being used by the aerospace companies in the UK.

This is an interesting and important issue, for a number of reasons. First, as we shall elaborate below, the increasing difficulty of recruiting experienced technicians, coupled with employers' desire to deal with the problems posed by an ageing technician workforce, is leading them to place considerable emphasis in their workforce planning on apprenticeship training. In particular, as we shall see, five employers that had discontinued their apprenticeship schemes in the 1990s or early 2000s have restarted them within the past five years in order to deal with the problems posed by an ageing technician workforce and the increasing difficulty of recruiting experienced technicians. Second, as will also become apparent, some non-MROs employers in particular are changing their approach to filling associate professional/technical occupations; their frustration with graduates' lack of practical skills, combined with their appreciation of the skills and loyalty of vocationally educated workers, is encouraging them to rely less on hiring recent university graduates to fill such roles and to turn instead to training people in-house using Higher Apprenticeships. The aerospace manufacturers' growing appreciation of the advantages, in terms of practical experience and skills, is of course reminiscent of the belief, widely shared amongst MROs, that the vocational route provides a more appropriate means of training licensed aircraft engineers than do more university-based approaches (see Section 3.1.8 above).

4.1 RECRUITMENT

We explore now the ease with which organisations can hire technicians of the kind they need ready-made from the external labour market. In the case of the MROs, seven of the 10 organisations that expressed a view on the matter stated that they have difficulties recruiting licensed engineers, especially those with particular combinations of type licences. Only two MROs, both of which formed part of well-known airlines, found it relatively straightforward to hire workers of this kind.

The MROs' experience was more mixed when it came to recruiting trained, but unlicensed, aircraft fitters/mechanics, with an even split between organisations that had problems recruiting people who could slot straight into such roles and ones that found it relatively straightforward. Two of the organisations involved in the maintenance and modification of military aircraft said that they found it hard to recruit experienced technicians. Overall, then, the state of play when it comes to organisations involved in the maintenance, repair, modification and overhaul of civil and military aircraft is one where the vast majority of organisations find it hard to recruit licensed engineers, and a slim majority also have difficulties in recruiting experienced unlicensed aircraft mechanics.

Both of the manufacturers of major aircraft structures found it straightforward to hire experienced people, who were attracted by the relatively high pay and good career prospects offered by these large organisations. One did, however, express some concern at the possibility of recruitment becoming increasingly difficult in cyclical upswings in the aerospace industry. The picture was somewhat different in the case of the eight case study organisations that were involved in the manufacture of aircraft components and sub-systems/systems (two of whom, as noted earlier, are also MROs, and one of which also maintains military aircraft). The prevailing opinion, expressed by representatives of six of the eight case study organisations that fall into this category, is that the external recruitment of skilled workers is hard and getting harder. As one interviewee put it, 'It's very difficult to get the right skills as they're just not out there.' Two of the larger organisations also pointed out that, even though they might be able to entice experienced workers away from other firms in their local area, doing so would be counter-productive because that would involve them damaging firms in their own supply chain. Hence, as one interviewee put it, 'The experienced hire approach is something we have to change'.[15]

Some of the most acute difficulties have been experienced by manufacturers that have sought to recruit staff skilled in composite manufacturing. Of the five employers visited who were involved in the manufacture of composite components or sub-systems/systems, four have found it well-nigh impossible to hire anything like enough people – either as permanent employees or contractors - who are skilled at working with composite materials, whether they be (semi-skilled) laminators or technicians. The problem manifests itself in two ways: firstly, in a shortage of applicants; second, in the poor quality of the limited number of people who do apply, in the sense that all too many applicants have a distinctly limited awareness of good practice when it comes to dealing with composite materials. As one interviewee put it, commenting on his organisation's efforts to recruit people who are skilled at working with composites, 'It's been a nightmare.'[16] Faced with such difficulties, employers have invariably turned to various forms of in-house training in order to acquire the skills in composites manufacturing they need, including – but not restricted to – apprenticeships. And it is to the topic of apprentice training that we now turn our attention.

4.2 APPRENTICESHIP

4.2.1 Definition and involvement

Apprenticeship training may be defined as a programme of learning, usually for young people, that couples on-the-job training and experience at a workplace with part-time, formal technical education, and which leads to an externally recognised vocational qualification (Steedman et al., 1998: 11; Ryan et al. 2007: 129). All but one of the 21 case study organisations offer apprenticeships (the sole exception being a small MRO/component manufacturer). Seven also offer Higher Apprenticeships, with two more considering doing so. And of the 11 MROs, six are Part-147 licensed organisations that train category 'B' licensed aircraft engineers.

15 For similar findings about the difficulty of hiring experienced engineering technicians in other sectors, see Lewis and Gospel (2011: 32) and Lewis (2012a: 25-26). On the pressing need for additional technician skills more generally, in sectors other than aerospace, see UKCES (2010a: 6, 30-34, 2010b: 182) and The Economist (2012: 34).

16 Similar findings are reported in UKTI (2010: 25), Aerospace Growth Partnership (2012: 18, 20) and in SEMTA and NSAPI (2011: 3). Also see The Economist (2012: 34). For an attempt to help overcome such skill shortages by helping skilled workers who have been made redundant from the armed services and the defence industry to contact employers within advanced manufacturing who need the skills they possess, see Aerospace Growth Partnership (2012: 23-24).

For the purposes of describing their approach to apprentice training, the case study organisations are divided into three groups, each containing firms that have gone about training apprentices in a broadly similar way (see Table 3).

Table 3: Approaches to Apprenticeship Training: A Summary

Type of organisation	Total number of organisations	Number of organisations that train (i) apprentices and (ii) licensed aircraft engineers	Average intake of apprentices	Average apprenticeship intensity[a]
Manufacturers of civil aircraft structures, parts and sub-systems[b]	10	(i)9 (ii)0	50 craft, 30 technical	8% craft, 10% technical
Maintain, repair, and modify military aircraft[c]	2	(i)2 (ii)0	13[c]	15%[c]
MROs[d]	9	(i)9 (ii)7	19	8%

a: Apprenticeship intensity is defined as the total number of apprentices in training for a particular kind of role (either skilled trades or associate professional/technical) divided by of the total number of workers currently employed in such roles in the organisation.

b: Includes two organisations that both manufacture components and act as MROs, but which either do not take apprentices at all or do so only for occupations associated with component manufacture.

c: Averages based on data from two military-related aerospace companies only, with one firm – that manufactures components as well as maintains military aircraft – excluded.

d: Excludes two MROs that also manufacture components, one of which takes no apprentices, the second of which takes apprentices only for its component-manufacturing activities, not for its MRO-related work.

4.2.1.1 Apprentice training in aerospace manufacturing

Consider first the 10 firms in the sample that are involved in aerospace manufacturing, a group that includes the two firms that build major aircraft structures, five specialist component and sub-system/system manufacturers, two firms that combine component manufacture with MRO work, and one that manufactures components and sub-systems as well as maintaining military aircraft. All but one of these organisations takes apprentices. (The one that does not offer apprenticeships is a relatively small MRO/component-maker that, by its own admission, has little history of training.) The organisations in this group with the four largest training programmes, the smallest of which has an annual intake of 40 apprentices, hold the SFA funding contract and so take responsibility for organising the apprentices' training themselves, rather than delegating it to a third party such as a private training provider. In the remaining five cases, the SFA contract is held by a specialist private training provider or FE college, which helps the employer to organise the training programme. The number of well-qualified applicants comfortably outstrips the number of places on offer in all cases, with some firms mentioning ratios of applicants to places of over 20 to 1. Completion rates are over 90% in every case.

All but one of the nine manufacturing organisations that take apprentices differentiate explicitly between those apprentices who are destined for skilled trades roles and those who will occupy associate professional/technical occupations upon completing their training, offering separate training programmes with different entry requirements for the two groups of trainees.[17] 'Craft apprentices', as those apprentices who are in training for skilled trades roles are often known, usually aim to achieve a qualification at level 3. In keeping

17 The one exception is a components/sub-system/system manufacturer, all of whose apprentices take HNCs (level 4) in mechanical or electrical/electronic engineering.

with the role descriptions provided in Section 4.2 above, the qualifications tend to be NVQs and BTEC or City and Guilds level 3 awards in subjects such as aeronautical engineering (for aircraft fitters), mechanical engineering (for machinists), electrical/electronic or mechanical engineering for those fitters who make mechanical and/or electronic/electronics components or sub-systems/ systems, and manufacturing engineering (for composites team leaders).[18] The most common entry requirement is four GCSEs (including maths, English and a science) at grade C, though minimum admissions standards do vary from four GCSEs (including maths, English and a science) at grade D or above to five GCSEs (including maths English and a Science) at grade B or higher.

The average intake of craft apprentices in the eight organisations in this group who take them is around 50 per annum. Comparisons of apprenticeship activity between different employers and at different times are potentially clouded by differences in skilled employment, with larger employers taking on more apprentices simply because they have to sustain a larger technician workforce. An allowance can be made for this by calculating the apprenticeship intensity, that is the total number of apprentices in training for skilled trades roles as a percentage of the total stock of workers currently employed in such roles in the organisation. This averages around 8% in this group of organisations.

Distinct training programmes for 'Technical apprentices' – as those young people who are being trained for associate professional/technical occupations are often known – are offered by all nine of the manufacturers that take apprentices.[19,20] The goal of the young people taking technical apprenticeships is to achieve qualifications at level 4 (e.g. HNC) or level 5 (Foundation Degree, often as part of a Higher Apprenticeship) in subjects such as aerospace/aeronautical engineering, manufacturing engineering, mechanical engineering, or electrical/ electronics engineering, with a view to filling roles such as draughtsman, junior design engineer, manufacturing engineer, production engineering, and quality engineer. Unsurprisingly, entry requirements for such training programmes tend to be somewhat higher than for the corresponding craft apprenticeships, ranging from four GCSEs at grades A-C (including maths, English and a science) to A-levels in maths and physics for those young people taking Higher Apprenticeship programmes that in some cases are intended to lead ultimately to a full honours degree.[21] The average intake into these schemes is around 30 across the nine organisations in question, though that figure is skewed upwards considerably by the very large intakes of technician apprentices taken by two big organisations, without whom the average intake would be about 10 per year. The

18 The apprenticeships taken by aircraft fitters and machinists in firms that work with composites materials now usually include modules on working with composites engineering. In a similar vein, the manufacturing engineering apprenticeships taken by trainees destined for the role of composites team-leader in firms that fabricate composite parts and structures now include specialist modules in pre-preg laminating, and in the finishing, bonding, repair, and testing of composites parts. More established technicians will normally receive instruction in working with composite materials via informal, uncertficated in-house training schemes.

19 The division between the craft and technical streams is not, of course, hermetically sealed. Many firms also allow talented and able people who have performed well in their craft apprenticeship programmes to progress down the technical route by taking HNCs and Foundation Degrees.

20 It is also worth remarking at this juncture that, as noted in Sections 3.1.3 and 3.4 above, the manufacturers who fabricate aerospace components and structures using carbon pre-preg and resin infusion techniques tend to train the majority of their rank-and-file laminators in-house. In seeking to acquire laminators, such firms typically hire unskilled workers, selected primarily for their manual dexterity and attention to detail, and put them on internal training programmes that, in addition to instructing them in best-practice techniques for laminating, also drive home the significant - and potentially extremely expensive - consequences of failing to follow the correct procedures for dealing with composite materials. Trainees emerge from these programmes with uncertificated level 2 skills. (Pre-preg laminators are, as noted in Section 3.1.3 above, usually semi-skilled workers). Training programmes of this kind are discussed in more detail in Lewis (2012b). The fact that the programmes in question take workers only to level 2 (whereas genuine apprentices aim at intermediate – that is, level 3-4 – skills), along with the fact that the training takes place almost entirely on-the-job (with trainees receiving none of the formal, off-the-job technical education that is arguably central to apprenticeship training), implies that they do not count as apprenticeships as that term is used here (cf. Ryan et al. 2006: 362-64; Hogarth et al. 2012: 4, 11; also see Section 3.4 and n. 18 above).

21 See Section 4.2.3 below for a longer discussion of Higher Apprenticeships.

apprenticeship intensity – that is, the total number of apprentices in training for associate professional/technical occupations as a percentage of the total stock of workers currently employed in such roles in the organisation – averages around 10% in these organisations.

4.2.1.2 Apprentice training for the maintenance, modification, and repair of military aircraft

Three organisations are involved in the maintenance, modification, and repair of military aircraft. Two do this as their sole line of business. The third, as mentioned above, also makes components and sub-systems/systems for aircraft. All three organisations hold the SFA contract for their apprenticeship scheme and train young people to become (unlicensed) aircraft mechanics.[22] In each case, the trainees take BTEC or City and Guilds qualifications at level 3 in aeronautical engineering. Neither of the specialist maintenance organisations offers separate craft and technician apprentices schemes, though one is considering beginning to take Higher Apprentices as a means of training people for first-line managerial roles whilst still ensuring that they have a good grounding in practical work. The two specialist organisations take an average of 13 apprentices each year, giving an average apprenticeship intensity of 15%.

All three organisations require apprentice aircraft mechanics to have at least four to five GCSEs at grades C or above, including English, maths and a science. One organisation is thinking of increasing its requirement in GCSE mathematics to a grade B, on the grounds that where apprentices struggle to complete their training programme, it is the mathematical component of the off-the-job element of the apprenticeship that is the stumbling block. Completion rates are 90% or higher in all three cases.

4.2.1.3 Apprenticeship training in MROs

Of the 11 MROs amongst the case studies, one does not take apprentices at all, while another only takes apprentices for the component-making part of its business, not the MRO side.[23] Of the remaining nine MROs, seven Part-147 licensed organisations that train category 'B' licensed aircraft engineers, while the other two trains apprentices but without taking them to licensed status.

The most common way of organising the apprenticeship training, adopted by six of the seven Part-147 organisations and also by the two MROs that take apprentices but do not train licensed aircraft engineers, involves the apprentices spending much of their first year on block release, either at a local college or sometimes in the MROs' own training workshops, taking an NVQ2 in performing engineering operations in order to develop their basic hand skills and awareness of health and safety, and starting a level 3 qualification, mostly commonly a City and Guilds but sometimes a BTEC certificate, in aeronautical engineering or

22 Since these organisations deal with military aircraft, they are not subject to the same EASA regulations as the organisations that maintain, repair and overhaul civil aircraft, being regulated instead under the Ministry of Defence's Maintenance Approved Organisation Scheme (MAOS). It is noteworthy for our present purposes that they do not require EASA-licensed aircraft engineers to issue certificates of release for aircraft. For more on this, see http://www.mod.uk/DefenceInternet/AboutDefence/WhatWeDo/AirSafetyandAviation/MAA/MaosFrequentlyAskedQuestions.htm.

23 The one organisation that does not take apprentices does send some of its workers for off-the-job training in laminating, at a local college of further education. However, the training in question is limited to instruction in the practical side of the job, as assessed via an NVQ. Given the importance to apprenticeships of formal technical education designed to impart the relevant underpinning knowledge, the trainees in question are not classified as apprentices for the purposes of this study (see Section 4.2.1.1 above).

aerospace engineering and maintenance.[24] On the job training in the workplace will commence in the second year of the apprenticeship, with the off-the-job training for the City and Guilds or BTEC award continuing via day release, so that the apprenticeship framework will be completed by the end of year 3 of the programme. Those young people who complete this 3-year portion of the training are ready to work as unlicensed aircraft mechanics. In the case of the 7 Part-147 licensed organisations that train licensed engineers, young people who wish to achieve licensed engineer status will spend a fourth year, if they aspire to a category 'A' licence, and a fifth year, if they wish to acquire a category 'B' licence, taking the relevant EASA examinations and acquiring the requisite practical experience. All being well, they should then – after a total of five years training - be able to qualify as category 'B' licensed engineers, after which – as noted in Section 3.1.8.3 above - they will need to spend an additional four to six months working on a particular type of aircraft in order to gain the type licence that enables them to issue certificates of release.

The seventh MRO that trains licensed aircraft engineers takes a rather different approach, aiming to take people up to category 'B' licensed engineer status via a four year programme that involves them doing a Foundation Degree rather than a conventional apprenticeship. Students on this programme – and they are students, not employees – spend their first year on bock release at a local college, doing an NVQ2 in performing engineering operation and a BTEC level 3 in aerospace engineering. Years two to four see them take the EASA examinations alongside a Foundation Degree in aerospace engineering. Most of the on-the-job training takes place in year four of the programme. However, whilst in theory the young people should be ready to apply for their category 'B' licence after completing their fourth year, early reports indicate that in practice, as it is currently structured, the programme does not equip students with the relevant practical skills to work effectively in the hangar, necessitating an additional period of practical training. This is in line with the point, made by many interviewees and reported in Section 3.1.8 above, that the case of the licensed engineer appears to be one where there are considerable advantages, especially in terms of the acquisition of practical skills and experience, to be had in following a work-based approach to learning rather a programme more closely aligned with university study.

Only the two MROs associated with airlines hold the SFA contract to train apprentices. The remaining seven devolve formal responsibility for organising the training to a private training provider. The average annual intake across all these organisations is around 19 apprentices per annum, a figure that falls to an average intake of around 10 apprentices if one very large airline-based MRO, which currently takes upwards of 100 apprentices each year, is excluded from the calculations. Apprenticeship intensity is a little over 8%. Apprentices are normally required to have four to five GCSEs at grades A-C, including English, maths and – usually – a science. Interviewees from several MROs emphasised that, in addition to academic requirements, they also paid considerable attention to applicants' practical skills, as evidenced not only by the applicants' performance in

24 Those MROs that have decided to develop a capacity to repair and modify composite materials are investing in purpose-built composites training facilities and incorporating modules on composite materials into their apprenticeship training programmes. Moreover, even in the case of MROs that prefer to outsource the repair of composite parts by sending them either to a specialist MRO or back to the manufacturer, it is important that staff at all levels are aware of the basic properties of composite materials and of the kind of behaviour that is required in dealing with them. So, to take a commonly-mentioned example, it is important in the case of airline-based MROs that all staff, ranging from licensed engineers and mechanics to baggage-handlers, know that if something is dropped onto or driven into a composite part, then although that part might look undamaged, its structural integrity may have been compromised, so that it is necessary to call an expert to have it tested.

practical tests set as part of the selection process but also by their hobbies. (The employers were looking for young people who liked to spend their spare time dismantling and reassemblies motorbikes and cars, building model aeroplanes, and so forth.) Interviewees from two MROs underlined the point that they did not only want to take candidates who were very strong academically. They were also interested in those who only just met the minimum academic requirements, but were more practically inclined and talented and who would as a result become, and most likely remain for all of their career, good unlicensed mechanics (or, in the words of one interviewee, 'do-ers … who will carry out our core business of fixing aeroplanes').[25] All but one of the organisations reported that its training programme is highly over-subscribed, citing figure of six, 15 and even 40 applicants per place. Completion rates tend to be high, typically being cited as 90% or above.

4.2.2 Rationale

The organisations that take apprentices usually mentioned one or more of the following three reasons for doing so. The first, mentioned by 17 of the 20 firms that take apprentices, was that apprenticeship enables them to acquire specialist technician skills in a context where there is a limited availability of the relevant kind of worker on the external labour market (see Section 4.1 above). The most striking example of this is probably to be found in those organisations that make composite components and structures, where expanding firms are finding it well-nigh impossible to hire experienced workers with the relevant skills and as a result have little option but to fill the gap by training those workers in-house.[26] But similar stories were told by interviewees from firms in all of the different parts of the aerospace sector considered for this study. In the words of one employer, 'We can't recruit people off the street to do the kind of work we require ... [so] apprenticeships are integral and vital to our business.' Moreover, even in those cases - typically involving large organisations that offer above-average pay and career prospects - where employers felt that they would not find it too difficult to recruit skilled workers, they were reluctant to do so on a large scale, the reason being that – since many of those workers would come from firms in their own supply chain – such recruitment would indirectly damage their own organisation. As one interviewee put it, 'There are [almost] no skilled workers outside and [even] if we can find them we will hurt ... our business partners.'

The second major rationale for training apprentices, mentioned by 13 of the 20 case study organisations that do so, is succession planning. Of the 10 organisations that provided some kind of data on the age profile of their technician workforce, four cited an average in the 50s, while one other did not provide a figure for the average age but mentioned that 40% of its workforce is due to retire within the next ten years (cf. SEMTA 2009: 13, 15).[27] This age profile was attributed by

25 A similar point was also made one of the large component and sub-system/system manufacturers. While many of the apprentices who come through its very successful training scheme progress on to HNCs and degrees, and move rapidly into managerial roles, this causes problems for the part of the business in which they were initially trained, which does not have the opportunity to benefit much from their skills before they are promoted to other parts of the organisation. This is a source of some frustration, to which the selection of more practically-inclined apprentices, who are less likely to progress rapidly, and who are therefore more likely to remain on the shop-floor for longer than the more academically-inclined 'high-flyers', is a solution. Analogous cases can be found in the case of employers in the space sector (see Lewis 2012a: fn 24).

26 This is true not only of technician-level skills, but also – as noted above - of the level 2 skills that laminators are typically required to possess. For more on this see, including evidence that such shortages extend well beyond aerospace to encompass all those sectors that make use of composites, see Lewis (2012b).

27 For similar findings, albeit in a report that tends to focus on the graduate-level workforce and is based on a limited set of data, see Roland Berger Strategy Consultants (2009: 3, 9). It is worth noting in this context that one analysis of Labour Force Survey data indicates that around a third of all Science, Engineering and Technology technicians – defined so as to include both Skilled Trades and Associate Professionals – are 50 years of age or older (Mason 2012: 19-20).

several interviewees, both in firms and sector-level bodies, to the fact that many companies scaled back, or closed entirely, their apprenticeship training schemes in the 1990s and early 2000s, relying instead on recruiting experienced middle-aged technicians (e.g. from the armed forces), thereby leading to the present situation where there is a dip in the profile of the technician workforce in the region of 35-45 years of age (cf. SEMTA 2009: 17).[28] Furthermore, four of the organisations that cited an average age in the 40s mentioned that the figure was so low only because apprenticeship training had been used to bring it down in recent years. In all these cases, apprenticeships are being used as a means of succession planning, with a view to creating a workforce with a more balanced age distribution.

One additional benefit to be had from using apprenticeship training as a means of succession planning is that doing so affords firms the opportunity to alter their skills profile so that it is better suited to their current business needs. Perhaps the most notable example of this was provided by three of the four airline-related MROs, which argued that over the years the skills profile of their technician workforce had become, in the words of one interviewee, rather 'top heavy' in the sense that there are too many category 'B' licensed engineers and too few unlicensed mechanics and category 'A' licensed engineers. This has led to a situation where the category 'B' licensed engineers have had to do more hands-on work, of a kind that could just as well be done by unlicensed mechanics or category 'A' licensed engineers, than either the employers or the licensed engineers themselves would like. As one interviewee summarised the situation, 'We haven't got enough do-ers.' In all three cases, it was felt that apprenticeship training could help to deal with the problem; as the older 'B' licensed engineers retire, the organisations are aiming for many of their current apprentices to become unlicensed mechanics or category 'A' licensed engineers, not 'B' licensed engineers, which will help to redress the balance between the different types of worker within their technician workforce. This will benefit both the remaining category 'B' engineers, who will be able to concentrate on their more interesting diagnostic work and on certifying, and also the employers, who will no longer be paying (more expensive) category B licensed engineers to do work that could be done just as well, if not better, by (less expensive) category A licence-holders or unlicensed mechanics.

The third major rationale for apprenticeship training, cited by 11 of the 20 case study organisations that take apprentices, is that it affords employers the opportunity to introduce the young people to the organisation's culture and to instil in them the values, standards and norms of behaviour - such as teamwork, attention to detail, leadership, and the ability to take responsibility and act in a trustworthy fashion - desired by the employers. This process of socialisation takes place both in the workplace and also, in many cases, through apprentices' involvement in various activities designed to catalyse their personal development, including outward bound courses, the Duke of Edinburgh's Award Scheme, and charitable projects. While the latter lie outside the narrow requirements of the government apprenticeship framework, they help employers to mould the character of their young employees. As one HR manager put it, 'Apprenticeships help embed company values and develop wider employability

28 Also see Steedman (2011: 2), where data showing a decline in the number of level 3 apprentices trained each year in Britain between 1996 and 2010 can be found.

skills and behaviours.' While it is of course possible to do this with older workers, whose attitudes and habits have already been formed but may be susceptible to modification, employers pointed out that it is easier to do so with young people, whose habits and standards are less ingrained. As one apprenticeship training manager put it, 'To get them the values of the organisation we want them young.'[29]

One important value that several employers argued is promoted by apprenticeship is loyalty, most notably in the sense that newly qualified apprentices are thought to be likely to remain with the organisation that trained them rather than being susceptible to being lured away by other firms. While two smaller firms in particular were concerned about the possibility of their apprentices being poached, many more organisations argued that apprenticeship was a means of building loyalty and reducing labour turnover. The most common reason for this, mentioned by eight employers, reflects employers' belief that, by offering their apprentices good training followed by a realistic prospect of promotion up through the organisation, they can demonstrate to the young people that they are valued, that the employer is willing to invest in them, and that they have a good opportunity to develop their career within the organisation, thereby reducing the likelihood that they will want to leave. As one employer put it when asked whether the prospect of poaching deterred it from training apprentices, '[We're] not worried one bit. If you treat them [the apprentices] right and get them embedded in the organisation, then they won't want to leave.' In this way, the employers argued, the provision of apprentice training can signal to young people that they are valued by their employer and that they will have ample opportunity to develop their career whilst remaining at the organisation that initially trained them, rather than having to move elsewhere to do so, thereby cultivating their loyalty and commitment to their first employer (cf. Marsden and Ryan 1995: 71). Consistent with this, several of the organisations were keen to point out to apprentices that a significant proportion (ranging from 30% to 70%) of their managers had begun life as apprentices, thereby underlining to the young people that there are well-defined career paths within their organisations from an apprenticeship to senior roles.[30] Two employers went even further than this, pointing out that internal studies had shown that apprentices were both more likely to stay with the organisation than more experienced recruits, and also that – thanks to their superior hands-on knowledge of the business - they were likely to be promoted faster than graduates. The overall message conveyed by these employers, then, is that if apprenticeships are complemented by other human resource management practices concerning continued training and career progression, they can help to persuade apprentices that their future lies with their current employer rather than elsewhere, thereby building loyalty, reducing turnover and helping firms to ensure that they earn a positive return on their investment in training. And it is for such reasons that one interviewee referred to apprenticeships 'the best way to instil company loyalty and behaviours.'[31]

4.2.3 Higher Apprenticeships

The Higher Apprenticeship in Engineering Technology involves apprentices gaining: an NVQ2 in Performing Engineering Operations, so that they learn basic hand skills; an HNC, HND or Foundation Degree in (some branch of)

29 For similar observations by employers in other sectors, see Ryan et al. (2007: 140, 145-46), Lewis et al. (2008: 7, 15), Lewis (2012a: 27) and Hogarth et al. (2012: 10).

30 Also see Skills Commission (2011: 17).

31 For similar points, see Ryan et al. (2007: 140-41) and Lewis (2012a: 31-32).

Engineering, to give them appropriate theoretical knowledge; and an NVQ4 in Engineering Leadership that assesses their competence at more advanced engineering activities such as creating and evaluating engineering designs, specifying and evaluating engineering processes, and implementing quality assurance methods and procedures (SEMTA 2011). Five of the case study organisations – all involved in manufacturing either major aircraft structures or components/sub-systems/systems – currently take Higher Apprentices. In these cases, the Higher Apprenticeship usually, though not invariably, involves a Foundation Degree in Aeronautical Engineering. Apprentices are typically also offered the opportunity of a 'top-up' year to take the young person to a full honours degree, in some cases in just three years overall.

Entry requirements vary a little between the different organisations, ranging from three GCSEs (including maths, English and physics/chemistry) at grade C or above plus two A levels at grade C or higher in maths and science (physics/chemistry), to six GCSEs at grade B or above (including maths, English and a science) plus A-levels at grade B or higher in maths and physics. Firms typically also make it possible for people who have done well in their level 3 apprenticeship to progress on to their Higher Apprenticeship programme. The number of Higher Apprentices varies significantly between organisations, with two taking just five or so per year while three others currently recruit upwards of 40 in each annual intake.

The use of Higher Apprenticeship is motivated by a number of considerations. First, employers like the Higher Apprenticeship because it offers a combination of theoretical and practical learning that equips the Higher Apprentices with a superior capacity to apply their skills and knowledge in the workplace than is possessed by many new graduates (who typically require a two year in-house training programme once they join a company) (cf. SEMTA 2009: 13, 18). Consequently, freshly qualified Higher Apprentices are often better prepared to make a useful contribution to the business in associate professional/technical roles such as manufacturing engineer, junior designer, quality engineer than are people who have been recruited straight from university, who are often said to lack the requisite practical skills for such technical positions.[32] This tendency has been reinforced in the case of one or two manufacturers by a change in their strategic direction, with less emphasis likely to be placed in the future on large design-and-build contracts and more on the maintenance and servicing of equipment, a change that is believed to imply a greater need for technicians at the associate professional level relative to chartered engineers.[33] Second, having received more in-house training and practical experience from their employer than most graduates, the Higher Apprentices often have more realistic expectations of what their job involves, and greater loyalty to the firm that invested in them. Consistent with this, internal studies carried out by some of the employers in question indicate that Higher Apprentices have a broader range of skills, and tend to be promoted faster and have lower turnover rates than their university-educated counterparts. Third, two firms also mentioned that the combination of technical and managerial skills offered by the Higher Apprenticeship was appealing as a means of training people for first-line management roles (e.g. project management). Fourth, employers also thought that the Higher Apprenticeship

32 Also see DIUS (2009: 26), where it is reported that 'employers [in STEM-related sectors such as engineering] are experiencing a shortage of staff with technical and practical work experience.'

33 For more on the 'servitization of manufacturing', as this process is known, see Baines *et al.* (2009) and BIS (2010b: v, 8-9).

afforded them the opportunity to appeal to talented and ambitious young people who might in the past have thought about going straight from school to university but who now, after the rise in university fees, may be attracted by the prospect of obtaining a university degree whilst gaining practical experience and without accumulating large debts. In this way, it is thought, the use of Higher Apprenticeships will enable firms to increase the supply of talented individuals entering their organisations.

Three other organisations said that they were contemplating taking Higher Apprentices, for similar reasons to those just outlined. Two of these organisations were airline-based MROs, while the third is involved in the maintenance of military aircraft. While the MROs are, as noted above, sceptical of Foundation Degrees as a means of training licensed aircraft engineers, preferring to rely on the craft apprenticeship route to develop people for such roles, they are considering using Higher Apprenticeships as a means of training junior design engineers and airworthiness engineers, who (respectively) help to design repairs for certain types of problem found on aircraft and assist in ensuring that all the maintenance activity undertaken by the MRO is carried out to the correct standard.

This case study evidence may be brought to bear on the question of the balance that Science, Engineering and Technology employers strike between employing university-educated graduates and vocationally educated technicians to fill associate professional/technical roles (Mason 2012: 25-27). Mason notes that over the past 10-15 years such employers have been motivated to employ university graduates to fill such roles, primarily because they do not incur the cost of training graduates, whereas they do pay for most of the cost of training those technicians who have been developed via apprenticeships. However, Mason also cites recent case study evidence showing that employers' frustration with the limited practical skills and experience possessed by graduates is in some cases now prompting them to rethink their strategy for filling technician posts, leading in particular to a greater reliance on apprenticeship training on the grounds that technicians who have been developed via the vocational route are more likely to have the practical skills and commercial understanding needed by businesses. While, as Mason rightly notes, further research is needed to establish how widespread this change in strategy is, the evidence reported above concerning aerospace companies' increasing reliance on Higher Apprenticeships lends further support to the proposition that concerns about graduates' lack of practical skills and commercial understanding are leading some employers to rely less on graduate recruitment and more on vocational education and training to fill associate professional/technical positions.

4.2.4. Impediments to the use of apprenticeship training and Higher Apprenticeships

Ten of the case study organisations, in particular those involved in aircraft maintenance and those looking for training in techniques for working with composites materials, expressed dissatisfaction with the quality of the training offered by local colleges of further education. Employers mentioned a number of problems. One concerned poor communication on the part of colleges, who were said to have failed to inform employers about apprentices' absences from college and to have registered apprentices for the wrong qualifications (four cases). A second set of difficulties centred on inadequately trained college lecturers, who were said to be unfamiliar both with the techniques and materials currently used in industry and also the standards to which aerospace mechanics are supposed to adhere, and on high turnover of college staff, which had led to discontinuity of teaching (five cases). Third, and relatedly, there was significant dissatisfaction with the quality of the practical, hand-skills training being provided in college workshops for apprentices spending the first part of their training on block release (five cases). In the words of one training manager, the colleges 'don't work to current national standards for practical training' so that, as another interviewee put it, 'You can get them through the NVQ2 too quickly without proper training'.[34] After having seen how his trainees were treated, another interviewee commented that he 'came out feeling that it was a certificate assembly line', with colleges being uninterested in doing anything more than the bare minimum required to award the NVQ. Or, as another training manager put it, the colleges are 'not interested in providing an education, only in bums on seats … They just want to draw down the funding.' Symptomatic of the overall impact of the difficulties experienced by employers is that two are currently working with their third local college, while one other is dealing with its fourth. Two other employers have become so frustrated with the quality of the practical training offered by colleges that they have given up sending apprentices to college for the NVQ2 and have chosen instead to invest in their own training workshops so as to provide the instruction in practical skills in-house.[35]

Out of the 20 case study employers that take apprentices, seven hold the SFA contract and are therefore in direct receipt of the funding that the government provides to support apprenticeships. Four of these organisations in particular are highly critical of what they see as the excessive bureaucracy involved in being an SFA contract-holder, including: duplicate requests for data from various government agencies; excessively complex systems for monitoring contracts; unnecessarily labyrinthine procedures for claiming funding; and changes to the governance framework that are announced at very short notice. In the words of one training manager, 'It's difficult to swallow. On the one hand they [the government] say they want to support apprenticeships but [on the other hand] they make the funding an absolute nightmare.'[36] One particular concern about funding, emphasised by three of the employers that are training Higher Apprentices, concerns the difficulties caused by the split in funding between Higher Education Funding Council for England (HEFCE), which funds the Foundation Degree, and the SFA, which funds the other parts of the training. The unfortunate consequence of this disjuncture is that employers offering Higher Apprentices have to grapple with the requirements of not one but two funding bodies, adding unnecessarily to the administrative load they must bear.[37]

Six employers expressed concerns about the attitudes towards vocational education and training displayed by schools, arguing that – perhaps because of the influence of league tables - schools seemed to be biased towards encouraging

34 The Royal Aeronautical Society has voiced similar concerns, referring in a recent submission to the House of Commons Select Committee on apprenticeships to the existence of problems caused by 'a lack of understanding about engineering apprenticeship requirements, particularly in a field such as aircraft maintenance, among FE colleges' and concluding that, 'Lack of training support here is the key reason that [a] number of MRO businesses are in decline' (2012: points 3, 7).

35 Similar problems with college provision are reported by Lewis and Gospel (2011: 33), in the case of university science and engineering departments that train apprentices, and by Lewis (2012a: 31), in the case of employers in the space industry. Also see Wolf (2011: 126).

36 Also see OECD (2009: 5, 19-22), LSIS (2011), UKCES (2011), and Wolf (2011: 62).

37 This problem has been noted for some time (see, for example, Ryan et al. 2007: 136). However, it has yet to be addressed, to the frustration not only of some of the employers involved in this study but also of those whose views are reported in Skills Commission (2011: 13-14, 43-44) and BAE Systems (2012: point 1).

young people to go to university rather than encouraging them to consider apprenticeships. Put slightly differently, these employers felt that, all too often, schools viewed apprenticeships as suitable only for less able pupils, rather than as an option that could be valuable for more able young people (including those who ultimately might want to go to university). Three employers, all MROs, were also disappointed by what they saw as the side-lining of practical training in schools, as evidenced by a diminishing willingness on the part of schools to offer Design and Technology training and by the declining quality of those school workshops that remained.

It is also worthwhile noting, against the backdrop provided by the various difficulties listed above, that one potentially significant deterrent to the use of apprenticeships appears not to be a major problem in practice. The potential problem arises from the possibility that, having completed their training, apprentices will be lured away from the firm that sponsored them, depriving that organisation of the opportunity to recoup its investment and therefore deterring it from engaging in apprenticeship training in the future. In actual fact, however, poaching appears not to have been a significant problem. On the contrary, as noted in Section 4.2.2 above, a majority of the case study organisations that expressed a view stated that apprenticeship is a means of building loyalty amongst their employees and thereby reducing labour turnover. Moreover, even in the two cases where organisations expressed concern about poaching, their worries were not sufficient to persuade them to stop training apprentices.

4.3 UPGRADE TRAINING

Apprenticeship is not the only form of training that employers can use in order to develop their own technicians. As noted in Section 3.4, another possibility involves the use of (internal) 'upgrade training', whereby an employer takes some of their own semi-skilled workers and gives them additional training in order to raise their skills from level 2 to level 3, so that they are able to fill skilled trades roles. Six of the case study organisations reported that they make use of this form of training.

The biggest use of internal upgrade training, measured in terms of the number of workers involved, is found in the two manufacturers of major aircraft structures. Both of these organisations have well-established upgrade training programmes that enable semi-skilled aircraft assemblers, who typically possess level 2 skills, to acquire the skills required to become skilled (level 3) aircraft fitters. In one case, the trainees take exactly the same programme as apprentices, receiving the same certificates if they are successful, while in the other they take the NVQ3 only. In both cases the number of workers currently in training exceeds 100. Even so, there remain significantly fewer upgrade trainees than apprentices.

Three of the component manufacturers also provide opportunities for their semi-skilled staff – who might occupy roles such as storemen or composites laminators - to train to level 3 so as to become, for example, skilled mechanical fitters or machinists. In some cases, these upgrade trainees take the same courses as the apprentices. In others, the training is confined to the on-the-job element of the apprenticeship framework and is not formally certificated. In these cases, the numbers of upgrade trainees tend to be rather smaller than the number of apprentices.

Finally, one MRO – associated with an airline – reports that it makes use of internal upgrade training. In this case, the training is provided for some of the MRO's semi-skilled workers, who typically have level 2 qualifications in engineering and whose duties involve them carrying out simple maintenance and repairs of mechanical and electronic systems that are not related to airworthiness (e.g. removal and refitting of internal cabin components such as call buttons, seat lights, video screens, etc.). The upgrade training involves them being trained up to become unlicensed level aircraft mechanics. Numbers in this case are small relative to the very large number of apprentices being trained.

In these six cases, then, employers make a non-trivial use of upgrade training as a means of filling skilled trade roles. However, in none of the cases examined here does the use of upgrade training come close to usurping the role of apprenticeship as the principal means of training technicians.

In addition to such internal upgrade training, three (other) MROs make use of what might be called external upgrade training. This involves them taking people from outside their organisation who have been trained in aircraft maintenance and who have acquired considerable practical experience, usually in the armed forces, and providing them with any top-up training they need in order to certify their skills and become licensed aircraft engineers. In contrast to the internal upgrading of semi-skilled workers described above, therefore, this external upgrade training is offered to workers who are new recruits to the firms providing it, and who already have level 3 skills, but who need additional training and certification to occupy the associate professional/technical role of licensed aircraft engineer.[38]

4.4 CAREERS: ONGOING TRAINING AND PROFESSIONALISM DEVELOPMENT

4.4.1 Ongoing Training

This section reports on the kind of ongoing training provided for more established technicians. Many of the larger aerospace employers in particular have extensive HR functions engaged in various activities related to strategic workforce planning, seeking to align the recruitment and (ongoing) training of workers with the medium- and long-term requirements of their business. Through the appraisal process, workers in these companies are afforded the opportunity to compare their current skills and competences against those required for the next role they (and their employer) wish (them) to fill, with appropriate training being provided to bridge any gap between the two. The vast majority of the non-MROs sponsor suitable vocationally-educated people to HNCs (if these are not already the expected goal of the firm's apprenticeship programme), HNDs, Foundation Degrees and full honours degrees. As noted in Section 4.2.2 above, significant proportions of the managers in several of these organisations have risen to their current position via the vocational route, testifying to the organisations' commitment to establishing and sustaining robust career paths for technicians.

In the case of the MROs in particular, EASA regulations demand that licensed aircraft engineers have two days of continuing training every two years, covering for example new legislation, lessons from incidents, refreshers on technical issues, new developments in technology, and 'human factors' (European Commission 2003: 52, 59). Thus, as is typically the case with licensing schemes, licence-holders

38 For another example of such external upgrade training, from the space industry, see Lewis (2012a: 22-23).

are required to maintain their competence by engaging in continuing personal development and training. In addition, employers, in particular those that are Part-147 approved training organisations and offer training as part of their commercial operations, sometimes send their own licensed aircraft engineers on the training courses they put on – for example, on particular types of aircraft – either as refreshers or to give them additional type licences, so as to increase the organisation's capacity to repair various kinds of aircraft. Finally, the increasing use of composite materials in aircraft has led those MROs that have decided to build a capacity in composites to send some of their licensed engineers on courses offered by manufacturers such as Boeing so as to develop their knowledge of, and competence in, the techniques involved in testing and repairing composite materials.

4.4.2 Professional Registration

Worries both about the status of vocationally-educated technicians vis-à-vis graduates, and also about the coherence and visibility of career paths for vocationally-educated workers, have recently prompted policy-makers and professional bodies to develop and highlight opportunities for people with vocational qualifications to achieve various kinds of professional recognition. The aim is to demonstrate to young people in particular that the vocational route is not second best and that it can lead to a high-status occupation with good career prospects, thereby encouraging more talented young people to become technicians in the first place. In the case of the engineering disciplines that are so central to the aerospace industry, a concerted effort is currently being made to encourage apprentices and technicians to seek professional registration, initially to become Engineering Technicians but with a view to advancing to Incorporated Engineer and ultimately to Chartered Engineer as their experience and skills develop (Skills Commission 2011: 17-18, 30-35; Technician Council 2012).

Six of the 10 non-MRO employers considered in this study that train apprentices have had their scheme accredited either by the IET or the IMechE, or both, while one is in the process of doing so. The upshot is that apprentices in these firms will be eligible for an EngTech award upon completion of their training, so that they become registered Engineering Technicians. In the words of one training manager, it is 'important' to do this because 'what you want is for young people to get professional qualifications and recognition and EngTech is what a technician is'. Three of the larger organisations have also mapped their Higher Apprenticeship scheme onto the requirements for Incorporated Engineer, so that their Higher Apprentices can register for IEng., while a fourth is in the process of doing so. These employers believe that registration potentially offers benefits not only to the individuals but also to the firms: it can help employers to ensure that their approach to training is consistent with external benchmarks such as the UK-Spec,[39] so the company can be confident that its people are competent ('It gives us a framework to monitor workers' development'); especially in the majority of cases where the employer pays the apprentices' registration fees, it gives workers a sense that their employer is willing to invest in them, thereby 'helping to recruit and retain high quality … technicians'; and it is also good for business because it demonstrates to potential clients that the firm has a well-qualified, professional workforce ('It looks good when bidding').

39 The UK-Spec – or, to use its full title, the UK Standard for Professional Engineering Competence - sets out the requirements that must be satisfied for various levels of professional registration (Engineering Council 2010).

The picture is rather different in the case of the MROs. Of the 10 MROs that take apprentices, only two have had their schemes accredited by one of the professional engineering bodies. Perhaps this ought not to be surprising. In the case of the MROs, as we saw in Section 3.1.8 above, there already exists a clearly-defined, well-known and oft-followed vocational route, mapped out according to externally-assured standards and involving both assessments of competence and knowledge and also requirements for ongoing training, that takes people from an apprenticeship to higher levels of professional recognition, namely those associated with being a category 'A' or a category 'B' licensed aircraft engineer. And the existence of these routes and, in particular, the prospect of becoming a licensed aircraft engineer, has clearly – according to many interviewees – been one of the most important factors in attracting many young people to careers in aircraft maintenance.[40] Therefore, far from indicating that employers and workers in MROs are uninterested in any form of professional registration, the relatively small number of employers who register their apprentices for EngTech is more a reflection of the existence of a well-established alternative path to professional status, whose use is of course encouraged by the fact that EASA regulations stipulate that MROs must have licensed aircraft engineers to issue certificates of release for aircraft.

40 While the prospect of progression to licensed engineer status is an important draw, it should not be forgotten that many people working in MROs are content to remain as unlicensed aircraft mechanics, having a fulfilling – and highly valued – career doing hands-on work in the hangar (see Section 4.2.1 above).

5. CONCLUSIONS AND RECOMMENDATIONS FOR POLICY

We return in this conclusion to the six questions posed in the Introduction, summarising what the evidence gathered for this study suggests about how they can be answered.

Q1: What kinds of roles do the technicians employed in the aerospace industry in the UK occupy, and what are their main duties?

Technicians account for somewhere in the region of 50% of the total workforce in most of the case study organisations visited for this study, except for those MROs that either form part of an airline or engage in the manufacture of composite components, where – thanks to the employment of large number of non-technical and/or semi-skilled staff - technicians constitute no more than 25% of the total workforce. Technicians with level 3 qualifications tend to occupy skilled trades roles such as aircraft fitter, electrical or mechanical fitter, aircraft mechanic, machinist, composite team-leader, and NDT technician. Those technicians who have level 4-5 qualifications usually fill associate professional/technical roles, including manufacturing/production engineer, draughtsman/junior design engineer, quality engineer or licensed aircraft engineer.

Q2: What qualifications do the technicians who work in the aerospace industry typically possess?

For the most part, there is a clear distinction between skilled trades roles, for which a level 3 qualification is usually required, and associate professional/technical occupations, whose occupants need level 4-5 qualifications such as an HNC, HND, Foundation Degree, or – in the case of licensed aircraft engineers – a category 'B' licence. However, there are some roles that appear to straddle the boundary between the skilled trades and associate professional/technical categories. For example, while in some component and sub-system/system manufacturers, mechanical and electrical/electronic fitters are normally qualified to level 4, in others they are required to possess no more than a level 3 qualification. The same is true of NDT technicians. Perhaps most intriguingly of all, the machinists who operate the automated production processes used to make certain composites parts are said to require level 3-4 qualifications, the ambiguity over the level of underpinning knowledge they must possess reflecting the novelty of the technology with which they are working.

Q3: How do aerospace employers acquire the technicians they need? What balance do employers strike between hiring experienced technicians from the external labour market and training them in house and, if they rely on training, what form does it take?

All but one of the manufacturers of aircraft structures components and sub-systems/systems that supplied data suggested that over half of their technicians were home-grown, primarily through apprenticeships but also – in the cases of the two manufacturers of major aircraft structures – through the internal upgrade training of their own semi-skilled aircraft fitters. Matters are more mixed in the case of the MROs: around half have tended to rely most heavily on apprenticeship, supplemented by recruitment; the balance between recruitment and training is reversed in the other half of sample of MROs, a group that includes the smaller organisations, which have tended in the past to rely mostly on recruitment to acquire their mechanics and licensed engineers.

Q4: Are there skills shortages?

A majority of MROs find it hard to recruit licensed aircraft engineers, while a small majority also have difficulties recruiting experienced aircraft mechanics. While the manufacturers of major aircraft structures found it relatively straightforward to hire experienced aircraft fitters, a majority of the firms that manufacture components and sub-systems/systems felt that recruitment was hard and getting harder. Some of the most severe shortages are faced by firms seeking to recruit technicians skilled in working with composite materials; aerospace employers, like those in other sectors, find it extremely difficult to acquire such workers from the external labour market. Overall, then, it appears that aerospace companies are facing similar difficulties to those described in a recent survey of medium-sized businesses in the UK, whose findings indicate that, 'The main challenge for British firms … is getting hold of workers with the right skills' (The Economist 2012: 34). Moreover, even some of the large firms that find it relatively straightforward to recruit are reluctant to rely on that approach, fearing the harm that such a strategy would do to firms in their supply chain and, therefore, ultimately to themselves. Employers appear to be responding to the increasing difficulty of recruitment by turning towards apprenticeship training, with five of the case study organisations whose apprenticeship training schemes had fallen into abeyance in the 1990s or early 2000s restarting them over the past five years. Moreover, motivated partly by a dissatisfaction with the practical experience possessed by university graduates, and also by the skills and loyalty of those associate professionals who have come through the vocational route, several of the manufacturers of large aircraft structures, components and sub-systems/systems are making more and more use of Higher Apprentices as a means of filling higher-level technician positions.

Q5: What provision do aerospace employers make for the ongoing training and career development of their technicians?

Almost all of the organisations invest considerable resources in nurturing the careers of their technicians, both through the provision of additional training - including sponsorship to HNC, HND, Foundation Degree and full honours degree - and also through affording them a realistic chance of promotion and a career advancement within their organisation. A slim majority of the non-MRO employers support their apprentices for registration for EngTech, the first rung on the ladder towards chartership. In contrast, MROs tend not to register their apprentices, for the simple reason that there exists a well-established, credible alternative to professional registration, namely licensing.

Q6: What – if anything – should government do to help aerospace employers in their efforts to acquire skilled technicians?

A number of recommendations for policy emerge from the findings presented above, connected primarily with helping firms to acquire the skilled labour they need and thereby to deal with the shortages of skilled workers described above.

The first concerns the role of further education colleges in apprenticeship training. While, as we have seen, aerospace firms are making more and more use of apprenticeships, sometimes reviving schemes that have been dormant for several years, the evidence gathered for this report suggests that the infrastructure they need to offer high quality training is not always in place. In particular, some employers are often let down by the quality of the support they receive from colleges, whether that be because of the poor quality of the hand skills training provided in college workshops or through the inefficient administration by colleges of the off-the-job component of the apprenticeship.

These issues must be addressed if aerospace employers are going to offer high quality apprenticeships, and thereby meet their need for technicians. Determining the right approach requires the collection of additional evidence, but possible solutions include:

- sharpening the incentives that encourage colleges to invest in their workshops;
- providing college lecturers with secondments in industry, so that they can learn more about current industry best practice.[41]

Another potentially helpful initiative would involve those small and medium-sized aerospace firms that wish to take apprentices 'piggy backing' on the established training schemes offered by larger aerospace employers. Such 'over-training', as it is known, might involve:

- the larger organisation simply assuring the quality of the provision offered by local colleges, so that the other firms could be confident that their apprentices would be well trained;
- alternatively, the larger organisations might take a more direct role, for example – in the case of those firms that have their own training school – by providing the hand skills training for other firms' apprentices during the latter's period of block release.[42] (Lewis 2013)

So far as the large employers that hold SFA contracts are concerned, two beneficial reforms would be:

- to reduce the burden of bureaucracy involved in running an apprenticeship scheme, in particular by eliminating multiple requests for the same data and by reducing the complexity of the contract-monitoring system,
- to simplify the funding regime by creating a single funding source for apprenticeships at level 3 and levels 4-5.

Finally, the careers advice provided to young people should also be improved. In particular:

- young people need to be made aware that the vocational route can lead to high quality training, that taking it does not preclude going to university at some point, and that it offers the prospect of high-quality training and swift progress along a well-defined career path;
- in the case of aircraft maintenance in particular, young people should be offered better advice about precisely which career goals are best pursued via a university-based Foundation Degree route and those, such as licensed aircraft engineer, which are arguably better followed from the foundation provided by a traditional apprenticeship.

The aerospace industry already provides fine apprenticeship training and excellent career opportunities for many young people. The removal of some of the impediments that hamper employers in their efforts to train young people, coupled with the

41 Some promising initiatives are already under way. For example, the Composite Skills Alliance is taking measures to improve the quality of college provision in composites (see Composites Skills Alliance 2012).
42 For similar suggestions, see ADS Group (2012: paragraph 5.2), Royal Aeronautical Society (2012: point 8), and UKCES (2011: 3, 27-28). Also see Rolls Royce (2012: points 8, 9, 12-15).

implementation of measures designed to extend the provision offered by large employers to apprentices from other firms, can open up opportunities for high-quality training to more young people, to the benefit not only of the apprentices themselves but also of their employers and the economy more generally.

REFERENCES

ADS Group (2011). *UK Aerospace Industry Survey 2011.* London: ADS Group.

ADS Group (2012). 'Apprenticeships: Written Evidence Submitted by ADS Group Limited.' House of Commons Select Committee on Business, Innovation and Skills. Available online at: http://www.publications.parliament.uk/pa/cm201012/cmselect/cmbis/writev/1843/app095.htm. Accessed 24th April 2012.

Aerospace Growth Partnership (2012). *Reach for the Skies: A Strategic Vision for UK Aerospace*. London: ADS and BIS.

BAE Systems (2012). 'Apprenticeships: Written evidence submitted by BAE Systems.' House of Commons Select Committee on Business, Innovation and Skills. Available online at: http://www.publications.parliament.uk/pa/cm201012/cmselect/cmbis/writev/1843/app016.htm.

Baines, T.S., H.W. Lightfoot, O. Benedettini and J.M. Kay (2009). 'The Servitization of Manufacturing: A Review of Literature and Reflection on Future Challenges.' *Journal of Manufacturing Technology Management*, 20: 547-567.

BIS (2009a). *Skills for Growth: The National Skills Strategy*. Cm 7641. London: TSO.

BIS (2009b). *The UK Composites Strategy*. London: Department of Business, Innovation and Skills.

BIS (2010a). *Skills for Sustainable Growth: Strategy Document*. London: Department of Business, Innovation and Skills.

BIS (2010b). *Manufacturing in the UK: An Economic Analysis of the Sector*. London: Department of Business, Innovation and Skills.

CAA (2007). *The Engineer's Licensing Guidance Document*. London: The Civil Aviation Authority. Available online at: https://www.caa.co.uk/docs/33/ELGDBook_07_WebVersion.pdf. Accessed 15th May 2012.

Composites Skills Alliance (2012). *The Composites Skills Alliance*. Darlington: Composites Skills Alliance.

DIUS (2009). *The Demand for Science, Technology, Engineering and Mathematics (STEM) Skills*. London: Department for Innovation, Universities & Skills. Available online at: http://www.bis.gov.uk/assets/biscore/corporate/migratedD/publications/D/Demand_for_STEM_Skills. Accessed 8th June 2012.

EASA (2010). *Maintenance organisation Approvals - Part 145 + AMC/GM Part 145.* Luxembourg: Publications Office of the European Union. Available online at: http://www.easa.europa.eu/rulemaking/docs/technical-publications/EASA_Part-145.pdf. Accessed 14th July 2012.

EITB (1970). *The Technician in Engineering.* Watford: Engineering Industry Training Board.

EITB (1980). *The Craftsman in Engineering.* Watford: Engineering Industry Training Board.

Engineering Council (2010). *UK Standard for Professional Engineering Competence: Engineering Technician, Incorporated Engineer and Chartered Engineer Status*. London: The Engineering Council. Available online at: http://www.engc.org.uk/ecukdocuments/internet/document%20library/UK-SPEC.pdf. Accessed 16th June 2012.

European Commission (2003). 'Commission Regulation (EC) No 2042/2003, Of 20 November 2003: On the Continuing Airworthiness of Aircraft and Aeronautical Products, Parts and Appliances, and on the Approval of Organisations and Personnel Involved in these Tasks.' Brussels: The European Commission. Available online at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:315:0001:0165:EN:PDF. Accessed 15th May 2012.

Evan, W. (1963). *The Engineering Technician: Dilemmas of a Marginal Occupation.* Cambridge, Mass.: MIT School of Industrial Management Working Paper #36-63.

Gurit (2012). *Guide to Composites*. Isle of White: Gurit. Available online at: http://www.gurit.com/guide-to-composites.aspx. Accessed 18th June 2012.

HM Treasury and Department of Business, Innovation and Skills (2010). *The Path to Strong, Sustainable and Balanced Growth*. London: HM Treasury and BIS. Available online at: http://www.bis.gov.uk/assets/biscore/corporate/docs/p/10-1296-path-to-strong-sustainable-and-balanced-growth.pdf. Accessed 24th April 2012.

HM Treasury and Department of Business, Innovation and Skills (2011). *The Plan for Growth*. London: HM Treasury and BIS. Available online at: http://cdn.hm-treasury.gov.uk/2011budget_growth.pdf. Accessed 24th April 2012.

Hogarth, T., L. Gambin and C. Hasluck (2012). 'Apprenticeships: Where Next?' *Journal of Vocational Education and Training*, 64: 41-55.

House of Commons Library (2011). 'Apprenticeships Policy.' Standard Note SN/EP 3-052. Updated 04 November 2011. London: House of Commons.

Jagger, N., M. Sigla and F. Sumption (2010). *SET Based Technicians: Lessons from the UK and European Labour Force Surveys*. Report 475. Brighton: Institute for Employment Studies.

Kleiner, M. and A. Krueger (2010). 'The Prevalence and Effects of Occupational Licensing.' *British Journal of Industrial Relations*, 48: 676-87.

Lewis, P. (2013). *The Over-Training of Apprecntices by Large Employers in Advanced Manufacturing in the UK*. London: The Gatsby Charitable Foundation.

Lewis, P. (2012a). *Space for Technicians? An Analysis of Technician Duties, Skills, and Training in the UK Space Industry*. London: The Gatsby Charitable Foundation.

Lewis, P. (2012b). *Technician Skills and Training in Advanced Manufacturing: The Case of Composites*. London: The Gatsby Charitable Foundation.

Lewis, P. and Gospel, H. (2011). *Technicians under the Microscope: A Study of the Skills and Training of University Laboratory and Engineering Workshop Technicians*. London: The Gatsby Charitable Foundation. Available online at: http://www.kcl.ac.uk/sspp/departments/management/people/academic/lewisgatsbyreport.pdf

Lewis, P., P. Ryan and H. Gospel (2008). 'A Hard Sell? The Prospects for Apprentice Training in British Retailing.' *Human Resource Management Journal*, 18: 3-19.

Liepmann, K. (1960). *Apprenticeship: An Enquiry into its Adequacy under Modern Conditions*. London: Routledge & Kegan Paul.

LSIS (2011). *Employer Reference Group – Simplifying End-to-End Apprenticeship Processes for Employers*. Coventry: Learning and Skills Improvement Service. Available online at: http://www.cbi.org.uk/media/1121626/lsis_simplifying_apprenticeships.pdf. Accessed 9th June 2012.

Marsden, D. and P. Ryan (1995). 'Work, Labour Markets and Vocational Preparation: Anglo-German Comparisons of Training in Intermediate Skills.' In L. Bash and A. Green (eds.), *Youth, Education and York.* London: Kogan Page.

Mason, G. (2012). *Science, Engineering, and Technology (SET) Technicians in the UK Economy.* London: The Gatsby Charitable Foundation.

OECD (2009). *A Learning for Jobs Review of England and Wales.* Paris: Organisation for Economic Cooperation and Development.

Roland Berger (2009). *Skills and Demographics in the Aerospace & Defence Industry: Discussion Document.* London: Roland Berger Strategy Consultants.

Rolls Royce (2012). 'Apprenticeships: Written Evidence Submitted by Rolls Royce.' House of Commons Select Committee on Business, Innovation and Skills. Available online at: http://www.publications.parliament.uk/pa/cm201012/cmselect/cmbis/writev/1843/app040.htm. Accessed 28th May 2012.

Royal Aeronautical Society (2012). 'Apprenticeships: Written Evidence Submitted by the Royal Aeronautical Society.' House of Commons Select Committee on Business, Innovation and Skills. Available online at: http://www.publications.parliament.uk/pa/cm201012/cmselect/cmbis/writev/1843/app034.htm. Accessed 28th May 2012.

Ryan, P., P.A. Lewis and H. Gospel (2006). 'Educational and Contractual Attributes of the Apprenticeship Programmes of Large British Employers.' *Journal of Vocational Education and Training*, 58: 359-83.

Ryan, P., P.A. Lewis and H. Gospel (2007). 'Large Employers and Apprenticeship Training in the UK.' *British Journal of Industrial Relations*, 45: 127-53.

Sandford Smith, D., P. Lewis and H. Gospel (2011). 'Registration and Technical Education.' In *Technical Education for the 21st Century*. London: The Gatsby Charitable Foundation. Available online at: http://www.gatsby.org.uk/techedu.html.

SEMTA (2009). *Skills and the Future of Advanced Manufacturing: A Summary Skills Assessment for the SSC Advanced Manufacturing Cluster*. Available online at http://www.cogent-ssc.com/research/Publications/ADVMFG_FINAL_March2010publish.pdf. Accessed 15th June 2012.

SEMTA (2011). *Apprenticeship Framework: Higher Apprenticeship in Engineering Technology*. Watford: SEMTA.

SEMTA and NSAPI (2011). *Composites Skills Alliance*. Watford: SEMTA.

Skills Commission (2011). *Technicians and Progression*. London: Policy Connect. http://www.policyconnect.org.uk/sites/default/files/Technicians%20and%20Progression%20-colour%20final(2).pdf. Accessed 28th April 2012.

Spilsbury, M. and R. Garrett (2011). 'The Future Demand for Technicians and Underlying STEM Skills.' London: The Gatsby Foundation. Available online at http://www.gatsby.org.uk/pdfs/Technical_Education_21C/The%20future%20demand%20for%20technicians.pdf. Accessed 13th June 2011.

Steedman, H. (2011). *Apprenticeship Policy in England: Increasing Skills Versus Boosting Young People's Job Prospects*. London: London School of Economics Centre for Economic Performance.

Steedman, H. Gospel and P. Ryan (1998). *Apprenticeships: A Strategy for Growth*. London: Centre for Economic Performance (LSE). Available online at: http://eprints.lse.ac.uk/20248/1/Apprenticeship_A_Strategy_For_Growth.pdf. Accessed 18th May 2012.

Technician Council (2012). *Professional Technician*. London: The Technician Council. Available online at: http://www.professional-technician.org.uk/about.php. Accessed 24th April 2012.

The Economist (2012). 'Britain's Mittelstand: The Thriving Middle Class.' *The Economist,* 16th June 2012. Available online at: http://www.economist.com/node/21556971. Accessed 18th June 2012.

UKCES (2010a). *Skills for Jobs: Today and Tomorrow. Volume 1*: Key Findings. Wath-upon-Dearne: UKCES. Available online at: http://www.ukces.org.uk/assets/ukces/docs/publications/national-strategic-skills-audit-for-england-2010-volume-1-key-findings.pdf. Accessed 24th April 2012.

UKCES (2010b). *Skills for Jobs: Today and Tomorrow. Volume 2*: the Evidence Report. Wath-upon-Dearne: UKCES. Available online at: http://www.ukces.org.uk/assets/ukces/docs/publications/national-strategic-skills-audit-for-england-2010-volume-2-the-evidence-report.pdf.

UKCES (2011). *Employer Ownership of Skills: Securing a Sustainable Partnership for the Long Term*. Wath-upon-Dearne: UKCES.

UKTI (2010). *UK Composites Supply Chain Study*. London: UK Trade & Investment.

Wolf, A. (2011). *Review of Vocational Education – The Wolf Report.* London: Department for Education.