The competitiveness of the UK aerospace industry

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Abstract

The aerospace industry is often regarded as one of Britain's last remaining world class, high technology manufacturing industries and this paper assesses its international competitiveness. Various statistical indicators are used to measure competitiveness, based on published data at the industry and firm level, supplemented with information derived from company interviews. Indicators include productivity, output, firm size, development time-scales, labour hoarding, exports and profitability. The empirical results of this paper suggest that, over the period 1980-2000, the UK aerospace industry improved its competitiveness compared with the USA and the EU.

Introduction

The UK aerospace industry is often regarded as one of "Britain's last remaining world class, high technology manufacturing industries" (SBAC, 2000, p3; IGT, 2003). This paper assesses the international competitiveness of the industry. Competitiveness is determined by, and reflected in, price-cost factors and non-price factors. Price-cost factors reflect industry and company efficiency (eg. factor productivity; lean manufacturing), the opportunities for achieving economies of scale, scope and learning and the extent of rivalry. Non-price factors include research and development (R&D), development time-scales, delivery schedules, export finance, reliability and the provision of spares and support over the life-cycle. A related taxonomy is that competitiveness is embodied in five competitive forces comprising threats from new entrants and substitute products and services, the bargaining power of buyers and suppliers and rivalry amongst existing competitors. These five competitive forces are a function of industry structure and determine long-run industry profitability (Porter, 1990, p35).

The five competitive forces provide an analytical framework for assessing the UK aerospace industry's competitiveness. Various statistical indicators are used to measure competitiveness, based on published data at the industry and firm level. The indicators include productivity, output, firm size, development time-scales, labour hoarding, exports and profitability.

The UK aerospace industry

The UK aerospace industry comprises firms involved in the design, development, manufacture and support of aircraft, helicopters, missiles and space systems (eg. satellites). It includes aircraft and systems, engines, equipment and maintenance, repair and overhaul companies supplying military and civil markets in both the UK and overseas.

Government is central to understanding aerospace industries in the UK and elsewhere. Governments are major buyers of aerospace equipment for their armed forces and they can use their buying power to influence the size, structure, conduct and performance of their national industries. Government also influences the civil aircraft market through its allocation of national landing and over-flying rights, its provision of financial support for civil aircraft development programmes and exports, and its ownership and support for national airlines. In the UK, both the aerospace industry and its airlines are privately-owned.

Table 1 shows some of the UK aerospace industry's stylised facts. Over the period 1980-2002, real sales and export shares increased whilst employment declined substantially. Also, the relative contributions of military and civil markets changed markedly, reflecting the disarmament following the end of the Cold War. The R&D-intensity of the industry is reflected in some 10% of sales devoted to R&D. Even these simple descriptive statistics showing rising trends in export shares and a high proportion of output exported suggest that this is a competitive industry. This position is reinforced by the fact that in 2002, about two-thirds of UK civil aerospace sales were exported.

Table 1 here

The UK aerospace industry is highly imperfect comprising domestic monopolies in military and civil aircraft (BAE Systems), helicopters (Agusta Westland), and engines (Rolls-Royce), a duopoly in missiles (MBDA; Thales: Racal and Shorts Missile Systems) and oligopoly in the equipment sector (BAE Avionics; Thales; Smiths; Cobham). The major UK aerospace firms are also partners in European collaborative programmes. BAE is involved in Eurofighter Typhoon (UK; Germany; Italy; Spain), Airbus (wings, representing 20% of the Airbus company) and missiles (MBDA); AgustaWestland in joint European helicopter programmes and Rolls-Royce is a partner in associated European collaborative engine projects. BAE dominates the UK aerospace industry, accounting for some 75% of the industry's sales in 2002. BAE also dominates the UK defence market with its involvement as a major supplier of air, land and sea systems as well as defence electronics.

The UK aerospace industry has considerable development and manufacturing assets overseas, especially in the USA. For example, BAE owns US avionics firms and Rolls-Royce owns the US Allison engine company. In 2002, total employment in the USA of UK aerospace industry assets was almost 26,000 personnel. Similarly, many overseas companies have either located in the UK or purchased UK aerospace companies (eg. Goodrich; Thales).

Since the end of the Cold War, the UK, European and US aerospace industries have experienced substantial consolidation. In the UK, major mergers and take-overs led to the creation of BAE Systems (British Aerospace and GEC Marconi Electronics), AgustaWestland (helicopters: a merger between Agusta/Italy and

Westland/UK, with the UK interest sold to Agusta in 2004) and the Thales acquisition of Racal and Shorts Missile Systems. In Europe, EADS represented a merger of Aerospatiale Matra (France), Daimler Chrysler (Germany) and CASA (Spain). US mergers and take-overs resulted in a smaller number of major aerospace companies, forming a major competitive threat to UK and European firms. Boeing acquired Rockwell and McDonnell Douglas; Lockheed Martin acquired General Dynamics Aircraft, a merger of Lockheed and Martin Marietta and the acquisition of Loral; Northrop acquired LTV Aircraft, then merged with Grumman followed by the acquisitions of Litton and Newport News Shipbuilding; and Raytheon acquired Beech Aircraft, BAe Business Jet, TI Defence and Hughes Aerospace and Defence.

A comparative assessment

The UK aerospace industry's position in the world market can be assessed by comparing it with the USA, the EU and other rivals. The US aerospace industry dominates the world market. In 2000/02 and on the basis of sales and employment, the US industry was some four times larger than the UK industry; and if size indicates the opportunities for achieving economies of scale, learning and scope, then the US industry has a competitive advantage over the rest of the world. Outside the EU, other major rivals include Canada and Japan (Table 2). Within the EU, the UK aerospace industry is the largest employer followed by France, Germany and Italy.

Table 2 here

The five competitive forces

Assessing the industry using Porter's five competitive forces model requires a distinction between military and civil aerospace markets. In the UK military market, the Government is a major buyer and funder of development programmes and can use its buying power to regulate profits. Government also determines entry and exit and typically UK defence contracts are subject to competitive procurement allowing foreign firms to bid for such contracts. Usually, there is significant rivalry between existing competitors, mainly European (EADS; Dassault; Saab) and US firms (Boeing; Lockheed Martin; Northrop Grumman; Raytheon). Oligopoly in the world market results in close substitutes with rivalry in combat aircraft and military helicopters.

However, the threat of new entry is limited, mainly because of high entry barriers and costs due to the need for costly and fixed R&D expenditure which on defence work is usually borne by government. Also, further entry barriers arise from economies of scale and learning. Nonetheless, large defence electronics companies provide an entry threat. Substitutes for an effective combat aircraft take many years to develop (eg. 10+ years) and whilst buyers are budget-constrained, they are not price-sensitive. Rivalry tends to be based on non-price factors, especially R&D which determines the technical features of military aircraft (eg. speed; range; weapons capability).

Civil markets are different, especially on the demand side, where governments are not major buyers. UK airlines form a privately-owned oligopsony, dominated by British Airways. Within the world market, there are large numbers of state-and privately-owned airlines demanding large and regional jet airliners. There are also large numbers of buyers for business jets and for light aircraft for pleasure use. On the supply side within the world market, there are duopolies in large jet airliners (Airbus, Europe; Boeing, USA) and regional jet airliners (Bombardier, Canada; Embraer, Brazil). The large jet airliner industry is characterised by high entry barriers, reflecting high R&D costs and scale and learning economies. However, duopoly results in close substitutes for both regional and large civil aircraft. Nonetheless, substitutes for a commercially-successful large jet airliner might take some 6 years to develop with break-even occurring some 10-15 years into production and pay-back periods extending a further 20 years or more. Even on regional jet airliners, orders for 40-60 aircraft are the minimum required for a commercial launch. These unique economic characteristics of civil aircraft development mean that this is not a market offering short-term profitability.

Duopoly prime contractors can use their buying power on major new programmes to obtain favourable deals with their major suppliers, especially the engine companies. The world aero-engine market is an oligopoly comprising Pratt and Whitney (United Technologies, USA); General Electric, USA; Rolls-Royce, UK; and Snecma, France. These companies compete vigorously for their engines to be used on new civil aircraft programmes (eg. Airbus 380; Boeing 7E7). There is similar rivalry between a small number of major equipment companies for a share of such new projects.

Both the large and regional jet airliner industry has been characterised by exits. In 2003, the UK, as a prime contractor, exited from the regional jet airliner market (similar exits occurred for Fokker, Netherlands and Fairchild Dornier, Germany). However, a number of nations are seeking to enter the regional airliner industry (eg. China; Indonesia; Spain). For both existing and new entrants, Government is involved in the civil aircraft market through the provision of state financial support for new aircraft programmes. The UK Government provides a risk sharing, repayable investment in the form of launch investment with repayments through a levy on sales. Studies of international financial supports show that "there is a very large imbalance in the absolute levels of support provided by other governments to their civil aerospace industries, particularly the USA, and a material imbalance with the rest of Europe"(IGT, 2003). Estimates show that the US support may be at least seven times and possibly as high as twelve times greater than the level of support available in Europe. Despite the lower levels of state support available, the UK industry has achieved significant success in creating world-class competitors. However, nations are in a prisoner's dilemma subsidy war which extends to include local and regional government (eg. with regions in various nations offering competitive subsidies to attract aerospace firms, especially suppliers).

In the Porter model, industries in which the pressure from one or more of the five competitive forces is intense are ones where few firms are very profitable for long periods (Porter, 1990, p35). The UK aerospace industry has at least three intense competitive forces, namely, powerful buyers in both military (government) and civil markets (prime contractors), fierce competitive rivalry and substitute products: hence the prediction that UK aerospace will have few firms which are very profitable for long periods. The remainder of this paper assesses the UK aerospace industry competitiveness using various statistical indicators mostly for the period 1980 to 2000. Inevitably, there is no single 'best' indicator of performance, so that a balanced assessment requires several performance measures.

Assessing the Competitiveness of the UK Aerospace Industry

(i) Labour productivity

Productivity is one of the determinants of competitiveness. This section focuses on industry labour productivity based on sales per employee, since this is the measure for which international data are readily available. The UK aerospace industry's labour productivity relative to the USA and the EU improved over the period 1980 to 2000. The 1980 productivity gap between the UK on the one hand and the EU and USA industries on the other was reduced substantially by 2000 (Table 3).

Table 3 here

The DTI publishes an annual Value Added Scoreboard which provides data for a sample of UK and European companies (first published in 2002). These show value added productivity defined as value added per employee and value adding efficiency or wealth creation which is value added divided by input costs of labour and equipment depreciation. For the combined sample of UK and European companies, the rank correlation between VA per employee and VA efficiency was r = 0.22; that between VA per employee and profitability was r = 0.174; and that between VA per employee and VA share of sales was r = 0.043, none of which were significant.

Table 4 here

Table 4 shows that for aerospace and defence companies, the European average for value added per employee was some 20% higher than the corresponding figure for the UK. The high value added productivity companies comprised Dassault Aviation, EADS and SAAB; and the lowest value added productivity company was Bombardier (formerly Shorts, Belfast) whose productivity was 65% and 55% of the UK and European averages, respectively. Comparing firms in similar markets, Dassault's value added productivity was almost 90% higher than that for BAE Systems; EADS productivity was some 40% higher than Airbus UK; but Rolls-Royce productivity was some 15% higher than its French rival, Snecma. Dassault scores highly on all the criteria shown in Table 4: value added efficiency; a higher current value added efficiency than its four year average; a middle position on vertical integration; and a high profit margin. However, the rankings are sensitive to the choice of performance indicator. Using value added efficiency (wealth creation), its four year average and profit margins, the UK averages are slightly higher than those for Europe, with the UK also showing a higher degree of vertical integration. A higher value added efficiency for the average of UK companies compared with the European average reflects their higher efficiency in creating wealth.

(ii) Output

Output is a major determinant of unit costs and hence competitiveness in the aerospace industry. Larger output allows the greater 'spreading' of fixed R&D costs and also results in learning economies which lead to rising productivity as output increases. A limited interview survey of UK firms (reported in Braddon and Hartley, 2002) found that learning remained important but it has been affected by modern manufacturing techniques, new materials and business practices. The interviews suggested that whilst learning is still relevant, "the curve might now be steeper than it used to be", that it has been affected by lean methods and supply chain changes and that "on the Joint Strike Fighter, BAE is comparable to Lockheed Martin." Three further comments were made on learning economies. First, that scale differences between the USA and the UK are not as important as they used to be. Second, that UK labour costs are lower. Third, that more capital-intensive methods are now used since greater precision is needed for modern aircraft manufacture which results in fewer opportunities for labour learning. Overall, the consensus view was that UK aerospace unit cost curves were lower than US unit cost curves.

There is also evidence of a major change in UK aerospace learning curves. Between the 1950s and 1970s, UK learning curves tended to 'flatten-out' at about 100 units, reflecting the small-scale of UK aircraft output. For example, on eight UK civil aircraft projects, average output was 143 units ranging from 53 units ((VC10) to 440 units (Viscount). In contrast, US learning curves of that period showed continuous learning (eg. up to 5000 units on the Phantom combat aircraft). On eight large US jet airliners, average output by end-1974 was 525 units ranging from 100 units (Lockheed Tristar) to 1088 units (Boeing 727). Currently, for some projects, UK learning curves now show continuous learning reflecting a larger scale of output.

A distinction needs to be made between military and civil aircraft. Industry performance on civil aircraft is probably a more accurate indicator of market competitiveness: civil aircraft markets are less subject to state protection and military projects are greatly affected by government procurement policies, including export licensing regimes. On civil aircraft, the European Airbus is achieving US scales of output. For example, on the Airbus A320 family, total output exceeded 2100 units by end-2003. Here, it has to be remembered that Airbus was a new entrant to the large jet airliner market as recently as 1970, when the market was dominated by US companies, namely, Boeing, McDonnell Douglas and Lockheed. In 2004, there is an industry duopoly comprising Airbus and Boeing.

Airbus is distinctive in being an example of a competitive and hence successful European international collaborative organisation. It provides a 'model' for other collaborative arrangements, especially for European military aerospace projects (cf. Eurofighter Typhoon). Using scale of output, market penetration and market share criteria, Airbus is a successful and competitive organisation (but the costs of achieving this market position would need to be included in any economic evaluation). Airbus differs from other European collaborations in at least three ways. First, as a single company (now an integrated company), it represents a different form of collaboration (cf. European military aircraft collaborations which are project-specific with the partner companies retaining their identity). Second, Airbus is not constrained by the commitment to raise the technological capability of the partner nations (eg. as occurred on collaborative military aircraft projects). Indeed, Airbus is less constrained by *juste retour:* in fact, it is claimed that the *juste retour* used by Airbus has been beneficial in creating areas of technical expertise and specialisation (eg. BAE focus on wing technology for Airbus: ITC, 2001). Third, to survive Airbus has to be competitive in responding to the varied and changing demands of the world civil aircraft market. Unlike military collaborations, there is no guaranteed market for Airbus aircraft (cf. the partner nations on Eurofighter Typhoon which fund its R&D costs and provided firm production orders for the aircraft).

On military aircraft, the US aerospace industry has the benefit of a large protected home market. The US Joint Strike Fighter (JSF, now the Lockheed Martin F-35) illustrates the scale differences between the UK, other European nations and the USA. The original planned requirement was 2852 JSF aircraft for the US Forces compared with a UK requirement for 150 aircraft. Faced with such scale differences in military markets, the UK can respond by reducing unit costs compared with the USA; by exporting; and by international collaboration (eg. UK involvement in Eurofighter Typhoon and JSF). On exports, the UK Hawk is a good example achieving both high output levels (over 800 aircraft) and a high proportion of output exported (almost 80% exported). Similarly, Eurofighter shows how European collaboration results in output levels closer to those in the USA and considerably greater than European national scales of output. For example, the partner nation's planned order for Eurofighter is 620 units, comprising 232 units for the UK, 180 for Germany, 121 for Italy and 87 for Spain. However, collaboration departs from the 'ideal case' leading to inefficiencies associated with complex international management and monitoring arrangements and restrictive work sharing requirements. UK estimates suggest that the total development costs on the four nation Eurofighter were almost twice as high as an alternative national aircraft; but typically, the UKs cost share equates to one third of total development costs. Similarly, the scale economies achieved on collaborative production programmes are in the region of half those on national programmes; and delays on collaborative programmes average almost one year (NAO, 2001).

(iii) Size of firms

The US competitive advantage in the scale of output, especially for military aircraft, is also reflected in its advantage in firm size. Large firms are able to obtain economies of scale and scope and in recent years there has been considerable merger activity creating larger aerospace firms. US firms dominate the world's top 10 aerospace firms, accounting for 7 out of the top 10 in 1996, 2000 and 2002. BAE Systems was the only UK aerospace company in the top 10 in 1996, 2000 and 2002, ranking fourth in each year. In contrast, the newly-created EADS ranked third in 2000 and second in 2002 .

Table 5 shows the top 15 aerospace companies between 1996 and 2002. Interestingly, 9 of the top 15 companies remain unchanged throughout the period (including BAE Systems and Thales/Thomson-CSF). Comparisons with Boeing for 2002 show the scale advantage of the US company: based on sales, EADS was 53% and BAE was 34% of the size of Boeing. Similarly, in aero-engines in 2002, Rolls-Royce was 55% of the size of General Electric. Within the top 15, between 1996 and 2002, the UK and European firms have not achieved any substantial increase in their average size in relation to the top US firms. This suggests that the US aerospace mergers after 1996 have been more successful in creating relatively larger firms. Also, over this period, UK industry mergers have created relatively larger aerospace firms than in Europe.

Table 5 here

(iv) Development time-scales

The time taken to develop an aircraft from start to delivery is a further indicator of competitiveness. Traditionally, the US aerospace industry developed both civil and military aircraft faster than the UK and European industries. For example, between 1945 and 1969, the average UK development times for military aircraft were 8 years 4 months compared with 6 years 3 months for the USA; and for civil aircraft, the average development times were 4 years and 4 months and 3 years and 7 months, respectively (Elstub, 1969).

Since 1980, the position has changed. On large jet airliners, Airbus is now competitive with Boeing on development times (where Airbus involves a UK component on the wings, engines and other equipment). Table 6 shows development times for a similar group of Airbus and Boeing civil aircraft, with similarity defined by their characteristics. Airbus aircraft were developed some 4-7% faster, with Airbus being faster from start to first flight, but slightly slower from first flight to Certificate of Airworthiness. Interestingly, this evidence confirms that European collaboration in civil aircraft has created a competitive industrial organisation. Regression analysis of various measures of development time against aircraft characteristics, a time-trend and a country of manufacture dummy variable gave a significant and negative coefficient for the time-trend only. As expected, the country of manufacture dummy was not significant.

Table 6 here

The traditional competitive advantage of the US industry in development times for military combat aircraft is shown in the following regression equation. This allows for combat aircraft characteristics:

$$TCS = 143.71 - 0.12S + 2.32W^{*} + 0.02R + 54.40CM + 0.39T$$
$$\quad (1.97) \quad (1.99) \quad (2.69) \quad (1.26) \quad (2.36) \quad (0.26)$$

$$\bar{R}^2 = 0.70$$

where TCS = total time from contract start to service (months);
S = speed; W = weight; R = range; CM = a dummy variable for USA = 0 and rest of world = 1; and T = a time-trend based on date of first flight.
The equation was based on a sample of 11 US, European, Russian and Japanese modern combat aircraft (see also notes to Table 7).

The equation shows a significant and predicted positive impact of weight on development times; but surprisingly, other aircraft characteristics, namely, speed and range were not significant. The country of manufacture dummy is almost significant, showing a substantial US advantage in development times (some 4.5 years).

On current generations of combat aircraft, development times are similar between Europe and the USA, confirming that the US no longer has a competitive advantage in this aspect of industry performance. On three current generation

European combat aircraft (Gripen; Rafale; Typhoon) average development times were 181 months compared with an average of 209 months for two US combat aircraft (F-22 and JSF, neither of which have yet entered service). Since the end of the Cold War, development times have been 'stretched' reflecting defence budget problems and less urgency due to a reduced threat. Using pairwise comparisons, the European collaborative Typhoon has been developed in a considerably shorter time, namely, 214 months, than the US F-22 aircraft which is due in service in late 2005 (231 months). Admittedly, the US F-22 is a more complex, high-performance aircraft which is more advanced than any of the current European combat aircraft. Overall, the evidence shows that the traditional US competitive advantage on development times for civil and military combat aircraft no longer applies.

v) Labour hoarding

The speed at which firms vary their labour force in response to changes in output is another indicator of their competitiveness. A slow response suggests labour hoarding and labour retention policies. Once again, the US 'model' is of an aerospace industry which adjusts its labour force quickly to variations in output. The statistical evidence suggests that since 1980, the UK aerospace industry's employment has become more responsive to variations in output (cf Table 7: equations (2) and (3)). Also, the UK industry's employment responsiveness to changes in output is considerably higher than for the French aerospace industry and similar to that for the EU industry (Table 7: equations (1), (4) and (6)). Moreover, whilst the UK industry's employment responsiveness remains below that for the US aerospace industry, there was evidence of it approaching US levels.

Table 7 here.

Exports

Exports and market shares are often used as major indicators of competitiveness. In 2000, civil and military exports accounted for 60% of the UK aerospace industry's turnover. Civil aerospace sales accounted for almost 55% of the UK industry's turnover in 2000; and some two-thirds of this civil business was exported with civil aerospace exports accounting for 36% of total UK industry sales (SBAC, 2000). On civil aircraft, the UK industry designs and manufactures the wings for Airbus; and UK firms are also suppliers of engines and equipment to Airbus, Boeing and to the regional aircraft manufacturers. These exports reflect the fact that the UK is a world leader in wings, aero-engines and equipment some of which are represented on Airbus civil aircraft.

Airbus was a new entrant to the large jet airliner industry with its first deliveries in 1974 to a market which had been dominated by US firms (Boeing; Lockheed; McDonnell Douglas in the early 1970s). Since then Airbus has increased its share of the world market for large civil aircraft, achieving a 38% share in 2000 with the market changing from a US-dominated oligopoly to a European-US duopoly. Table 8 shows the trends in Airbus penetration of the world market. Two points can be made about entry time and costs. First, it took Airbus 21 years to achieve a market share of over 30%. Second, Airbus entry involved substantial costs for

European taxpayers, especially in France and Germany and particularly for the Airbus A300 and A310. By December 2003, Airbus had delivered 780 A300/310 aircraft compared with 2109 units of the A320 family which is similar to Boeing scale of output for its successful airliners.

Table 8 here.

The military-civil sales ratio has changed substantially since 1980 when military sales accounted for about 65% of the UK aerospace industry's sales and civil sales the remaining 35%. In 2000, military sales accounted for 46% of the UK aerospace industry's sales, shared equally between domestic and export customers (SBAC, 2001). In comparison, the military-civil ratios of sales for the EU and the US aerospace industries were 30/70 and 40/60, respectively.

Military aerospace exports dominated UK defence equipment exports over the period 1980 to 2000, especially in the 1990s with sales to the Middle East. However, defence exports are determined by both economic and political factors which makes it difficult to assess competitiveness. Even standard competitiveness measures such as equipment prices are misleading, since they can reflect different national subsidies to producers, differences in national preferential purchasing, various financial support arrangements (eg state export credits), offsets, a willingness by the supplying nation to waive R&D levies and the provision of gifts-in-kind (eg equipment and training free of charge). Equipment prices can also be for the basic equipment or might include various amounts of spares, training and support services. Political factors are also important, especially the supplying nations views on the political and military importance of the buying country (eg. allies and friends; ethical criteria; willingness of rival nations to supply).

Table 9 shows examples of the unit prices of various military aircraft. Amongst trainers, the UK Hawk appears to be competitive on price. This is confirmed by its status as a world leader for subsonic combat aircraft with 27% share of the world market compared with a 26% share for the USA over the period 1986 to 1997 (based on volume data: DoS, 2000). For both trainers and combat aircraft, some of the price data are for aircraft in the early stages of development whilst others are for aircraft in-service (eg.in-service aircraft at 2000 included Hawk, Gripen, F-15, F-16, Harrier and SU-27). Amongst combat aircraft, the F-16, Gripen and SU-27 are relatively cheap, whilst the US F-15E and F-22 are costly aircraft, but technically advanced. The collaborative Eurofighter Typhoon (with the UK as a partner) is cheaper than the US F-15 and F-22 but more expensive than Rafale. If the Lockheed Martin JSF is successful and its estimated costs are achieved (major assumptions), it will be a competitive aircraft and a major threat to Typhoon and Rafale.

Table 9 here.

Statistical analysis of the determinants of UK aerospace exports was constrained by the available data. Some limited, exploratory equations were estimated and examples are shown in Table 10. The time-trend variable gave the expected significant and positive coefficient for civil exports; but a surprising negative coefficient for total exports. The end of the Cold War resulted in a negative impact on total and military exports. Passenger miles gave an expected positive impact on total exports, but a surprising negative coefficient for civil exports. There was no evidence of a 'crowding-out' effect from UK military equipment spending. Military equipment imports were positively associated with total UK military exports, which might reflect the general level of demand in world military markets.

Table 10 here.

A relatively new feature of the UK aerospace industry is its global dimension with both inward and outward foreign direct investment. The UK industry has considerable aerospace manufacturing assets overseas. In 2000, these subsidiaries recorded sales of £5.55 billion and employed 47,000 personnel outside the UK. Some 60% of these overseas sales and employment were located in the USA (UK firms with US subsidiaries included BAE, Rolls-Royce and Smiths), so allowing UK firms to achieve entry into the US market, especially its defence market. Similarly, some overseas companies have located in the UK or acquired UK aerospace companies (eg. Bombardier/Shorts; Agusta-Westland; TRW; Thales). As a result, the UK aerospace industry now comprises both UK and foreign-owned companies located in the UK.

Profitability

In competitive markets, profitability can be regarded as the final indicator of industry performance and competitiveness. Over the period 1985 to 2000, the UK aerospace industry achieved the highest median profit rate on sales, exceeding both the EU and the USA. The UK industry's annual profitability exceeded that of the EU in twelve of the sixteen years and exceeded that of the USA in ten of the sixteen years. The data are shown in Table 11. It is, however, recognised that national aerospace markets are imperfect: the EU and US markets are characterised by national monopolies and oligopolies, respectively, and both have national preferential purchasing policies (eg Buy America Act). In principle, the UK market is different with its competitive procurement policy for military equipment, so that its profitability record is a more accurate reflection of international competitiveness. Moreover, the UK industry's profitability record was achieved despite the US industry's advantage with its larger scale output and larger firms.

Table 11 here

Profitability data are also available at the company level and these are shown in Table 12, based on the year 2000. There are two features of this Table. First, the profitability of the two UK major aerospace firms, BAE and Rolls-Royce, generally exceeded that of their major and much larger US rivals, namely, Boeing and Lockheed Martin. Second, the profitability of some of the UK equipment suppliers exceeded that of the much larger UK and US companies (BAE; RR; Boeing; Lockheed Martin).

Conclusion

The UK aerospace industry is the largest in the EU. The USA is the UK industry's major rival and provides the 'benchmark' for assessing its performance. On this basis and using the indicators reviewed in this paper, the UK industry improved its competitiveness over the period 1980 to 2000. There were improvements in labour productivity, output levels, development times, employment responsiveness and export performance. The results are summarised in Table 12.

Table 12 here

Statistical indicators confirm past and current performance and competitiveness but do not guarantee future successful competitiveness. The main problems facing the UK aerospace industry arise from the lack of new R&D programmes to provide the next generation of projects. Some of this new R&D will require government funding (IGT, 2003). Technical change is also a challenge to the future UK aerospace firm. The possible emergence of unmanned combat air vehicles (UCAVs) could revolutionise air warfare and lead to the end of manned combat aircraft and an increased emphasis on electronics and electronic warfare. For civil aircraft, the UK's future looks to be through an involvement in collaborative Airbus programmes. Also, the future absence of any UK-designed military and civil aircraft will mean the increasing importance of its equipment suppliers.

Benchmarking against the US aerospace industry and continued competition with its US rivals will provide a major competitive stimulus for the UK aerospace industry. Evidence suggests that "the more a given manufacturing industry is exposed to the world's best practice high productivity industry, the higher its relative productivity (the closer it is to the leader). Competition with the productivity leader encourages higher productivity" (Bailey and Solow, 2001). On this basis, part of an industry's productivity disadvantage reflects organisational slack and/or reluctance to change and innovate. Failure by the UK aerospace industry to adjust to change will mean more exits and the loss of its world leader companies.

REFERENCES

AECMA (200; 2002). **The European Aerospace Industry: Facts and Figures,** AECMA, Brussels.

Bailey, M.N. and Solow, R.M. (2001). International productivity comparisons built from the firm level, **Journal of Economic Perspectives**, 15, 3, Summer, pp .151-172.

Braddon, D. and Hartley, K. (2002), **UK Aerospace Competitiveness Study.** Department of Trade and Industry, July.

DTI (2004). **The Value Added Scoreboard, 2004**, DTI, London.

DoS (2000). **World Military Expenditures and Arms Transfers, 1998**, US Department of State, US Government Printing Office, Washington DC.

Elstub (1969). **Productivity of the National Aircraft Effort**, HMSO, London

Flight (1997; 2002; 2003). Aerospace Top 100, August, **Flight International**, Surrey.

Janes (2001). **Jane's All the World's Aircraft,** Jane's Information Group, Coulsdon, Surrey.

ICT (2001). **Competitive Assessment of US Large Civil Aerostructures Industry**, US International Trade Commission, Washington DC, June.

IGT (2003). **An Independent Report on the Future of the UK Aerospace Industry,** Aerospace Innovation and Growth Team, DTI, London, June.

NAO (2001). **Maximising the Benefits of Defence Equipment Co-operation**, National Audit Office, The Stationery Office, London.

Porter, M.E. (1990). **The Competitive Advantage of Nations**, Macmillan, London.

SBAC (2000; 2002). **UK Aerospace Facts and Figures**, SBAC, London

Table 1. UK Aerospace Industry, 1980-2002

	1980	**2000**	**2002**
Sales (£ billion, 2002 prices)	12.90	18.85	16.14
Employment	241,997	150,,651	117,256
R&D share of sales (%)	Na	10.0	10.8
Exports as share of sales (%)	47	60	63
Civil share of sales (%)	36	54	55
Military share of sales (%)	64	46	45

Note: Sales are unconsolidated sales which is the sum of each company's total aerospace turnover.

Source: SBAC (2002)

Table 2. The World's Aerospace Industries

	Sales 2000 (Euro billion, current prices)	Sales 2002 (Euro billion, current prices)	Employment 2000 (000)	Employment 2002 (000)
USA	105.6	102.7	595.9	531.9
EU	72.3	74.6	429.1	407.8
Japan	13.4	11.4	33.0	31.0
Canada	13.6	14.5	91.5	78.8
Others	9.4	9.0	70.0	103.0
Total	214.2	212.2	1219.5	1152.5

Notes:
(i) USA and EU turnover is for consolidated turnover. For the EU, consolidated turnover represents all sales to end-user customers and to aerospace firms outside the EU. Employment figures at year end and are based on direct employment. EU figures include the UK.

(ii) Others is an estimate excluding China and CIS

Source: AECMA (2000; 2002)

Table 3 Labour Productivity (Aerospace), 1980 - 2000

	UK	**EU**	**USA**
1980 Index (US = 100)	77	99	100
2000 Sales per employee Index (US=100)	£96,183 (89)	£102,698 (95)	£108,012 (100)

Note: All sales figures are consolidated sales. US figures are based on AECMA estimates.
Source: AECMA (2002)

Table 4. Value added Productivity: UK and European Companies, 2004

Company	Value added per employee (£000)	Value added efficiency (%)	Value added efficiency: 4 year average (%)	Value added share of sales (%)	Operating profit as share of sales (%)
All UK Companies	44.7	143.4	149	30.1	4.4
All UK Aerospace and Defence	45.0	118.1	125	39.9	2.5
BAE Systems	45.7	105.4	119	39.3	na
Rolls-Royce	51.4	115.9	121	34.8	3.4
Smiths	47.4	139.8	143	48.7	12.4
Airbus	49.1	120.9	na	26.5	4.6
Cobham	47.5	147.6	146	51.2	14.7
Bombardier	29.6	113.5	124	48.8	1.8
Meggitt	54.5	134.9	147	50.2	8.4
Dunlop Standard Aerospace	50.1	152.9	163	43.9	14.5
Ultra Electronics	49.1	140.8	141	45.2	11.4
EUROPE: All European Aerospace and Defence companies	54.1	116.2	120	38.1	2.3
EADS	67.7	112.4	109	33.4	0.3
Thales (F)	51.0	110.9	112	39.5	2.1
Finnmeccanica(It)	47.5	123.6	128	40.1	5.8
Snecma (F)	45.2	116.2	129	39.4	4.0
Dassault Aviation (F)	85.2	155.7	147	43.1	14.6
SAAB (Sweden)	54.9	117.5	121	57.5	7.0

Notes:

(i) Value added (VA) efficiency is VA divided by labour costs and depreciation. The DTI Scoreboard refers to this measure as wealth creation.
(ii) VA efficiency 4 year average shows that a company is becoming more efficient if its current VA efficiency is higher than its 4 year average.
(iii) A high VA sales ratio shows a high degree of vertical integration.
(iv) The UK sample is based on the top 800 UK companies; and the European sample is based on the top 600 European companies, including UK companies.

Source: DTI (2004)

Table 5. Top 15 Aerospace Firms

2002		2000		1996	
Firm Ranking	**Aerospace Sales ($m)**	**Firm Ranking**	**Aerospace Sales ($m)**	**Firm Ranking**	**Aerospace Sales ($m)**
Boeing	53,344	Boeing	51,407	Lockheed Martin	26,068
EADS (E)	28,182	Lockheed Martin	23,977	Boeing	22,681
Lockheed Martin	26,562	EADS	23,336	McDonnell Douglas	13,447
BAE Systems	18,236	BAE Systems	19,661	British Aerospace	11,635
Northrop Grumman	18,126	Raytheon	15,443	Aerospatiale (F)	9,948
Raytheon	17,449	United Technologies	12,358	United Technologies	8,852
United Technologies	13,216	General Electric	10,779	DASA (G)	8,636
General Electric	11,141	Honeywell	9,988	Hughes Electronics	8,314
Honeywell International	8,855	Northrop Grumman	7,782	Northrop Grumman	8,071
Thales (F)	8,035	Bombardier	7,112	Raytheon	7,769
Bombardier (C)	7,194	Rolls-Royce	6,890	General Electric	6,302
General Dynamics	6,970	TRW	6,237	Thomson-CSF (F)	6,264
Rolls-Royce	6,179	Thales	5,977	Allied Signal	5,714
Snecma (F)	6,130	Snecma	5,204	GEC (UK)	5,653
Finmeccanica (Italy)	5,041	Mitsubishi Heavy Industries (J)	4,841	Rolls-Royce	4,616
Average size: UK v USA	63%		77%		61%
Average size: Europe v USA	61%		67%		70%
Average size: EU v UK	97%		87%		113%

Notes: i) Sales figures are in current prices and are for aerospace sales only. Most companies have other sales, but total sales figures are not reported here.
ii) C = Canada; E = Europe; F = France; G = Germany.
iii) Average size of firm is based on firms in the top 15.

Sources: Flight (1997; 2002; 2003)

Table 6. Average Development Times for Civil Aircraft

Aircraft	Development Times (months)			Aircraft Characteristics			
	Start to first flight	First flight to CoA	Total Time	Speed (mph)	Weight (lbs)	Passengers	Range (miles)
Airbus (n=7)	43.4	13	56.4	595	325,179	252	4653
Airbus (n=6)	43.8	11	54.8	602	318,748	250	4716
Boeing (n=7)	48.9	9.9	58.7	606	388,078	240	4516

Notes:
i. Airbus n=7 sample: A300;A310; A320; A319; A321; A340; A330. The sample n=6 excluded the A300 with a first flight in 1972. All other Airbus airliners had a first flight date of 1982-95.
ii. Boeing n=7 sample: B737 Next Generation; B747-400; B757; B767; BMD11; B717-200, all with first flight dates of 1981-98.
iii. Weight is maximum take-off weight; months are rounded to nearest month; CoA is award of Certificate of Airworthiness.

Source: Janes (2001)

Table 7. Employment Equations

Dependent variable	Constant	Coefficients of:							
		Log Q	t	Log Lt-1	,[1]	,[11]	8	$\bar{R}^2$	d
1) LogLt (UK)	3.59* (2.35)	0.38** (5.02)	-0.04** (4.74)	0.42** (3.45)	0.38	0.65	0.58	0.980	2.1
2) LogLt (UK)	0.87 (1.97)	0.35** (5.64)	-0.02** (6.62)	0.69* (15.12)	0.35	1.14	0.31	0.968	1.3
3) LogLt (UK)	-2.65 (1.21)	0.65** (4.26)	-0.02* (2.75)	0.69** (5.35)	0.65	2.1	0.31	0.961	1.7
4) LogLt (EU)	3.90** (4.55)	0.41** (5.28)	-0.02** (3.34)	0.39** (4.00)	0.41	0.67	0.61	0.988	2.1
5) LogLt (USA)	2.80** (3.88)	0.42** (5.19)	-0.003 (1.14)	0.46** (8.17)	0.42	0.77	0.54	0.985	2.4
6) LogLt (FR)	4.21** (3.91)	0.16* (2.35)	-0.01* (2.34)	0.51** (5.26)	0.16	0.33	0.49	0.96	2.0

Notes:

i) All equations are log linear: logLt = log a + bt + c logQ + d log Lt-1 where ,[1]= c; ,[11]= c/ 8; d = 1 - 8 where 8 = lagged adjustment of actual to desired employment.

ii) Lt = employment; t = an exponential time trend representing technology and the capital stock; Q = value of turnover in constant 1999 prices (US $ millions); Lt-1 = lagged dependent variable.

iii) Equations (1) and (3) included a dummy variable for end of Cold War (not significant); equation (4) included a dummy for end of Cold War in 1991 (significant); equation (5) included slope shift dummies for mergers and dummies for end of Cold War (none were significant); equation (6) also included a dummy for end of the Cold War (not significant).

iv) Equations (1), (3), (5) and (6) based on 1980–2000; equation (2) based on 1948-2000; equation (4) based on 1980-1999. Equations (1), (4) and (6) use consolidated turnover; equations (2) and (3) use unconsolidated turnover.

v) t-ratios in brackets; R^2 is adjusted for degrees of freedom; d = Durbin Watson statistic; * significant at 5% level; ** significant at 1% level.

Table 8. Airbus and Boeing Sales, 1974 - 2000

Gross deliveries (units)	**1974**	**1980**	**1985**	**1990**	**1995**	**2000**
Airbus	5	38	42	95	124	311
Boeing (incldg McDonnell Douglas)	284	363	282	527	261	504
Airbus share (%)	1.7	9.5	13.0	15.3	32.2	38.2

Source: DTI (2002).

Table 9. Military Aircraft Unit Prices

Aircraft	Unit Price (US$ millions)
Trainers	
Hawk (UK)	18-21
MAKO (EADS)	22-25
KTX-2 (S. Korea)	18-20
Combat Aircraft	
Eurofighter Typhhon	68
Rafale (France)	58
Gripen (Sweden)	35
F-15E (USA)	75
F-16 (USA)	24-25
F-18 E/F (USA)	50
F-22 (USA)	183
Joint Strike Fighter (JSF:USA)	31-38 (different versions)
Harrier AV8B (UK-US)	36
Mitsubishi F-2 (Japan)	115
SU-27 (Russia)	35

Sources: Variuos aviation and defence magazines (eg Defense News; Aviation Week; Janes Defence Weekly; Flight; Fug Revue; Air Forces Monthly). All data are for 1999, 2000 or 2001.

Table 10. UK Aerospace Exports.

Dependent Variable	Constant	Coefficients of:					$\bar{R}^2$	d
		t	Cold War Dummy	PASM	DSP	MIMP		
1) TEXP	-6.95 (1.89)	-0.64** (3.36)	-1.66* (2.72)	0.02** (5.45)	0.0002 (0.55)	0.20 (0.11)	0.93	2.1
2) TMX	4518.4 (1.78)	67.09 (0.66)	-1661.6* (2.48)		-0.23 (1.21)	2.53* (2.14)	0.79	1.7
3) TCX	8417.7* (2.28)	711.55** (3.54)	-207.5 (0.32)	-16.33** (4.69)	-0.12 (0.73)		0.85	1.9

Notes:
i) TEXP = total UK aerospace exports; TMX = total UK military aerospace exports; TCX = total UK civil aerospace exports. All value data in £ billions, 1999 prices. Equations (1) and (2) are based on 1980-1998; equation (3) based on 1980-2000. All equations are linear.

ii) t = time-trend; dummy variable (1,0) for the end of the Cold War was based on either 1991 or 1992; PASM = world passenger miles (billions); DSP = UK military equipment spending; MIMP = UK military equipment imports lagged one year.

iii) Other details as in Table 7.

Table 11. Industry Profitability [Profit as percentage of sales (%)]

Year	Aerospace Industry		
	UK	EU	USA
1985	5.5	5.2	3.1
1986	5.0	4.2	2.8
1987	4.4	3.5	4.1
1988	3.4	3.8	4.3
1989	4.2	3.2	3.3
1990	2.8	2.4	3.4
1991	2.2	2.4	1.8
1992	-1.2	-0.6	-1.4
1993	2.2	0.7	3.6
1994	0.5	0.0	4.7
1995	5.4	0.0	3.8
1996	4.8	2.2	5.6
1997	6.2	3.9	5.2
1998	6.9	6.7	5.0
1999	6.4	6.8	6.5
2000	6.4	4.9	4.7
Median	4.6	3.4	4.0

Sources: AECMA; SBAC; USAIA

Table 12. Competitiveness Indicators, 1980-2000

Indicator	**UK industry performance relative to USA**
1. Labour productivity	Improving
2. Output (a) Civil (b) Military	Airbus achieving US scales of output UK/JSF = US scales of output Eurofighter = higher output
3. Development times	US no longer has competitive advantage
4. Labour hoarding	UK employment responsiveness has improved and is approaching US levels.
5. Exports	a. Military aerospace exports dominated UK defence exports; b. World leader for subsonic combat aircraft; c. Airbus: rising share of world market
6. Industry profitability	Higher than USA

THE COMPETITIVENESS OF THE UK AEROSPACE INDUSTRY

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Abstract

Porter's five competitive forces model provides an analytical framework for assessing the UK aerospace industry's competitiveness in this paper. Various statistical indicators are used to measure competitiveness, based on published data at the industry and firm level, supplemented with information from company interviews. The indicators include productivity, output, firm size, development time-scales, labour hoarding, exports and profitability. The empirical results of this paper suggest that, over the period 1980-2000, the UK aerospace industry improved its competitiveness compared with the USA and the EU.

Introduction

The UK aerospace industry is often regarded as one of "Britain's last remaining world class, high technology manufacturing industries" (SBAC, 2000, p3; IGT, 2003; TIC, 2005). This paper assesses the international competitiveness of the industry. Competitiveness is determined by, and reflected in, price-cost factors and non-price factors. Price-cost factors reflect industry and company efficiency (eg. factor productivity; lean manufacturing), the opportunities for achieving economies of scale, scope and learning and the extent of rivalry. Non-price factors include research and development (R&D), development time-scales, delivery schedules, export finance, reliability and the provision of spares and support over the life-cycle (for further discussion on the meaurement of international competitiveness, see Manzur et al, 1999 and Kambhampati U.S., 2000). A related taxonomy is that competitiveness is embodied in five competitive forces comprising threats from new entrants and substitute products and services, the bargaining power of buyers and suppliers and rivalry amongst existing competitors. These five competitive forces are a function of industry structure and determine long-run industry profitability (Porter, 1990, p35).

The five competitive forces provide an analytical framework for assessing the UK aerospace industry's competitiveness. Various statistical indicators are used to measure competitiveness, based on published data at the industry and firm level. The indicators include productivity, output, firm size, development time-scales, labour hoarding, exports and profitability.

The UK aerospace industry

The UK aerospace industry comprises firms involved in the design, development, manufacture and support of aircraft, helicopters, missiles and space systems (eg. satellites). It includes aircraft and systems, engines, equipment and maintenance, repair and overhaul companies supplying military and civil markets in both the UK and overseas.

Government is central to understanding aerospace and similar industries in the UK and elsewhere (see, for example, Bonte, 2003). Governments are major buyers of aerospace equipment for their armed forces and they can use their buying power to influence the size, structure, conduct and performance of their national industries. Government also influences the civil aircraft market through its allocation of national landing and over-flying rights, its provision of financial support for civil aircraft development programmes and exports, and its ownership and support for national airlines. In the UK, both the aerospace industry and its airlines are privately-owned.

Table 1 shows some of the UK aerospace industry's stylised facts. Over the period 1980-2002, real sales and export shares increased whilst employment declined substantially. Also, the relative contributions of military and civil markets changed markedly, reflecting the disarmament following end of the Cold War. The R&D-intensity of the industry is reflected in some 10% of sales devoted to R&D. Even these simple descriptive statistics showing rising trends in export shares and a high proportion of output exported suggest that this is a competitive industry. This position is reinforced by the fact that in 2002, about two-thirds of UK civil aerospace sales were exported.

Table 1. UK Aerospace Industry, 1980-2002

	1980	**2000**	**2002**
Sales (£ billion, 2002 prices)	12.90	18.85	16.14
Employment	241997	150651	117256
R&D share of sales (%)	Na	10.0	10.8
Exports as share of sales (%)	47	60	63
Civil share of sales (%)	36	54	55
Military share of sales (%)	64	46	45

Note: Sales are unconsolidated sales which is the sum of each company's total aerospace turnover.

Source: SBAC (2002)

The UK aerospace industry is highly imperfect comprising domestic monopolies in military and civil aircraft (BAE Systems), helicopters (AgustaWestland), and engines (Rolls-Royce), a duopoly in missiles (MBDA; Thales: Racal and Shorts Missile

Systems) and oligopoly in the equipment sector (BAE Avionics; Thales; Smiths; Cobham). The major UK aerospace firms are also partners in European collaborative programmes (see Bishop, 2003). BAE is involved in Eurofighter Typhoon (UK; Germany; Italy; Spain), Airbus (wings representing 20% of the Airbus company) and missiles (MBDA); AgustaWestland in joint European helicopter programmes and Rolls-Royce is a partner in associated European collaborative engine projects. BAE dominates the UK aerospace industry, accounting for some 75% of the industry's sales in 2002. BAE also dominates the UK defence market with its involvement as a major supplier of air, land and sea systems as well as defence electronics.

The UK aerospace industry has considerable development and manufacturing assets overseas, especially in the USA. For example, BAE owns US avionics firms and Rolls-Royce owns the US Allison engine company. In 2002, total employment in the USA of UK aerospace industry assets was almost 26,000 personnel. Similarly, many overseas companies have either located in the UK or purchased UK aerospace companies (eg. Goodrich; Thales).

Since the end of the Cold War, the UK, European and US aerospace industries have experienced substantial consolidation (for a discussion of the welfare effects of increased industrial concentration in manufacturing industries, see Gopinath et al, 2004). In the UK, major mergers and take-overs led to the creation of BAE Systems (British Aerospace and GEC Marconi Electronics), AgustaWestland (helicopters: a merger between Agusta/Italy and Westland/UK, with the UK interest sold to Finmeccanica in 2004) and the Thales acquisition of Racal and Shorts Missile Systems. In Europe, EADS represented a merger of Aerospatiale Matra (France), Daimler Chrysler (Germany) and CASA (Spain). US mergers and take-overs resulted in a smaller number of major aerospace companies, forming a major competitive threat to UK and European firms. Boeing acquired Rockwell and McDonnell Douglas; Lockheed Martin acquired General Dynamics Aircraft, a merger of Lockheed and Martin Marietta and the acquisition of Loral; Northrop acquired LTV Aircraft, then merged with Grumman followed by the acquisitions of Litton and Newport News Shipbuilding; and Raytheon acquired Beech Aircraft, BAe Business Jet, TI Defence and Hughes Aerospace and Defence.

A comparative assessment

The UK aerospace industry's position in the world market can be assessed by comparing it with the USA, the EU and other rivals. The US aerospace industry dominates the world market. In 2000/02 and on the basis of sales and employment, the US industry was some four times larger than the UK industry; and if size indicates the opportunities for achieving economies of scale, learning and scope, then the US industry has a competitive advantage over the rest of the world. Outside the EU, other major rivals include Canada and Japan (Table 2). Within the EU, the UK aerospace industry is the largest employer followed by France, Germany and Italy.

Table 2. The World's Aerospace Industries

	Sales 2000 (Euro billion, current prices)	Sales 2002 (Euro billion, current prices)	Employment 2000 (000)	Employment 2002 (000)
USA	105.6	102.7	595.9	531.9
EU	72.3	74.6	429.1	407.8
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Total	214.2	212.2	1219.5	1152.5

Notes:
(i) USA and EU turnover is for consolidated turnover. For the EU, consolidated turnover represents all sales to end-user customers and to aerospace firms outside the EU. Employment figures at year end and are based on direct employment. EU figures include the UK.

(ii) Others is an estimate excluding China and CIS

Source: AECMA (2000; 2002)

The five competitive forces

Assessing the industry using Porter's five competitive forces requires a distinction between military and civil aerospace markets. In the UK military market, the Government is a major buyer and funder of development programmes and can use its buying power to regulate profits. Government also determines entry and exit and typically UK defence contracts are subject to competitive procurement allowing foreign firms to bid for such contracts. Usually, there is significant rivalry between existing foreign competitors, mainly European (EADS; Dassault; Saab) and US firms (Boeing; Lockheed Martin; Northrop Grumman; Raytheon). Oligopoly in the world market results in close substitutes with rivalry in combat aircraft and military helicopters. However, the threat of new entry is limited, mainly because of high entry barriers and costs due to the need for costly and fixed R&D expenditure which on defence work is usually borne by government. Also, further entry barriers arise from economies of scale and learning. Nonetheless, large defence electronics companies provide an entry threat. Substitutes for an effective combat aircraft take many years to develop (eg. 10+ years) and whilst buyers are budget-constrained, they are not generally price-sensitive. Rivalry tends to be based on non-price factors, especially R&D which determines the technical features of military aircraft (eg. speed; range; weapons capability).

Civil markets are different, especially on the demand side, where governments are not major buyers. UK airlines form a privately-owned oligopsony, dominated by British Airways. Within the world market, there are large numbers of state-and privately-owned airlines demanding large and regional jet airliners. There are also large numbers of buyers for business jets and for light aircraft for pleasure use. On the supply side within the world market, there are duopolies in large jet airliners (Airbus, Europe; Boeing, USA) and regional jet airliners (Bombardier, Canada; Embraer, Brazil). The large jet airliner industry is characterised by high entry barriers, reflecting high R&D costs and scale and learning economies (Graham, 2001). However, duopoly results in close substitutes for both regional and large civil aircraft. Nonetheless, substitutes for a commercially-successful large jet airliner might take some 6 years to develop with break-even occurring some 10-15 years into production and pay-back periods extending a further 20 years or more. Even on regional jet airliners, orders for 40-60 aircraft are the minimum required for a commercial launch. These unique economic characteristics of civil aircraft development mean that this is not a market offering short-term profitability.

Duopoly prime contractors can use their buying power on major new programmes to obtain favourable deals with their major suppliers, especially the engine companies. The world aero-engine market is an oligopoly comprising Pratt and Whitney (United Technologies, USA; General Electric, USA; Rolls-Royce, UK; and Snecma, France). These companies compete vigorously for their engines to be used on new civil aircraft programmes (eg. Airbus 380; Boeing 7E7). There is similar rivalry between a small number of major equipment companies for a share of such new projects.

Both the large and regional jet airliner industry has been characterised by exits. In 2003, the UK as a prime contractor, exited from the regional jet airliner market (similar exits occurred for Fokker, Netherlands and Fairchild Dornier, Germany). However, a number of nations are seeking to enter the regional airliner industry (eg. China; Indonesia; Spain). For both existing and new entrants, Government is involved in the civil aircraft market through the provision of state financial support for new aircraft programmes. The UK Government provides a risk sharing, repayable investment in the form of launch investment with repayments through a levy on sales. Studies of international financial supports show that "there is a very large imbalance in the absolute levels of support provided by other governments to their civil aerospace industries, particularly the USA, and a material imbalance with the rest of Europe"(IGT, 2003). Estimates show that the US support may be at least seven times and possibly as high as twelve times greater than the level of support available in Europe. Despite the lower levels of state support available, the UK industry has achieved significant success in creating world-class competitors. However, nations are in a prisoner's dilemma subsidy war which extends to include local and regional government (eg. with regions in various nations offering competitive subsidies to attract aerospace firms, especially suppliers).

In the Porter model, industries in which the pressure from one or more of the five competitive forces is intense are ones where few firms are very profitable for long periods (Porter, 1990, p35). The UK aerospace industry has at least three intense competitive forces, namely, powerful buyers in both military (government) and civil markets (prime contractors), fierce competitive rivalry and substitute products: hence the prediction that UK aerospace will have few firms which are very profitable for long periods. The remainder of this paper assesses the UK aerospace industry competitiveness using various statistical indicators mostly for the period 1980 to 2000. Inevitably, there is no single 'best' indicator of performance, so that a balanced assessment requires several performance measures.

Assessing the Competitiveness of the UK Aerospace Industry

(i) Labour productivity

Productivity is one of the determinants of competitiveness. This section focuses on industry labour productivity based on sales per employee, since this is the measure for which international data are readily available. The UK aerospace industry's labour productivity relative to the USA and the EU improved over the period 1980 to 2000. The 1980 productivity gap between the UK on the one hand and the EU and USA industries on the other was reduced substantially by 2000 (Table 3).

Table 3 Labour Productivity, 1980 - 2000

	UK	EU	USA
1980 Index (US = 100)	77	99	100
2000 Sales per employee Index (US=100)	£96183 (89)	£102698 (95)	£108012 (100)

Note: All sales figures are consolidated sales. US figures are based on AECMA estimates.
Source: AECMA (2002)

The DTI publishes an annual Value Added Scoreboard which provides data for a sample of UK and European companies (first published in 2002). These show value added productivity defined as value added per employee and value adding efficiency or wealth creation which is value added divided by input costs of labour and equipment depreciation. For the combined sample of UK and European aerospace companies, the rank correlation between VA per employee and VA efficiency was r = 0.22; that between VA per employee and profitability was r = 0.174; and that between VA per employee and VA share of sales was r = 0.043, none of which were significant.

Table 4. Value added Productivity: UK and European Companies, 2004

Company	Value added per employee (£000)	Value added efficiency (%)	Value added efficiency: 4 year average (%)	Value added share of sales (%)	Operating profit as share of sales (%)
All UK Companies	44.7	143.4	149	30.1	4.4
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EUROPE: All European Aerospace and Defence companies	54.1	116.2	120	38.1	2.3
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Notes:
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(iv) The UK sample is based on the top 800 UK companies; and the European sample is based on the top 600 European companies, including UK companies.

Source: DTI (2004)

Table 4 shows that for aerospace and defence companies, the European average for value added per employee was some 20% higher than the corresponding figure for the UK. The high value added productivity companies comprised Dassault Aviation, EADS and SAAB; and the lowest value added productivity company was Bombardier (formerly Shorts, Belfast) whose productivity was 65% and 55% of the UK and European averages, respectively. Comparing firms in similar markets, Dassault's value added productivity was almost 90% higher than that for BAE Systems; EADS productivity was some 40% higher than Airbus UK; but Rolls-Royce productivity was some 15% higher than its French rival, Snecma. Dassault scores highly on all the criteria shown in Table 4: value added efficiency; a higher current value added efficiency than its four year average; a middle position on vertical integration; and a high profit margin. However, the rankings are sensitive to the choice of performance indicator. Using value added efficiency (wealth creation), its four year average and profit margins, the UK averages are slightly higher than those for Europe, with the UK also showing a higher degree of vertical integration. A higher value added efficiency for the average of UK companies compared with the European average reflects their higher efficiency in creating wealth.

(ii) Output

Output is a major determinant of unit costs and hence competitiveness in the aerospace industry. Larger output allows the greater 'spreading' of fixed R&D costs and also results in learning economies which lead to rising productivity as output increases (see Frantzen D, 1998). A limited interview survey of UK firms (undertaken in 2001/02) found that learning remained important but it has been affected by modern manufacturing techniques, new materials and business practices. The interviews suggested that whilst learning is still relevant, "the curve might now be steeper than it used to be," that it has been affected by lean methods and supply chain changes and that "on the Joint Strike Fighter, BAE is comparable to Lockheed Martin." (Braddon and Hartley, 2002). Three further comments were made on learning economies. First, that scale differences between the USA and the UK are not as important as they used to be. Second, that UK labour costs are lower. Third, that more capital-intensive methods are now used since greater precision is needed for modern aircraft manufacture which results in fewer opportunities for labour learning. Overall, the consensus view was that UK aerospace unit cost curves were lower than US unit cost curves.

There is also evidence of a major change in UK aerospace learning curves. Between the 1950s and 1970s, UK learning curves tended to 'flatten-out' at about 100 units, reflecting the small-scale of UK aircraft output. For example, on eight UK civil aircraft projects, average output was 143 units ranging from 53 units ((VC10) to 440 units (Viscount). In contrast, US learning curves of that period showed continuous learning (eg. up to 5000 units on the Phantom combat aircraft). On eight large US jet airliners, average output by end-1974 was 525 units ranging from 100 units (Lockheed Tristar) to 1088 units (Boeing 727). Currently, for some projects, UK learning curves now show continuous learning reflecting a larger scale of output (for a wider discussion of learning curves in a related industry, see Chung, 2001).

A distinction needs to be made between military and civil aircraft. Industry performance on civil aircraft is probably a more accurate indicator of market competitiveness: civil aircraft markets are less subject to state protection and military projects are greatly affected by government procurement policies, including export licensing regimes. On civil aircraft, the European Airbus is achieving US scales of output. For example, on the Airbus A320 family, total output exceeded 2100 units by end-2003. Here, it has to be remembered that Airbus was a new entrant to the large jet airliner market as recently as 1970, when the market was dominated by US companies, namely, Boeing, McDonnell Douglas and Lockheed. In 2004, there is an industry duopoly comprising Airbus and Boeing.

Airbus is distinctive in being an example of a competitive and hence successful European international collaborative organisation. It provides a 'model' for other collaborative arrangements, especially for European military aerospace projects (cf. Eurofighter Typhoon). Using scale of output, market penetration and market share criteria, Airbus is a successful and competitive organisation (but the costs of achieving this market position would need to be included in any economic evaluation). Airbus differs from other European collaborations in at least three ways. First, as a single company (now an integrated company), it represents a different form of collaboration (cf. European military aircraft collaborations which are project-specific with the partner companies retaining their identity). Second, Airbus is not constrained by the commitment to raise the technological capability of the partner nations (eg. as occurred on collaborative military aircraft projects). Indeed, Airbus is less constrained by *juste retour:* in fact, it is claimed that the *juste retour* used by Airbus has been beneficial in creating areas of technical expertise and specialisation (eg. BAE focus on wing technology for Airbus: ITC, 2001). Third, to survive Airbus has to be competitive in responding to the varied and changing demands of the world civil aircraft market. Unlike military collaborations, there is no guaranteed market for Airbus aircraft (cf. the partner nations on Eurofighter Typhoon which fund its R&D costs and provided firm production orders for the aircraft).

On military aircraft, the US aerospace industry has the benefit of a large protected home market. The US Joint Strike Fighter (JSF, now the Lockheed Martin F-35) illustrates the scale differences between the UK, other European nations and the USA. The original planned requirement was 2852 JSF aircraft for the US Forces compared with a UK requirement for 150 aircraft. Faced with such scale differences in military markets, the UK can respond by reducing unit costs compared with the USA; by exporting; and by international collaboration (eg. UK involvement in Eurofighter Typhoon and JSF). On exports, the UK Hawk is a good example achieving both high output levels (over 800 aircraft) and a high proportion of output exported (almost 80% exported). Similarly, Eurofighter shows how European collaboration results in output levels closer to those in the USA and considerably greater than European national scales of output. For example, the partner nation's planned order for Eurofighter is 620 units, comprising 232 units for the UK, 180 for Germany, 121 for Italy and 87 for Spain. However, collaboration departs from the 'ideal case' leading to inefficiencies associated with complex international management and monitoring arrangements and restrictive work sharing requirements. UK estimates suggest that the total development costs on the four nation Eurofighter were almost twice as high as an alternative national aircraft; but typically, the UKs cost share equates to one third of total development costs. Similarly, the scale economies achieved on collaborative production programmes are in the region of half those on national programmes; and delays on collaborative programmes average almost one year (NAO, 2001).

(iii) Size of firms

The US competitive advantage in the scale of output, especially for military aircraft, is also reflected in its advantage in firm size. Large firms are able to obtain economies of scale and scope and in recent years there has been considerable merger activity creating larger aerospace firms. US firms dominate the world's top 10 aerospace firms, accounting for 7 out of the top 10 in 1996, 2000 and 2002. BAE Systems was the only UK aerospace company in the top 10 in 1996, 2000 and 2002, ranking fourth in each year. In contrast, the newly-created EADS ranked third in 2000 and second in 2002 .

Table 5 shows the top 15 aerospace companies between 1996 and 2002. Interestingly, 9 of the top 15 companies remain unchanged throughout the period (including BAE Systems and Thales/Thomson-CSF). Comparisons with Boeing for 2002 show the scale advantage of the US company: EADS was 53% and BAE was 34% of the size of Boeing. Similarly, in aero-engines in 2002, Rolls-Royce was 55% of the size of General Electric. Within the top 15, between 1996 and 2002, the UK and European firms have not achieved any substantial increase in their average size in relation to the top US firms. This suggests that the US aerospace mergers after 1996 have been more successful in creating relatively larger firms. Also, over this period, the UKs mergers have created relatively larger aerospace firms than in Europe.

Table 5. Top 15 Aerospace Firms

2002		2000		1996	
Firm Ranking	**Aerospace Sales ($m)**	**Firm Ranking**	**Aerospace Sales ($m)**	**Firm Ranking**	**Aerospace Sales ($m)**
Boeing	53,344	Boeing	51,407	Lockheed Martin	26,068
EADS (E)	28,182	Lockheed Martin	23,977	Boeing	22,681
Lockheed Martin	26,562	EADS	23,336	McDonnell Douglas	13,447
BAE Systems	18,236	BAE Systems	19,661	British Aerospace	11,635
Northrop Grumman	18,126	Raytheon	15,443	Aerospatiale (F)	9,948
Raytheon	17,449	United Technologies	12,358	United Technologies	8,852
United Technologies	13,216	General Electric	10,779	DASA (G)	8,636
General Electric	11,141	Honeywell	9,988	Hughes Electronics	8,314
Honeywell International	8,855	Northrop Grumman	7,782	Northrop Grumman	8,071
Thales (F)	8,035	Bombardier	7,112	Raytheon	7,769
Bombardier (C)	7,194	Rolls-Royce	6,890	General Electric	6,302
General Dynamics	6,970	TRW	6,237	Thomson-CSF (F)	6,264
Rolls-Royce	6,179	Thales	5,977	Allied Signal	5,714
Snecma (F)	6,130	Snecma	5,204	GEC (UK)	5,653
Finmeccanica (Italy)	5,041	Mitsubishi Heavy Industries (J)	4,841	Rolls-Royce	4,616
Average size: UK v USA	63%		77%		61%
Average size: Europe v USA	61%		67%		70%
Average size: EU v UK	97%		87%		113%

Notes: i) Sales figures are in current prices and are for aerospace sales only. Most companies have other sales, but total sales figures are not reported here.
ii) C = Canada; E = Europe; F = France; G = Germany.
iii) Average size of firm is based on firms in the top 15.

Sources: Flight (1997; 2002; 2003)

(iv) Development time-scales

The time taken to develop an aircraft from start to delivery is a further indicator of competitiveness. Traditionally, the US aerospace industry developed both civil and military aircraft faster than the UK and European industries. For example, between 1945 and 1969, the average UK development times for military aircraft were 8 years 4 months compared with 6 years 3 months for the USA; and for civil aircraft, the average development times were 4 years and 4 months and 3 years and 7 months, respectively (Elstub, 1969).

Since 1980, the position has changed. On large jet airliners, Airbus is now competitive with Boeing on development times (where Airbus involves a UK component on the wings, engines and other equipment). Table 6 shows development times for a similar group of Airbus and Boeing civil aircraft, with similarity defined by their characteristics. Airbus aircraft were developed some 4-7% faster, with Airbus being faster from start to first flight, but slightly slower from first flight to Certificate of Airworthiness. Interestingly, this evidence confirms that European collaboration in civil aircraft has created a competitive industrial organisation. Regression analysis of various measures of development time against aircraft characteristics, a time-trend and a country of manufacture dummy variable gave a significant and negative coefficient for the time-trend only. As expected, the country of manufacture dummy was not significant.

Table 6. Average Development Times for Civil Aircraft

Aircraft	Development Times (months)			Aircraft Characteristics			
	Start to first flight	First flight to CoA	Total Time	Speed (mph)	Weight (lbs)	Passengers	Range (miles)
Airbus (n=7)	43.4	13	56.4	595	325,179	252	4653
Airbus (n=6)	43.8	11	54.8	602	318,748	250	4716
Boeing (n=7)	48.9	9.9	58.7	606	388,078	240	4516

Notes:
i. Airbus n=7 sample: A300;A310; A320; A319; A321; A340; A330. The sample n=6 excluded the A300 with a first flight in 1972. All other Airbus airliners had a first flight date of 1982-95.
ii. Boeing n=7 sample: B737 Next Generation; B747-400; B757; B767; BMD11; B717-200, all with first flight dates of 1981-98.
iii. Weight is maximum take-off weight; months are rounded to nearest month; CoA is award of Certificate of Airworthiness.

Source: Janes (2001)

The traditional competitive advantage of the US industry in development times for military combat aircraft is shown in the following regression equation. This allows for combat aircraft characteristics:

$$TCS = 143.71 - 0.12S + 2.32W^{*} + 0.02R + 54.40CM + 0.39T$$
$$(1.97) \quad (1.99) \quad (2.69) \quad (1.26) \quad (2.36) \quad (0.26)$$

$$\bar{R}^2 = 0.70$$

where TCS = total time from contract start to service (months); S = speed; W = weight; R = range; CM = a dummy variable for USA = 0 and rest of world = 1; and T = a time-trend based on date of first flight. The equation was based on a sample of 11 US, European, Russian and Japanese modern combat aircraft (see also notes to Table 7).

The equation shows a significant and predicted positive impact of weight on development times; but surprisingly, other aircraft characteristics, namely, speed and range were not significant. The country of manufacture dummy is almost significant, showing a substantial US advantage in development times (some 4.5 years).

On current generations of combat aircraft, development times are similar between Europe and the USA, confirming that the US no longer has a competitive advantage in this aspect of industry performance. On three current generation European combat aircraft (Gripen; Rafale; Typhoon) average development times were 181 months compared with an average of 209 months for two US combat aircraft (F-22 and JSF, neither of which have yet entered service). Since the end of the Cold War, development times have been 'stretched' reflecting defence budget problems and less urgency due to a reduced threat. Using pairwise comparisons, the European collaborative Typhoon has been developed in a considerably shorter time, namely, 214 months, than the US F-22 aircraft which is due in service in late 2005 (231 months). Admittedly, the US F-22 is a more complex, high-performance aircraft which is more advanced than any of the current European combat aircraft. Overall, the evidence shows that the traditional US competitive advantage on development times for civil and military combat aircraft no longer applies.

v) Labour hoarding

The speed at which firms vary their labour force in response to changes in output is another indicator of their competitiveness. A slow response suggests labour hoarding and labour retention policies. Once again, the US 'model' is of an aerospace industry which adjusts its labour force quickly to variations in output. The statistical evidence suggests that since 1980, the UK aerospace industry's employment has become more responsive to variations in output (cf Table 7: equations (2) and (3)). Also, the UK industry's employment responsiveness to changes in output is considerably higher than for the French aerospace industry and similar to that for the EU industry (Table 7: equations (1), (4) and (6)). Moreover, whilst the UK industry's employment responsiveness remains below that for the US aerospace industry, there was evidence of it approaching US levels.

Table 7. Employment Equations

Dependent variable	Constant	Coefficients of: Log Q	t	Log Lt-1	$,^{1}$	$,^{11}$	8	$\bar{R}^2$	d
1) LogLt (UK)	3.59* (2.35)	0.38** (5.02)	-0.04** (4.74)	0.42** (3.45)	0.38	0.65	0.58	0.980	2.1
2) LogLt (UK)	0.87 (1.97)	0.35** (5.64)	-0.02** (6.62)	0.69* (15.12)	0.35	1.14	0.31	0.968	1.3
3) LogLt (UK)	-2.65 (1.21)	0.65** (4.26)	-0.02* (2.75)	0.69** (5.35)	0.65	2.1	0.31	0.961	1.7
4) LogLt (EU)	3.90** (4.55)	0.41** (5.28)	-0.02** (3.34)	0.39** (4.00)	0.41	0.67	0.61	0.988	2.1
5) LogLt (USA)	2.80** (3.88)	0.42** (5.19)	-0.003 (1.14)	0.46** (8.17)	0.42	0.77	0.54	0.985	2.4
6) LogLt (FR)	4.21** (3.91)	0.16* (2.35)	-0.01* (2.34)	0.51** (5.26)	0.16	0.33	0.49	0.96	2.0

Notes:

i) All equations are log linear: logLt = log a + bt + c logQ + d log Lt-1 where $,^{1}$= c; $,^{11}$= c/ 8; d = 1 - 8 where 8 = lagged adjustment of actual to desired employment.

ii) Lt = employment; t = an exponential time trend representing technology and the capital stock; Q = value of turnover in constant 1999 prices (US $ millions); Lt-1 = lagged dependent variable.

iii) Equations (1) and (3) included a dummy variable for end of Cold War (not significant); equation (4) included a dummy for end of Cold War in 1991 (significant); equation (5) included slope shift dummies for mergers and dummies for end of Cold War (none were significant); equation (6) also included a dummy for end of the Cold War (not significant).

iv) Equations (1), (3), (5) and (6) based on 1980–2000; equation (2) based on 1948-2000; equation (4) based on 1980-1999. Equations (1), (4) and (6) use consolidated turnover; equations (2) and (3) use unconsolidated turnover.

v) t-ratios in brackets; $\bar{R}^2$ is adjusted for degrees of freedom; d = Durbin Watson statistic; * significant at 5% level; ** significant at 1% level.

Exports

Exports and market shares are often used as major indicators of competitiveness. In 2000, civil and military exports accounted for 60% of the UK aerospace industry's turnover. Civil aerospace sales accounted for almost 55% of the UK industry's turnover in 2000; and some two-thirds of this civil business was exported with civil aerospace exports accounting for 36% of total UK industry sales (SBAC, 2000). On civil aircraft, the UK industry designs and manufactures the wings for Airbus; and UK firms are also suppliers of engines and equipment to Airbus, Boeing and to the regional aircraft manufacturers. These exports reflect the fact that the UK is a world leader in wings, aero-engines and equipment some of which are represented on Airbus civil aircraft.

Airbus was a new entrant to the large jet airliner industry with its first deliveries in 1974 to a market which had been dominated by US firms (Boeing; Lockheed; McDonnell Douglas in the early 1970s). Since then Airbus has increased its share of the world market for large civil aircraft, achieving a 38% share in 2000 with the market changing from a US-dominated oligopoly to a European-US duopoly. Table 8 shows the trends in Airbus penetration of the world market. Two points can be made about entry time and costs. First, it took Airbus 21 years to achieve a market share of over 30%. Second, Airbus entry involved substantial costs for European taxpayers, especially in France and Germany and particularly for the Airbus A300 and A310. By December 2003, Airbus had delivered 780 A300/310 aircraft compared with 2109 units of the A320 family which is similar to Boeing scale of output for its successful airliners.

Table 8. Airbus and Boeing Sales, 1974 - 2000

Gross deliveries (units)	**1974**	**1980**	**1985**	**1990**	**1995**	**2000**
Airbus	5	38	42	95	124	311
Boeing (incldg McDonnell Douglas)	284	363	282	527	261	504
Airbus share (%)	1.7	9.5	13.0	15.3	32.2	38.2

Source: DTI (2002).

The military-civil sales ratio has changed substantially since 1980 when military sales accounted for about 65% of the UK aerospace industry's sales and civil sales the remaining 35%. In 2000, military sales accounted for 46% of the UK aerospace industry's sales, shared equally between domestic and export customers (SBAC, 2001). In comparison, the military-civil ratios of sales for the EU and the US aerospace industries were 30/70 and 40/60, respectively.

Military aerospace exports dominated UK defence equipment exports over the period 1980 to 2000, especially in the 1990s with sales to the Middle East. However, defence exports are determined by both economic and political factors which makes it difficult to assess competitiveness. Even standard competitiveness measures such as equipment prices are misleading, since they can reflect different national subsidies to producers, differences in national preferential purchasing, various financial support arrangements (eg state export credits), offsets, a willingness by the supplying nation to waive R&D levies and the provision of gifts-in-kind (eg equipment and training free of charge). Equipment prices can also be for the basic equipment or might include various amounts of spares, training and support services. Political factors are also important, especially the supplying nations views on the political and military importance of the buying country (eg. allies and friends; ethical criteria; willingness of rival nations to supply).

Table 9 shows examples of the unit prices of various military aircraft. Amongst trainers, the UK Hawk appears to be competitive on price. This is confirmed by its status as a world leader for subsonic combat aircraft with 27% share of the world market compared with a 26% share for the USA over the period 1986 to 1997 (based on volume data: DoS, 2000). For both trainers and combat aircraft, some of the price data are for aircraft in the early stages of development whilst others are for aircraft in-service (eg.in-service aircraft at 2000 included Hawk, Gripen, F-15, F-16, Harrier and SU-27). Amongst combat aircraft, the F-16, Gripen and SU-27 are relatively cheap, whilst the US F-15E and F-22 are costly aircraft, but technically advanced. The collaborative Eurofighter Typhoon (with the UK as a partner) is cheaper than the US F-15 and F-22 but more expensive than Rafale. If the Lockheed Martin JSF is successful and its estimated costs are achieved (major assumptions), it will be a competitive aircraft and a major threat to Typhoon and Rafale.

Table 9. Military Aircraft Unit Prices

Aircraft	Unit Price (US$ millions)
Trainers	
Hawk (UK)	18-21
MAKO (EADS)	22-25
KTX-2 (S. Korea)	18-20
Combat Aircraft	
Eurofighter Typhoon	68
Rafale (France)	58
Gripen (Sweden)	35
F-15E (USA)	75
F-16 (USA)	24-25
F-18 E/F (USA)	50
F-22 (USA)	183
Joint Strike Fighter (JSF:USA)	31-38 (different versions)
Harrier AV8B (UK-US)	36
Mitsubishi F-2 (Japan)	115
SU-27 (Russia)	35

Sources: Various aviation and defence magazines (eg Defense News; Aviation Week; Janes Defence Weekly; Flight; Flug Revue; Air Forces Monthly). All data are for 1999, 2000 or 2001.

Statistical analysis of the determinants of UK aerospace exports was constrained by the available data. Some limited, exploratory equations were estimated and examples are shown in Table 10. The time-trend variable gave the expected significant and positive coefficient for civil exports; but a surprising negative coefficient for total exports. The end of the Cold War resulted in a negative impact on total and military exports. Passenger miles gave an expected positive impact on total exports, but a surprising negative coefficient for civil exports. There was no evidence of a ‘crowding-out’ effect from UK military equipment spending. Military equipment imports were positively associated with total UK military exports, which might reflect the general level of demand in world military markets.

Table 10. UK Aerospace Exports.

Dependent Variable	Constant	Coefficients of:					$\bar{R}^2$	d
		t	**Cold War Dummy**	**PASM**	**DSP**	**MIMP**		
1) TEXP	-6.95 (1.89)	-0.64** (3.36)	-1.66* (2.72)	0.02** (5.45)	0.0002 (0.55)	0.20 (0.11)	0.93	2.1
2) TMX	4518.4 (1.78)	67.09 (0.66)	-1661.6* (2.48)		-0.23 (1.21)	2.53* (2.14)	0.79	1.7
3) TCX	8417.7* (2.28)	711.55** (3.54)	-207.5 (0.32)	-16.33** (4.69)	-0.12 (0.73)		0.85	1.9

Notes:
i) TEXP = total UK aerospace exports; TMX = total UK military aerospace exports; TCX = total UK civil aerospace exports. All value data in £ billions, 1999 prices. Equations (1) and (2) are based on 1980-1998; equation (3) based on 1980-2000. All equations are linear.

ii) t = time-trend; dummy variable (1,0) for the end of the Cold War was based on either 1991 or 1992; PASM = world passenger miles (billions); DSP = UK military equipment spending; MIMP = UK military equipment imports lagged one year.

iii) Other details as in Table 7.

A relatively new feature of the UK aerospace industry is its global dimension with both inward and outward foreign direct investment. The UK industry has considerable aerospace manufacturing assets overseas. In 2000, these subsidiaries recorded sales of £5.55 billion and employed 47,000 personnel outside the UK. Some 60% of these overseas sales and employment were located in the USA (UK firms with US subsidiaries included BAE, Rolls-Royce and Smiths), so allowing UK firms to achieve entry into the US market, especially its defence market. Similarly, some overseas companies have located in the UK or acquired UK aerospace companies (eg. Bombardier/Shorts; Finmeccanica/ Agusta-Westland; TRW; Thales). As a result, the UK aerospace industry now comprises both UK and foreign-owned companies located in the UK.

Profitability

In competitive markets, profitability can be regarded as the final indicator of industry performance and competitiveness. Over the period 1985 to 2000, the UK aerospace industry achieved the highest median profit rate on sales, exceeding both the EU and the USA. The UK industry's annual profitability exceeded that of the EU in twelve of the sixteen years and exceeded that of the USA in ten of the sixteen years. The data are shown in Table 11. It is, however, recognised that national aerospace markets are imperfect: the EU and US markets are characterised by national monopolies and oligopolies, respectively, and both have national preferential purchasing policies (eg Buy America Act). In principle, the UK market is different with its competitive procurement policy for military equipment, so that its profitability record is a more accurate reflection of international competitiveness. Moreover, the UK industry's profitability record was achieved despite the US industry's advantage with its larger scale output and larger firms.

Table 11. Industry Profitability

Profit as percentage of sales (%)

Year	**Aerospace Industry**		
	UK	**EU**	**USA**
1985	5.5	5.2	3.1
1986	5.0	4.2	2.8
1987	4.4	3.5	4.1
1988	3.4	3.8	4.3
1989	4.2	3.2	3.3
1990	2.8	2.4	3.4
1991	2.2	2.4	1.8
1992	-1.2	-0.6	-1.4
1993	2.2	0.7	3.6
1994	0.5	0.0	4.7
1995	5.4	0.0	3.8
1996	4.8	2.2	5.6
1997	6.2	3.9	5.2
1998	6.9	6.7	5.0
1999	6.4	6.8	6.5
2000	6.4	4.9	4.7
Median	4.6	3.4	4.0

Sources: AECMA; SBAC; USAIA

Profitability data are also available at the company level and these are shown in Table 12, based on the year 2000. There are two features of this Table. First, the profitability of the two UK major aerospace firms, BAE and Rolls-Royce, generally exceeded that of their major and much larger US rivals, namely, Boeing and Lockheed Martin. Second, the profitability of some of the UK equipment suppliers exceeded that of the much larger UK and US companies (BAE; RR; Boeing; Lockheed Martin).

Table 11. Company Profitability, 2000

Company	Profit on sales (%)	Profit on capital (%)
BAE	7.8	5.6
Rolls-Royce	8.0	12.9
GKN	8.0	24.8
TRW	18.9	11.6
Cobham	17.1	25.2
Smiths	18.5	24.6
Hunting	2.1	13.5
Bombardier (Shorts)	13.7	Na
Meggitt	24.6	14.5
Ultra Electronics	13.9	35.3
Martin Baker	14.4	Na
UK Sample Average	9.6	Na
UK Aerospace Industry Average	8.8	12.6
Boeing	6.6	14.2
Lockheed Martin	4.8	6.0

Note: Sample average is for all the UK companies shown in the Table; UK Industry average is based on UK companies in top 100 aerospace companies (Flight 2001b)

Sources: SBAC (2000); Flight (2001 b)

Conclusion

The UK aerospace industry is the largest in the EU. The USA is the UK industry's major rival and provides the 'benchmark' for assessing its performance. On this basis and using the indicators reviewed in this paper, the UK industry improved its competitiveness over the period 1980 to 2000. There were improvements in labour productivity, output levels, development times, employment responsiveness and export performance. The results are summarised in Table 12.

Table 12. Competitiveness Indicators, 1980-2000

Indicator	UK industry performance relative to USA
1. Labour productivity	Improving
2. Output (a) Civil (b) Military	Airbus achieving US scales of output UK/JSF = US scales of output Eurofighter = higher output
3. Development times	US no longer has competitive advantage
4. Labour hoarding	UK employment responsiveness has improved and is approaching US levels.
5. Exports	a. Military aerospace exports dominated UK defence exports; b. World leader for subsonic combat aircraft; c. Airbus: rising share of world market
6. Industry profitability	Higher than USA

Statistical indicators confirm past and current performance and competitiveness, but do not guarantee future successful competitiveness. The main problems facing the UK aerospace industry arise from the lack of new R&D programmes to provide the next generation of projects. Some of this new R&D will require government funding (IGT, 2003). Technical change is also a challenge to the future UK aerospace firm. The possible emergence of unmanned combat air vehicles (UCAVs) could revolutionise air warfare and lead to the end of manned combat aircraft and an increased emphasis on electronics and electronic warfare. For civil aircraft, the UKs future looks to be through an involvement in collaborative Airbus programmes. However, the 2005 WTO dispute between the EU and USA raises doubts about the future of UK (and European) Government repayable launch investment for civil aircraft programmes (TIC, 2005). Also, the future absence of any UK-designed military and civil aircraft will mean the increasing importance of its equipment suppliers.

Benchmarking against the US aerospace industry and continued competition with its US rivals will provide a major competitive stimulus for the UK aerospace industry. Evidence suggests that "…the more a given manufacturing industry is exposed to the world's best practice high productivity industry, the higher its relative productivity (the closer it is to the leader). Competition with the productivity leader encourages higher productivity" (Bailey and Solow, 2001). On this basis, part of an industry's productivity disadvantage reflects organisational slack and/or reluctance to change and innovate. Failure by the UK aerospace industry to adjust to change will mean more exits and the loss of its world leader companies.

REFERENCES

AECMA (2000; 2002). **The European Aerospace Industry: Facts and Figures,** AECMA, Brussels.

Bailey, M.N. and Solow, R.M. (2001). International productivity comparisons built from the firm level, **Journal of Economic Perspectives**, 15, 3, Summer, pp.151-172.

Bishop P (2003, Collaboration and firm size: some evidence from the UK defence industry, **Applied Economics,** vol. 35, December, pp. 1965-1969.

Bonte W (2003). Does federally-financed business R & D matter for US productivity growth, **Applied Economics,** vol. 35, no. 15, October, pp. 1619-1625.

Braddon D and K Hartley (2002), **UK Aerospace Competitiveness,** Department of Trade and Industry; July.

Chung S (2001). The learning curve and the yield factor: the case of Korea's semiconductor industry, **Applied Economics,** vol. 33, no. 4, March, pp. 473-483.

DTI (2004). **The Value Added Scoreboard, 2004**, DTI, London.

DoS (2000). **World Military Expenditures and Arms Transfers, 1998**, US Department of State, US Government Printing Office, Washington DC.

Elstub St.J (1969). **Productivity of the National Aircraft Effort**, HMSO, London

Flight (1997; 2002; 2003). Aerospace Top 100, August, **Flight International**, Surrey.

Frantzen D (1998). R & D efforts, international technology spillovers and the evolution of productivity in industrial countries, **Applied Economics,** vol. 30, November, pp. 1459-1469.

Gopinath M, Pick D and Y. Li (2004). An empirical analysis of productivity growth and industrial concentration in US manufacturing, **Applied Economics,** vol. 36, no. 1, January, pp. 1-7.

Graham D J (2001). Productivity growth in British manufacturing: spatial variation in the role of scale economies, technology growth and industrial structure, **Applied Economics,** vol. 33, May, pp. 811-821.

Janes (2001). **Jane's All the World's Aircraft,** Jane's Information Group, Coulsdon, Surrey.

Khambampati U.S. (2000). Industry competitiveness: leadership identity and market shares, **Applied Economics Letters,** vol. 7, no. 9, September, pp. 569-573.

ICT (2001). **Competitive Assessment of US Large Civil Aerostructures Industry**, US International Trade Commission, Washington DC, June.

IGT (2003). **An Independent Report on the Future of the UK Aerospace Industry,** Aerospace Innovation and Growth Team, DTI, London, June.

Manzur M, Wong W-K, and Chee I-C (1999). Measuring international competitiveness: experience from East Asia, **Applied Economics,** vol. 31, no. 11, November pp. 1383-1391.

NAO (2001). **Maximising the Benefits of Defence Equipment Co-operation**, National Audit Office, The Stationery Office, London.

Porter, M.E. (1990). **The Competitive Advantage of Nations**, Macmillan, London.

SBAC (2000; 2002). **UK Aerospace Facts and Figures**, SBAC, London

TIC (2005). **The UK Aerospace Industry**, Trade and Industry Committee, House of Commons, HC 151-I, Stationery Office, London.