Britain's "Manifest Industrial Destiny": The Culture of High Technology and Industrial Performance in the Twentieth Century

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As a subject for scholarly commentary and debate, the long relative decline of Britain's industrial economy has an enduring fascination for historians seeking to illuminate its causes. If asked to write a critical review of the "declinist" literature of the last thirty years undergraduate historians would be confronted by an array of competing, sometimes complementary, hypotheses, most of them grounded in academic objectivity, but with some notable and passionate polemics [Aldcroft, 1964; Landes, 1972; Bacon and Eltis, 1978; Olson, 1982; Pollard, 1982; Ingham, 1984; Wiener, 1985; Barnett, 1986; Elbaum and Lazonick, 1986; Newton and Porter, 1988; Porter, 1990]. Insofar as there are unifying themes in the literature, they may be categorized as "the cultural critique" and "the politics of welfare," the former focusing on inherited social and institutional structures inimical to growth, and the latter concerned with the disincentive effects of a rising tide of social expenditures at the behest of the state. Of the myriad explanations of Britain's industrial malaise it is significant, perhaps, that at the popular level the interpretations of Wiener and Barnett have attracted the lion's share of critical attention. Both authors share the common assumption that British society, from the late nineteenth century, has never come to terms with the values of "industrialism" despite its evident desire to enjoy the fruits of economic growth. While Wiener refers to the subversion of an original ethos of ongoing industrial progress at the hands of the aristocracy and liberal intelligentsia after 1850, Barnett castigates the post-1940 architects of the welfare state for preempting a vigorous postwar program of industrial modernizations in favor of social service expenditures. Needless to say, both theses have been subject to severe criticism, not least on account of their highly selective use of evidence and unsubstantiated generalizations [Coleman, 1987; Collins and Robbins, 1990; Harris, 1991]. More to the point, they have been challenged on their own terms by scholars who deny not only that cultural conservatism underwrote competitive failings [Rubinstein, 1993], but also that the British state (defined in the broadest sense) was anti-industrial and therefore opposed to technological advance. In the latter context, the most striking invocation of a

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counter-culture diametrically opposed to the interpretations of Wiener and Barnett is coincident with David Edgerton's account of *England and the Aeroplane*, with a particular focus on the concept of "liberal militarism" [Edgerton 1991a, 1991b]. According to Edgerton the declinist tradition in British economic history has resulted in a gross misconception of the true nature of the English state and nation. The principal vehicle for Edgerton's challenge to the notions of cultural atrophy and technological stagnation is the long-standing English obsession with aircraft and aviation generally, dating from before the World War I. In many ways the aircraft industry is representative of scientific and engineering excellence: it encapsulates the symbiotic relationship between technology and human progress, and its manifold achievements have regularly captured the public imagination. For Edgerton, the importance of the industry in its English setting can be gauged from the fact that on the eve of World War I Britain possessed the strongest air services in the world: in the 1920s it was the world's leading producer, while in the symbolic year of 1940 it outproduced the German industry by 50 percent. From 1950 until the 1970s, moreover, Britain was the largest producer of aircraft after the United States and the Soviet Union. Throughout the twentieth century the industry has occupied a central place "within the grand design of English strategy" and it is this factor, stressing the close links between the aircraft industry and the state, which provides the essential core of Edgerton's revisionism. If the aircraft industry was nurtured and protected by successive governments, both of the left and the right, how can this possibly be reconciled with a so-called anti-industrial and technological bias, let alone an obsessive concern with socialist (and pacifist) – inspired welfare expenditures?

Edgerton's evocation of a distinctive counter-culture – the "warfare state rather than the welfare state" – underlines the inherent ambivalence in British attitudes towards high industrial endeavors. Here is a nation which accorded considerable prestige to an industry operating at the frontiers of technology with brilliant innovations to the credit of its scientists, engineers and technologists. Yet at the same time, societal attitudes towards engineering, technical, and vocational education in general have been marked by indifference, bordering on hostility on the part of the educated elite. Business historians are generally agreed that the low social prestige accorded to "education for industry" was a notable phenomenon before 1900 at a time when Germany and the United States were beginning to make striking advances in such provision. Throughout the twentieth century, moreover, it is evident that the more talented of the nation's youth have been attracted into the established professions, avoiding the world of industry, which has presented an uncongenial image to graduates [Landes, 1972, p. 344; Wrigley, 1986 pp. 162-88].[1] To that extent the Wiener thesis rings true. More to the point, however, is the difficulty of accepting Edgerton's counter-culture as a decisive challenge to the declininst tradition in the face of the objective fact of

[1] For a more optimistic view of British educational provision for the period to 1914 see Pollard [1989, pp.115-213].

Britain's relative decline as a manufacturing and trading nation during the present century [Supple, 1994]. It is an equally valid perspective to accept Edgerton's revisionism – to the extent that it highlights a distinctive pro-technology culture – but to argue that the "warfare state" made its own independent contribution to industrial decline.

Having noted the proliferating choice of theories of decline it may appear superfluous to add to their number. However, as the remainder of this paper will show, the Edgerton thesis has highlighted an emerging weakness in Britain's microeconomic base which has hardly featured in the litany of decline as expounded by economic and business historians. As Edgerton has eloquently demonstrated, the aircraft industry and the state have been locked together in a mutually dependent relationship. The industry has long been reliant on government funding and orders, and governments have underwritten the industry, first as a supposedly cost-effective way of sustaining imperial cohesion and a balance of power in Europe, and second as a means of preserving a world political and military role semi-independent of the United States. To pursue the cultural theme, it was the political culture of the British state itself which produced this relationship. It was a culture, moreover, which was entirely consistent with relative industrial decline. In the following section the paper will extend the Edgerton thesis beyond the aircraft industry in order to confirm the British commitment to high-technology ventures. The third section will then analyze the links between high technology and comparative industrial decline.

Britain as a Technological Nation

In placing the aircraft industry at the center of his analysis Edgerton makes the case for a "warfare state" with ease, deploying a number of interrelated themes. At his most ephemeral he examines the social, political, and ideological aspects of British aviation between the wars in the context of the stereotypical view of interwar England as "liberal, internationalist and anti-militarist." It is certainly true that the British state could hardly be termed "militarist" in the Hitlerian "nation in arms" sense. Nor should the strength of pacifist sentiment at all levels of society be underrated. But this is to miss the essential point that military strategy "was determined autonomously in the highest levels of the state machine: the Committee of Imperial Defence, the Cabinet and the Treasury." According to Edgerton these organs of the state subscribed to "a liberal conception of war" in which military conflict was defined in economic and technological terms with a private sector armaments industry primarily responsible for logistic supplies. This "liberal militarism" originated well before 1914, but its roots were greatly strengthened by the human carnage of World War I, which was unacceptable to pacifists and strategists alike. For the latter, a European land commitment involving mass armies was a military cul-de-sac: future strategic responses should be governed by technology focusing on a professional mechanized army augmented by air power. From these considerations the preference of the interwar Treasury for

the aeroplane in military defense planning is readily understandable: a strong airforce not only economized on manpower – "it was also the cheapest and most effective way of meeting the German challenge" [Edgerton, 1991a, p.43]. Thus, as historians of rearmament have emphasized, by 1939 the Air Ministry was the most generously funded of service departments. Although the public image of Britain's subsequent aeronautical history is bound up with the heroic "few" of 1940 in their Spitfires and Hurricanes, the overwhelming commitment of the RAF in wartime was directed towards the strategic bombing of Germany. As Edgerton concludes,

> the most important thing the emphasis on the bomber should tell us about England...is that England was a technological nation. The RAF, centred in Bomber Command, its huge industrial base employing over one and a half million people, and its massive numbers of largely non-combatant personnel, some one million, represented a technological way of warfare... Contrary to myth the average English service man had at his disposal a much greater quantity of materiel than did his German enemy, or his Soviet ally, though less than his American cousin [Edgerton, 1991a, p. 65].

It is not possible in a short paper to do full justice to the breadth and detail of Edgerton's arguments concerning the cultural significance of the aeroplane in British history. It must suffice to say that the themes identified above as applicable to the first half of the twentieth century are sustained into the post-1945 period. Thus "the sonic boom of the scientific revolution" in the late 1940s through to the 1960s, the product of unprecedented state-sponsored technological endeavours, is presented as a counterpoint to the anti-industrial ethos of the welfare state. As Edgerton comments,

> This was the context of the extraordinary enthusiasm for the Brabazon airliner, the Fairey Delta, and the Concorde, not to mention the AW52 flying wing or the Rolls Royce flying bedstead. This enthusiasm for the aeroplane was not, however, simply technological enthusiasm: aeroplanes represented the modern side of the English heritage, England's distinctive contribution to the world. Each one combined something of the heroic spirit of the Battle of Britain and the communal endeavour of the blitz [Edgerton, 1991a, p. 90].

At the popular level contemporary aeronautical achievements were paraded before cinema audiences in the form of Pathé newsreels, memorable chiefly for their bombastic and chauvinistic commentaries. Similar functions were fulfilled by such films as *The Sound Barrier* and *The Dambusters*, the former celebrating the inauguration of the jet age and the latter commemorating the wartime exploits of Bomber Command. With their heroic visual images and stirring musical scores these films struck resonant chords in the British people: technological achievements had been central to the offensive war effort and

provided a substantial guarantee (in combination with the embryonic nuclear deterrent) of the country's great power status. This imagery of "a lethargic nation raised to genius by emergency, and saved by heroic, aristocratic pilots and shy boffins" was all the more potent in advance of the Suez crisis of 1956, an event which proved decisive both in precipitating the final dissolution of the empire and in reinforcing British economic and military dependence on the United States. The fact that British technical programs continued after 1960 – epitomized in the TSR 2 bomber project – was indicative of a reluctance to confront urgent economic and military realities, a fact confirmed by the deeply hostile Conservative media reactions to defense project cancellations [Edgerton, 1991a, pp. 61-91].

Moving from ephemeral issues to realities, the status of high technology in Britain can be gauged from the resources committed to it. It hardly needs to be said that in this respect the aircraft industry came of age during World War II. Annual production peaked in 1943 when 26,263 units were completed compared with 2,827 in 1938. In 1935 the industry employed 35,000 workers with output valued at £14 million. The comparable figures for 1944 were 300,000 and £800 million respectively. Taking account of ancillary suppliers, approximately 1.7 million workers were dependent on the industry either directly or indirectly. Total capital investment during the war amounted to £350 million – £63.5 million of which was spent on factories and £39.6 million on plant and machinery. In the light of these quantities Barnett, as a critical observer of the industry's performance, concluded that its wartime development was "without parallel in British history in terms of scale, speed and cost – and by state participation. Here was the centre of gravity of the entire British war effort" [Barnett, 1986, p. 146]. But having acknowledged the industry's quantitative achievements Barnett presents critical evidence of structural and entrepreneurial weaknesses which were especially noticeable in comparison with the North American industry. Certainly, physical production increased as a result of the greater use of American-made machine tools, but productivity, defined in terms of structural weight produced per worker, was 150% higher in the United States and 20% higher in Germany. Moreover, the British industry's much-vaunted design achievements were heavily dependent on foreign innovations. That said, there were undoubted successes, especially in an Anglo-German context. Britain's shadow factory system made a vital contribution to the production of bomber aircraft, producing 45% of all heavy variants and up to two-thirds of their light counterparts. In Germany, however, the contribution of the motor vehicle industry to aircraft production was delayed until the later stages of the war, and the industry as a whole never operated at more than 50% of capacity. Use of scarce materials was more efficiently organized in Britain, while the productive system as a whole was never subject to the crippling disputes over priorities that afflicted German industry. As for trade union resistance to dilution, contrary to the impression conveyed by Barnett, British and American experience, as reflected in the proportion of women workers employed, was approximately the same, whereas German aircraft workers resisted dilution until 1944.

In its postwar setting the aircraft industry was at "the very heart of the national technological effort" [Edgerton, 1991a, p.91]. It enjoyed "considerable prestige and popular esteem," and, as a result of its phenomenal wartime expansion had emerged as "a powerful economic and strategic element in British manufacturing" [Hayward, 1989, p.45]. This role was considerably enhanced as a result of the rearmament program inaugurated in 1950 which raised defense expenditure to unprecedented peacetime levels. Measured in current prices, total defense expenditure increased from £750 million in 1948 to £1.5 billion in 1954 with spending on the aircraft industry rising proportionately, from £96 million to £210 million. From a postwar low of 143,000, employment had increased to 279,00 by 1954, rising to 311,936 in 1957, figures which should be compared with the 387,000 employed in the motor vehicle industry in 1959. Although the industry's output, measured in real terms by value, displayed only modest growth during the 1950s and 1960s it should be noted that total output was dominated by military programs with a ratio of 3:1 over civil production. Thus, the rate of growth of output fully reflected the substantial inflation of the post-Korean rearmament phase after 1950. By the mid-1960s, moreover, exports accounted for more than 20% of the industry's sales, with an exports-per-employee average of £750 compared to an average of £500 for manufacturing as a whole [Hayward, 1989, p. 126].

The truly fundamental indicator of the aircraft industry's economic significance after World War II is to be found in its critically important position in Britain's R&D effort. This fact is a major component of the Edgerton thesis in that by the mid-1950s government expenditure on R&D in the aircraft industry was only slightly below the conflated total for private and nationalized industries.

Table 1: *UK R&D Expenditure, £m current prices*

	1950-51	1955-6	1961-2	1964-5
Ministry of Supply R&D	89	157		
Ministry of Aviation R&D			210	252
State-funded R & D in aircraft industry	30	65	101	110
DSIR R&D	5	6	15	25
Total state-funded R&D	114	196	289	434
Industry-funded R&D	24	77	248	328

Source: Edgerton, 1991a, Table 5.1, p. 92.

As Table 1 reveals, this pattern was to persist into the 1960s when account is taken of Ministry of Aviation R&D expenditures. In view of the fact that the proportion of government-funded R&D to output in the aircraft industry rose from 17% in the latter 1940s to 23% in 1964, Edgerton's conclusion that its "R and D intensity" was indicative of "an industry devoted to innovation" appears apposite [Edgerton, 1991a, p. 91].

A final challenge to the historiography of decline is the aircraft industry's proximity "to the ideal many critics of English industry said, and say, England should have." As Edgerton points out, "It was made up of large firms committed to technological change, employed many highly qualified engineers, and had close links with the state" [Edgerton, 1991a, p.95]. Even before a major program of rationalization, inaugurated in the late 1950s, the industry was highly concentrated by contemporary British standards. In the mid-1950s the leading firms in the industry – Vickers-Armstrong, Hawker Siddeley, Rolls Royce, Bristol, English Electric, and de Havilland – were responsible for up to 90 per cent of total industry output. Following the amalgamations of the late 1950s and 1960s the new Hawker Siddeley group (Hawker Siddeley Aviation) emerged as Britain's second largest manufacturing employer with 123,000 workers in 1965. At the same date the recently formed British Aircraft Corporation (BAC) employed 37,000 workers, but was itself owned jointly by the much larger engineering firms of Vickers, English Electric, and Bristol Aeroplane. In 1966 Bristol Siddeley Engines was absorbed by Rolls Royce resulting in total firm employment of 88,000 workers. As for the upper managerial echelons of both the pre- and post-grouping companies, most were dominated by engineers, some having worked their way up from the shop-floor, but others, such as Sir Arnold Hall, managing director of Hawker Siddeley from 1963 to 1981, possessing advanced university training. Indeed, Hall had ended his academic career as Zaharoff Professor of Aviation at Imperial College. In the mid-1970s BAC's divisional boards contained significant numbers of graduate engineers, many of them the products of a post-1945 university system which had responded vigorously to the engineering man-power needs of the aircraft industry. In addition to the established centers of aeronautical engineering at Cambridge and Imperial College, new departments and specialist groupings were created at Manchester, Queens Belfast, Queen Mary College, London, Glasgow, Hull, Bristol, and Southampton. Equally significant was the foundation in 1946 of the Cranfield College of Aeronautics as a non-university postgraduate institution.

The high status of graduate engineers in the aircraft industry was also reflected at lower levels in the workforce where an unusually high proportion of workers was employed as managers, administrators, technicians, and clerks. This is prima facie evidence of the industry's capital intensity. Wages of aircraft industry workers, moreover, were well above the average for the manufacturing sector as a whole, and the contentment of the shopfloor workforce was enhanced by the nature of the product – its production complexity and technological sophistication. In these respects there could be no greater contrast with the "alienated" and strike-prone workforce in the motor vehicle industry.

Edgerton's case for the status and prestige accorded to high technology ventures in Britain is undeniably powerful. It can be buttressed by yet further activities which are inconsistent with cultural antipathy to technological advance and industrial progress. Two examples will suffice, one from the late nineteenth century and Edwardian periods, and the other from the three decades after 1945. In the former case the role fulfilled by the aircraft industry

at a later date was virtually replicated in that part of the shipbuilding industry devoted to naval construction. In the same way that the RAF was viewed as the most cost effective means of containing the German threat after 1936, the Royal Navy fulfilled the same role in the decade-and-a-half before 1914. The senior service, moreover, was supplied with products which were not only at the technological frontier of heavy weaponry, but were manufactured utilizing state-of-the-art industrial processes. With their products "as far removed from articles of general commerce as the best of contemporary science, materials and process engineering could take them" the private sector armaments firms "drew upon contributions from metallurgists, ballisticians, chemists and engineers," paying "sophisticated attention to accurate steel analysis, precise heat control and very small dimensional tolerances" [Trebilcock, 1977, p.4]. These firms were the leading innovators in the use of alloy steels and nickel alloys, and their R&D commitment was correspondingly large. In the early 1900s, Vickers, the leading British armaments manufacturer, employed a design staff of 300-400 individuals. By that time the leading gun makers were habitually allocating 6-12 per cent of net annual profits to their "scientific departments", whilst "research appropriations of £80-100,000 per annum were not unheard of in the busiest years of the 1900s" [Trebilcock, 1977, p. 4]. Wiener's image of an Edwardian England colored by Beatrix Potter and E. M. Forster is thus a distortion of reality. The society which begat "A Shropshire Lad" was also the society which lavished vast budgets on a Royal Navy that was "probably...the largest technologically-oriented institution in the world, operating Dreadnoughts powered by steam turbines fed by oil-fired boilers and which communicated by wireless telegraphy" [Edgerton, 1991a, p.12].

An equally potent reminder of the technological aspirations of the British state is provided by the development of nuclear power. The significance of this is all the more compelling since the decision to embark on an R&D program was taken in secret by a Labour government committed to the creation of a postwar welfare state. The initial investments in a research and experimental establishment at Harwell, nuclear piles and a chemical separation plant at Windscale, and a gaseous diffusion plant at Capenhurst were prompted by military considerations, and although Britain was to take a leading role in the civil application of nuclear power in the 1950s, the development of atomic weapons in the pursuit of an independent nuclear deterrent remained the dominant consideration. In an era accustomed to regard the virtues of nuclear power and weaponry with extreme skepticism it requires a leap in historical retrospect to appreciate the status and prestige accorded to the new technology in its early phases. For politicians, the nuclear deterrent guaranteed Britain's status as a first class power, capable of exercising "the diplomatic leverage necessary to play the role of peacemaker between the two super-powers – a role which both Conservative and Labour leaders considered Britain peculiarly qualified to fill" [Wallace, 1970, p. 211]. The rhetoric of world status was articulated most impressively by Harold Macmillan, but as the godfather of the "age of affluence" he would no doubt have conceded that the general public was just as impressed by the prospect of unlimited supplies of cheap energy

held out by nuclear technology. These further examples of technological chauvinism detract from the Wiener and Barnett theses. They also lend little support to that section of the declininst tradition which lays stress on the technical backwardness of British industry, and the ignorance of advanced engineering principles on the part of senior managers and executives. However, as the following section will reveal, a plausible case can be advanced for the argument that the sustained British commitment to high technology in general and to the aircraft industry in particular, made its own independent contribution to relative industrial decline: in a context of mounting global competition, the pursuit of technological excellence could be no guarantee of commercial success, even when the relevant firms enjoyed the closest relationship with the state.

High Technology and Britain's Industrial Decline

In the three decades after 1945, the British aircraft industry was the third largest producer in the world after the United States and the Soviet Union. It has already been noted that by contemporary British standards the industry was highly concentrated. Although the existence of separate design teams within the same firm served to dilute the concentration ratio in the 1940s and 1950s, it might be thought that subsequent mergers and acquisitions helped resolve the duplication of effort. However, the formation of Hawker Siddeley Aviation in 1958 and of BAC in 1960 did not lead to a fundamental rationalization of the productive structure. In terms of airframe groups Hawker Siddeley employed 50,580 workers in 1965 compared with 36,920 in BAC, but employment in the latter was concentrated in ten centers compared with Hawker Siddeley's nineteen. None of the 29 factories employed more than 10,000 workers and only seven had more than 5,000 workers. Of the engine makers Rolls Royce was the largest, employing 36,053 workers in nine factories, 18,000 of them at Derby. Employment in the second largest firm, Bristol Siddeley Engines, was far more concentrated with 31,021 workers in only four main plants [Plowden, 1971]. When compared with its U.S. competitors the relatively small scale of the post-rationalization British industry is apparent. In the early 1960s, for example, Boeing employed 129,000 workers, North American 92,000, and Lockheed 90,000, in far fewer plants than their British counterparts. The larger scale of the American industry was a direct result of a much larger domestic market for aircraft, both civil and military. Thus, in the period 1955-61, when the U.S. home market accounted for 75% of world military and space purchases and 50% of civil purchases, military production runs averaged 530 aircraft and their civilian counterparts 320 aircraft. The comparable figures for the British industry, with approximately 10% of world demand, were 177 and 68 respectively [Plowden, 1971; Gardner, 1981, p. 16]. The influential Elstub report, published in 1969, in analyzing the 3:1 productivity gap (measured in terms of value added per man year) between the British and American industries, concluded that the greater efficiency of the latter was not so much the product of the greater capital intensity of U.S.

production, but of differences in the scale of production [Elstub, 1969]. In Britain, short production runs meant fewer units over which to amortize the fixed costs of new aircraft, and the "learning curve" was correspondingly shorter. At the same time, the U.S. industry benefited from an organizational structure whereby the large prime contractors could take advantage of scale economies in the production of sub-assemblies by specialist suppliers. A smaller scale of production also meant that the British industry experienced more frequent productivity declines as the workforce contemplated the more frequent prospect of unemployment. The route to high productivity lay clearly in an enhanced scale of production which would have allowed the UK industry to capitalize on its labor cost advantage. In this respect, the tailoring of aircraft designs to specifically British needs was a further barrier to long production runs. This practice was rife in the 1950s and it cast a long shadow forwards. In the 1960s, for example, in marked contrast to the American industry, British firms failed to develop "families" of airliners as a means of extending the learning curve [Freeman, 1978, p.68]. In assessing the comparative efficiency of the British aircraft industry the fact that it may have been inferior to its European counterparts is less important than the productivity gap vis à vis American producers. The latter, after all, were Britain's principal market rivals throughout the postwar period and one of the keys to commercial success was to gain access to the dynamic economies of scale enjoyed by such firms as Boeing and Lockheed. One obvious means of achieving enhanced productivity was via international collaboration, a strategy endorsed in the report of the Plowden "Committee of Inquiry into the Aircraft Industry," published in 1971 [Plowden, 1971]. However, as the examples of Concorde and the RB-211 engine reveal, cross-border collaboration could prove financially disastrous. British attempts to withdraw from the former in the face of escalating costs were frustrated by legal and political complications, while Rolls Royce's breakthrough into the American market via its contract with Lockheed was seriously threatened by technical delays and financial penalties.

As is well known, Rolls Royce was rescued from bankruptcy by government action when the company was nationalized in 1971, a move which was ostensibly at variance with an industrial policy stance geared to "disengagement" and the abandonment of "lame duck" firms and industries. In retrospect, there was little chance of Rolls Royce being permitted to succumb to market forces. As the epitome of British engineering prestige and excellence it fulfilled a vital strategic role in British defense planning, quite apart from its contribution to the balance of payments and to regional employment. The crisis in the company's affairs and the manner of its resolution provided a spectacular manifestation of the mutually dependent relationship between the aircraft industry and the state [Young and Lowe, 1974, pp. 148-55]. From the standpoint of business efficiency there are good grounds for arguing that the relationship was a destructive one. In the first instance, the growth of an armaments industry from the late nineteenth century onwards "enabled some of the most important companies of the period to grow and innovate within the confines of the established institutional structure" [Kaldor, 1980, p. 115]. In

referring to the growing reliance before 1914 of firms such as Vickers, Armstrongs, and Beardmores on government contracts, Mary Kaldor has concluded, with justification, that defense orders reduced the incentive to innovate for the commercial market:

> It was thus not simply a matter of postponing the kind of restructuring necessary for the survival of the old industries. It was also a matter of not entering the new ones. Armstrongs, for example, had a plan in 1906, two years before the Model T, to mass-produce 6000 cars. The proposal was rejected by the directors on the grounds that the profit would be less than on a single river gunboat [Kaldor, 1980, p. 117].

Before 1914 the adverse effects of defense expenditure on Britain's industrial structure were well hidden by the general buoyancy of staple industry markets in general at home and abroad. This was also a period when technical "spin-off" from the military to civilian sectors was of positive benefit to overall economic progress. As Trebilcock has demonstrated, the introduction of new alloys by warship builders fed quickly into civilian use. Navies, moreover, were world pioneers in turbine and diesel engine development and it should not be forgotten that process innovations directed towards standardization were introduced first for the manufacture of small arms [Trebilcock, 1973]. In the period after 1945, however, it is arguable that military and civil technologies have followed increasingly divergent paths as the former has become ever more complex and exotic. Indeed, there is good evidence to suggest that where military spin-off did occur it had an adverse effect on industrial performance [Porter, 1990, p. 273]. The aircraft industry provides an excellent case study of "negative" spin-off insofar as the dependent relationship between the military and civil sectors produced a misallocation of resources. As Malcolm Chalmers has observed, "production and export of civilian aircraft and parts depends to some extent on knowledge and skills acquired in military production and vice versa" [Chalmers, 1985, p. 120]. The effect of this relationship in practice was to encourage governments to subsidize, at considerable cost, the civil aerospace industry. The cases of Rolls Royce and Concorde, already cited, underline this fact. A report to the Department of Industry in 1976 on *The Economics of Industrial Subsidies* calculated that since 1946 the state had invested £1,500 million (at 1974 prices) in civil aerospace for a return of less than £150 million, hardly surprising in view of the competitive advantage enjoyed by American producers catering for the needs of domestic and world markets. Judged by commercial criteria, and discounting lost interest, sales of only one British civil airliner resulted in a profit in the twenty years after 1945: the aircraft in question (the Vickers Viscount) was unusual in that it was one of the few British products possessing an international market appeal [Department of Industry, 1976; Gardner, N.K., 1976]. As for Concorde, the economist P.D. Henderson calculated that by 1976 the cost to the British taxpayer at 1975 prices amounted to £1,320 million. Allowing for interest and other development costs in the final stages of the project, the final cost was £2,320 million, a

colossal sum exceeding even the £2,100 million net loss arising from the AGR program in civil nuclear power. For Henderson, the relevant outlays were indicative of a kind of "bipartisan technological chauvinism," the product of a naive cross-party belief in Britain's "manifest industrial destiny" [Henderson, 1977].

A further objection to the allegedly beneficial effects of military spin-off arises from the growing complexity of military technology which has placed "an emphasis on custom-built, highly sophisticated, low volume production in direct contrast to the emphasis on high volume inexpensive products for civilian markets" [Chalmers, 1985, p. 121]. Naval shipbuilding may have generated positive spin-off before 1914, but as the Geddes report on the modern industry concluded,

> The community of interest between naval and civil ship research workers can be exaggerated. Naval research is to a large extent concerned with obtaining extreme performance from ships at a cost per ton greatly in excess of that practicable for a merchant ship. The problems involved in this are different from those involved in research aimed at reduction of sea transport costs [Geddes, 1966, p. 129].

In the field of electronics an early British lead in novel technologies, such as computer-aided design and microprocessors as a result of military-funded research, failed to be translated into more general applications. This was in marked contrast to the Japanese electronics industry which concentrated on civilian markets by adapting American militarily-derived innovations during the 1970s and 1980s. The British industry built up cells of highly specialized and sophisticated expertise, working at the technological frontier with little or no relevance to international competitive advantage [Sciberas, 1980, p. 289]. This non-commercial orientation was compounded by the structure of the defense market in Britain, characterized by "bilateral monopoly, or of a monopsonist faced by a tight oligopoly." Thus,

> Determining what is spent, where...[is] substantially a political process – how much the government is prepared to spend on defence in the light of other priorities, how spending is divided between the Services and between each of Britain's military roles. And like good oligopolists, those seeking contracts try to avoid price competition and concentrate instead on all kinds of non-price factors, of which the most important is to vary and "improve" the product in line with the perceived interests of the various military constituencies [Kaldor, Sharp and Walker, 1986, pp. 42-3].

The consequences of this institutional rivalry was a marked tendency towards technological embellishment leading, in Mary Kaldor's words, to a "Baroque arsenal" of weapons proliferation [Kaldor, 1982]. This in turn underwrote ever shorter production runs, a trend which, contrary to

expectation, was intensified by international collaboration as different countries insisted on "maintaining broad national capabilities rather than agreeing on a true division of labour" [Kaldor, Sharp, and Walker, 1986, p. 44].

It would be surprising if the peculiar characteristics of the defense procurement process did not have an effect on managerial performance in encouraging risk averseness on the part of contractors. Indeed, an influential study of the application of military technology to civil use found that firms with a heavy dependence on defense contracts were less innovative and more risk averse than their civilian counterparts [Maddock, 1983]. The attractions of defense contracts are exemplified in the case of Ferranti, at one time a leading innovator in the civilian computer industry. However, as Geoffrey Tweedale has pointed out, the company was subject to a conservative managerial ethos on the part of the owning family. Thus, "as the computer industry began to take off, the Ferrantis placed their money where it was safest – in small defense computing systems or in control systems computers that were spin-offs from military contracts" [Tweedale, 1992, p. 118]. This gave the company a profitable market niche, but as Tweedale concludes, this was consistent with Ferranti's demise as a production and market leader in the world computer industry. It is, perhaps, no coincidence that as global competition intensified from the mid-1970s onwards, Britain's manufacturing sector became increasingly dependent on military procurement with a notable surge forward across the economic recession of the early 1980s.

Table 2: *The Increasing Dependence of UK Manufacturing Industry on Defense Sales* 1974-84 (£m)*

	(A) Manufacturing GDP	(B) Engineering GDP	(C) Defense Production**	% C/A	C/B
1974	22,772	8,328	1,440	6.3	17.3
1975	27,537	10,124	1,940	-.0	19.2
1976	31,617	11,635	2,291	-.2	19.7
1977	38,003	14,167	2,854	-.5	20.1
1978	43,580	16,519	3,287	-.5	19.9
1979	48,646	18,200	3,928	8.1	21.6
1980	53,027	20,188	5,275	9.9	26.1
1981	53,942	20,711	6,114	11.3	29.5
1982	58,331	22,413	-002	12.0	31.2
1983	62,514	23,391	-651	12.2	32.7
1984	68,375	N.A.	3,410	12.3	N.A.

Source: Kaldor, Sharp and Walker, 1986, Table 2, p.33

*Note: These figures do not strictly compare like with like since GDP is a measure of value added and equipment procurement is a measure of final consumption What is important is the trend.

**Defense production = Defense equipment procurement plus identified defense exports less identified defense imports.

The consequences of the statistical trends indicated in Table 2 were that during the period 1974/5 to 1984/5 military expenditure as a proportion of GDP rose from 5.1% to 6.1% and as a proportion of public expenditure from 10.4% to 13.1%. By the mid-1980s British defense expenditure was running at the levels of the early 1960s before the Wilson government's "East of Suez" withdrawal and curtailment of defense projects.

There is a final issue of significance in the relationship between military spending and industrial decline. This concerns the allocation of resources, both human and capital, between the civil and defense sectors. Two aspects of this relationship are worthy of consideration: first, the distribution of R&D expenditures, and second, the deployment of highly trained personnel. In relation to the former there were two distinctive aspects of the pattern of R&D expenditures in the UK after 1950. The first was the high concentration in the aerospace sector, especially in comparison with West Germany and Japan. This was complemented by the great preponderance of government-sponsored expenditures which were directed to a few areas of high technology dominated by defense equipment [Freeman, 1978, p. 66; Channon, 1973, p. 231]. In 1955 total R&D expenditure in the UK amounted to £187 million, the highest figure for any country in Western Europe, yet 63 per cent of the total was spent on military projects with less than one-third funded by private industry. More to the point, *nearly two-thirds of private industry research was related directly to defense contracts* [Saul, 1979, p. 125; Layton, 1969, p. 53; Keegan, 1972, pp. 137-48]. Thereafter, there was some reduction in defense-related R&D in the light of numerous project failures and a trend after 1960 to purchase American equipment. However, as Table 3 demonstrates, from the early 1970s the proportion of total R&D spent on defense projects began to rise, with the result that by 1983 the UK was spending proportionately more on military R&D and less on civil R&D than any of her main industrial competitors, including the United States.

Table 3: *Gross Expenditures on Research and Development (GERD) as a Percentage of GDP and the Proportion Devoted to Defense*

	1964		1972		1978		1983	
	A	B	A	B	A	B	A	B
UK	2.32	33.2	2.13	26.2	2.20	28.2	2.26	29.2
U.S.	3.14	35.4	2.58	29.4	2.37	25.3	2.70	28.1
France	1.84	23.4	1.86	20.7	1.77	19.8	2.14	21.5
West Germany	1.41	11.3	2.20	5.4	2.24	5.8	2.58	4.3
Japan	1.47	0.5	1.83	0.5	1.93	0.4	2.47	0.3

A = GERD/GDP

B = Defense R&D/GERD

Source: Kaldor, Sharp and Walker, 1986, Table 4, p. 36.

Even more revealing is the fact that the principal beneficiary of this rising trend was private industry, which raised its share of defense-related R&D allocations from 54% to 65% between 1975 and 1984. The sectoral breakdown of R&D expenditures in the engineering sector in 1983/4, as indicated in

Table 4, reveals that aerospace was the most heavily dependent on the public purse, with 85% of government funding being awarded to military projects. In electronics, 45% of R&D was government financed, primarily by the Ministry of Defence, accounting for £472 million out of a total R&D expenditure of £633 million.

Table 4: *R&D Spending in UK Engineering Industries, 1983/4*

	Total Industry R&D	MOD Funds**	Other Government Funds
Mechanical Engineering	249.6	221.0	34.8
Electrical and Electronic Engineering	1641.0	472.0	79.5
Radio and Electronic capital goods	(633.3)	n.a.	n.a.
Electronic Components	(127.3)	n.a	n.a
Motor Vehicles	239.5	28.0	10.5
Shipbuilding	8.4	51.0	1.8
Aerospace	720.0	628.0	107.5
	2858.5	1400	234.1

* Industrial R & D funded from all sources

** These figures include the cost of intramural as well as extramural MoD research commitments and are not therefore to be set against the industrial R & D expenditures.

Source: Kaldor, Sharp and Walker, 1986, Table 6, p.38

In view of the British commitment to defense R&D, it is entirely feasible to write a postwar history of the principal beneficiary – the aircraft industry – in terms of proliferating R&D programs. Although the UK achieved some outstanding technological successes in civil and military aviation, especially in the light of the immense competitive strength of the leading American producers, the counterpart of this effort was the relatively low proportion of R&D expenditures geared to the needs of civilian industry in machinery, vehicles, and chemicals, precisely the sectors of manufacturing industry experiencing the most rapid market growth, and in which West Germany and Japan were to have their earliest and most important successes [Saul, 1979]. Despite impressive British performances in areas such as radar and aeroengines, the overall returns were low, and to make matters worse such high prestige activities made serious inroads into the supply of scarce scientific and engineering manpower. In 1968 the Brookings Institution study of *Britain's Economic Prospects* pointed to the chronic shortage of such personnel in conventional manufacturing in view of Britain's long standing underinvestment in scientific and technical education. In this respect the skill-intensive nature of the British R&D effort imposed a high opportunity cost on the economy as a whole [Peck, 1968, pp. 448-84]. Throughout the postwar period the West German and Japanese economies, in avoiding military and high technology projects, consistently employed "more and better engineers and technicians working in industries such as machinery, shipbuilding, and steel and metal products than the UK." In Britain, as Christopher Freeman has pointed out,

> the more exotic technologies and research-intensive organisations attracted the cream of the industrial scientific and engineering talent in the 1950s. Government laboratories in similar fields, such as Farnborough (aircraft), Malvern (radar) and the Atomic Energy Authority, also took a large share of the brightest engineers, scientists and technicians [Freeman, 1978, p. 68].

The harmful effects on Britain's international competitive advantage of human "crowding out" at the behest of high technology was recognized as early as the 1960s, by which time the aircraft industry was employing 16% of all qualified UK scientists and engineers. Writing in 1964, Carter and Williams commented that "It is easy to *impede* growth by excessive research, by having too high a percentage of scientific manpower engaged in adding to the stock of knowledge and too small a percentage in using it" [Carter and Williams, 1964, p. 194]. Similar sentiments were expressed in 1968 by the Central Advisory Council for Science and Technology which concluded that the employment of one third of all qualified scientists and engineers in R&D was consistent with excessive research intensiveness to the detriment of physical production for the commercial market place [Central Advisory Council, 1968, p. 9]. The general conclusion of these studies, therefore, was that British industrial performance was being adversely affected not just by defense-related R&D but by the *total* R&D effort, embracing civil as well as defense commitments. This point has been emphasized by Edgerton himself in drawing attention to the fact that analysts of comparative R&D spending in the 1960s were already concluding that there appeared to be little or no correlation between high levels of R&D expenditure and rates of economic growth. To the extent that the British economy was losing ground in absolute terms to West Germany, Japan, and France in the 1960s, it was doing so to countries "which had previously done less industrially funded research, as well as less state funded civil R&D and less defence R&D" [Edgerton, 1993, p. 15; Edgerton 1996a, pp. 48-66]. In the present context, the depressing implication of this conclusion is that in relation to the total R&D effort, Britain got the worst of both worlds in the 1950s and 1960s. It was not simply a matter of the military defense sector crowding out civil R&D, the latter was itself failing to sustain competitive advantage thereby underlining the fact that rates of economic growth are determined by a multiplicity of factors beyond the intensity of R&D.

Conclusion

The relative disadvantages of the distinctive British pattern of R&D expenditures have played a critical role in limiting the competitive advantage of the manufacturing sector in the four decades after 1950. In the specifically military sphere this fact has been recognized at frequent intervals beginning in the mid-1950s. Yet the impression remains that despite open acknowledgement of the consequences of such expenditure, both at the micro and macro-economic levels, the will to implement sustained programs of corrective action

has not been present. The most radical response to Britain's R&D predicament came from the Labour government in office from 1964 to 1970. In preaching the virtues of "the white heat of the technological revolution" the Prime Minister, Harold Wilson, was not simply hi-jacking the "sonic boom of the scientific revolution" for the political advantage of the Labour Party. For Wilson, the latter had been a serious drain on the public purse and had brought no countervailing advantages to Britain either politically or economically. Future government-industry relations should be directed towards the promotion of high growth manufacturing sectors catering for civilian markets both at home and abroad. It is in this context that the reorganization of the machinery of industrial policy and defense procurement should be judged. The formation of the Ministry of Technology, the Industrial Reorganisation Corporation, and the Department of Economic Affairs were essential ingredients of the new approach. In terms of Britain's global position, the Wilson government not only sustained the commitment for entry to the EEC, it also undertook a major review of defense expenditure, including R&D, leading to program cancellations and withdrawal of forces from "East of Suez" [Edgerton, 1998a, pp. 604-6]. Yet despite the attempt to secure a closer alignment between defense commitments and the resources available to sustain them, all that was achieved was a reduction in the rate of growth of defense expenditure. Indeed, by 1972-3 defense spending was as high in real terms as in 1964-5. It is true that defense R&D expenditure was reduced substantially from £1.72 million in 1965 to £1.32 million in 1970, but by the mid-1970s it had been raised dramatically so that in real terms it was higher than in the early 1960s. Ironically, the driving factors were the Chevaline and MRCA (Tornado) projects, both of them inaugurated by the Wilson government [Edgerton, 1996b].

At the outset of his premiership Wilson, in responding to China's first nuclear test explosion, had sought to reassure an anxious Indian government with the remarkable statement that Britain's frontiers lay "on the Himalayas and in the standard of living of the people of India" [Bartlett, 1977, p. 233]. In 1966, in contemplating defense cuts, Denis Healey as Minister of Defence, attempted to appease his critics with the comment that

> We have no intention of ratting on any of our commitments. We intend to remain and shall remain fully capable of carrying out all the commitments we have at the present time,... We do intend to remain in a military sense a world power [*The Times*, 1966].

In retrospect, it is clear that the first Wilson government came to office with a determination to rejuvenate industrial performance by limiting the damaging effects on the microeconomic base of military expenditures in general and military R&D in particular. In reality, however, the main thrust of its policies in this respect was to attempt to sustain the country's status as an Atlantic and world power at minimum cost. Despite Wilson's evident desire to raise the status of civil science and technology, his "white heat" rhetoric failed to be translated into effective action. To that extent, the later 1960s represented a lost opportunity to begin the process of restructuring British industry in favor

of international competitive advantage. It is all very well, however, for historians to indulge in retrospective wisdom. Economic actors and decision makers do not operate in a political vacuum: what might appear desirable in economic terms may prove impossible to achieve in the light of countervailing circumstances. In a fundamental sense, the Wilson government embodied the inherently contradictory attitudes of the British towards economic growth and industrial modernization. Both were desired, but not at the expense of surrendering the legacy of the past. In the final analysis it was the political culture of the British state which helped to underwrite economic decline by sponsoring R&D intensive defense and high technology ventures with little relevance to the commercial marketplace. In the process, a military and civil aerospace industrial complex was created in the image of the United States, but lacking the latter's competitive and market strengths.

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