Contributed paper

The origins of aerospace engineering degree courses

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Abstract

The development of degree courses specifically designed for aerospace engineers is described in relation to the change in needs of the industry since the demonstration of powered flight. The impact of two world wars and political decisions on the way universities have been able to meet the demand for graduates is discussed. The effect of these changes is examined in relation to the type of education received by current graduates compared with early courses.

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Introduction

The origins of the aerospace industry go back many centuries. Everyone is familiar with the story of Icarus who having designed a pair of wings, attempted to fly. He was successful but flew too close to the sun, whereupon the adhesive used as wing fastening melted due to thermal radiation and his flight ended in disaster. At the time this would have been regarded as science fiction, but clearly there was some awareness of aerodynamics (for wing design), adhesives and thermal radiation.

In retrospect, it is apparent that before successful man carrying powered flight could be demonstrated, there had been a period of intense study including experimental and theoretical analysis. The Royal Aeronautical Society, formed in 1866, preceded the first flight by some 37 years. As a learned society it encouraged the discovery and exchange of knowledge necessary for successful heavier than air flight.

Orville and Wilbur Wright, contrary to popular understanding, were extremely talented research workers as well as competent designers. To improve their understanding of wing aerodynamics they built a wind tunnel, a replica of which is in the Shuttleworth Collection at Old Warden, they studied bird flight intensively in order to develop a successful aerodynamic control system, using wing warping, and they designed and built a reciprocating engine which had a power to weight ratio of 12 lb/HP (7.3 Kg/Kw). This was superior to anything then available. In a letter written 2 years before their first demonstration of flight Wilbur wrote "... It is possible to fly without motors, but not without knowledge and skill" (Marvin and McFarland, 1953).

It is clear that learning is an essential and integral constituent of a successful aerospace industry. Knowledge had been sought for centuries prior to the first successful flight and the thirst for knowledge seems today to be unquenchable.

This paper first considers the history and development of the industry, including its changing needs. It is followed by the development of aerospace education, including the philosophy and course content of university courses. Finally, the impact of these changes is discussed.

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The UK industry

The report of the first successful flight was an inspiration for many to attempt to emulate the Wright brothers. In Europe, particularly in France and England, new designs evolved and by 1910 many successes had been registered, for example the first crossing of the English Channel. The commercial possibilities were beginning to emerge and in the UK the first aircraft manufacturing companies were set up. Among the earliest were Airco, later to become de Havilland, British and Colonial, later to become the Bristol Aeroplane Company and Vickers. Before 1920 Sopwith, later Hawkers, Armstrong Whitworth, Avro, Blackburn, Supermarine and English Electric had all commenced production. These companies and others were to merge severally in 1960 to form two airframe companies, Hawker Siddeley Aviation and the British Aircraft Corporation (Stamper, 1984). In 1978 these two companies together with Scottish Aviation merged to create British Aerospace, which in turn merged with the General Electric Company to form British Aerospace Systems plc in 1998. Whilst this was taking place international links were being established which led to the development of a number of aircraft including Concorde, Jaguar and Tornado. Airbus Industries was created by the coming together of aircraft companies in several countries principally France, Germany and the United Kingdom.

Other U K aircraft companies which remained outside the British Aerospace Systems organisation included Short Brothers, which moved to Northern Ireland after WW2. In 1960 Westlands, which started to specialise in helicopter design and manufacture after WW2, absorbed the helicopter divisions of Saunders – Roe, the Bristol Aeroplane Company and Fairey Aviation. More recently Westland helicopters have merged with Augusta, an Italian helicopter manufacturer to form a large European organisation. Handley Page which declined a request to merge, ceased operation in 1962. The reason for these changes are beyond the scope of this paper, but the effect upon the changing employment and skill needs of organisations has had a significant influence on the provision of educational courses.

At the commencement of hostilities in 1914, the British military regarded aviation with some suspicion. By the end of the war in 1918, aviation had emerged as a significant military force. The formation in the United Kingdom of the Royal Air Force (RAF) was a seal of recognition of this fact and led to detailed consideration of the role of aviation in warfare, and its effect upon aircraft design. Very little thought had been given to the development of civil aviation and the Europeans lagged behind advances in the USA.

In order to illustrate employment trends, the number of programmes undertaken by one aircraft organisation (Sopwith, Hawker, Hawker Siddeley, and British Aerospace, Kingston) over the period 1912 to 1988 has been considered (Fozard, 1987). At the birth of the industry, two or three projects might be started in one year and there would be perhaps one or two other projects in progress. Political factors had a crucial influence in the form of WW1, but as is shown, politics have always had a significant if not dominant influence on the development of the UK industry. At the end of hostilities, production of military aircraft ceased and employment prospects declined. By 1925 demand had started to recover and new designs were being produced. By the early thirties at any one time there might be up to five or perhaps six projects in progress but new aircraft designs were started much less frequently. By the end of the thirties, the increasing international tension which preceded WW2 led to increased demand for military aircraft. Following the end of WW2 and the advent of the "cold war" military projects continued but at a reduced rate. The noticeable factor is that during this period and up to the present, the number of projects started reduced but the project length increased. To illustrate this trend Figures 1, 2 and 3, developed from Fozard, 1987, show that the average length of project climbs steadily from two years in 1912 to almost 30 years by 1988. The Harrier, in one form or another, from conception to the end of manufacture, is expected to have a life of around 40 years if the early prototypes and demonstrators i.e. the P1127 and Kestrel are included. At a national level the number of UK government funded projects decreased dramatically over the period 1946 – 1984. [Figure 4], (Stamper, 1984).

As a consequence of the increasing complexity of aircraft, the numbers employed

Figure 1 Average Project Length - 1912–1939

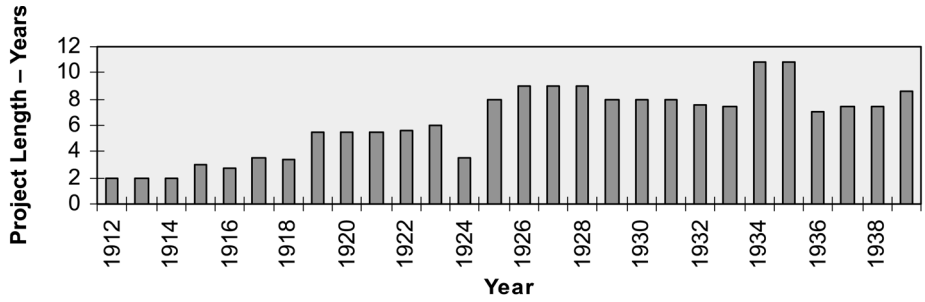


Figure 2 Average Project Length 1940–1960

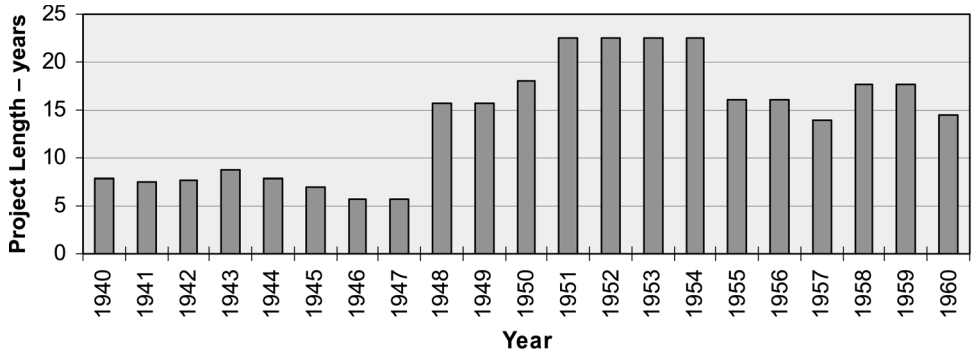
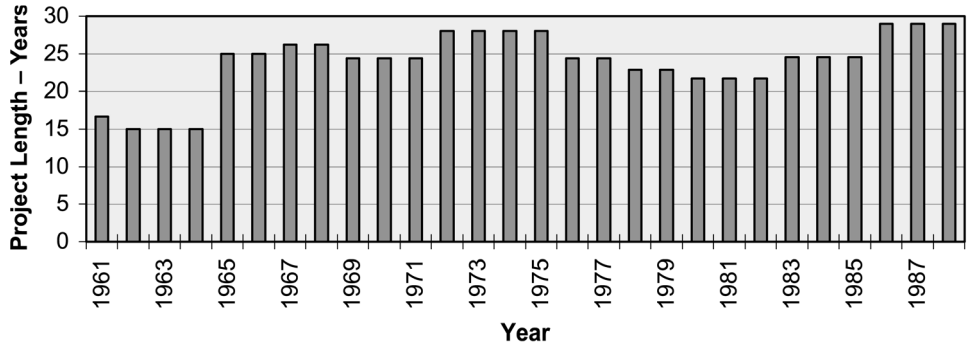


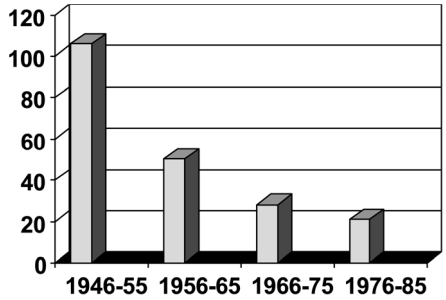
Figure 3 Average Project Length - 1961–1988



in design offices increased, and as the knowledge base widened the number of technical departments grew (Fozard, 1987) Figure 5. Employment prospects fluctuated depending upon the defence policy at the time and the level of international tension.

More recently, the trend has been for projects to become international. The cost of military and civil aircraft is now so great it is

Figure 4 Number of UK Funded Programmes (Fozard, 1987)



Source: Fozard (1987)

Figure 5 Technical Departments at Hawker Aircraft/BAe, Kingston (Fozard, 1987)

1935	1985
Design Office	Design Office
Technical Office	Stress & Aerodynamics
	Systems
	Ground & Flight Test
	Support Staff

Source: Fozard (1987)

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beyond the financial capacity of a company based solely in one country. Thus in Europe within the last twenty years, aircraft manufacturers have sought partnerships, for example, Airbus, or mergers, for example Westlands – Augusta.

As the industry expanded, specialist component companies evolved. The earliest example of this is of course Rolls-Royce PLC. Many other organisations are major suppliers to the aircraft industry of components such as landing gear, aircraft fittings, instrumentation, combustion equipment (for gas turbines) and perhaps most significantly avionic equipment.

So far consideration has been given only to manufacturers, but it must be recognised that airlines are significant employers of aerospace engineers. Maintenance and operations have become more sophisticated demanding similar skills and knowledge. All are significant employers of aerospace engineers, and it is the business of universities and colleges to satisfy this need. It must be recognised that the developments within the industry described above have had profound implications for those providing educational courses.

The development of Aerospace Education

Research and education was evident long before the first flight occurred. Sir George Caley, who died in 1857 some ten years before the establishment of the Royal Aeronautical Society, carried out an immense amount of research into aeronautics. The R Ae S was established to encourage research and the dissemination of knowledge. Soon after the first flight such was the interest in flying that public lectures were being given by eminent pioneers at East London College, now Queen Mary and Westfield College of the University of London, Northampton Institute, now City University, and Imperial College (Hancock, 1984). By 1908 a Dr AP Thurston had established a laboratory with a wind tunnel and structural test equipment at East London College and Sir Frederick Handley-Page an aviation pioneer was giving evening lectures at Northampton Institute.

At the turn of the century, engineering had become an established academic discipline at universities, although the areas of study were confined to Mechanical, Civil and Electrical Engineering. Aeronautical subjects in undergraduate courses were not introduced until the early 1920's. East London College pioneered the developments where a Diploma was awarded. In 1922 the University of London introduced aeronautical subjects within their BSc(Eng) programme.

The first Chair in Aeronautical Engineering was established at Cambridge, and optional papers in aeronautical subjects were introduced into undergraduate courses in 1921. Imperial College appointed its first professor in Aeronautical Engineering in 1920 but all teaching was confined to postgraduate study programmes. At Glasgow University a lectureship in Aeronautics was established in the same year.

The period following the end of WW1 was difficult for the industry. It had become expert in designing and building military aircraft but the demand evaporated. Civil aviation was in its infancy and the demand was small. The skills required for designing aircraft to fulfil this need were not so well developed. As a consequence there was little general desire to enter the industry and university courses did not attract many students. Industry, too, was suspicious of graduates. The recovery from the slump was slow and it was not until the mid 1930's that a serious revival began.

At this time courses were started at Southampton University College, later to become Southampton University, Loughborough College, later Loughborough University and Hull University. There were now a total of seven institutions in the UK offering undergraduate engineering courses which included optional aeronautical subjects.

Some consideration was being given to what education was needed by an aeronautical engineer. Sutton – Pippard, who had been involved in aircraft structures but was now a Professor of Civil Engineering, presented a paper (Sutton-Pippard, 1935) to the Royal Aeronautical Society. His remarks, which have been reported elsewhere (Hancock, 1984) are worth repeating.

> "University years should be devoted to the study of engineering science with as little emphasis as possible on the practical aspects of the work."

As Hancock commented, Sutton-Pippard recognised that practical training, subsequent of the degree, was essential and where that

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practical training included a measure of acquisition of workshop skills.

Pippard also stated

> "It has been found by most universities that three years (for a degree) is insufficient time to cover the necessary essential groundwork for an honours degree in engineering."

It should be pointed out that at the time courses in engineering included a year of study at intermediate level. Now, study at this level is undertaken and examined in schools by "A" Levels.

The topics studied in later stages of the course might include the normal subjects taken by mechanical engineering students. Pippard regarded Aerodynamics, Design of Aircraft Engines, Meteorology as postgraduate courses. At Queen Mary College however aeronautical subjects were included in the final year of their BSc course. In no undergraduate courses were there individual projects, group projects, management subjects nor any form of workshop training. However laboratory work in support of each technical subject was regarded as an essential element of the course.

The total number of graduates in aeronautical engineering produced prior to 1939 was small and industry generally felt no need of them. One exception was E W Hives (Pugh, 2000), later Lord Hives, Chairman of Rolls-Royce. Following a visit by some of his senior engineers to the German aircraft industry he wrote in a memorandum dated January 1937:-

> "Actually, the position is that we have relied too much on brawn and craftsmanship, and we have not sufficient brains in the factory."

Within a year he had employed Stanley Hooker, who after obtaining an honours degree in Mathematics at Imperial College, studied aerodynamics at Oxford obtaining a Doctorate in 1935. He was responsible for improving the performance of the supercharger for the Merlin engine (which powered the Spitfire, Hurricane and Lancaster), and for persuading the company to undertake the development of the jet engine.

The College of Aeronautics

The experience of WW2 demonstrated the need for highly trained manpower. As the conflict drew to a close, consideration was given to the development of aeronautical education in the post war period. A significant development was the report of the committee chaired by Sir Roy Fedden (MAP, 1944), which led to the foundation of the College of Aeronautics, and from which Cranfield University developed. By 1945 the Cranfield site had been selected and the first students arrived in 1946. This was and still is a postgraduate college specialising in aerospace teaching and research. It is located on a well equipped airfield and is able to undertake flight testing as well as full scale research. Students undertake taught masters programmes, specialist short courses, as well as research programmes for M Phil and PhD degrees. It does not offer undergraduate courses at its Cranfield campus. The College of Aeronautics today is part of Cranfield University which offers a broad spectrum of postgraduate courses. In 1944 Sir Roy Fedden wrote of the College of Aeronautics as "...an establishment to bridge the gap between the academic approach of universities and the hard practical needs of industry. The need for all-round engineers with a balanced outlook and proper appreciation of cost of timing as well as a sense of vision dedicated enthusiasm and high moral fibre." This is the Cranfield mission and that of engineering education today.

The Post War Years

Following the end of the war, six colleges were running first degree courses in aeronautical engineering. These were Cambridge, Glasgow and Queen Mary College, who were organising their own study programmes and Loughborough, Northampton and Southampton who took the University of London external degree. Hull, which before the war had been offering aeronautical courses, ceased this study programme as a result of pressure from the University Grants Commission.

In 1949 a report (RAC, 1949) by the Regional Advisory Council examined the educational provision for aeronautical engineering at degree and sub degree level in the south east of the UK. It was noted that most companies were either running their own technical college, e.g. Bristol Aeroplane Company, De Havilland Aircraft Company, Hatfield, or had strong links with a local technical college. [Table I].

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Table I Colleges associated with Aircraft Companies

Bristol Aeroplane Company	Own College Bristol
	Own College Hatfield (University of Hertfordshire)
de Havilland Aircraft Company	
Fairey Aviation	Southall Technical College
Handley-Page Aircraft Company	Northampton Polytechnic (City University)
Blackburn and General Aircraft Ltd	Twickenham Technical College
D Napier & Sons (engines)	Acton Technical College
Hawker Aircraft (Kingston) and Vickers Armstrong (Weybridge)	Kingston Technical College (Kingston University)
de Havilland Engines	Hendon & Willesden Technical College

These colleges were providing sub degree courses on a part time basis for apprentices and employees. Often senior staff from the local company would provide specialist lecture courses for the colleges. It was noted in the report that Kingston Technical College would be making application to offer the University of London external degree which would include aeronautical subjects. Together with Hatfield both eventually became universities.

The report also recorded degree courses at universities in the region and the numbers of students enrolled. In 1949, the total number of students enrolled at the three London colleges, i.e. Imperial College, Queen Mary and Northampton Polytechnic was 67 full time, 13 part time and 7 evening students. The full time students would be studying on a three year course so that average per year would be 22.

By 1956 further developments had taken place. Southampton had become a university and Manchester, Queen's University, Belfast and Imperial College, London were also offering degrees in aeronautical engineering. Additionally the Royal Aircraft Establishment's technical college at Farnborough introduced the London External Degree with aeronautical options. A number of the apprentices employed by the Royal Aeronautical Establishment (RAE) were able to take advantage of this facility. The college was well equipped and many of the lectures were given by senior staff from the RAE. Table II (data from the UCAS Handbook, 2000/2001) indicates the number of universities offering aeronautical degree courses and the corresponding numbers of students from 1935 to 2000.

In the years that followed many developments took place and these have been well documented. (Hancock, 1984, East, 1995). Table III lists significant events affecting all university courses and Table IV lists those affecting engineering courses.

The designation of Colleges of Advanced Technology, CATs, which very shortly became universities, the Robins Report and the establishment of the binary system had been designed to increase the opportunities for young people to undertake degree courses.

The great difficulty for these institutions is that funding did not support the very large increase in student numbers, [Figures 6 and 7] (National Committee Report, 1997). Aeronautical engineering is a high cost course and consequently suffers disproportionately during periods of financial stringency when it

Table II University Expansion

Year	No of Universities	Student numbers
1935	7	–
1949	6	67*
1955	9	–
1965	13	170
1975	13	
1985	16	350
1995	27	750
2000	30	1000+

* estimate

Table III Significant Events – Political

1958	Designation of Colleges of Advanced Technology
1963	Robins Report
1965	Binary System proposed – Establishment of Polytechnics
1992	Polytechnics designated Universities
1999	Bologna Declaration

Table IV Significant Events – Engineering

1980	Finniston Report
1984	Standards and Routes to Registration SARTOR - 1
1999	Standards and Routes to Registration SARTOR - 3

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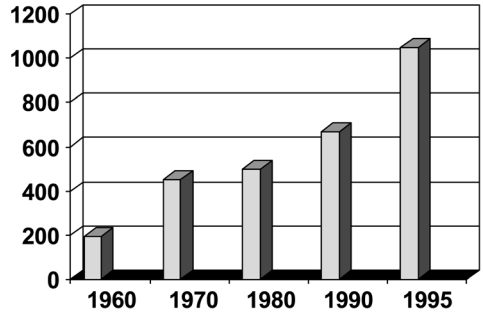
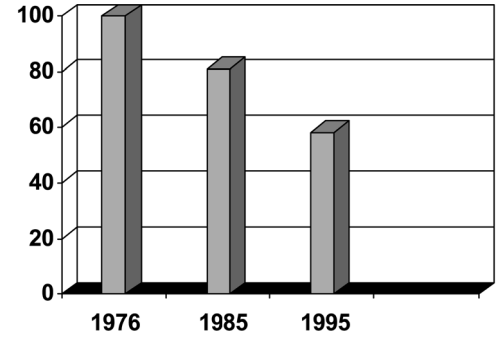
Figure 6 Number of Full Time Students (All subects) × 1000 (National Committee Report, 1997)



Source: National Committee Rpt. (1997)

Figure 7 Index of Funding per Student (National Committee Report, 1997)



Source: National Committee Rpt. (1997)

is more cost effective to operate non laboratory based degree courses.

During the period from 1960 until 1985 it had not been financially viable to start aeronautical engineering courses. The introduction of differential funding changed this policy when it became worthwhile to introduce new engineering courses. The course titles were no longer restricted to the traditional Aeronautical or Aerospace Engineering but included such titles as Avionic Systems, Aerospace Manufacturing Engineering, Aerospace Technology and Management, Aeronautical Engineering with study in Continental Europe and many more. This reflected the diversity of industrial needs and the attempt to satisfy those needs.

It had been noted (Pippard, 1935) that on entering industry the new graduate had much to learn before he was of value to his firm. This thought again came to the fore in the 1970s since apprenticeship schemes had become scarce. It was recommended (Finniston Report, 1980), that aspects of practical training should be incorporated into engineering degree courses.

In addition following a review of course content, design and the solution of practical problems came to be part of degree programmes together with an understanding of the awareness of costs (Hancock, 1984). Management subjects too became incorporated into courses. To make space for these additional topics within a three year programme traditional analytical subjects received a reduced time allocation.

Within the engineering industry there had been concern at the standards of new entrants to the profession. The Engineering Council became responsible for monitoring all engineering degree courses. Standards were set and universities inspected to ensure that courses were appropriate and to an approved standard. These courses were "Accredited" and holders of such degrees were able to satisfy the educational requirements for professional status i.e. Chartered Aeronautical Engineer.

SARTOR (Standards and Routes to Registration) which set out the accreditation requirements has been reviewed, 1999, and now all approved degree courses must be of four years duration and more stringent entry requirements are imposed. A list of all universities offering aeronautical engineering courses for the academic year 2000–2001 is shown in Table V. This is based on information supplied in the Universities and Colleges Handbook for 2000.

Many of the more recent changes in the UK are as a result of attempts to achieve parity with the requirements in other countries, particularly those members of the European Union. A significant factor in this is the Bologna Declaration, 1999, signed by the Education Ministers of 31 countries which seeks to rationalise the structure of university courses across Europe. The Declaration is not intended to dictate content, but to introduce commonality to course length and quality assurance techniques.

An example of the internationalisation of courses is the development of the Europads modular masters course which has now commenced in a number of centres in Europe. This surely is the latest move in the desire of universities to meet the requirements of an industry which is now becoming globalised.

Concluding remarks

It is clear that the aerospace industry has undergone immense changes over the last

Table V Universities offering Aerospace Degree Courses

University	Degree	Title
Bath	M Eng	Aerospace Engineering
		Aerospace Engineering with French
		Aerospace Engineering with German
Brighton	M Eng/B Eng	Mechanical and Aeronautical Design Engineering
Bristol	M Eng	Aeronautical Engineering
		Aeronautical Engineering with study in continental Europe
		Avionic Systems
	B Eng	
West of England, Bristol	M Eng/B Eng	Aerospace Manufacturing Engineering
		Aerospace Systems Engineering
Brunel, West London	M Eng/B Eng	Mechanical Engineering with Aeronautics
Cambridge	M Eng	Aeronautical Engineering
City	M Eng/B Eng	Aeronautical Engineering
		Air Transport Engineering
Coventry	M Eng/B Eng/B Sc	Aerospace Systems Engineering
		Aerospace Technology
		Avionic Systems
Cranfield (Royal Military College of Science - Shrivenham)	B Eng	Aeromechanical Systems Engineering
Farnborough College	B Sca	Aeronautical Engineering
Glasgow	M Eng/B Eng	Aeronautical Engineering
		Mechanical Engineering with Aeronautics
		Avionics (Electronics)
Hertfordshire	M Eng/B Eng/B Sc	Aerospace Engineering
		Aerospace Systems Engineering
		Aerospace Technology with Management
Imperial College (U L)	M Eng	Aeronautical Engineering
		Aeronautical Engineering with a year in Europe
		Aerospace Materials
Kingston	M Eng/B Eng	Aerospace Engineering
		Aerospace Engineering and Astronautics
		Aerospace Engineering Studies
		Aerospace Engineering Technology
Lincolnshire & Humberside	B Eng	Engineering (Aircraft Structures)
		Engineering (Avionics)
Liverpool	M Eng/B Eng	Aerospace Engineering
Loughborough	M Eng/B Eng	Aeronautical Engineering
	B Sc	Air Transport Management
Manchester	M Eng/B Eng	Aerospace Engineering
		Aerospace Engineering(Integrated European Programme)
		Avionics and Aerospace Systems
UMIST Manchester	M Eng/B Eng	Aerospace Engineering
Northbrook College	Foundation Degree[b]	Aeronautical Engineering
N E Wales Institute	B Eng/BSc[c]	Aeronautical Electronics (Avionics)
		Aeronautical/Mechanical Engineering
Queen Mary & Westfield (U L)	M Eng /B Eng	Aerospace Engineering
		Avionics
The Queen's University Belfast	M Eng /B Eng	Aeronautical Engineering
Salford	M Eng/B Eng/BSc	Aeronautical Engineering
		Aerospace Business Systems

(continued)

Table V

University	Degree	Title
Sheffield	M Eng/B Eng	Aerospace Engineering
Southampton	M Eng/B Eng	Aerospace Engineering
		Aerospace Engineering with European Studies
Stockport College	B Eng[d]	Aeronautical Engineering
Strathclyde	M Eng	Mechanical Engineering with Aeronautics
Surrey	B Eng[e]	Aerospace Engineering
York	B Eng	Avionics -

[a] Validated by University of Surrey.; [b] Subject to validation.; [c] Validated by University of Wales.; [d] In conjunction with Manchester. Salford and UMIST.; [e] Subject to approval

century. Its needs in terms of human resources are now very different, but there is one underlying factor that has not changed. As Wilbur Wright noted "…man cannot fly without knowledge and skill" and the need for these commodities has never been greater. It is the task of universities to help to fulfil this need.

Just as aircraft have become ever more complex, the range of knowledge and skills required has expanded well beyond the imagination of those early pioneers. To satisfy this the variety of courses related to the industry is now very wide.

The courses are no longer narrowly focussed on research and design. Degree courses now need to provide quality graduates in a range of skills which will meet the needs of the designers and manufacturers of airframes, systems, propulsion gas turbines, components, avionics as well as civil and military operators.

The industry is now becoming globalised and today's graduates need to be able to communicate with their colleagues in other countries and perhaps even more importantly have an appreciation of the culture. Aerospace departments in universities are responding to this challenge by offering courses which provide opportunities for study of languages and periods of study in other countries. An international masters course in aerospace engineering, Europads, has been launched.

The pressure on universities and students is now very considerable. Industry expects the courses to be relevant and the graduates to "hit the ground running". This is being achieved against the background of falling financial support both to universities and students.

Aerospace degree courses cannot, and never have, been able to provide all the knowledge and skills required by an aeronautical engineer for life. Students must be inspired to continue to learn for the rest of their careers.

The changes in course content, particularly over the last 30 years, have no doubt produced a graduate who is more readily employable and industrially relevant. A contribution to the organisation's income is generated within a very short time of joining and the new entrant is very aware of the focus of the firm's activities. The introduction to degree courses of projects, including an appreciation of manufacturing processes, group projects, business and perhaps languages has brought considerable benefits, but at the price of a significant reduction in the study of basic technical subjects. This has been compounded by a reduction in overall contact time so that the effect is certainly rather greater than might be imagined. For example a 3 year degree course in the mid 1950's might contain up to 3000 hours of study all allocated to technical subjects and mathematics. By the mid 1970's the course would be of around 2200 hours still largely technical subjects but now perhaps including project work and some management. Currently a four year M Eng might consist of around 1700 hours with perhaps 70 per cent of this time devoted to the study of technical subjects. Simple arithmetic shows that there is now only 40 per cent of the time spent on these subjects that there was 40 years ago.

A major task of engineers is to initiate innovation and this innovation is surely based on a knowledge of the technology. If current graduates are being deprived of technical knowledge will this not be reflected in a lack of invention and innovation? The price of making graduates instantly employable may be at the cost of the technology base of British Industry. Now that the one hundredth anniversary of the first man carrying powered

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flight is close, perhaps it is appropriate to examine again the content of courses in aerospace engineering and acknowledge the wisdom of Orville Wright "man may fly without engines, but not without knowledge and skill."

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