World War to Cold War: Formative Episodes in the Development of the British Aircraft Industry, 1943-1965

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Abstract

This thesis studies the evolution of the aircraft industry as it emerged from the Second World War and its relationship with the State, running through to the re-evaluation of this State-industry relationship from the late 1950s and into the 1960s.

It takes, for this purpose, major formative events which, it is argued, had a defining influence on the shape of industry and its relationship with government, beginning with the reconstruction plans for the huge war-time industry, formulated within the Ministry of Aircraft Production with a powerful input from Sir Stafford Cripps.

Thus considerable attention is given to the development of the Whittle jet engine and its effect on British aviation. A new assessment stresses the importance of the jet to hopes in Britain for the capability of the industry, but also discusses and uncovers the reasons for the strains in the war-time relationship between Whittle and the MAP which nearly proved fatal to the project.

The role of the government research at the Royal Aircraft Establishment, Farnborough, which was crucial to the industry during the competitive contest of Cold War aeronautical development, is also examined. Detailed case studies of the progress of civil and military engine and aircraft programmes are used in this period to examine the nature of the government/industry relationship and its changing pattern over time.

This study takes the position that the progress of the British aircraft industry in the post-war period must be explained not only in terms of evolving national defence objectives and technological developments, but also in terms of day-to-day institutionalised government policy and episodic major political shifts. This analysis therefore represents the intersection of a history of technology with a socio-cultural and political account.

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Chapter 1: Introduction

This study considers a major area of post-war industrial policy and industrial activity in Britain - the planned conversion of the vastly expanded wartime aircraft industry for the post-war era and its administration for two decades after the war.

National policy towards the aircraft sector in this period represented an attempt to create a major structural shift in British industry and to capitalise on what was perceived as the type of manufacture that Britain should increasingly move towards - a modern industry with a high conversion ratio, relying on the competitive advantage of a workforce which encompassed both advanced technological abilities and sophisticated production skills.

The aircraft industry had been augmented enormously before and during the war, growing from about 35,000 production workers in 1935 to ten times that by 1939 and rising to 1.7m at the peak in 1943. Accompanying this rise was a huge increase in plant and investment in production equipment, almost entirely provided at public expense. This whole production ensemble was knitted together by the Ministry of Aircraft Production (MAP) into a hybrid industry/state organisation with a specifically British complexion. Whereas, during the Second World War, the USA might be said to have operated a national aircraft purchasing programme, Britain operated a national aircraft production programme which achieved an extraordinarily close integration of government and industry. In essence, its task was to maximise the flow of aircraft production in the light of the over-riding constraints of labour force and assembly plant.

Howlett has argued that, for a centrally planned economy to sustain a war effort for six years, people must be found "with an ability to evolve and run an organizational structure capable of coordinating the thousands (possibly millions)

of interdependent decisions".[1] Thus during the war the MAP became quite unlike a peacetime ministry and recruited businessmen, managers and economists. Under conditions in which the market was suspended and the government was the sole purchaser for the output of the industry, it became evident that good control and performance could only be achieved by accurate statistical information on production and utilisation, combined with close monitoring on the ground at the firms. Nevertheless, the administration of these complex programmes was an art that improved throughout the period.[2]

The success achieved in the MAP production programmes had a powerful effect on perceptions of the utility of such a highly centralised planning organisation for the post-war direction of industry. Edgerton has discussed Sir Stafford Cripps' role, as the final and longest-serving Minister for Aircraft Production, in arguing for the continuance of the 'expert' departments - the wartime supply ministries - as agents of civil industrial policy in the post-war period. In the reconstruction discussions Cripps made the explicit argument that appropriate tools were now at hand for the post-war economic management of industry:

> The Government has acquired, through the Departments ... the knowledge, the contact and the influence to secure the very varying degrees of assistance, of guidance, and of reorganisation which the industries ... will be found to need.[3]

Subsequently, in public speeches, Cripps held out the prospect of a "progressive

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1
W P Howlett, *The Competition between the Supply Departments and the Allocation of Scarce Resources in the Second World War*, PhD thesis, Cambridge July 1998, p.169.

2
Sir Alec Cairncross, in *Planning in Wartime*, (Macmillan, London, 1991), and also in 'How British Aircraft Production was Planned in the Second World War', *Twentieth Century British History*, Vol. 2, No. 3, 1991, pp. 344-359 has drawn attention to the importance of judgement in this process.

3
CAB 87/7, Cabinet Reconstruction Committee Minutes, 8 March 1944, R(44)42, quoted in D E H Edgerton, *State Intervention in British Manufacturing Industry, 1931-1951: A Comparative Study for the Military Aircraft and Cotton Textile Industries*, PhD thesis, Imperial College, London, 1986, pp. 193, 211-219.

active government which will be prepared to carry through a programme after the war ... to make certain that we are on the right road to progress" and that "never in the history of the world has an unplanned and uncontrolled private economy succeeded in getting rid of unemployment. ... The [industrial] production of the country must be considered as a great public service".[4]

With regard to the aircraft industry itself, from 1943 the view began to be advanced, again particularly by Stafford Cripps that this national investment in an enormously expanded industry should be husbanded as a national asset for postwar reconstruction, with "the minimum retrogression" from the engineering capacity that had been brought into being.

Following the election of the Labour government in 1945 MAP was amalgamated with the existing wartime Ministry of Supply to form a new and more powerful post-war Ministry of Supply (and aircraft production) with responsibility for the development and production of both military and civil aircraft. This arrangement reflected the arguments put forward by Stafford Cripps during the closing years of the war. However, it would be wrong to attribute a desire for the continuance of central planning solely to Labour party thought. Many Conservatives, too, were impressed by the collaborative working patterns of the war. For example Reginald Maudling, while working in the Secretary of State's Private Office at the Air Ministry during the war, came to believe that it would be a mistake to return to the pre-war relationship in which "bureaucrats and businessmen had always been very much at arm's length" and became convinced that government and industry would have to cooperate much more closely in the post-war world, using the contacts established in the war for "a combined effort to increase Britain's prosperity".[5]

4
Constituency address at Bristol, 1945, and while electioneering at Widnes, 6 May 1945, quoted in Eric Estorick, *Sir Richard Stafford Cripps*, (William Heinemann: London, 1949), pp 324-327. At the Labour Party Conference in 1945 Cripps also referred to "a national plan for our industries" in the light of the achievement of MAP in which "we have had fifteen thousand firms to control and plan".

5
Reginald Maudling, *Memoirs*, (London, 1978). pp 35-36. Maudling served as Minister of Supply, Chancellor of the Exchequer and as Home Secretary in post-war Conservative

Britain's post-war inheritance in aviation therefore comprised both a hugely enlarged and now more technologically adept aircraft industry than in the inter-war period, but also a model of a mechanism for its administration, inherited from the MAP. Associated with this was an 'implicit' or institutionalised departmental policy which reflected the experience of civil servants in the wartime direction of programmes, but which also had expanded to include the aims and ambitions of the reconstruction agenda. What therefore passed over into the post-war world, was not only the now more enlarged and more capable aircraft companies, but a relationship with an overseeing 'expert ministry'. The history of the post-war industry is therefore, to a considerable extent, the history of this relationship, intertwined inextricably with technical developments and technical possibilities emerging from the government research establishments (and particularly RAE, Farnborough), as well as from the firms themselves.

The Structure of the Study

These events launched, in effect, an experiment in administration and industrial policy that lasted for at least two decades after the war. The intention of this thesis is primarily to study the progress of this relationship, although it also considers other MAP/MoS initiatives and institutions which are strongly linked to the progress of Britain's aeronautical ambitions in the post-war period. A major question addressed by this study concerns whether the model of the wartime supply ministry with its close control of projects and output translated to the post-war world. Did the Ministry of Supply succeed in emulating the planning achievements of the wartime MAP in its direction of the post-war industry and in performing the economic role anticipated for it?[6]

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governments.

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These remarks should not be taken to imply an uncritical eulogy for the MAP's direction of production throughout the war. Under Beaverbrook, as Minister in 1940, and subsequently under his successors J T C Moore-Brabazon and then Colonel J J Llewellyn, the MAP tended to rely on the exhortatory effect of unrealistic production targets, with Llewellyn issuing, for example, a "Clarion Call" for more bombers in September 1942. There was also a temptation to use secrecy and competition vis-a-vis other departments in an attempt to maximise allocations of labour and materials. However, from late 1941; the development of a department of

The thesis sets out to examine the progress of the ambitions outlined above through case studies of specific 'formative episodes' in the evolution of the aircraft manufacturing industry and its relationship with government. It takes as its period 1943 to 1965, since 1943 marks, within MAP, the beginning of discussions on reconstruction, the peacetime shape of the aircraft industry, and the post-war pattern of administration. It will be argued that the ambitions and intentions set out in this late war period actually endured in the day-to-day implicit policies of the MoS and its successors, and also at senior levels of government, for two decades after the war. It is suggested that 1965 represents the date of a more overt perception (which actually had been growing since the late 1950s), that their were problematic elements in British aircraft sector, particularly with regard to costs, the time for projects to come to fruition and the ability of the industry to compete in world markets. It was also beginning to be understood that these were, at least in part, a consequence of the pattern of administration. The year 1965 therefore represents a transition or 'fault line' in the continuance of this policy which was set on track at the end of the war. This was marked, most visibly, by the cancellation of the TSR 2 strike bomber and by the publication of the Plowden report on the aircraft industry.

Much of the large volume of literature on aviation concerns companies and individuals - engineers, designers and pilots. However, for the post-war period, rather few writers, with the exception of David Edgerton, have engaged with aviation as essentially a government-directed and financed activity.[7] Thus

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programmes and statistics under John Jewkes led increasingly to informed and realistic production planning and coordination. See Cairncross, 'Planning in Wartime', (n. 6, above), pp. 9-43. However, problems still remained with the direction of advanced high technology programmes which will be discussed in chapter three in connection with the Whittle jet.

7
The general run of 'industry histories' engage little with political and administrative questions except to excoriate public civil servants for interference in the industry. Charles Gardner's *British Aircraft Corporation; a history*, (London, 1981) is characteristic of this genre. Thus the work (pp. 106, 121) describes Solly Zuckerman, as Chief Scientific Adviser to the Ministry of Defence, as "a South African Professor of Zoology" without referring to his wartime work on strategic bombing, and criticises the aeronautical experience of the members of the Plowden Committee without acknowledging Plowden's wartime post as Chief Executive in the Ministry of Aircraft Production. See also Derek Wood, *Project Cancelled*, (London, 1975) p. vii, which characterises the government direction of the industry as "an incredible mixture of wrong decisions ... and continuous vacillation".

Edgerton has made an important contribution by pointing out the under-recognised role of the Ministry of Supply in the historiography of post-war Britain. He argues that the supply ministries "played the most active and innovative role" during the war and bequeathed "expertise in central direction of industrial resources to post-war Britain". Moreover, he points out that the MoS did aspire to 'pick winners' and, with the Japanese Ministry of International Trade and Industry (MITI) in mind, suggests that the MoS

> was the scientific technological and industrial powerhouse of the British state, and pursued the discriminatory, interventionist and technological policies which many critics have said British governments have not, but should have, pursued. [8]

Edgerton is concerned to counter 'declinism' in British historiography and points out, for example, the huge sums disbursed by the MoS for defence production and its R&D programme, which he assesses as the largest ever funded in Britain, (at £110m in 1951).[9] However, he does not (perhaps wisely) seek to evaluate the success of the MoS in its assigned role. By contrast, this study does attempt an evaluation and suggests that the "expertise in central direction of industrial resources" learned through war production was illusory in the changed conditions of peace and following the departure of much of the specially recruited talent that had made MAP programming effective. Moreover, this study suggests, as will be described in more detail below, that the effect of MoS patronage was actually to delay the emergence of an entrepreneurial culture in the British aviation sector. In the post-war era firms such as de Havilland were certainly not averse to operational and technological risks as their experimental and test flight programmes often tragically showed, but very few developments

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David Edgerton, 'Whatever happened to the British warfare state? The Ministry of Supply, 1945-1951', in H.Mercer. N.Rollings and J D Tomlinson (eds.) *Labour Governments and Private Industry, The Experience of 1945-1951*, (Edinburgh, 1992), pp. 110- 111.

9
David Edgerton, 'Whatever happened to the British warfare state? The Ministry of Supply, 1945-1951', in H.Mercer. N.Rollings and J D Tomlinson (eds), *Labour Governments and Private Industry, The Experience of 1945-1951*, (Edinburgh, 1992). pp. 102-105.

in the period, civil or military, could proceed unless the financial risks were fully underwritten by the Ministry of Supply.

Another point on which this study diverges from those of Edgerton concerns political allegiances to the aircraft industry. To Edgerton, the financial appetite of the industry was finally curbed, in the mid-1960s, by Labour politicians like Dennis Healey and Anthony Wedgwood Benn, in the face of "continuing Tory and industry hostility".[10] There may well have been a coincidence of interest between some Tories and those directing the aircraft industry but the interpretation reached in this study is rather different. It argues that the essential late war reconstruction brief for the Ministry of Supply was taken up as 'implicit' or institutionalised departmental policy which continued under both Labour and Conservative administrations until a growing tension became evident. According to this view, what occurred was the working out of an evolutionary historical process. As it happened, the 'fault line' opened up under a Labour administration but this study finds evidence of growing scepticism and 'hard-heartedness' towards the industry in senior Conservative circles which, I suggest, would have led to a similar result under a Tory administration; certainly no subsequent one attempted to return to the more open-handed practices of the period up to 1965.[11]

This study takes the position that the progress of the British aircraft industry in the post-war period must be explained not only in terms of evolving national defence objectives and technological developments, but also in terms of the day-to-day institutionalised departmental policy and also episodic major political shifts. This analysis therefore represents the intersection of a history of technology with a socio-cultural and political account.

10
David Edgerton, 'The "White Heat" Revisited; the British government and technology in the 1960s, *Twentieth Century British History*, No. 1, (1986), p. 11.

11
The forced and unwelcome protective nationalisation of Rolls-Royce, following receivership in 1971, by the Heath government should not be taken as evidence against this. In the long run the completion of the Rolls-Royce RB 211 engine proved an excellent national investment.

The Growth of the Industry

To put the study in context, it is necessary to return again to the subject of the huge wartime enlargement of the British aircraft industry, since that was the essential precondition for the events studied here. To Barnett, this wartime effort was "a mass industry improvised" although Ritchie's more recent study has argued convincingly that the expansion of British aircraft production was carefully planned.[12] To Edgerton, high British aircraft production is unsurprising and results, he argues, from 'liberal militarism' or "a British Way in Warfare which has relied on technology rather than manpower". He also suggests that Britain was probably the largest exporter of aircraft in the world in the inter-war period.[13]

However, Edgerton's commitment to correcting critiques of British technological capability and to the refutation of 'declinism' in the historiography, perhaps leads him to overlook the disparity between developments in British and in America - the nation then emerging as the key comparator in the period.[14] The staples of British military exports were second-rank fighter aircraft - the type mainly used for training at home, such as Armstrong-Siddeley Siskins and Scimitars. The customers were countries such as China, Norway and Portugal - hardly, to use the naval term 'first rate' powers. Also popular were the sound but simple de Havilland small biplane airliners and sports aircraft.

These were all useful products but a numerical assessment of export success ignores the vast difference in technological sophistication between these types

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12
Corelli Barnett, *The Audit of War*, (London, Macmillan, 1986), pp. 125-142 and Sebastian Ritchie, *Industry and Air Power, the Expansion of British Aircraft Production, 1935-41*, (London, 1997).

13
David Edgerton, *England and the Aeroplane*, (Manchester, 1991), and in 'Liberal Militarism and the British State', New Left Review, No 185, Jan-Feb 1991, pp. 138-169.

14
For example, David Edgerton, 'The Prophet Militant and Industrial; the Peculiarities of Corelli Barnett', *Twentieth Century British History*, Vol 2, No. 3, 1991, pp. 360-379.

and those powering the dawning American civil airline revolution.[15] J T C Moore-Brabazon registered the "severe shock" brought by a realisation of "the astonishing efficiency of American civil aviation" in 1935 when "the performance of the Douglas in the race to Melbourne opened our eyes".[16] Until late in the 1930s (with the de Havilland Flamingo) Britain produced no civil aircraft of the 'Douglas DC 3 generation' - the twin-engined, smooth skinned, all-metal machines with retracting undercarriages, flaps, and variable pitch propellers which are now regarded as the ancestors of modern airliners and which sprang from the rapidly evolving milieu of American air transport.

It is certainly not suggested here that Britain was unable to produce technologically advanced aircraft, but that the necessarily smaller size of the industry meant that it could not do this across the board. In fact 1935, the date of Brabazon's "severe shock", was also the year in which the RAF expansion scheme C was launched - a demand which, as Ritchie has shown, was equivalent to the total UK production capacity then existing for civil and military aircraft.[17] This re-armament eliminated the possibility of developing a new generation of competitive British civil types. The effects of this military load continued well into the post-war period and certainly also compromised the

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This discussion is not intended to paint a picture of unrelieved backwardness. Technological capability is, necessarily, a patchwork of different techniques and capacities for practical and theoretical analysis, disseminated over a wide range of firms and institutions. There were, for instance, two first class engine makers, which enabled Britain to produce, when necessity gave the urgent call, first class military aircraft. However it is noteworthy, in the context here, that the superb Rolls-Royce Merlin, the outstanding engine of the war, was a demanding piece of equipment which required a military establishment for its maintenance. Post-war attempts to convert it to a civil application showed it to have poor serviceability compared to American types. (Meeting with Sir David Huddie, 29 Ocober 1997).

16
Papers of Lord Brabazon (J T C Moore-Brabazon) Royal Air Force Museum archives, Hendon, AC 71/3, Box 70. J T C Moore-Brabazon subsequently became Lord Brabazon of Tara, the chairman of the Brabazon committees discussed in chapter two. In the 1934 MacRobertson air race from London to Australia, the specially built winning de Havilland Comet racing aircraft was closely followed by a Douglas DC-2 operated by KLM which had followed the longer regular airline route and carried six passengers and 400 lbs of mail. The progenitors of the modern airliner can be regarded as the stressed-skin American types that entered service between 1932 and 1935; the Boeing 247, Douglas DC 1, DC 2, DC 3, and the Lockheed L10 Electra.

17
Ritchie 'Industry and Air Power' (n. 7 above), pp 41-42.

implementation of the Brabazon committee programme for new British civil types. Thus, in the 1930s, the American aviation industry was undergoing a step-change in the capability of the whole air transport system, while, at the same time, Britain was re-arming and developing a new generation of military types.

Chapter 2

The theoretical basis for the type of post-war planned direction of the aircraft industry, emanating from Stafford Cripps, has been touched on above. This chapter looks in some detail at the development of the policy within MAP for the maintenance of war potential and the gradual realignment of that policy for industrial production and reconstruction. Part of these plans involved ambitious intentions to build new civil airliners which would be competitive with American types. The ensuing chapters follow the progress of these intentions.

Chapter two also studies the conversion of the MAP into a component of the new 'expert' supply ministry, the implementation of conversion plans for the industry and the progress of British ambitions for civil air transport which had developed as the war came to an end.

Chapter 3

The story of the Whittle jet is an important thread in the development of the post-war aircraft industry, affecting the type of aircraft that were built but also contributing to the wider belief in the importance of technology, from a moral and psychological point of view, in post-war Britain. The surprising equanimity with which Britain retreated from a global Imperial role, rested, it is argued here, on this 'defiant modernism' and the assumption of British technological ability. The new 'empire' of high science and a regenerated industry, would sustain the nation and, in this spirit, the jet engine became regarded as one of

the important symbols of new technique.[18]

The wartime progress of the jet is, therefore, studied as an example of the national intention to devise new technologies. The account here takes issue with normal hagiographic accounts of Whittle's engine work and suggests, moreover, that the MAP's administration of the programme was irresolute, particularly after 1940 when difficulties were building up between Whittle's company, Power Jets, MAP and the selected production contractor, the Rover car company.

There has been little independent evaluation of the Whittle programme since that of Schlaiffer in 1950, with the exception of Edward W Constant's notable study. Constant has used his concept of "the turbojet revolution" to support an extension of the Kuhnian analysis of the successions in scientific theories to explain technological change.[19] However, it is argued here that this approach tends to obscure the reasons for the real problems that the programme encountered.

The programme suggests that MAP's greatest success was in large-scale production programmes, albeit administered with adequate flexibility to allow continual improvements to sustain the fighting quality of the aircraft.[20] By contrast the Whittle project was a pure advanced technology project, requiring other enabling scientific and technical steps that had not yet been made, but was

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18
Robert Bud has shown how important, for the same reasons, was the story of penicillin to post-war Britain with the legend of its discovery by Fleming - an almost incidental act - thus assuming primacy, like a creative Archimedean "Eureka" moment, over the therapeutically more essential American perfection of bulk fermentation for its manufacture. Robert Bud, 'Penicillin and the New Elizabethans', British Journal for the History of Science 31(1998): 305-33.

19
Robert Schlaiffer and S D Heron, *The Development of Aircraft Engines and Fuels*, (Harvard School of Business Administration, 1950). Edward W Constant II, 'A Model for Technological Change Applied to the Turbojet Revolution', *Technology and Culture*, 14 (1973): pp 553-572 and Edward W Constant II, *The Origins of the Turbojet Revolution*, (Baltimore, 1980).

20
For example see 'The Doctrine of Quality' in M M Postan, D Hay and J D Scott, *Design and Development of Weapons*, (HMSO, London, 1964), pp. 1-15.

intended, nevertheless, for production 'off the drawing board'. The problems identified in this analysis anticipate later Cold War development programmes when many more projects were initiated which were at or beyond the limits of available technology. The British war-time jet programme had been rescued, in effect, by the multiplication of effort across several other firms including Rolls-Royce and de Havilland and these events go some way towards explaining the wasteful post-war practice of parallel development and procurement and perhaps points to a reason why advanced technology projects were spread across so many firms.

Chapter 4

The reconstruction agenda, set out within the Ministry of Aircraft production from 1943, launched a far more deliberate programme than has generally been appreciated. However, apart from the organisational system, which has been discussed, whereby the MAP served as the model (and the actual administrative core) for the post-war MoS in its relationship with the aircraft industry, there was also substantial infrastructural support put in place towards the end of the war, specifically with the intention of improving the competitive position of the British post-war aircraft industry.

Studies of the establishment of these new institutions are almost entirely absent in the historiography and they are included here because they represent concrete evidence for the seriousness of the MAP reconstruction plans in aeronautics. They included the creation of the new postgraduate Cranfield College of Aeronautics and ambitious plans for a new national aeronautical research centre at Bedford, (referred to by Cripps as being "of vital importance to the county's future"). The development of this latter establishment also relates to the nationalisation of Whittle's Power Jets company by Cripps to form a nucleus for national gas turbine research - a move which has been generally misinterpreted and which is analysed in the previous chapter.

The immediate post-war British programme to utilise German aeronautical

science has also been widely ignored, in spite of its successful ambition to utilize German research hardware on a huge scale, as well as securing German intellectual property in aeronautics and recruiting leading aeronautical engineers and scientists. This exploitation programme relates closely to the Bedford and Cranfield initiatives.

Chapter 5

Britain's aircraft sector, in the 1950s is properly regarded as an ensemble which comprised a highly centralised government research capability, a large (many said excessive) number of aircraft and engine firms and a government procurement agency, the Ministry of Supply, which implemented the requirements of the Air Staff and, in principle, the civil air lines.

This system was placed under enormous pressure, in the post-war era, to produce aircraft and weapons of the highest technical quality as a response to the emergence of the Cold War, to the continuing conviction that Britain should retain 'Great Power' status with a global reach, and in the light of a growing realisation of the offensive threat posed by Soviet nuclear capability. The Royal Aircraft Establishment (RAE) was the main resource for research and advanced projects work in this period and was crucial to these aeronautical developments. It was, moreover, the largest research establishment in Europe.

The activity of the RAE has received attention in internalist histories of British aviation but, again, it has had little attention in the wider historiography.[21] It is studied here partly as a corrective, since so much aeronautical history has been written from the perspective of the firms and their designers, and has ignored

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21
An exception is M J Lighthill in 'The Royal Aircraft Establishment' in Sir John Cockroft (ed), The Organisation of Research Establishments (Cambridge, 1965, pp. 28-54. The present author's chapter 'The Royal Aircraft Establsihment from 1945 to Concorde' in R Bud and P Gummett (eds) *Cold War, Hot Science: applied research in Britain's defence laboratories*, (London 1999) pp 29-58, which draws on the work presented here, is an attempt to put the work of the RAE in a wider context.

the influence, indeed the centrality, of the RAE to much that was done in the post-war period. A knowledge of this influence and of the type of work done at the RAE is essential to an understanding of the capability of the firms and of British aviation in general in this period.

Chapter 6

The sixth chapter looks more deeply into the progress of aircraft and engine projects during the post-war period and follows on from some of the early post-war procurement decisions touched on in chapter two.

Over much of the period aviation policy was carried forward by officials, acting largely in the spirit of the Crippsian reconstruction agenda, and responding to Cold War pressures on defence, so this is an mainly an account of 'practical' departmental policy as administered by officials over the period acting very much in the spirit discussed above where the interventionist, promotional role inherited from wartime and reconstruction had become institutionalised as implicit departmental policy.

The under-recognised importance of the Ministry of Supply in the post-war era has been pointed out by David Edgerton in the work *Labour Governments and Private Industry* which set out for historians the importance of the post-war MoS and its enormous remit. Edgerton called the Ministry the "scientific, technological and industrial powerhouse of the British state" and suggested that it pursued "the discriminatory, interventionist and technological policies which many critics have said the British government have not, but should have, pursued".[22] The work here (particularly taken together with chapter 2) looks at the progress of these interventionist policies and the detail of the actual administration of projects through a number of case studies. Edgerton's study

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22
David Edgerton, 'Whatever happened to the British warfare state? The Ministry of Supply, 1945-1951', in *Labour Governments & Private Industry*, eds H Mercer, N Rollings and J D Tomlinson, (Edinburgh, 1992), p.111.

necessarily finishes in 1951 (the date of the return of the Conservative government to power), but it is the contention in the work here that the same essential orientation of the MoS towards the aircraft industry continued into the 1960s under successive Conservative administrations. This implicit policy only gradually became modified in the light of experience as the perception grew in government departments and among politicians of both major parties both that aviation expenditure was unsupportable and that a new method of procurement and administration was needed.

The perceived centrality of the Ministry in export and explicitly commercial matters is evident in the records; it was a period in which government officials could refer to their role as "backing the aircraft industry in its joint endeavour with us to break into world markets".[23]

These events suggest that the popular view that Britain has never had an 'industry ministry' comparable say, to MITI in Japan is not correct. For several decades after the war the Ministry of Supply, and its successors fulfilled the role of providing broad industrial support and the encouragement of innovation, coupled with the task of procuring aircraft and aeronautical material for the services and the civil airline corporations. The pattern of this work is therefore to study particular episodes which, it is argued, were critical to the development of industry from 1943 and for two decades after the war, and to discuss how the structures and habits of this wartime mechanism for the control and development of the industry functioned in the post-war world.

23
PRO AVIA 65/59, 'Comet Aircraft Production Policy', note by Sir James Helmore, January 1955. (Author's emphasis).

Chapter 2: Aircraft Production and Planning for Post-War Reconstruction

Introduction

The post-war British aircraft industry was the offspring of the war-time industry. National investment in military aircraft production had established a far larger capacity than could have arisen from purely commercial imperatives. The transition of this industry to peace reflected, in part, the perceived need to retain production capacity for defence, but also reflected the desire to utilise this national investment to contribute to Britain's economic recovery, particularly through the development of a significant civil aircraft programme. This chapter studies the progress of these ambitions and some of the difficulties that were met in the late war and early post-war period.

These events are closely bound up with the administrative arrangements for the industry and the establishment of the peacetime Ministry of Supply (MoS) out of the two war-time ministries of Supply and Aircraft Production. Thus these events are, in a sense, an example of government intervention in industry, although it is perhaps more informative to describe the relationship as a government/industry partnership since the greater part of the production capacity of the sector was government-created and since the design work of the firms was fundamentally reliant on the advanced research being done at the (MoS administered) Royal Aircraft Establishment, which became the largest research centre in Europe in the post-war period.

For these reason also, the question of public or private ownership of the aviation firms does not emerge as a burning issue in the period for, in addition to the above factors, the government exercised immense control as the source of finance for almost all the projects undertaken by the industry and, in effect, as the customer for both its civil and military output. However, since the issue of

nationalisation is important in the period this chapter also looks at the question in the light of studies by Howlett and Edgerton on the war-time nationalisation of aircraft concerns.[1] This issue is also touched on in a subsequent chapter on the Whittle jet.

The study shows the centrality of Stafford Cripps to the development of reconstruction plans for the industry and their survival into the post-war period with the incorporation of the Ministry of Aircraft Production (MAP) into the post-war MoS. The research into these events follows on from studies by Edgerton but extends it through research using government records of the development of reconstruction policy in the aircraft sector, supplemented by secondary sources. This study shows that Cripps was personally more involved in the development of these policies than has previously been described. This section, and episodes in subsequent chapters, also show the dilution of this ambitious dirigiste spirit within the MAP/MoS after the departure of Cripps in 1945.[2]

Preparing for Peace

During the Second World War the Ministry of Aircraft Production (MAP) controlled the largest industrial sector in Britain. The MAP had been formed out

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1
David Edgerton, 'Public ownership and the British arms industry, 1920-1950', and Peter Howlett, 'The Thin End of the Wedge?: nationalisation and industrial structure during the Second World War' in Robert Millward and John Singleton (eds.), *The Political Economy of nationalisation in Britain 1920-1950*, (Cambridge, 1995).

2
D E H Edgerton in *State Intervention in British Manufacturing Industry, 1931-1951: A Comparative Study for the Military Aircraft and Cotton Textile Industries*, PhD thesis, Imperial College, London, 1986 pp. 209-219 and subsequently David Edgerton, 'Whatever happened to the British warfare state? The Ministry of Supply, 1945-1951', in H.Mercer. N.Rollings and J D Tomlinson (eds) *Labour Governments and Private Industry, The Experience of 1945-1951*, (Edinburgh, 1992). Curiously, Cripps' biographers do not appear to have understood the importance of his time in the highly centralised and highly planned milieu of the MAP to his political development. Peter Clarke, *The Cripps version; the Life of Sir Stafford Cripps*, 1889-1952, (London 2002), the latest and in many ways the most complete biography, significantly entitles the chapter on this period merely as "Entr'Acte 1943-5" (interlude!). Eric Estorick, *Sir Richard Stafford Cripps*, (William Heinemann: London, 1949), does briefly suggest the importance of Cripps' MAP sojourn.

of the Supply departments of the Air Ministry in 1940 and reflected Churchill's belief, formed as Minister of Munitions in the First World War, that it was "a fundamental principle" that the authority for production must rest in the hands of a separate ministry. In his view, a procurement department located within the Air Ministry, (the inter-war pattern) was vulnerable to the continually changing demands of the Service users which "would have a crippling effect on output".[3] The foundation of MAP also reflected disquiet at the rate of build-up of the British air forces.

The efficiency of British aircraft production has also been challenged but, to summarise recent historiography, the prevailing view is that on the basis of sheer numbers and of the fighting qualities of its aircraft British war production was a considerable success.[4] The approach of the end of the war, therefore, saw Britain with a hugely inflated aircraft sector. Unlike the First World War, where the companies had been left largely to make the best of things, a role was deliberately planned for the post-Second World War era. It was, after all, a planned war.

What was the effect of MAP thinking on the post-war industry? This chapter

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3
Winston Churchill, at meeting of Defence Committee, 7 March 1945, PRO CAB 70/5, quoted by Sir Alec Cairncross, 'How British Aircraft Production was Planned in the Second World War', *Twentieth Century British History*, Vol. 2, No. 3, 1991, pp. 344-359.

4
The view expounded by Corelli Barnett in *The Audit of War*, (London, 1986) that British aircraft production was inefficient, is encapsulated most notably in his assertion that a Spitfire Mk VC required 13,000 man-hours to build, against 4000 for a Messerschmitt 109G, and that Britain produced 1.19 lb of aircraft structure per man-day as opposed to Germany's 2.76 lb. This view has been challenged by David Edgerton in *England and the Aeroplane*, (Manchester 1991): 79-82 and refuted by Peter Howlett in *The Economic History of Britain*, Vol III 1939-1992, (Cambridge, 1994): 10-13. More recently Jonathan Zeitlin in 'Flexibility and Mass Production at War' *Technology and Culture*, January 1995, Vol 36, No. 1, pp. 46-79, has recalled the war-time emphasis on "the doctrine of quality" for RAF equipment described by Postan in M M Postan, D Hay and J D Scott, *Design and Development of Weapons*, (London, HMSO, 1964). Zeitlin finds, particularly in Rolls-Royce performance, an almost ideal relationship between quality and output that anticipated the modern concept of 'flexible manufacturing'. In addition he has argued that UK productivity approached American figures for long runs. Sebastian Ritchie, *Industry and Air Power, the Expansion of British Aircraft Production, 1935-1941*, (Frank Cass, London, 1997) has shown the careful planning that took place from 1935 to put in place the industrial capacity that was required for the British production achievement.

aims to show that it was pattern of administration developed during the MAP's period of great power administering war production, combined with the vision developed by Sir Stafford Cripps for the industry, that was carried forward into the post-war era and which set the character of government-industry relations in aviation for some decades, albeit in a gradually attenuating form. This is, therefore, a study of policy, both in the formal sense of overtly stated policy aims and, in the informal sense of 'micro policy' as represented by the culture and ethos of the MAP and its successor, the Ministry of Supply, and expressed in an assumption of common purpose and aims among the members of the Department. This derived, in large part, from the strategic plans for the future of the industry developed during the tenure of Stafford Cripps as Minister for Aircraft Production, and which was developed in large measure by him.

British thinking about the conversion of the industry began remarkably early in the war, certainly in the summer of 1943 and initially the discussions centred on the problems of the change-over to peace-time employment, if there was to be a two-stage ending to the war.[5]

At the outset the MAP regarded the huge scale of the enterprise that it controlled as the main element of the problem. A paper to the Joint War Production Staff set out the extent of the Ministry's empire. It is also a useful summary of the aircraft production sector in 1943. It noted that:

a) The aircraft industry employed about 35,000 in 1935, about 360,000 at the beginning of the war and nearly 1,700,000 today.

b) Practically the whole of the employment given by MAP is to the Engineering and Allied Industries of which MAP controls

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5
PRO AVIA 15/1915, 'MAP Reconstruction Committee', Memorandum by the Minister without Portfolio, 15 June 1943. Sir William Jowitt (Minister without Portfolio) noted the problems for production that might arise after the collapse of Germany. "After the tide of war had retreated 10,000 miles it would be politically impossible to continue the compulsory retention of unwilling workers. ... The revival of the export trade under these twilight conditions will have its own special problems".

today 40% of the total capacity; six out of every 10 engineering firms have some MAP work.

c) Of the total MAP labour force, 23% is concentrated in the London and South Eastern region, 20% in the Midland region and 18% in the North western region.

d) Nearly a quarter of a million (about one seventh of the whole MAP's employment) are working in shadow factories.

e) As a measure of the importance of sub-contracting, it should be noted that of the direct contractual expenditure of MAP three quarters is with some 50 firms, whereas altogether about 15,000 factories are working to some extent for MAP.[6]

In addition, MAP also claimed that four fifths of the larger general engineering concerns with 1000 or more operatives did some MAP work.

The three initial aims put by the Government for reconstruction which applied clearly to this major industrial sector controlled by the MAP were the maintenance of war potential, full employment, and an increase of exports by 50% over pre-war levels.[7]

Within MAP an internal Reconstruction Committee was formed to plan for peace, which included the economist John Jewkes and Eric Mensforth (then Chief Production Adviser), as well as senior civil servants. The meetings were fixed once monthly from August 1943.[8] A little later Edwin Plowden, then

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6
Ibid. MAP draft policy paper on reconstruction, RC (1943) 2, February 1944.

7
Ibid. The MAP draft paper on reconstruction noted that: "The Chancellor of the Exchequer in the debate on social insurance (Hansard, Vol.386, No.31) gave the government's view that of all priorities "*our contribution to international security would come first*, and that whatever the bill, we should have to pay it. *Second, in order of priority the Chancellor put the need to secure full employment.*". The Treasury paper on the Social Security Plan (RP [43] 5) pointed out that "having lost most of our dollar assets and incurred very heavy sterling liabilities, even with the most careful arrangements, our post-war Exchange position, itself vital for full employment, such be one of great anxiety. *It is therefore necessary to increase the volume of export trade at least fifty per cent over pre-war.*". (Original emphasis).

8
Ibid. Letter from the Permanent Secretary, MAP, 16 June 1943, to Sir W Lindsay Scott, Second Secretary, on the setting up of a special division to deal with reconstruction questions and the setting up of a Departmental Committee. "The committee will consist of yourself,

Director General of Light Metals Production (DGMP) but soon to become Chief Executive of MAP, was asked to join and it is a telling indication of the collaborative spirit of the time that Plowden was recommended to Cripps not just on his experience of the light alloy industry but for his ability, business experience and his "moderate capitalist views".[9]

At this stage in the war, and with the memories of re-armament at emergency pace in the late 1930s still vivid, much thought was given to the "maintenance of war potential". This was problematic. As we have seen from the MAP figures, the scale of the industry required to sustain the air war was vast and it was assumed that some similar scale of effort would be required in a future war. Thus, in the year 1943/1944, MAP expenditure was around £800m and the industry was producing more than 20,000 aircraft a year. Preserving industrial capacity on that scale by mothballing plant was discussed but would be obviously wasteful. Another problem was that it was extremely hard to conceive of alternative ways in which the huge capacity for light alloy production (principally aluminium alloy, and some magnesium) that had been specially built up, and which was essential to the scale of war-time aircraft manufacture, could be usefully absorbed.

The capacity for forging, casting and forming aluminium alloy had been multiplied sixteen times over pre-war levels amounting to a throughput of 365,000 tons a year. Without some method of absorbing this capacity it was felt

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Archie Forbes, Mensforth, Owen, Jewkes and myself".

9
Ibid. "I suggest for your consideration that Mr Plowden, DGMP, should be added to the MAP Reconstruction Committee. The future of the light metal industry is an important part of our work and Mr Plowden is more closely in touch with this than anybody. His ability, business experience and "moderate capitalist" views would also make him valuable over the whole field". Minute of 20 January 1944 to Second Secretary, Lindsay Scott, who annotated "I mentioned this at this morning's meeting with the Minister. Approved, LS". Plowden had, in fact, been involved in the Reconstruction Committee from since August 1943 onwards due to the crucial contribution of light alloy production, when R S Edwards wrote "Dear Plowden, I don't know whether you have heard of the creation of the MAP Reconstruction Committee but such a committee has come into existence, its members being the Personal Secretary, Second Secretary, PAS (L), Mr Mensforth, Professor Jewkes, R Owen, and myself as secretary. At its meeting this coming Friday the Committee will be discussing.....the proposal that the time is ripe to approach the Light Metals Industry with regard to post-war problems....could you possibly arrange to be available for this item?".

that an essential enabling step in aircraft manufacture would wither. Various discussions were held with the industry to discuss civilian uses for aluminium in order to keep plant in existence. The metal was still too expensive, it was believed, to replace steel in car bodies, but, clutching at straws, it was agreed that kitchen foil which had been imported before the war from Germany - an annual consumption of 2000 tons - should be supplied from British sources. Another scheme which, in fact, was realised was the manufacture of a standard pattern of prefabricated aluminium house to help cope with the post-war housing shortage. This housing project shows how all such schemes to preserve war potential carried an unwelcome cost, for by August 1945 the Minister of Supply and Aircraft Production was asking for additional funds to subsidise that proportion of the £1320 unit price which "could not be justified on housing grounds ... to tide these industries over the awkward transition from war to peace" and for the maintenance of war potential.[10] In fact, some £75m was to be expended on aluminium houses over the three financial years from 1946, almost equalling, in the period, the amount spent on aero engines (£81m) and substantially exceeding that spent on the procurement of radar and signals equipment (£35m).[11]

Thus the light alloy industry could find no panacea to sustain capacity although it was pointed out that pre-war weight limits on trucks had been relaxed in order to allow the use of cast iron in gearboxes and axle casings and the restrictions should be re-imposed. Commercial air transport was regarded as the only real opening.[12]

10
PRO AVIA 15/3857, 'Aluminium Houses - Policy Questions'. The Chancellor of the Exchequer demurred. "The suggestion is not one I can accept. Parliament has provided a specific sum for a specific purpose and it would be contrary to all the principles of Parliamentary control to attempt to supplement this sum by votes". There was no identifiable portion of the cost, he argued, "not justified on housing grounds".

11
PRO AVIA 49/93-98, 'Monthly Statistical Reports', quoted in P A Winston, *The British Government and Defence Production, 1943-50*, PhD thesis, Cambridge, 1982.

12
The scale of the transition problem can be visualised from the fact that in 1943 the aluminium stock in the hands of the producers and the Government was assessed at five years normal requirement. There is an intriguing parallel with Italy here where aluminium production had been stimulated both as a contribution to the aircraft industry and as a particular symbol of

The problem of maintenance of war potential for the actual assembly of aircraft and engines continued to loom large into the post-war era, but in MAP during the war a philosophy was developed which appeared reconcile the conflict between this requirement and national economic needs.[13] This was summarised by Sir Lindsay Scott (Second Secretary in MAP) who referred to

> the elaborate industrial planning which Germany had undertaken in readiness for this war. ... In planning for re-expansion we must seriously consider the same technique. With a given peace-time budget we should lean towards creating a state of readiness rather than towards expenditure on production of a large number of aircraft.[14]

It appears that thinking in the MAP came to be influenced by intelligence appreciations of German re-armament and particularly by an article published in the Ministry of Economic Warfare's *Intelligence Weekly*. This argued that after 1919:

> Germany [had] evolved a new economic theory, the theory of Wehrwirtschaft. This conceived of the state as requiring an economic structure that would serve it efficiently in peace today, but must serve it no less efficiently if the state were plunged into war tomorrow. ... It was both the cheapest and the most secret form of re-armament. The Allies could destroy arms and machinery. They could not destroy or prevent planning. As Herr Rathenau remarked when Peace had scarcely been signed "They have taken away our weapons; we must forge a new one out of industry".[15]

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modernity. After the war, the 'Mussolini metal' was redeployed extensively in new ways. Its special suitability for casting in small production runs contributed to the sculptural forms which quickly developed in a whole range of Italian consumer products ranging from motorcycles to coffee machines. In Britain, less 'frivolous' uses were found for the material and it did not stimulate industrial design in the same way.

13
This debate took place, of course, in the light of the then current experience and the sense that war potential would require enormous production potential capable of supporting the "thousand bomber raids" of the Second World War. This was to be replaced in the post-war era by a new model of air power based on smaller numbers of aircraft embodying far higher technology designed to carry nuclear weapons. This shift, and the short war that these weapons implied, were to make concerns about the maintenance of a mass aircraft industry irrelevant.

14
PRO AVIA 15/1915.

15
The significance of this paper from the M.E.W. Intelligence Weekly, dated 9.9.43 is less in the argument it contains, which might be refuted on various grounds, than in the fact that it is filed in the MAP file on reconstruction and is the only extraneous piece among the departmental minutes and drafts in AVIA 15/1915.

The approach adopted by Stafford Cripps to the reconstruction problem had strong echoes of this analysis of Germany's preparations. He argued that in time of war the rapid expansion of the aircraft industries relies on "a strong and extensive engineering industry", and that this potential to expand would allow Britain to be able "to fulfil our obligations to preserve world peace without devoting our resources to current production of military aircraft to an extent which would impose a prohibitive strain on the exchequer and a serious restriction of social progress".

But there was a more visionary quality in Cripps' prescription which went far beyond his responsibility for the aircraft industry. He wrote that:

> I conceive that there are other and purely economic grounds for making the maintenance of a large and vigorous engineering industry - both larger and more progressive that which we had before the war - a major aim of our industrial policy. It is to such industries, and no longer to coal and cotton, that we must principally look for that enlargement of our export trade which it is agreed we must promote, and the achievement of our policy of full employment in the immediate post-war years will hardly be attained if two million of our engineering workers are thrown out of employment and the factories and plant ... stand idle, contributing nothing to national prosperity.
>
> I accordingly recommend the maintenance of an engineering industry substantially in excess of that existing before the war, and representing the minimum retrogression that which now exists, be accepted as a major objective of the Government's industrial policy".[16]

Cripps' policy was concerned as much with a restoration of prosperity as with war potential. The huge capital investment in MAP facilities should, he argued, be used for a major step forward in industrial regeneration. "I conceive", he wrote, "that a special responsibility rests on MAP to make its capital assets available as the basis of a large engineering industry ... Government-owned assets should be applied to the reconstruction of a large peacetime engineering

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16
PRO AVIA 15/1915. Edwin Plowden has recalled that Cripps saying "I consider myself to be one of the best draftsmen in the country, and I itch to re-write almost every paper that crosses my desk. ... I refrain from doing so because ... I should never get the best out of my officials". Edwin Plowden, *An Industrialist in the Treasury*, (London, 1989), p. 21. However, In the case of the evolving drafts of MAP paper on reconstruction it is clear from a study of the file that Cripps had a very considerable role in casting and drafting it.

industry. ... I should welcome endorsement of my colleagues for the view that, to the fullest extent practicable, Government-owned assets should be applied to the reconstruction of a large peacetime engineering industry".[17]

These proposals were taken by Cripps to the first meeting of the Cabinet Reconstruction Committee in December 1943 where it was suggested by colleagues that "if we were to aim at maintaining an engineering industry substantially larger than that existing before the war, some measure of planning and control would have to be maintained. ... Before any plans could be made for a large engineering industry it would be necessary to determine what that industry would make, where it would sell its products, and how they would be paid for".[18]

It must be said that the Reconstruction Committee do not appear to have definitely endorsed the proposal, but it was considered sympathetically. Hugh Dalton, for example, noted that he was glad to see proposed "a measure of continued control by the Government in peacetime, making use of the experience and contacts of the Supply Departments" and, in what can be seen as a glimpse of the manifesto for the coming post-war Labour government, he agreed with Cripps that "a new approach is needed, much more in keeping with the great public enterprises of this war".[19] More explicitly, Cripps argued for a continuing post-war role for the 'expert Ministry' in economic regeneration.

> The problems of the major industries are complex ... and if the cooperation of industry is to be secured they involve personal contact with the leading men. The Government has acquired through the Departments dealing with these industries the knowledge, the contact and the influence to secure the very varying degrees of assistance, guidance, and of reorganisation which the industries ... will be found

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17
Ibid. The Minister of Aircraft Production, *The Future of Aircraft Production*, [R.C. 9(43)10], 14 October 1943. There are evolving drafts of this paper which was under preparation for the Cabinet Reconstruction Committee.

18
PRO CAB 87/5, First Meeting of the Cabinet Reconstruction Committee, 20/12/1943.

19
PRO CAB 87/6, 'Cabinet Reconstruction Committee'.

to need.[20]

Thereafter, MAP certainly went on to act as if a role in assisting and guiding the aircraft industry in the transition to peace was accepted policy. Moreover, this function subsequently became explicit with the creation of the post-war Ministry of Supply by the new Labour government in October 1945, which, as discussed further below, merged the wartime ministries of Supply and Aircraft Production.

Complex negotiations took place between the aircraft constructors and the MAP over the conditions under which they would take over MAP plant and factories. Frequently the MAP took the manufacturer's side against the Treasury, which wanted more rigorous conditions, and in this MAP could appeal to 'maintenance of war potential'. Attempts were made to persuade firms to buy some of the MAP-owned capacity (and some, such as Rolls-Royce did) but the Society of British Aircraft Constructors (SBAC) represented that "the impact of taxation had prevented even the provision of normal reserves".[21] MAP officials also noted with equanimity a tendency by mid-1944 for the aircraft firms to "restrict declaration of profits and in effect create secret reserves", viewing this as "prudent financial policy" in view of the prospects of coming cuts in production orders.[22]

It was also claimed by the firms that their own machinery had been "worked to death on expansion contracts" in the early part of the war before the MAP had supplied machine tools and it would be unjust to make them pay the

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PRO CAB 87/7 R (44)42, Memorandum by the Minister of Aircraft Production (Sir Stafford Cripps) 'Government and the Major industries', 8 March 1944, quoted in David Edgerton, Mercer, Rollings and Tomlinson, '*Labour Governments*', (n. 2 above).

21
PRO AVIA 65/1731, 'Post-war financing of the Aircraft Industry'. See also W K Gowing and M M Gowing in *British War Economy*, (HMSO, 1949), pp 534-546 which considers war-time reconstruction plans although there is no specific mention of the MAP.

22
Ibid. "I should, perhaps, also observe that recently one firm has published accounts declaring lower profits and consequent lower recoveries as EPT [Excess Profits Tax] although there would not appear to be any real reduction in production and presumably in profit anticipations". DDC (2), 26/7/1944 and reply of ADA (2) of 27/7/1944.

(hypothetical) market rate for the replacements. They asked for the first call on Crown assets (machine tools) operated by them in their works.[23]

The total value of machine tools provided by government for aircraft production was estimated by MAP in June 1943 at £200m.[24] This was considerably in excess of what could be absorbed by the post-war aircraft industry. Much of the stock was disposed of by MAP through sales and was bought by the general engineering and the automotive industries. This vast disposal exercise has led David Edgerton to challenge the conventional view of the condition of British industry in the years after the war and to remark that, contrary to the usual assessment, much of the production equipment "was not clapped out; it was brand new".[25]

In the event, most of the production capacity that the aircraft firms wished to retain was in fact passed to them, and this was tacitly accepted in the statement of the Committee on Internal Economic Problems (Production Department's Sub-committee) that 'whatever the long run plans with regard to location of industry, *it will be necessary to make use as far as possible of Government created capacity in the immediate post-war years*', while the President of the Board of Trade announced that 'we must first decide which factories will be wanted for arms production after the war. That is primarily for the Services and Supply Departments to settle but we are anxious that full use shall be made for whatever is the best peace-time purpose of all these factories after the war'.[26]

23
PRO AVIA 15/1915, notes of meeting at ICI House, Millbank with the SBAC, 16 September 1943.

24
Ibid. "The expansion of capital equipment for the aircraft programme has involved capital commitments (up to June 1943) amounting to £350m, of which £150m has been incurred on buildings and £200m on plant".

25
These disposals have been discussed by David Edgerton in 'Public ownership and the British arms industry, 1920-1950', in Millward and Singleton (n. 1 above) and in Mercer, Rollings and Tomlinson, '*Labour Governments*', (n. 2 above).

26
PRO AVIA 15/1915, (author's emphasis).

The outcome was that firms were able to rent, rather than buy, factory and plant, paying a percentage of a valuation that depreciated yearly. This arrangement was clearly attractive for, at the time of the Plowden Report in 1965, five out of seven factories in the British Aircraft Corporation were still government-owned.[27] Although, by then, the Bristol company had bought the Filton plant and airfield it had not done so by 1950 and managed to extract £3559, 19s 7d. from the MoS for the removal of blackout materials and the re-instatement of roof-glazing, in spite of an earlier view in the MoS that the Ministry was not liable for this.[28]

Thus the spirit in which the aircraft industry was treated in the post-war era, it is argued, was established to a considerable degree by the plans formulated for reconstruction within MAP at the end of the war. Subsequent chapters will adduce more evidence for the contribution of this thinking to the character and development of the industry. Although there was an inevitable dilution of this 'Crippsian' vision with time, and with the departure of Stafford Cripps from MAP in 1945, elements of his new strategic approach survived for decades and were to underpin the long-standing, and often debated, policy of support to the industry.

27
Report of the Committee of Inquiry into the Aircraft Industry, (HMSO), London, 1965, Cmnd 2853, Appendix C, Table IV, p. 117.

28
PRO AVIA 15/2485, 'Bristol Shadow Factory Disposal'. Bristols confirmed to the Department that the rent of £5000 p.a. "may be regarded as taking this improvement into consideration".

The Civil Aircraft Programme

In February 1943 the War Cabinet decided that work on the design of new types of civil aircraft and the conversion of existing military types should proceed "as and when this could be done without impairing the war effort. ... The Government's objective ... was to secure the production after the war of British transport aircraft, civil and military, of a scale and quality in keeping with our world position".[29]

Lord Brabazon, a former Minister of Aircraft Production and famous pioneer aviator, was asked to form a committee to study the prospects for British civil aircraft.[30] This episode is well known, in a general way, and has often been represented as an unrealistic or insufficiently serious attack on the problem. For instance, the Bristol aircraft designer, Archibald Russell, later opined that "Brab had loads of charisma. ... One might reflect that the hero of such experience and reputation, with all at his command, ought to have won greater success" adding that the committee's first action (defining the requirement for the future Bristol Brabazon de luxe transatlantic airliner) was "a high dive into the deep end without looking to see if there was any water there".[31]

Unfortunately the problems of the overly ambitious Brabazon airliner have coloured views about the Committee's work but its general orientation, and many of its recommendations for other aircraft were sound.[32] The Committee worked with considerable vision and thoroughness. The failures of the British

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PRO AVIA 15/1915.

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As J T C Moore-Brabazon he had become the first Englishman to fly, in a Voisin in France during 1908. He also held the first British pilot's licence - the Aero Club of Great Britain's Aviator Certificate number one.

31
Sir Archibald Russell, *A Span of Wings*, (Airlife, Shrewsbury, 1992), p. 80.

32
This account does not concur, for example, with Keith Hayward, *The British Aircraft Industry*, (Manchester, 1989), p. 42, who regarded the Brabazon programme as "deeply flawed in conception and implementation". The flaws were more in the implementation.

civil aircraft programme to achieve all that was hoped for it, which will be examined in subsequent sections, are almost entirely due to factors outside the Brabazon committee's control. Thus it considered the provision of a range of aircraft types for all the important commercial sectors and routes and drew up detailed specifications for each. The design criteria, in particular, were highly considered. They specified all the relevant performance and safety criteria such as speed, rate of climb, behaviour with one engine shut down and so on, but went beyond that to define aircraft which would be competitive in the international airline market against American competition. The Committee drew attention, for example, to the need to reduce man-hours required for engine changes and a wide range of service operations. Passenger conditions were also specified, with the air conditioning on long-haul aircraft "to provide no less than 60 lbs of air per minute. ... The ventilation of the lavatory compartment shall be such that any odours which originate in them will not be admitted to any other compartment". The targets for temperature, pressure and the noise level "a maximum of 60 phons" were all set out.

It should be noted that this British civil programme took place against the background of a rapidly spreading American aviation network and an American industry that was burgeoning with advanced new transport designs. It was quickly evident that Britain was going to be outpaced and British negotiators, including Lord Beaverbrook (as Chairman of the Commercial Air Transport Committee) tried to slow the pace of negotiations on international air regulation with Adolf Berle, the American State Department's civil aviation representative, suggesting, in August 1944 "a postponement of your project for moving out onto the civil air routes of the world. Instead, we request an International Air Conference".[33]

Berle appealed in the spirit of internationalism and free trade noting that:

> In many parts of the world it is now obvious that the war area is receding and civil needs are ... reasserting themselves. ... The highest

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33
PRO CAB 127/186, draft of telegram, Beaverbrook to Berle, 24 August 1944.

> considerations of humanity and common sense as well as the inherent interest of establishing ... normal commercial life dictates the extension of civil air travel".[34]

Even if a conference were to produce complete agreement, Berle argued, it would take time to implement and he asked for an immediate interim arrangement to be set up.

However, these difficult discussions were taking place in a pre-existing mood of suspicion between Britain and the USA over the air transport services that were being provided during the war, for such services were seen as laying the foundations for post-war airline operations, both through their role in training aircrew and in allowing the development of the necessary infrastructure such as communications and navigation aids, airport equipment and so on. In particular, the extension of Pan American into areas previously opened up and operated by Imperial Airways gave particular cause for mistrust in Britain.

Thus when Pan American was allowed to operate a service to assist the Allied military effort in the Middle East and Africa, Arthur Tedder, as commander of Allied air forces in the theatre quickly discerned "the cloven hoof of Pan American ... They are about to open a booking office in Cairo for passenger services" and telegraphed colourfully to London that "sheep's clothing of USAAC [United States Army Air Corps] will not change habits or diets of the wolf". Tedder considered that the Americans were actively developing their routes in advance of any formal agreement "quite regardless of our interests [and] despite the fact that they are only able to do so with our active assistance."

He commented that "our American 'friends' were some of the toughest business men I had come across" and noted that by June 1942 Pan American had, without authorization and without consulting any of the authorities in Cairo, instituted a weekly scheduled air service between Cairo and Teheran, via Baghdad and Basra, "on the pretext of returning United States ferry crews. ...

34
Ibid. Berle to Beaverbrook, 23 August 1944.

Pan American ... were attempting to leave no stone unturned in infiltrating to the maximum extent, legally or illegally".[35]

However, from the American perspective, Britain also was guilty of bending the rules and Berle observed that:

> The government of the US notes that ... in substance British Overseas Airways Corporation operates as a militarised service where convenient, and a commercial service wherever practical, and is actually performing the service of a fare-carrying common carrier in the areas from which the war has actually receded, although on a priority basis. On the other hand, the American Air Transport Service is a wholly militarised service which neither collects fares nor performs any ... of the services of a common carrier. The disparity between these two arrangements is so great as to raise a real danger of considerable [American] public reaction".[36]

The threat of hostile American public opinion was also raised with respect to landing rights for American carriers abroad. In order to prosecute the war the United States had constructed a large number of airfields throughout the world, many of them on the territory of the British Empire, and, it was claimed, American opinion demanded reasonable use of all airfields constructed by them. Nevertheless, Britain had a reasonably strong position. There was the American fear that Britain "might be driven back on an All Red policy" and retreat from the internationalisation of air transport. Moreover the right of any nation to carry passengers internally could not be challenged and Britain had hinted that, for this purpose, the Commonwealth might be claimed as a political unit, analogous to the states of the American union.[37]

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Lord Tedder, *With Prejudice*, (Cassel, London, 1966). "It appeared to us ... that we should have difficulty in preventing the extension of Pan American's activities to the Far East, and ... there was apparently no intention of making the service a military one, as we had been led to believe. On the contrary, many of the passengers would be civilians, most of them connected only indirectly with the war effort". See also Erik Benson, 'Suspicious Allies: Wartime Aviation Developments and the Anglo-American International Airline Rivalry, 1939-45, *History and Technology*, 17, 2000, pp. 21-42.

36
PRO CAB 127/186.

37
Alan P. Dobson, *Peaceful Air Warfare: the United States, Britain, and the politics of international aviation*, (Oxford, 1991), pp. 125-172.

The upshot of Anglo-American negotiation was the international conference in Bermuda in early 1946 which led to British acceptance of the International Air Transport Association (IATA) and the establishment of the complex but remarkably durable rules to regulate rates and national relationships which thereafter regulated international air transport for many decades.[38] This represented a step down from the British position at the earlier conference at Chicago in November 1944, partly, perhaps, because of the concurrent approach to the USA for a major loan to assist Britain with its post-war economic problems and the end of Lend-Lease.[39]

However, the diplomatic contest was to prove more or less irrelevant to British aspirations in civil aviation for, while Britain was not without bargaining power for negotiations over landing rights, overflying and the whole structure of international air transport, the prospects for manufacturing competitive British civil aircraft and for organising efficient airline services were bleak. In 1943, American airlines were operating 300,000 route miles compared with 72,000 operated together by RAF Transport Command and British airlines. The Civil Air Transport Committee, chaired by Beaverbrook, listed the advantages of the USA in civil air transport. This included an output of 400 airliners a month, with nine types in production and 13 multi-engined types under development, whereas Britain had none at all in production. The United States was also researching the problems of civil airline operation through its Civil Aeronautics Board and the Civil Aeronautics Administration - government bodies with a combined staffing of 9000 people. The committee noted that:

> Britain has had no opportunity or manpower available for a detailed study of these questions. ... The Americans are operating more than 1000 transport aircraft on regular services. We are operating 250, mostly American types. Nineteen separate civil airlines are operating inside and outside the USA and ... have gained a great wealth of experience. We have only one company and hence only one line of

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38
Ibid, pp. 173-210.

39
Ibid. One official recalled that "the loan was very much at the back of everybody's mind".

experience.[40]

At the same time British industry was unable to make any significant progress on the promised new civil types for, even as the war drew to a close, it was to prove extraordinarily difficult to prize adequate industrial and design capacity away from the RAF.

Thus Beaverbrook wrote to Sir Archibald Sinclair, Secretary of State at the Air Ministry in August 1944 noting that:

> what we need at once is 50 Lancasters converted for long-range transport operations. ... During my chairmanship of the C.A.T. [Civil Air Transport] committee there has been plenty of hope and expectation but no aircraft. If we can provide aircraft now there is still a hope for British Civil Aviation.[41]

The Air Ministry expressed sympathy but suggested, from a security point of view, that Britain could not afford to end the war with "a second-rate air force". The MAP countered that as secrecy was not a problem the armed forces could be combed for "alien draughtsmen", although those concerned with implementing the civil programme made the obviously valid point that good new civil aircraft could only be designed by experienced designers from the industry. Indeed, an Air Ministry official noted that although about 260 draughtsmen had been found from various sources specifically for work on civil types, only 60 of these were actually engaged on civil work "because inexperienced men were useless for work in the early stages of design at which the civil types now were".[42] Nevertheless, the Air Ministry (representing the RAF position) refused to agree to the MAP suggestion that urgent civil types should enjoy equal priority with those military types which were not regarded as essential to front-line combat operations.[43]

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PRO CAB 127/186, CAT (43) 9th meeting, 'Advantages of the USA in Civil Air Transport'.

41
PRO AIR 19/323, 'Civil Aviation: aircraft requirements, 1944'.

42
Ibid. Minute by VCAS (Vice Chief of Air Staff), 25 May, 1944.

43
Ibid. The Air Ministry "could not bring itself to agree with MAP that urgent civil types should enjoy equal status with 'non-designated' military types".

The comments of Sir William Hildred, Director General of Civil Aviation and a member of the Brabazon committee, show the frustration of those who wished to see Britain make a start in air transport again. He queried whether all of the huge amount of current military work was useful, remarking that "I have no wish to pry into military secrets but there must surely be some military work which could now be set on one side ... What ... is the need for the Windsor or the Buckingham?". He observed that:

> The RAF ...intend to cling the whole of the present aircraft design staff. ... they are going to use a lot of it (and indeed are doing so now) for post-war military work. ... They are not entitled to do this ... they will have to face Parliament, the Treasury and the taxpayer ... clinging like this ... to the detriment of civil work. [We are faced] with an absolute impossibility. Get 500 trained men from somewhere and then you can have your Brabazon designs. The situation ... cannot be met by half measures or shilly-shallying. This is a matter for the War Cabinet".[44]

However, in the mood of the times, the requirements of the RAF proved too pressing and only piecemeal design efforts were allocated at the firms to civil types. In fact the stated requirements for draughtsmen and designers on civil projects would have been quite inadequate even if they had been met in full, and are a measure of the slight unreality of all the initiatives to put British civil production on a comparable level to the American. Against the worthy desire to release 500 trained men to be spread over six Brabazon types can be set the observation by Sir Roy Fedden, the former Bristol engine chief, who found in 1943, at the Lockheed factory, 500 staff working on the design of the new Constellation airliner alone. At the peak of the design effort the total for that aircraft had been 700 men with 1.7 million drawing office hours expended on it.[45] Some might consider Fedden a partial witness, as a technocratic zealot and tireless campaigner for his industry, but numerous observers from government, the RAF and elsewhere, brought by war procurement work into contact with the American aircraft industry, commented on the disparity with Britain. There

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44
Ibid.

45
Fedden Mission to America, Final Report, June 1943, Science Museum archives.

were also reservations both inside and outside MAP about the resolve of the aircraft manufacturers to act energetically. Lord Beaverbrook, for example, while representing British interests during the international civil air transport negotiations, observed at the same time that "this industry looks as if it's a hotbed of cold feet".[46]

46
Quoted by Sir Peter Masefield in 'The Brabazon Committees', lecture to the Royal Aeronautical Society, 28 October 1995.

The Amalgamation of MAP and the Ministry of Supply

The case for the amalgamation of the Ministry of Aircraft Production with the Ministry of Supply had been put by Cripps to the Machinery of Government Committee in November 1944.[47] Although no decision was reached by the Coalition Government it was clearly Cripps' view that was carried over to the 1945 Labour Government which merged the two in October 1945.[48] It is hard to avoid the conclusion that the ethos of the MAP, with its sophisticated planning procedures and its amazing war-time production achievement, made it the dominant partner in this new body. This can, perhaps, be glimpsed from a MoS record of a joint meeting in September 1945 about the proposed merger which recorded that "The MAP representatives seemed disinclined for serious discussion".[49]

The strategic industrial role of the combined Ministry was clearly stated at the outset. In addition to "a central war potential motif" there was a wide-ranging responsibility for engineering which the MoS itself defined as "all kinds of products, mainly of metal, which involve relatively complex engineering procedures."[50] It noted that the whole sector of military supply, two and a half

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47
PRO CAB 66/59 WP (44)713, 'The Organisation of Supply, Memorandum by the Minister of Aircraft Production', 21 November 1944, ADM L/17794, MG (44)28 and 'Organisation of Supply, Memorandum by the Chairman of the Machinery of Government Committee', (Sir John Anderson) 20 December 1944, (Quoted by David Edgerton in 'Liberal Militarism and the British State', *New Left Review*, No 185, Jan-Feb 1991, p. 154.

48
PRO AVIA 49/75, 'Functions and Responsibilities of Ministry of Supply'. The Cabinet decision of 2 October 1945 was that "A Ministry of Supply - responsible *inter alia* for specialised stores for the Army and RAF - should be a permanent feature of the machinery of government".

49
PRO AVIA 12/28, 'Details of Merger of Ministry of Supply and Ministry of Aircraft Production'. "In the time at our disposal *and in that atmosphere* it seemed more important to us to get some sort of statement of fact as to the respective organisations and their differences". (Author's emphasis).

50
PRO AVIA 49/75. In addition, naturally, to aircraft "it would include munitions, aircraft, all engines, motor vehicles, bicycles, machine tools, hand tools, small tools, electrical machinery and equipment radio, precision instruments, watches, clocks bearings, rolling stock, cables, lamps, refrigeration plant, metal housing fitments and general engineering products. It would exclude ... musical instruments, metal toys, metal furniture and jewellery".

million persons strong, absorbed over £750m of defence spending and contributed 40% of visible exports. The MoS, it argued therefore "has the best understanding, the frequent contacts and the technical knowledge to help it meet the difficult Government objectives of high exports and the dollar export drive".[51]

When the exhibition, "Britain Can Make It" opened at the Victoria and Albert Museum in September 1946, Stafford Cripps, as President of the Board of Trade which sponsored it, saw there the visible evidence of the transformation of war production to produce the broad economic progress that he had argued for in the reconstruction debates. He wrote:

> Here we are able to prove, by selected examples of British consumer goods, most of them already in the shops or in quantity production, not only that Britain *can* make it - for the War proved that beyond a doubt - but that Britain can make goods that are new, beautifully designed and efficient. ... Here are the goods which, because they are designed for economical mass production, will enrich the homes and daily lives of each one of us".

The title of the exhibition was a good one, said Cripps, showing that "we have passed from the years of endurance to the years of achievement, from destruction to creation.[52]

Why was the Aircraft Industry not Nationalised?

One curiosity about the transition of the aircraft manufacturing industry from war to peace is that it escaped serious consideration for nationalisation. It was not apparently, in spite of its huge war-time size, viewed as one of the "commanding heights" of the economy although civil air transport was to be in

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51
PRO AVIA 49/75.

52
Sir Stafford Cripps, President of the Board of Trade, forward to *'Britain Can Make It'*, supplement to the *Board of Trade Journal*, 28 September 1946, and in article 'Spitfires to Saucepans', pp 4-5. The priority given to exports meant that many of the goods were not in practice available and the exhibition was cynically dubbed by some "Britain can't have it".

the hands of national corporations.

There were several reasons for this. First we can consider the industry's enormous war-time prestige. Its most famous products - particularly the Spitfire, the Mosquito and the Lancaster bomber, with their sonorous Rolls-Royce engines - were the most obvious symbols of British war-time aviation technique and were held by press and radio reports - and their actual presence overhead - constantly in the public eye. Post-war nationalisation of such an obviously successful industry would have been seen as a clearly hostile and punitive action. As Edgerton has noted, after 1941 the armament and aircraft firms were seen "as having created new scientific weapons in full collaboration with labour. It was not an industry which needed the strong medicine of nationalisation to bring it up to scratch".[53]

But there was a dislocation between the popular view and the perception within the MAP which was more equivocal about the industry's abilities. The talent of particular design teams in the airframe sector was esteemed, Vickers had a good reputation for production management, and Rolls-Royce had won almost unconditional respect through unswerving adherence to its own technical judgement and for being right.[54] But the general organisation, the finances and the 'spirit' of the companies came in for considerable criticism.

Writing in July 1945, for example, Sir Lindsay Scott, a senior official at the MAP, gave a detailed exposition of the department's view.

> The industry is at present highly bureaucratised, producing what it is told to produce by the Department, substantially guaranteed against unemployment and financial loss, and content to accept the low profit

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David Edgerton, in Millward and Singleton, '*Political Economy*', (n. 1 above).

54
PRO CAB 102/51, D A Parry, 'The Production of Reciprocating Engines 1935-1945'. "Rolls-Royce never failed to show their peculiar mixture of engineering ability and intransigence". Sir Alec Cairncross, noted "Ernest Hives of Rolls-Royce ... had ... an extraordinarily accurate judgement. ... We could trust Hives for an honest ... opinion on the development prospects of the Rolls family of engines and we never found his judgement at fault". Sir Alec Cairncross, *Planning in Wartime*, (Oxford 1991), p. 19.

rates which the absence of any considerable risk-bearing rightly entails. We have made some efforts, with the late Minister's assent, to stir the industry from its lethargy in the civil aircraft field, but so far without success. The industry which has been the largest in the country is ending the war inadequately financed to undertake the development and production which will be required in time of peace. Not more than half a dozen aircraft companies are in reasonably sound condition. ... If we continue to finance the industry, and if it continues in its present bureaucratised condition, there will be no alternative in ten years time to its nationalisation".[55]

The administration of the aircraft industry by MAP was, in many respects, unlike a normal civil service administration. As we have seen this was, in part, due to the fact that the MAP directly owned much of the production facilities and itself disbursed enormous sums to existing manufacturers, so that normal pre-war contractual arrangements and practices such as competitive tendering were neither relevant nor practicable. The position of the MAP with regard to the firms can be glimpsed from the profit figures which the Ministry recorded. Thus in 1941 Rolls-Royce earned just 5.4% on 'cost of sales' but was allowed by MAP only 4.4% on the basis of calculations as to how much of that production relied on Ministry-owned machine tools. By 1944 the profit allowed to Rolls-Royce by MAP was a mere 2.05%. The justification for this, as implied above, was the high level of MAP investment but also the national emergency and the great will on all sides to contribute in the highest degree.[56]

The MAP could also point out the low commercial risk in their contracts and that profits were high relative to the company's own capital employed. Thus for Rolls-Royce the 1943 year profit figure was 33.4% on company's capital employed, but 4.29% on cost of sales (of which 2.35% was actually allowed by

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PRO AVIA 65/1731, 'Post-war financing of the aircraft industry', Sir Lindsay Scott to Secretary and to Chief Executive, MAP, 13/7/1945.

56
When the Lord Beaverbrook asked Rolls-Royce to prepare a full set of manufacturing drawings for the Merlin and Griffon engines for shipment to America to augment production the Rolls-Royce chairman, Lord Herbert Scott was disturbed at parting with a valuable company asset on an unstated financial basis. Sir Arthur Sidgreaves as managing director took a more sanguine view. "If their having the drawings would enable us to win the war we would willingly give them without any claim. If we lose the war it certainly won't matter about the drawings". (Quoted in Ian Lloyd, *Rolls-Royce, the Merlin at War*, (Macmillan, London, 1978).

MAP). A company such as Airspeed, which was poorly capitalised pre-war was showing a profit of 62.5% on its own capital in 1943 while Armstrong Whitworth's profit on this basis peaked at 165.66%.[57] Nevertheless, whatever the moral case, the tiny profit earned on turnover seems to be the right indicator to take in assessing the ability of the companies to be able to adequately finance new post-war production, for this figure related more realistically to the costs of producing newer, more complex aircraft in larger numbers than had been contemplated from their own resources in the period before government-financed expansion.

Of course public ownership for the industry also implied public finance, whereas it was the desire of the Ministry and the Treasury to escape this and to encourage the firms to generate their own finance for new projects. MAP officials referred to a "policy of carefully restricted financial assistance [to revive] the spirit of commercial initiative" and that "the over-riding consideration was to encourage contractors to put down the money in the first place, because ... expenditure of contractors' own money ... has a valuable psychological effect in tending to make them more self-reliant, and to get them out of the war-time habit of being spoon-fed".[58]

However, the deep and irreconcilable paradox in this argument, (which formed the background to the MAP's desire to have discretion in the financial conditions for the disposal of its own plant and facilities to the industry) was the continuing need or wish to use the industry as an instrument of government policy, whether in a strategic government-directed attack on the international air transport market, or in the maintenance of war potential. "It is to be borne in mind, and should be appreciated by the Treasury", MAP noted "that some of the capital and development expenditure which we want to encourage the firms to undertake will be near to or beyond the limits of commercial prudence. ... If

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57
PRO AVIA 65/1731.

58
Ibid. Minute of 8/11/45."If they spend their own money they have a direct incentive to economy, and to avoid the provision of the frills and refinements which they are apt to press for from us".

we want rapid development in design and in productive capacity to be financed in any degree by industry we must be ready either to relieve the firms of some share of the risk or offer them higher profits".[59]

Another reason for the absence of plans to nationalise the industry was that Sir Stafford Cripps, in his strategic planning for the sector, did not consider it necessary, in view of MAP's perceived success in running aircraft production, observing to a socialist audience in 1945 that "the fact that the actual operation of industry remained in private hands has not mattered seriously, since the Supply departments have been able to exercise the pressure necessary and in extreme cases to take over the control of the individual factory or firm".[60] Cripps' approach was ambitious, dirigiste, and strategic, but he appeared to consider, like his officials, that the best hope of fostering a British aviation industry that could make a useful contribution to national prosperity lay in encouraging development of its own initiative. Indeed, Cripps was offered the bait, one might say, by Labour members of the War Cabinet in the first meeting of the Reconstruction Committee where "some members expressed the view that a higher proportion of the post-war aircraft industry should be under direct Government control".[61] It was also suggested that pre-war re-armament had been slow, due to the reluctance of private industry to convert to war production, and that this constituted a strong case for government control. However, Cripps turned the suggestion aside by reminding colleagues of his proposal "that at least one factory should be retained for Government

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59
Ibid. Note by Sir Lindsay Scott, 23/11/1945.

60
Sir Richard Stafford Cripps, 'Post-war Problems of Industry', speech to the Oxford University Socialist Club, 9 March 1945, quoted in Edgerton, Ph.D thesis, (n. 2 above). Eric Estorick, (n. 2 above) p. 327, quotes Cripps as saying "we have no interest in preserving or destroying private enterprise except to create efficiency in our production".

61
PRO CAB 87/5, Cabinet Reconstruction Committee, 1st Meeting, 20/12/1943. Cripps' paper to the Committee asked for "one Government factory to stimulate and supplement the design and development of the industry and to provide a yardstick against which the industry's efforts might be measured. I ask the assent of my colleagues to plan at any rate, at least one such Government factory". Drafts showing the evolving text of Cripps paper 'The Future of Aircraft Production' are in the MAP file 'Departmental Reconstruction Committee', PRO AVIA 15/1915.

operation".[62]

Finally, the practical point should not be overlooked. The legislation for steel nationalisation took some two and a half years to prepare and implement. The aircraft industry, we have seen, was regarded as a problem as well as an asset; it was divided into numerous companies of widely differing sizes, capabilities and structures, and it was supported by what has been called "a vast archipelago" of subcontracting firms. Many of these, for example, including tyres, brakes, hydraulics, sparking plug and magneto makers, might not necessarily have aircraft work as their sole business, but their products were indispensable for the industry. Segregating and selecting these for nationalisation would have been an administrative and legislative minefield and no one sought to try.

Civil Airliners: Initial Post-war Tensions

The system set in place in the closing stages of the war for civil aircraft procurement by the MAP was carried over into the merged Ministry of Supply (MoS) which as we have seen now combined the functions the war-time Ministry of Supply and the MAP.

The MoS thus entered the post-war era with the strong sense, within the new, that it would sponsor the design and development of civil types and promote the civil aircraft production programme. Although the Treasury argued for clarity in accounting which would reveal any element of subsidy the MAP/MoS view was that it should negotiate a sale price which would not include an element for development "unless directly related to the type" and that "while some items

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62
Cripps was presumably referring to the Short Aircraft Company. For an account of the nationalisation of Shorts see Peter Howlett, 'The Thin End of the Wedge?: nationalisation and industrial structure during the Second World War' in R Millward and J Singleton, '*Political Economy*' (n. 1 above). The argument blaming the aircraft constructors rather than, say, politicians, for the pace of re-armament was clearly weak. Both Lord Londonderry and Lord Swinton, as successive Secretaries of State for Air, had been forced out of office for deficiencies in the pre-war RAF equipment programme.

[are] identifiable as civil aviation much of the expenditure could not be so segregated". Officials also advanced the idea of "favourable leases" to civil operators and also sought to deliberately blur the basis on which civil projects were being financed, emphasising to the Treasury the supposed difficulty in separating out the development costs "since the civil types are being financed out of payments made on military contracts". The argument was also advanced that the costs of aircraft supplied to the British Overseas Airways Corporation (BOAC) should also be excluded "as BOAC for the moment must be regarded as ... on war service". There was, additionally, a diplomatic reason for downplaying the expenditure on civil aircraft R&D, in spite of Treasury pressure to disclose true costs and to adhere to "orthodox financial arrangements to which Parliament rightly attaches importance", in that publication of a realistic figure, estimated at some £8m to £10m, was expected to cause difficulties over Lease-Lend negotiations, and raise the suspicion in America that its military aid was being diverted to establish a peacetime competitor industry in Britain. Lord Swinton, as Minister for Civil Aviation, therefore proposed putting the research, development and production figure at just £1.5m and "strongly objected to giving the US public a stick to beat us with".[63]

This manoeuvre was opposed by the Treasury and may also have been viewed as diplomatically risky, but the proposal underlines how far one major current in official thinking had diverged from the more formal ideal expressed in some quarters a year or so earlier that it was "important that our industry is able to produce civil types on commercial terms, which will enable them to compete in world markets" and that, if there was to be subsidy, it would be healthier that "it should be openly revealed, rather than hidden away in some complicated financing system".[64] The idea of a notional civil/military split for R&D was therefore used by MoS but this was inevitably opaque. In the event, the government/industry ensemble entered the post-war era already conditioned to a

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63
PRO AVIA 15/2478, 'Ministry of Civil Aviation, Financial and Accounting Arrangements', minute of 2 May 1945.

64
PRO AVIA 65/1731, 'Post-war financing of the aircraft industry 1944-1945'.

kind of collusive and complicated system of aircraft financing which was intended to serve a wide, and probably irreconcilable, array of policy aims.

But by January 1947 the British airlines were starting to resist the statutory role of the MoS in aircraft development and procurement. Sir Henry Self, (Permanent Secretary in the MoS) noted that "certain of the airline operators are challenging the decision that aircraft which they require shall be ordered by the Ministry of Supply. They argue that they should order their aircraft direct from the manufacturers ...".[65]

MoS officials argued that only the Ministry could act in the national interest since the design resources must be "fairly allocated" between civil and military interests. "The MoS must participate in all major developments and its participation will be of benefit to individual users. Any other arrangements would mean putting the clock back and would be contrary to the whole trend of administration ...".[66] The MoS advanced a striking number of arguments to defend the procedure by which it supervised all development, including the fact that without MoS involvement "technical vetting would be in the hands of the Air Registration Board. A Certificate of Airworthiness from them might not in all instances be sufficient technical proof that the aeroplane is adequate for its tasks".[67] This was a striking argument, and proof, one might adduce, of a dangerous arrogance in the department for the Air Registration Board was also a government organisation - the one, in fact, with the statutory responsibility to establish the airworthiness of new types. Falling back on the war-time habits of control, the argument was also put that although "it is very difficult to prove that money is saved through bulk purchase by the MoS on behalf of all users ... the Ministry's long experience of aircraft contracts and its knowledge of the general financial position of the aircraft firms and of their overhead costs etc.

65
PRO AVIA 55/30, 'Committee on Ordering Procedure for Aircraft'.

66
Ibid.

67
Ibid.

cannot but fail to be an advantage in price negotiation". The powerful influence of the RAF over procurement also surfaced in the argument that the airlines' desire to order directly without the mediation of the Ministry of Supply was an attempt to 'jump the queue', as suggested by the assertion of Sir Leslie Hollinghurst (AMSO) that "the [airline] Corporations could only get better prices and deliveries at the expense of the services".[68]

Nevertheless, BOAC and BSAA (British South American Airways) did secure some independence, partly by refusing to attend meetings with the MoS to discuss procedures for ordering, and in the case of BSAA, ignoring the MoS procedure and placing direct orders with the companies for spares and overhauls. A compromise position was proposed and the Prime Minister directed that "while the orders should continue to be placed by the Ministry of Supply and not by the Corporations themselves, in order to secure the advantages of bulk purchase and to co-ordinate civil and military production, the Ministry should place orders as the agent of, and in agreement with, the Corporations".[69]

However, BOAC was intransigent and R G Strauss (by then successor to John Wilmot as Minister of Supply) noted in November 1947 that the Prime Minister's directive on ordering procedure was not being followed by the Corporations. BOAC had refused, in writing, to discuss contracts with his Ministry or to co-operate in the purchase of the D.H 106 [the de Havilland Comet] for which the corporation was negotiating directly with de Havillands, and that "in the case of the D.H. 106 there were no prototypes in the accepted sense of the word"[70] Ministry officials also commented that the Comet "is an anomaly - a product of the Corporation's orders", queried whether the AID inspection standards were sufficiently high, and commented on the

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68
Ibid.

69
Ibid.

70
Ibid.

"uncooperative attitude of the firm", their insistence on being given a free hand, and the difficulty in finding any way "of checking the design standards being used".[71]

The wider strategic implications of the Comet crashes are touched on in chapter five. However, it is worth noting that the Comet programme, contrary to the MoS views above, was not simply a response to a BOAC order but an imaginative idea from de Havillands which gained powerful moral support from Lord Brabazon. Against the background of the other civil projects which, as we have seen, were stalled largely by the RAF and Air Ministry insisting on the retention of design and production effort for military aircraft, Brabazon strongly recommended it to the Cabinet in June 1944, noting that "its appearance ahead of any rivals would be a timely reminder of the pioneering work done on jet propulsion in this country". He also commended the valuable operating experience it would provide and its "great advertising value". The jet airliner, he argued, would get "the best and quickest value for post-Armistice aviation that can be got from the diversion of a small percentage of design effort now. ... We have no hesitation in recommending that such an aircraft should be built".[72]

Thus the Comet acquired a powerful symbolic status which relates closely to national perceptions of the importance of the Whittle jet which will be studied in the next chapter. The Comet's rapid progress can also be seen as a direct response to the impenetrable difficulties placed in the way of almost all the other civil programmes by the Air Ministry and the RAF. As it was, the metal fatigue failures that lay ahead can be viewed, in part, as the result of this intransigence, forcing the company, and the project, into a kind of 'maverick' position in order to progress at all. If it had not fallen prey to these tragic structural failures the Comet would certainly have been seen as full justification for the independence that de Havilland and the BOAC board established to bring

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71
PRO AVIA 15/3429, 'Civil Aircraft Research Policy'.

72
PRO AIR 19/323, 13 July 1944, 'Third Interim Report of Second Brabazon Committee'.

this revolutionary aircraft into service.[73]

But although officials could, perhaps, have subsequently argued that the Comet disasters in 1954 could be taken as justifying the centralised MoS procedures the other types of aircraft that continued slowly to be procured through the now rickety Ministry system could hardly be said to vindicate it. Writing in 1958, after he had left the MAP, Ely Devons as former Chief Statistician there can be allowed the expression of hindsight on the programme which might be considered ahistorical from this author. He wrote:

> It is not possible or necessary to go into the detail of the sorry story of the series of unsuccessful civil aircraft, either designed as such or converted from basic military designs, produced in the immediate post-war years - the Brabazon I, the Shetland, Apollo, Marathon, Sandringham, Solent, Tudor, Hermes and Princess Flying Boat. This series of misfortunes completely discredited the idea, which so dominated thinking in the immediate post-war years, that the Ministry of Supply and the Ministry of Civil Aviation together could plan requirements ahead and therefore place general production orders on behalf of British operators.[74]

The organisation of the industry and the administrative machinery was the subject of persistent scrutiny. Following the crash of an Avro Tudor belonging to BSAA in 1948 a committee under Sir John Hanbury-Williams criticised the system of procurement under MoS supervision and recommended that the airlines should deal directly with the manufacturers and that the relationship should be on a more directly commercial basis. However, this liberalisation of civil aircraft production for the airlines, which was approved by the Attlee

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73
The uneasiness of the MoS officials over the Comet is a little-known element in the story. In February 1949, five months before the prototype flew, the Deputy Director of Aircraft R&D in MoS wrote that the aircraft was not being supplied "to a satisfactorily defined design standard. Thus, if some years hence an accident gives rise to the kind of investigation now in hand on the Tudor IV 'Star Ariel' M of S may be very vulnerable. ... We are in the hands of the ARB [Air Registration Board] ... in so far as their airworthiness standard is adequate we may be adequately covered". 'Civil Aircraft Research Policy', PRO AVIA 15/3429. The oddity of the MoS not accepting or agreeing airworthiness standards with the ARB as statutory authority has been remarked on above.

74
Ely Devons, 'The Aircraft Industry', in D Burn (ed), *The Structure of British Industry*, (Cambridge, 1958): 69-70.

government, was inevitably equivocal. There was still a complex relationship over ordering and funding, with the possibility of both subtle or overt pressure on the airlines, while, in turn, the airlines could argue for modifications to specifications and for subsidies to operate British types which may well have injured their wider saleability. Importantly too, for the aircraft manufacturing industry, the launch funding of civil projects and the whole framework of research and development finance on which they depended was still disbursed by the Ministry of Supply or its successors.[75] The further evolution of these systems and relationships is explored in chapter six.

75
David Edgerton has shown that the Ministry of Supply was the top spending government department, in the post-war years, on research and development. He gives figures suggesting that some £80m. was spent on civil aircraft projects alone from the end of the war up to 1955. David Edgerton in Mercer, Rollings and Tomlinson, '*Labour Governments*', (n. 2 above).

Chapter 3: The Development of the Whittle Engine

Introduction

The development of the jet engine in Britain during the Second World War was to have a profound effect both on the national imagination and on national perceptions of British capability in aviation. The jet also had a major influence on the structure of the post-war aircraft industry and jet development also connects to the creation of new government-financed institutions in British aeronautics that will be examined in the next chapter. Thus the jet project, and the various structural changes made during its course, are closely bound up with the modernising aims that Stafford Cripps, as Minister of Aircraft Production, had for the aircraft industry.

The programme, virtually from its inception, was sponsored and administered by the Air Ministry and, from 1940, by the Ministry of Aircraft Production (MAP). Therefore the progress of the jet from the original visionary promise of outstanding performance, through its troubled development engineering process and finally to production, forms the subject for a case study of unusual value in the context of this work. The previous chapter pointed up the size of the industrial sector directed by the MAP and its considerable achievement in maximising the production of aircraft combined with sufficient flexibility to allow the continual growth in performance that was essential in combat. The Whittle jet illustrates the management by MAP of an entirely different type of project - a radical innovation from a small new company which did not, in itself, possess sufficient resources, both human and financial, to complete the job alone. It will be argued that MAP direction in this case was far less sure, and that, contrary to the generally received view, it was too indulgent to Whittle for too long. Naturally high technology programmes such as this are inevitably harder to manage than long production runs of relatively stable products but we do have, as a comparator, development of the jet engine in America which

overtook Whittle's company in developing a reliable and airworthy unit after details of its design was provided to General Electric in October 1941. We have, also, in the case of the German jet engine, an alternative model, which will be examined, for the government direction and the conversion of an advanced concept into a viable product in war-time.

Thus the British jet programme is of great interest as a test of MAP's direction of an advanced technology, high risk project, and it is suggested that the patterns of administration developed through the project were carried over into the post-war Ministry of Supply in a period when many other projects which represented step-changes in technology and performance were in gestation. Put crudely, the response of MAP to difficulties with the Whittle jet development was to allow the emergence of a number of projects from rival firms rather than to force the development of the engine to take place in one competent concern capable of experimental design and manufacture. This did lead to the creation of a number of functional engines and capable design teams, although it must be judged a wasteful use of war-time resources. More tellingly, in the context of this study, it is argued that this response to jet problems conditioned MAP and the MoS to the wasteful practice of multiple procurement and multiple experimental projects in the post-war era.

The Origins of the British Jet

The linkage between jet work and government, however, begins in the 1930s and it is therefore necessary to step back in time for the start of this account. This chapter, therefore, examines the progress of the Whittle jet from pre-war developments and the launch of the Power Jets company, through the troubled war-time attempts to build and productionise the engine, and leading on to the development of a structure for the post-war gas turbine industry. The story is of great interest because the jet engine proved, in the post-war era, to be the most important contemporary development in aeronautics and a technology in which Britain had a very considerable capability which still endures. However, the debate is still alive about the way Whittle was treated and the episode raises wider questions about the British management of R&D and its translation into successful business. It is argued here that the jet programme was both more influential, in terms of providing a new orientation for the UK industry, but also less successful, with respect to the particular progress of the Whittle team, than has generally been appreciated. We must also examine the question that has often been raised as to whether the Air Ministry did too little to assist Whittle. Events in the Whittle saga are still debated and are more than a little mysterious.

The jet engine programme had a complex history, both in terms of engineering development, the official administration of the project, inter-firm collaboration, and the structure of Frank Whittle's firm, Power Jets. All these strands suggest, contrary to the accepted view, a considerable degree of flexibility, and indeed originality, on the official side in fostering the new engine and the new industry.

There was, at the outset, the establishment and funding of Power Jets, the company set up in 1936 to develop the Whittle engine, which, it is argued, was from the outset almost a surrogate official project, and not simply the independent entrepreneurial venture, battling against adversity, that is usually

depicted. Then there was the formation of the Gas Turbine Collaboration Committee which became an unusual mechanism for pooling experience across all the aero engine companies and government agencies engaged in the jet engine programme, almost irrespective of commercial rights. The nationalisation of Power Jets in 1944 and its merger with the turbine engine department of the RAE also suggests a contemporary open-mindedness about exploring new kinds of organisation, and there is finally the conversion of this government-owned company into a more conventional state research establishment - the National Gas Turbine Establishment (NGTE).

The Historiography of the Jet

The pioneering work of Frank Whittle on the jet engine and the subsequent nationalisation of his company, Power Jets, has been the subject of considerable attention in the history of technology; indeed the history of the jet has become an important case study within the subject and a paradigm for a particular kind of revolutionary technological change. At a more popular level, the received version of the British jet story has a compelling quality as "an exemplary episode, or mini-fable, with a simple, yet plausible before-and-after narrative structure.[1]

However, it is argued here that there has not been an objective or a complete account of these events and neither have the reasons for the nationalisation of Whittle's company been fully analyzed. Postan, Hay and Scott, in the official history, while not glossing over the difficulties encountered in development, certainly did not report fully the sense of frustration that existed within the MAP towards the project when it ran into difficulties or the resentment and even

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1
"... of the type that is adduced to show the mechanic arts as the initiating agent of change [in] the received version of popular history". Merritt Roe Smith and Leo Marx, *Does Technology Drive History? The Dilemma of Technological Determinism*, (Cambridge, Massachusetts, 1994).

hostility that developed towards Power Jets personnel.[2] It seems clear that these authors, although having access to a great range of records and with a considerable team to analyze and condense them, were writing at a time when the difficulties were past and when the jet engine was seen not only as a great British success, but also as a potent symbol of a new British identity in which a claimed technological superiority was becoming a defining quality and a replacement for a now declining imperial power. There was also a sense, among those involved in, or informed about, policy matters that Whittle personally had been treated less than fairly.

Whittle's own account, by contrast, dwells on the difficulties he and the Power Jets team experienced in their dealings with Government agencies and was written in a spirit of clear disappointment and even bitterness.[3] However, subsequent historiography has done little to analyze the sources of conflict or to discover to what extent the official disenchantment may have been justified. Indeed, the most influential recent scholarly work, by Edward W Constant II, serves, in effect, to underpin Whittle's own contention that the jet engine was so 'revolutionary' that neither piston aero engine companies nor government officials could judge it fairly or bring themselves to give the support that was merited. Thus Constant has used his concept of "the turbojet revolution" to support an extension of the Kuhnian analysis of the successions in scientific theories to explain technological change.[4]

In Constant's treatment, the established, highly successful piston engine design

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M M Postan, D Hay, J D Scott, *Design and Development of Weapons*, (London, 1964).

3
Sir Frank Whittle, *Jet*, (Frederick Muller, London, 1953). Whittle never deviated from the position he set out here for the rest of his life although he amplified the account in interview to produce an expanded version of this interpretation of events entitled *Whittle - the True Story*, by John Golley, (Airlife, Shrewsbury, 1987).

4
Edward W Constant II, 'A Model for Technological Change Applied to the Turbojet Revolution', *Technology and Culture*, 14 (1973): pp 553-572.

and manufacturing culture was disrupted and overthrown by the jet rather as the Ptolemaic view of the universe was overthrown by Copernican cosmology.[5] It is an important element of the Kuhnian position that this type of process will be accompanied by a kind of emotional resistance in the minds of practitioners, followed by a psychological step-change in perception "akin to a conversion experience".[6] Constant finds plenty of evidence, from Whittle's account, to support this contention but it is argued here that the analysis is problematical in that it tempts us to view contemporary 'anti-Whittle' opinions and actions merely as manifestations of a 'pre-jet' mental paradigm. It certainly seems odd that so sophisticated an analysis as Constant's largely supports Whittle's own view of the difficulties he met; Constant's history and Whittle's own are, in a sense, complementary. However, I suggest (and have argued elsewhere) that officials and engineers were far more open-minded towards the gas turbine than Constant, or indeed Whittle, have acknowledged.[7]

The popular histories naturally take an even more emphatic line on the supposed poor treatment meted out to Whittle, and often adduce the jet story as supporting element for the familiar assertion that "Britain is good at inventing but bad at developing" which has been analyzed by Edgerton.[8] Whittle's death

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5
Edward W Constant II, *The Origins of the Turbojet Revolution*, (Baltimore, 1980). This is a much longer analytical and narrative account of the introduction of the turbojet which rests on his earlier 1973 paper (n. 4 above) which initially set out his theoretical model.

6
See, for example, the contributions of J W N Watkins, T. Kuhn and K. Popper in *Criticism and the Growth of Knowledge*, ed. I Lakatos and A Musgrave, (Cambridge, 1970).

7
Andrew Nahum, 'Two-Stroke or Turbine? The Aeronautical Research Committee and British Aero Engine Development in World War II', *Technology and Culture*, April 1997, pp. 312-354. This work suggests that the development history of war-time engines does not reveal an 'emotional commitment' to the piston engine that a Kuhnian interpretation would imply. For example, Harry Ricardo, one of the greatest piston engine researchers wrote to Sir Henry Tizard in 1940 that "in the long run the turbine will be more reliable than the reciprocating units."

8
David Edgerton, *Science, Technology and the British Industrial 'Decline', 1870-1970*, (Cambridge, 1996), p. 30 and subsequent passages.

in 1996 produced a virtual orgy of this kind of comment, with even the most serious newspapers peddling accounts which verged on the absurd and revealed a startling ignorance both of the realities of engineering development and of historical analysis. Typical of the genre was the obituary in *The Guardian* which depicted "a genius frustrated by official disinterest and political manipulation" and which asserted, quite fictitiously, that the Air Ministry "repeatedly declared ... the idea was largely pie in the sky".[9] *The Daily Telegraph* referred to Whittle "at times using scrap metal" which intentionally conjured the image of the great inventor rootling for rusty scrap in a car breaker's yard[10] while *The Times* asserted that his ideas were "scoffed at" by the Air Ministry.[11]

All these accounts reveal, or affect, complete ignorance of the pre-existing background to gas turbine work in several countries and a technological determinism of the most naive kind. Rather few historians, or indeed engineers, given a moment to reflect, would assert that there would have been no jet engine without Whittle but the obituary in *The Independent*, contended, like

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9
Obituary; 'Sir Frank Whittle', *The Guardian,* 10 August 1996. This obituary also asserted that the Air Ministry chose "Dr W S Farren ... as their 'independent' consultant [who] was outspokenly hostile to Whittle's ideas" which shows how dangerously partial these accounts are. There is little evidence that Farren (later Sir William Farren, Director of the RAE and subsequently chief designer for the Avro company) was ever "outspokenly hostile" although in 1936 he was sceptical about high altitude, jet propelled flight and subsequently had reservations about the structure and commercial intentions of Power Jets *vis a vis* the Government interests. However, Whittle himself recorded that in 1938, during a hiatus in work on the engine when he was considering whether to return to mainstream RAF duties, Farren (then Deputy Director of Scientific Research at the Air Ministry) declared that the Ministry would only continue to support Power Jets if "I wished to go on, because their whole interest in the job rested upon their confidence in me ... If I gave up ... the work could stop; they would not consider appointing a successor". Sir Frank Whittle, (*Jet*, n. 3, above), p 81.

10
Obituary, *The Daily Telegraph*, 10 August 1996. Whittle's own statement was that, in 1938 "we were still gravely handicapped by finance. At least half the engine ought to have been scrapped because of general deterioration". Sir Frank Whittle, *Jet*, (n. 3 above), p 86.

11
In a novel interpretation, not used before, which has resonances with a punishment posting to the Russian front, the Times also suggested that Whittle's superiors felt that "his career as an inventor was detracting from his professional duties and he was sent ... to test seaplanes ... [where] he had several brushes with death". Obituary; Air Commodore Sir Frank Whittle, *The Times*, 10 August 1996.

those in most of the other newspapers, that "Whittle changed the lives of countless millions of people throughout the world". Ascribing a marvellous immutability to the historical account it asserted as fact that "the Ministry of Aircraft Production did not take the pressure off him and allow him to get on with the job is well documented and part of history".[12]

It is clear that the notion that Whittle accomplished his engine work against a background of official indifference or in the teeth, as it were, of Air Ministry opposition is so prevalent that it has entered the folklore of the subject both at a scholarly and at a popular level and this contention must be examined critically.

The account here is, I believe, largely new and will show that, contrary to the accepted historiography and to myth, Whittle was treated with considerable indulgence by the Air Ministry and by MAP. Fresh sources from the Power Jets side, and official papers, have made it possible to uncover the nature of the war-time relationship between Power Jets and the MAP and the sources of friction. It has also been possible to throw new light on the wartime nationalisation of Power Jets (an event that was particularly resented by Whittle's adherents) and to show that the impetus to take this politically tricky action gained sufficient force because it appeared to satisfy two quite different policy aims. There was, on the one hand, the desire of MAP officials to deal with the stalled jet engine programme and the acrimonious relationship with Power Jets. On the other hand there was Stafford Cripps' visionary and strategic intention to modernise Britain's industrial base (which has been examined in the previous chapter) and his intention to establish a vibrant aircraft sector sustained by vigorous government R&D establishments. In his scheme Power Jets, with its undoubted talents and brainpower, would become one of these centres.

12
The history implied is presumably the obituarist John Golley's own volume, (n. 3 above).

The Early History of Power Jets

Frank Whittle entered the Royal Air Force as an aircraft apprentice in 1923. The three year course in which he was enrolled was designed to produce the aircraft mechanics and service personnel required to repair and maintain RAF aircraft but, by exceptional ability and effort, he was one of only five apprentices (out of 600 in the initial intake) selected to go on to train as an officer cadet and pilot at Cranwell, the RAF training college. Whittle took a keen interest in aeronautical developments and in 1928 his contribution for the cadets' termly thesis was entitled *Future Developments in Aircraft Design*. He anticipated a large improvement in aircraft speed, coupled with an increase in the heights at which aircraft flew, in order to take advantage of reduced air resistance at high altitude. He recognised that in a conventional piston engine power falls off with altitude and considered in some detail, as part of this overall view of aircraft evolution, the efficiency and thermodynamic design of a gas turbine. He observed that although a steam turbine would be impractical for aircraft owing to the weight of boiler and condenser, nevertheless "the turbine is the most efficient prime mover known [so] it is possible that it will be developed for aircraft, especially if some means of driving [it] by petrol could be devised".[13]

At this time Whittle considered exclusively the use of an internal combustion gas turbine driving a propeller. However, in the following year he realised that a gas turbine could be constructed to produce a propulsive jet. This was original and transformed the gas turbine problem. The idea made the Whittle gas turbine/jet engine conceptually different to the well-established steam turbine, in which as much energy as possible is extracted as rotary shaft horsepower from the steam by successive turbine stages, and instead left as much energy as

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13
Frank Whittle, *Future Developments in Aircraft Design*, 1928, manuscript thesis, Science Museum archives.

possible in the exhaust gas stream to form a high velocity exhaust jet. This simplification of the gas turbine was to make Whittle's jet proposal attractive for development at a time when it seemed that the combined inefficiencies of the compressor, the turbine and the required reduction gearing and propeller drive would be, in aggregate, too great to make a propeller turbine unit viable.[14]

In 1929 Whittle's commanding officer arranged for him to discuss these ideas at the Air Ministry where he met W L Tweedie, a technical officer in the Department of Scientific and Industrial Research (DSIR) and A A Griffith of the RAE. The result, Whittle recorded, was "depressing" and he subsequently received a written opinion that the engine was impracticable (for the time being) because materials did not then exist capable of withstanding the high temperatures and stresses that would occur in the turbine stage of the engine.[15]

However, the important point about this episode is that Whittle had been taken seriously enough to be invited to discuss his proposals at high level.[16] Whittle,

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14
To avoid confusion it should be made clear that there are types of gas turbine today, such as turboprops, helicopter engines and land-based power generating sets, in which a sufficient number of turbine stages are provided to extract almost all the useful energy from the exhaust to give rotary shaft power and there is no residual jet thrust.

15
The widespread impression of Air Ministry prejudice against the gas turbine at this time derives from Whittle's account where he blamed his reception on "a very unfavourable report ... that had been written some years before". Whittle, *Jet*, (n. 3 above), pp 25 & 26). His impression of the tenor of this report, by W J Stern, of the Air Ministry Laboratory, South Kensington, has been repeated by almost all subsequent authors ('The Internal Combustion Turbine', Aeronautical Research Committee, Engine Sub-Committee Reports, No. 54, September 1920). In fact, it was a professional piece of work which considered the parameters for an aircraft gas turbine (rather than rejecting it out of hand) but noted that contemporary compressor efficiency was too poor to support a gas turbine cycle while heat-resisting materials for the turbine stage were not available. He opined that "the internal combustion turbine will not be rendered practical by the revolutionary design of some lucky inventor. The steam turbine engineer and the metallurgist ... are the people with whom the future development of the turbine rests". It should also be noted that Stern, as a member of a special panel of the Aeronautical Research Committee in 1930, did recommend construction of a turbine to the design of A A Griffith "if it would provide an unequivocal check on the theory". (Report of HE 1 Panel of the ARC Engine Sub-Committee, PRO DSIR 22/68).

16
Although the letter (probably written by A A Griffith) intimated that the Air Ministry did not

(continued...)

in his memoir, appeared not to realise how exceptional such access must have been for a newly commissioned Pilot Officer since Griffith was then one of the most eminent Air Ministry scientists, a member of the Aeronautical Research Committee (ARC), and had an important voice, through the ARC's Engine Sub-Committee, in the national direction of aero engine policy.[17] Griffith had also proposed his own gas turbine project (to drive an airscrew) as early as 1926, which derived from his new, and highly influential, aerodynamic theory for axial flow turbine and axial flow compressor design. It is an interesting historical point that, from 1937 workers at the RAE (in particular Hayne Constant) began a parallel 'government' gas turbine programme, though with less priority than Whittle was to receive. Ultimately, the main axial flow development of post-war British aero engines was to flow his work.[18]

From this perspective, the attitude of the Air Ministry can scarcely be viewed as

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16(...continued)
wish to pursue Whittle's scheme at that time it observed that "the internal combustion turbine will almost certainly be developed into a successful engine, but before this can be done the performance of both compressors and turbines will have to be greatly improved. However it has been of real interest to investigate your scheme and I can assure you that any suggestion submitted by people in the Service is always welcome". Quoted by W. Bailey, *The Early Development of the Aircraft Jet Engine*, 1995, (unpublished account from a wartime gas turbine worker at RAE, deposited with Royal Aeronautical Society, 1996, p. 9.) It was, Bailey observes, "a kind letter".

17
The ARC gave advice to the Air Ministry on future directions for research at the RAE and NPL as well as helping to set out desirable developments to explore in the Ministry's contracts with its industrial suppliers. For a study of the role of the ARC in inter-war aero engine development see Nahum, 'Two-stroke or Turbine', (n. 7 above).

18
A A Griffith, *An Aerodynamic Theory of Turbine Design*, RAE Report No. H.1111, 7 July 1926. Griffith's paper indicated that the then current axial flow compressors were inefficient because they operated with the blades in a stalled condition. Designing them in the light of aerodynamic theory and regarding them as rotating wings would, he argued, allow a large increase in efficiency and make possible a practical gas turbine. Griffith's ideas led to a line of transmission through the war-time RAE turbine work, which was the basis of an engine built by Metropolitan Vickers, to its successor, the post-war Armstrong Siddeley Sapphire, and thence to Avon and the main post-war Rolls-Royce engines. Griffith, in fact, joined Rolls-Royce as Chief Scientist in May 1939. From this perspective, the Whittle engine, with its use of a centrifugal compressor could be regarded merely as a temporary expedient. Griffith has another independent reputation in the field of materials science, also developed while at the RAE, for developing a new understanding and method of analysis for the initiation and propagation of cracks in materials under load.

negative or discouraging and its actions should be viewed as showing sympathetic recognition of Whittle's aptitude and potential. This can also be seen in the Ministry's decision to allow him to attend Cambridge University. Whittle completed the Officer's Engineering Course in 1933 with distinction. The Air Ministry had, in the past, sent one or two outstanding officers from this course on to Cambridge to take the Mechanical Sciences Tripos but this scheme had been officially terminated in the preceding year. However, Whittle asked for special consideration and, in view of his excellent results in the RAF engineering course, the Air Ministry, exceptionally, revived the scheme for him.[19] Additional evidence of favourable treatment for Whittle can be adduced from the fact that, following his achieving First Class Honours in the examinations in June 1936 at Cambridge, the Ministry approved an application from his tutor for him to spend an additional post-graduate year there working with the eminent aerodynamicist Sir Brian Melvill Jones.

The Formation of Power Jets Limited

While at Cambridge Whittle received, in May 1935, a letter from a former RAF colleague, Ralph Dudley Williams, c/o General Enterprises Ltd, Callard House, Regent Street, (Manufacturers of Genterprise All British Products)". Williams wrote;

> just a hurried note to tell you that I have just met a man who is a bit of a big noise in an engineering concern and to whom I mentioned your invention of an aeroplane, sans propeller as it were, and who is very interested ... Do give this your earnest consideration and even if

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19
"The Air Ministry had, a short time before, discontinued the practice of sending one or two officers selected from the [RAF] Engineering Course to Cambridge University to take the Mechanical Sciences Tripos. I therefore sent in a formal application that my case should be specially considered". The Air Ministry noted that "in view of this Officer's excellent work on the specialist [engineering] course they have decided as an exceptional case to allow this Officer to proceed to Cambridge University". Frank Whittle, *Jet*, (n. 3 above), p. 42.

you can't you might have something else that is good".[20]

General Enterprises, the unlikely bridgehead for the "turbojet revolution", in fact marketed an unglamorous and technically undemanding product - a coin-operated cigarette vending machine and had been formed with by Williams and his partner, J C B Tinling, also a retired RAF officer, with a loan of £1500 from Williams's sister. Williams recalled that the spur to his contacting Whittle again was a chance meeting at lunch with Tinling's father, a consulting engineer who observed, "there's a war coming - why don't you chaps get into the aircraft business".[21]

R D Williams had been a fellow cadet with Whittle at the RAF College, Cranwell, in the September 1926 intake. Their batman introduced them as they were to share "digs". Williams, in a striking phase that echoed the impact Whittle had on many of his associates, recalled later "I just fell for him".[22]

Whittle struck a deal with Williams and Tinling, whereby they would seek

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In the post-war period Ralph Williams changed his name to Rolph Dudley-Williams and embarked on a career in politics. He was elected Member of Parliament for Exeter, (1951-1956), Parliamentary Private Secretary to the Secretary of State for War (1958), and to the Minister of Agriculture, (1960-1964). He was created Baronet in 1964.

21
Sir Rolph Dudley-Williams (Personal communication, 1985), recalled that "Tinling's father was a consulting engineer - very able". . Subsequently Tinling's father, J A Tinling, attempted to claim a share of credit for the development of the jet, writing in 1944, that "an entirely false impression had been given to the world at large". His second wife, Daisy Tinling, claimed that "it should be known and publicly acknowledged that it was primarily my husband's vision and foresight in 1934 which led to the discovery of Whittle ... my step-son was merely an interloper who evidently set out from the start to crib his father's idea and only made a success through his father's financial connections. That may be very clever but it's not cricket.". In an article, ('A Wife's Part'), she expanded "but for my fancying a lobster at Verrey's, on that particular day, ... the Whittle plans would still be in the bottom drawer". J A Tinling to Power Jets Ltd, 21 January 1944, Daisy Tinling to Sir Maurice Bonham Carter, 27 January 1944, Daisy Tinling, 'Developing the Jet Plane', *The Recorder*, 1 April 1944, in Bonham Carter Papers, Science Museum archives.

22
Sir Rolf Dudley Williams, (n. 21 above). Sir Rolf recalled that "I was the person who got on with Frank best". They remained lifelong friends and, after the war, Whittle even gave an 'eve of poll' address for Williams who was standing as Conservative candidate, although Whittle then was a socialist.

commercial backing for the engine and would finance further patents. In return, they were to have each a quarter share of the commercial rights in the engine. Various approaches failed, until Tinling's father put them in touch with an able consulting engineer and patent agent, Mogens Bramson, who took the engine proposal to the City investment bank O T Falk.

Little has been written about the firm of O.T. Falk but its particular quality of unconventionality, compared to other merchant banks, and the personalities of its members, which included Lancelot Law Whyte and Sir Maurice Bonham Carter, forms a crucial part of the British jet engine story. The founder, Oswald Falk, had been Treasury Delegate to the 1919 Paris Peace Conference and had been described as "the only high-brow in the city". Whyte considered Falk personally to be "one of the Englishmen best informed on the political and military developments in Germany and the partners and senior employees as "all exceptionally intelligent men, ethically liberal, and intellectually radical". The bank was, he believed, "one of the important nuclei of anti-Hitler and pro-Churchill opinion in London at that time".[23]

Whyte was himself an unusual figure - a philosopher and an intellectual who had worked in, and kept up with, theoretical physics and who had a powerful interest in and sense of historical process.[24] After Cambridge, where he worked for a time in Rutherford's laboratory, he travelled to Göttingen in 1924,

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23
L L Whyte, *Focus and Diversions*, (New York, George Braziller, 1963), pp. 114-115. The status of O T Falk's as a nucleus of anti-Hitler opinion was stimulated by the period between 1927 and 1934 when Violet Bonham Carter, one of the most influential anti-appeasement campaigners (and wife of Maurice) conducted a *menage à trois* with her husband and O T ('Foxy') Falk. *Champion Redoubtable: the Diaries and Letters of Violet Bonham Carter, 1914-1945*, Mark Pottle (ed), (Weidenfield, London, 1997).

24
Ibid., pp. 54-55. Whyte took a scholarship for Trinity College, Cambridge, in 1914, but served in the artillery in the First World War. Returning to Cambridge he completed his degree and began experimental physics in Rutherford's laboratory but was unable to continue - an emotional dislocation he attributed to "almost monotonously happy" schooldays at the progressive Bedales school followed by the shock of the Battle of the Somme - "an image and a proof of how European idealism had befouled its home".

becoming friendly with Max Born and hearing Neils Bohr lecture on the new theory of the atom. Subsequently, in Germany, he met and had discussions with Einstein before deciding to leave academic life. He entered merchant banking through the mediation of Montagu Norman, Governor of the Bank of England.[25] Norman sent him to see Sir Maurice Bonham Carter, a partner at O T Falk.

Through his scientific training Whyte became the member of the bank most concerned with venture capital for proposals with a scientific or technical element, "raising money for the rare deserving cases". Thus he became a director in the early 1930s of Scophony, the company established to exploit John Logie Baird's television system but nursed "a secret hope ... that something wonderful would turn up for which I would throw over everything else". And although at first reluctant to meet when told by Bonham Carter that "a young flight lieutenant had invented a new aero-engine" he found this with Whittle. He wrote:

> It was like love at first sight, the impression he made was overwhelming. I have never been so quickly convinced, nor so happy to find one's highest standards met. Whittle held all the winning cards: imagination, ability, enthusiasm, determination, respect for science, and practical experience - all at the service of a stunningly simple idea: 2,000 h.p.with one moving part. This was genius, not talent. ... That night I told my wife that I had met one of the great inventive engineers of our time. ... it was like what I imagined was the experience of meeting a saint in a much earlier religious epoch: one surrendered to the enchantment of a single-minded personality born to a great task.[26]

Whyte's background in physics, his semi-mystical personality and his historical overview of the subject were crucial in conditioning his response to the Whittle jet. His reaction was more that of a historian of science and a physicist than that

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25
Ibid., pp. 112-113. According to Whyte, Norman broke his rule not to use his influence in City appointments because Whyte's sister and Norman's mother were both Christian Scientists. The City appealed to Whyte intellectually because "in the City one saw human desires being expressed in quantitative form. ... Did stock market prices quantify human lusts in the same way as the clinical thermometer converted human pathology into a numerical temperature?".

26
Ibid., pp. 138-139.

of a banker for, in evaluating it, he transferred directly to aero engineering the concept of 'elegance' which so often is advanced as a touchstone for the evaluation of mathematical proofs and scientific theories.[27] "The elegance of the idea won me. Every great advance replaces traditional complexities by a new simplicity. Here it was in the iron world of engineering".[28]

Armed with a favourable report from Bramson, who had now been asked formally by the bank to analyze the Whittle scheme, Whyte set out to raise capital and contacted Sir Henry Tizard for a supporting opinion. Tizard was, at that time, the chairman of the Aeronautical Research Committee (ARC) and the defence scientist who was uniquely trusted by the Air Ministry and the RAF.[29]

At the time of Whyte's approach Tizard was deeply immersed in the debate about the possibility of German bombers delivering 'a knock-out blow' to Britain and in the development of the revived air defence system for the UK. The Committee for the Scientific Survey of Air Defence, (more usually known as the Tizard Committee) had first met in January 1935, and, from the outset, became the nursemaid for the emerging technique of radar.[30] Tizard personally

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27
See, for example Graham Farmelo (ed.), It Must Be Beautiful; Great Equations of Modern Science, (London, 2002).

28
L L Whyte, 'Focus', (n. 23 above), pp 77-90. Whyte's immersion in the history of science may be glimpsed in his semi-mystical attachment to Kepler, the 16th century astronomer, to whom he wrote in his journal. He was fascinated by Kepler's emotional and imaginative search "to read the work of God" in the Heavens and his search for concealed numerical harmonies, finding in it a striking anticipation of Einstein's hopes for a unified theory. "Your unique significance in the history of physical theory became evident to me in the 1920s, and slowly I began the search for Kepler. This hunt had to go on beside my astrology (using Elephantine Tables of dividends to tell innocent folk which shares should go up)".

29
Tizard had experience of the technical and scientific evaluation of aircraft and weapons going back to the First World War when, as a scientist, he had learned to fly and had become involved with the new field of testing military aircraft but the respect in which he was held also derived from his incisive and pragmatic judgement. See Nahum 'Two-stroke or Turbine', (n. 7 above) for a discussion of Tizard's influence on the wider field of aero engine development and its linkage, through him, with the emerging technique of radar-directed interception.

30
PRO AIR 2/4481, 'Formation of a Scientific Committee on Air Defence'.

was central to the promotion of radar research and its implementation to create the radar 'chain' around the eastern and southern coast of Britain. However, he showed a striking strategic vision which went far beyond the actual technique of radar, for he realised that in order for it to become a powerful addition to air defence it had to be integrated into the operational control of aircraft. Thus even before radar was available to the service he set up a series of experiments which were performed by the RAF (the Biggin Hill Interception Trials) in which controllers used radio to set defending fighters onto 'dummy' intruders flying a known track, in order to explore the technique of interception and the 'vectoring' of the defenders.[31] These trials enabled the crucial new techniques for communication and for ground control of fighters to be developed, together with procedures for reporting, plotting and directing them to the intruders.[32]

The trial also showed that radar detection was only one element in successful defence and that "the interception problem was different to the detection problem".[33] The analysis of this work thus indicated a new direction for engine work. Prior to radar, defending aircraft (in which little reliance was actually placed) were expected to spend considerable time ready at height in "standing patrols" and a reasonable fuel consumption was needed. The Biggin Hill trials showed that the emphasis should change towards very high power engines, giving the maximum speed and rate of climb from take-off on receipt of the radar warning, even at the expense of heavy fuel consumption, and Tizard

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31
PRO AIR 2/2642, 'Interception Experiments for the Tizard Committee'.

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An enormous amount of detailed work has been subsumed, in most accounts of British air re-armament, under the rubric of 'radar'. Thus the Biggin Hill Interception Trials, designed to assess and develop the accuracy with which fighters could be set onto intruding aircraft, are evidence of his forward thinking as they were put in hand, at Tizard's instigation before the radar chain was in being and while it was still a hope rather than a reality. ('Interception Experiments', n. 31 above). See also R V Jones, 'Tizard's Task in the War Years' in W S Farren, "Henry Thomas Tizard", *Biographical Memoirs of Fellows of the Royal Society*, Vol 7, 1961, pp 331-348).

33
R V Jones, 'Tizard's Task in the War Years', (n. 32 above).

argued explicitly from 1935 for "the maximum excess speed over the bomber". Privately, he wrote to his friend Harry Ricardo, the engine research engineer (also an influential fellow member of the ARC Engine Sub-Committee), that "what I want is an engine which gives a terrific power for its size and weight ... through a high consumption so that long distance bombing machines could not compete". [34]

The Whittle engine clearly fell into this category and the tactical defence thinking outlined here clearly lay behind the encouraging terms in which he wrote to Whyte stating that "I am particularly interested in this work because I think that, if we are to provide the high powers which will be necessary for the aircraft of the future, we must develop some kind of turbine". Indeed, one could go farther and suggest that it was only because the hypothetical jet (which had not yet run) appeared to fit closely into this emerging tactical requirement that it was considered at all, given the high level of demand on both the R&D and the productive capacity of the industry imposed by the RAF expansion programme.

Tizard, however, noted that he had a very high opinion of Whittle, who had "the ability, energy and enthusiasm for work of this nature" and an intimate knowledge of practical conditions. "This combination of qualities is rare", he wrote, "and deserves the utmost encouragement".[35] Tizard rated it highly probable, given adequate finance, that Whittle would succeed in producing the new powerplant.

O T Falk put considerable store on Tizard's letter, quoting it to possible

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HTT 77, letter to Harry Ricardo, 25 May 1938, and paper 'Future Designs of Fighting Machines', September 1938, HTT 10/1, Tizard Papers, Imperial War Museum. Also PRO DSIR 22/58 to 22/68, ARC Engine Sub-Committee minutes, particularly for 10 January 1936.

35
H T Tizard to L L Whyte, 22 June 1937, Tizard Papers, Imperial War Museum, HTT 153a. Tizard added as postscript "Of course I do not mean to imply that success is certain. All new schemes of this kind must be regarded as 'gambles' in the initial stages. I do think however that this is a better gamble than many I know of, on which much money has been spent!".

investors and it is interesting to note another point that Tizard made which also confirms the linkage with re-armament for he observed that "my general opinion of the importance of this work leads me to express the hope that the money will be raised privately so that the knowledge that it is going on will not be widespread". This and other observations suggest that the capitalization of Power Jets could be regarded almost as a surrogate official venture, or certainly an officially sanctioned one. A letter drafted by Maurice Bonham Carter to Lord Wakefield, head of the Castrol petroleum company and a well-known promoter of aviation, summarised the thinking behind this position, which appears to have been tacitly accepted both within the Air Ministry and in Power Jets.

> It is generally agreed ... that at this stage, both to avoid delay and the restrictions necessarily imposed by finance from the Treasury, the initial expenditure should come from private sources. ... I am approaching a very few private individuals only who recognise the nature of the business and its public interest.[36]

Within this circle the phrase "public interest", I suggest, then signified air re-armament. To the banker Peter Samuel, Bonham Carter made more explicit the quasi-official support for the project and the understanding, among those responsible for finding finance for Power Jets, of the essential contribution that it was expected public money would make. He noted that:

> it is of course accepted by all concerned that the development of such an engine to the stage of commercial production requires a large expenditure far beyond any sum which we have in mind to raise now. We anticipate that material contributions towards this expenditure will be provided in due course from official sources by way of development grants. As you are aware, we are already in negotiation for an initial research grant. But it is agreed by all concerned (including, as you will see from his letter, Sir Henry Tizard) that in order to avoid the delay and the restrictions imposed by finance from the Treasury, the initial expenditure should be raised from private

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36
Papers of Sir Maurice Bonham Carter relating to Power Jets, (hereafter Bonham-Carter papers), Science Museum archives. Sir Maurice Bonham Carter to Lord Wakefield, 14 July 1937 (draft, possibly not sent). There were also some less politically aware clients of O T Falk who were nevertheless steered into the shares by Whyte or Bonham Carter and this led to trouble later.

sources.[37]

The new company was registered on 19 March 1936 and the basis of its constitution was the so-called Four Party Agreement between O T Falk, the Air Ministry, Whittle, and, together, Williams and Tinling. O T Falk were represented on the board of the new company by L L Whyte (as chairman) and Sir Maurice Bonham Carter as a director. The other directors were R D Williams and J C B Tinling, while the Air Ministry contributed Whittle as Chief Engineer at no cost to the company.[38]

Various authors, and Whittle himself, have made much play with the arrangement set out in the Four-Party Agreement whereby Whittle could act as honorary Chief Engineer to the new company "provided that the work ... shall not conflict with his official duties and ... shall not ... in any one week exceed a total of six hours". This is disingenuous. The Air Ministry may not have wished to openly admit that Whittle was assigned full-time to a privately financed company for the purposes of developing an engine that many regarded as fanciful, but that clearly was what occurred. During his extra postgraduate year at Cambridge up to June 1937, which the Air Ministry had approved, Whittle worked largely on his engine design. After this he was placed on the "Special

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Ibid. Sir Maurice Bonham Carter to The Hon. Peter Samuel, 20 July 1937. Bonham Carter also stressed that the company's expenditure was being conducted "on a very conservative basis", that the Board was receiving no fees and that "Flt. Lt. Whittle, who is seconded for service for this work, is remunerated by his normal pay as an officer in the Air Force".

38
The exact constitution of Power Jets, share allocations and voting rights is not germane to the arguments here but the financial history of the company is extremely well treated by R Schlaiffer in R Schlaiffer and S Heron, *Development of Aircraft Engines and Fuels*, (Boston, 1950), pp 336-348. This study, conducted principally by Schlaiffer at the Graduate School of Business Administration, Harvard, remains the most authoritative work on the technical and financial history of pre-war and wartime engine work conducted in the USA, Germany and Britain. At the first meeting of the Directors of Power Jets held on 26 March 1936 it was "resolved that Flight Lieutenant Whittle be appointed honorary chief engineer and technical consultant of the company for a period of five years ... at the discretion of the President of the Air Council". Bonham Carter Papers, (n.36 above).

Duty" list and was not assigned to a squadron or to an RAF station.[39] These measures make it clear that there was tacit acceptance of his central role at Power Jets and this, in itself, was a substantial contribution - a pilot who was acknowledged to be of the highest quality, trained at substantial public expense, was, at a time of deep foreboding about national defence, contributed to a rather risky engine development programme. As further evidence of exceptionally favourable treatment we should note that in this period Whittle was promoted to the rank of Squadron Leader, although he was excused the usual examination.[40]

We can see from the outset that the structure put in place to finance the Whittle jet was odd. It is true that it initially used private capital, although the single most substantial investment was from Lord Weir who was prepared to deploy funds in the national interest. Weir had been Controller of Aeronautical Supplies at the Ministry of Munitions in the First World War, where he had been assisted by Sir Maurice Bonham Carter and a firm friendship between them dated from that time. By May 1935 Weir had returned to munitions production, joining the Air Ministry as a special adviser to the Secretary of State. However, he took up shares in Power Jets privately through his engineering company G. & J. Weir. following a direct approach from Bonham Carter.[41]

Power Jets and the Air Ministry now began negotiations to establish a form of development contract whereby the Ministry would pay progressively for

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Quoted in Whittle, *Jet*, (n.3 above), p 50.

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Bill Gunston, *The Development of Jet and Turbine Aero Engines*, (Patrick Stephens Limited, Yeovil, 1995), p. 125.

41
Bonham-Carter papers (n. 36 above). Sir Maurice Bonham Carter to Lord Weir, 15 October 1937. He noted that "we have been able to settle a new agreement with Flt. Lt. Whittle ... which, as you are aware, has also involved some negotiation with the Air Ministry as he is a serving officer". Also Sir Maurice Bonham Carter to J G Weir, 15 and 27 October 1937, and reply, accompanying cheque for £3000, 2 November 1937. See also W J Reader, *Architect of Air Power, the Life of the First Viscount Weir of Eastwood*, (London, 1968), pp. 57, 200-225. Weir refused payment for his public service during re-armament and seems possible that he approached the Power Jets investment in the same spirit.

research and running experience with the engine. David Pye as Deputy Director of Scientific Research (DDSR) at the Air Ministry, with a special responsibility for engine development, proposed a series of staged payments to Whyte in July 1937 amounting to £5000. After twenty hours running and when the engine had reached a designated speed, the Air Ministry was then to purchase the unit for a further £5000 but would put it at the disposal of Power Jets for further running. This schedule was arrived at by Pye in discussion with his assistant, William Farren. Both these men have been depicted by Whittle as being sceptical about jet propulsion, and as obstacles to him, but this account prefers to take Pye's letter to Whyte, as Chairman at Power Jets, at face value. He wrote that "my only concern is to devise some kind of co-operation which would be financially acceptable to the Air Ministry, and would ensure that research proceeds actively with present unit".[42]

Pye also added that the series of contracts he proposed was "quite outside the normal run of such things [but] the whole project is exceptional and calls for exceptional treatment and if an arrangement on these lines would be acceptable to you I will do my best to see it through. It leaves no room for doubt that we at the Air Ministry regard the scheme ... as theoretically sound".[43]

In fact the sum offered was subsequently reduced to £5000, possibly on the advice of the Ministry's Contracts Directorate, which appeared to be uneasy about the firm's standing and its close relationship to a merchant bank. At this time the share capital raised by O T Falk and Partners was only of the order of

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Bonham-Carter papers (n. 36 above), D R Pye, Air Ministry to L L Whyte, 5 July 1937.

43
Ibid. The schedule proposed was:

1 £1000 for a full report on all work to end of July, running unit up to 12,000 rpm.
2 £2000 for 10 hours further observed running up to 14,000 rpm.
3 £2000 for 10 hours at speeds up to 18,000 rpm.
4 On completion of this research running, £5000 to be paid for the unit, with the intention to put it at your disposal for further running.
5 Separate research contracts for associated work such as experimental combustion chamber tests.

£5000 and, furthermore, Falks did not take up its option to extend its own shareholding to £20,000. Even Whittle's sympathetic biographer has had to admit the quandary in which this placed officials. "The Air Ministry ... wished to make an offer to the Company which would be sufficient to encourage further finance to back the project, but they mistrusted a group of financiers who began to get cold feet, after raising only £5000".[44]

Although these sums may now seem small the proposed initial government contributions amounting to £10,000 equates to about £240,000 in 2002 prices and should be related to the total authorised share capital for Power Jets of £25,000. In relation to the scale of the company's operations these were substantial payments. However, they were not adequate to sustain the experimental programme and it is fair to note that Air Ministry officials did have some misgivings about Power Jets. Certainly the capabilities of the new firm were meagre, compared to the companies they usually dealt with like Rolls-Royce and Bristol with huge numbers of operatives, draughtsmen, design engineers and so on. In 1938 Whyte approached the Air Ministry for further funding. The official history notes that:

> the Air Ministry did not rate the judgement or the resources of the firm very highly. The Director of Scientific Research had early expressed the fear that the Directors of Power Jets were over-optimistic about the speed with which results would be obtained. When Power Jets began to ask for help at the first hint of development difficulties, which were no greater than those which experienced engineering firms would have considered inevitable and taken in their stride, the authorities in the Air Ministry felt confirmed

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44 John Golley, *Whittle*, (n. 3, above), p 95. Postan, in the official history also makes the point that "in the past, as a matter of principle and convenience the Air Ministry had given financial assistance only to the well established firms in the aircraft and engine industry and did not give financial backing to bankers, investment houses or promoters, no matter how close their connection with the aircraft industry. And it so happened that ... Whittle was being sponsored by a City firm, and financial assistance to them would have been a new departure and a precedent. Postan et al., *'Design and Development'*, (n. 2, above) p. 193.

in their low opinion of Power Jets.[45]

We have seen that the constitution of Power Jets was unusual. There was the low-key Air Ministry contribution of Whittle, with partial official funding and encouragement. These were elements that were not, with hindsight, ideal, and which may have helped to sow the seeds of trouble later, but it is hard to see how a fully funded experimental jet programme could have been created, unless the Air Ministry had insisted on the development programme being placed with one of the Ministry's trusted contractors, such as Rolls-Royce. It is to the credit of officials they took the risk of proceeding with Power Jets at all and it seems clear that the basis on which the company was established was tacitly understood by both sides. Robert Schlaiffer, who wrote a masterly history of aero engine development in the immediate post-war period, and who had the advantage of communication with Sir Maurice Bonham Carter, noted that "it was realised by Falk and Partners from the beginning that the entire undertaking would ultimately have to be a partnership with the state, and the extensive rights granted to Whittle were granted to him in large part as a representative of the state".[46] The closeness of the enterprise to British re-armament efforts was also underlined by the understanding that Power Jets would abstain from approaching foreign sources for funds.

By 1938 there was a variety of high power engine work being conducted in Britain in response to the bomber threat. The Whittle jet was at one, more speculative, end of the "portfolio" of the R&D investments sponsored by the Air Ministry, and there was also an axial flow jet engine emerging at the RAE under the auspices of Griffith's 'disciple' Hayne Constant. Tizard had a great sense for energy in people and projects and also sought to promote the rival 'government' gas turbine at the RAE being built in association with Metropolitan-Vickers, but he noted that the company "was making progress but

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Postan, (n. 2, above), p. 193.

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Schlaiffer and Heron, *The Development of Aircraft Engines and Fuels*, (n. 38 above), p. 341.

only slowly. There was no real drive behind it".[47] By contrast he did sense this drive in Whittle. Unfortunately, his influence in engine developments, and defence science in general, waned during the war as a result of the well-known antipathy between him and Churchill's preferred scientific adviser, Frederick Lindemann. This was a tragic loss in many fields, but for the Whittle project in particular, Tizard's tremendous pragmatism and good sense, both for engineering development and for professional arrangements, might well have helped the jet enterprise

Radical and ambitious piston engine projects were also under way, including the Napier Sabre, a massively complex 24 cylinder H pattern engine designed by Frank Halford intended ultimately to give 3000 hp, and the Rolls-Royce Crecy, a novel 12 cylinder two-stroke designed by the eminent engine consultant Harry Ricardo and enthusiastically promoted by Sir Henry Tizard as a 'sprint' engine for interceptors. Finally, there was the 'blue chip' investment, the relatively conventional but highly optimised V-12 cylinder Rolls-Royce Merlin, then giving about 1000 hp and developed to take advantage of the newly available 100 octane fuel.[48]

It is important therefore, to see the Air Ministry's support for the Whittle engine, as one element in a strategic initiative in the engine field which, in itself, was part of a larger programme for the expansion and re-equipment of the Royal Air Force from 1935 onwards. In the context of this re-armament the Whittle engine was given, it is argued here, quite a reasonable share of resources, given that, by 1938, it was considered by the Air Ministry that

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HTT 11/27, Tizard Papers, Imperial War Museum. In 1941, perhaps in response to the problems with the Whittle engine, Tizard also initiated the policy under which other designers and engine firms were asked to engage in gas turbine design. The highly successful de Havilland programme was one result.

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Tizard had promoted the adoption of the new 100 octane fuel for fighters, in place of the existing 85 octane, from 1936 onwards through the Aeronautical Research Committee since it allowed engines to stand higher powers without 'knocking' (a form of destructive detonating combustion which can occur in a highly loaded spark ignition engine).

production had risen to "the utmost capacity of aircraft firms".[49] In these few years the RAF moved from biplane fighters with engines of 500 horsepower, capable of 200 mph, carrying two machine guns and which weighed about 3000 lbs (1360 kgs) to a new generation of equipment - the new Spitfire and Hurricane monoplane fighters with 1000 horsepower, eight machine guns, a 330 mph top speed and a weight of 6000 lbs (2724 kgs). In addition, there were entirely new techniques for the operation and control of these aircraft to be developed.

This re-equipment and training programme in itself constituted a revolution in equipment and in tactics for RAF and it must be acknowledged as a brilliant success.[50] The force that was created proved to be just adequate, during the Battle of Britain, to hold the Luftwaffe which had been established specifically to wage offensive war by one of the most technologically advanced and industrially competent nations on earth. Against the urgent needs of this radical re-equipment and re-training of the RAF it is reasonable to ask how much more resource should have been devoted to the Whittle jet or to any other long-range piece of weapons research.

This account, therefore, strongly contests the notion that the Air Ministry was remiss in not supporting Whittle more. As we have seen, the Air Ministry did find ways to facilitate Whittle's work, using an unconventional route, and came, by 1939, to support the work almost entirely from public funds. Thus the point at issue about Air Ministry involvement for the Whittle jet is not so much

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M M Postan, *British War Production*, (HMSO, London, 1952 and facsimile edition 1975), pp 17-18.

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The total strength of the RAF in 1929 was under 29,000 people. This force was expanded more than threefold, to over 90,000 in three years. When it is considered that the majority of RAF personnel required a considerable degree of technical training, while at the same time the technical complexity and capability of the equipment was increasing enormously the expansion must be seen as an extraordinary achievement. For Lord Swinton's observations on the expansion, as Secretary of State for Air from June 1935 until May 1938, see his *I Remember*, (Hutchinson, London, 1948), pp 104-150.

whether the invention was adequately supported but whether the Ministry should have done what it did in 1939 earlier - perhaps in 1935, or even in 1929. However, the essential point to note about the jet engine, which events were to prove, was that its development was premature. By 1939 the metallurgy, the techniques for machining complex shapes and for fabricating the new components needed for the engine, instruments for vibration measurement and even the theoretical tools for analysing airflow through a jet engine, were barely adequate for the task of creating a functioning engine. Had it not been for the urgent expansion of the Royal Air Force and the attention to British fighter defence capability, there would have been little rational reason to force development so far from what was known. The troubled war-time development of the Whittle jet, which we shall review below, supports the view that this was not an invention whose natural time had come.[51]

Wartime Development, the Relationship with the Ministry of Aircraft Production, Disillusion

Since the story of the British jet engine is, in the early and mid-war years, one of conflict and disappointment, it is intriguing to ask whether the causes of this conflict can be teased out beyond the simplistic identification of 'official disinterest and political manipulation' or 'the apathetic malaise of industry and government' - opinions that have already been touched on. For this it is necessary to follow the steps that were taken to convert the prototype into a

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Since the Air Ministry has been subjected to such persistent attacks it is useful to observe that impeccable engineering authorities were equally sceptical. When the visionary official in the German air ministry, Helmut Schelp, who did most to launch the German turbine programme, attempted to recruit Daimler-Benz for gas turbine work in 1938. Fritz Nallinger, the head of development, argued that though the turbine might one day be of use the time was not ripe and declined to do any work on it. R Schlaiffer, *'Development'*, (n 38 above), p. 387. Also see Postan et al., *'Design and Development'*, (n. 2 above), p. 209.

production engine for service use in some detail.

The new Power Jets company had no production facilities of its own and so had entered into an agreement with the steam turbine specialists British Thomson-Houston at Rugby for detailed design drawings and the manufacture of an experimental prototype. Whittle and the small number of Power Jets personnel also took up residence at the BTH factory and began conducting tests there from October 1936 although, after some frightening incidents during test runs, Power Jets were moved to a former BTH foundry nearby at Lutterworth. The engine went through two redesigns and, in October 1938, testing began on the third version which defined, in its general architecture, the form the Whittle jet engine was to take during the period that the inventor remained in control.

Successful results began to accumulate and by June 1939 Pye (now Director of Scientific Research) witnessed a twenty minutes test run at speeds of up to 16,000 rpm - an experience which, in Whittle's opinion, marked "a dramatic change in D.S.R's attitude", while Sir Henry Tizard who was present at a trial in January 1940 remarked, with an insouciance that he may have come to regret, that "a demonstration which does not break down in my presence is a production job".[52] Air Vice Marshall Tedder, as DGRD (Director General of Research and Development) at the Air Ministry also saw a test run and felt he was in the presence of "a real war winner, justifying the manufacture of an initial batch of engines and aircraft to match, straight off the drawing board".[53]

The ground test engine (known as the Whittle Unit or W.U.) then served as a model for a geometrically similar unit, the W.1, which was built from new

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Sir Frank Whittle, *Jet*, (n.3 above) pps. 88,96.

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Lord Tedder, *With Prejudice*, (London, Cassell, 1966), pp. 10-11. Tedder functioned at this time within the Department of the Air Member for Development and Production, under Sir Wilfrid Freeman, which, since mid-1938 had been responsible for ordering aircraft and engines. This department was the nucleus for the Ministry of Aircraft Production, created in May 1940.

components, developed and certificated for initial trials of the Gloster-Whittle E.28/39 aircraft. These trials were strikingly successful. In particular, the engine was regarded as remarkably trouble-free in view of the entirely new principle of operation. However, the E.28/39, conceived from the outset as a research and test vehicle, was not suited for development into a fighter since the thrust of the W.1 design was inadequate to allow a reasonable load of fuel and armament. For this reason, the design was put in hand in 1940 with the Gloster company for a twin-engined fighter aircraft, the F.9/40, (subsequently known as the Gloster Meteor), while a design contract was also placed with Power Jets for a development suggested by Whittle - an enlarged and more powerful (but architecturally similar) version of the engine, known as the W.2, intended for this aircraft. Many of the ensuing problems of the Whittle engine programme stemmed from this apparently unproblematical decision to enlarge the engine.[54] The W.2 thus became a new design, for which no direct test experience existed.

As we have noted Power Jets did not have the production resources to build aero engines in the quantity required for the RAF. Moreover, its relationship with the BTH company was deteriorating and Power Jets were coming increasingly to suspect that BTH was attempting to appropriate the jet engine as its own product. Neither did BTH have any experience of aero engine practice and so Whittle and Air Ministry officials looked for a technically competent engineering firm to build the jet and the Rover car company appeared to be an attractive candidate. It had a reputation for building good quality cars and could be regarded as an 'engineering led', rather than a 'production-led' company and therefore suitable for a new type of job like this. It was involved in the aero piston engine 'shadow' production scheme and the engineering direction of the company was in the hands of Maurice Wilks, as chief engineer, while his

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The enlarged impeller for the W.2, being heavier and more highly stressed, became liable to fatigue. In addition the gas velocity at the compressor outlet became supersonic on occasion, producing a shock wave which could destroy the impeller. The engine also acquired a destructive resonance period. These were all subtle problems which could not easily have been predicted in 1939. Impeller failures were frequently catastrophic, since the debris would pass through the engine and into the turbine.

brother Spencer was managing director.[55] Air Vice Marshall Tedder announced the selection of the Rover company in March 1940 and noted that the Ministry had decided to call in a firm with production experience and suitable plant "to undertake development manufacture" and to co-operate closely with Power Jets "to ensure that development designs went along suitable production lines".[56]

Tedder also expressed the hope that there would be "a very intimate basis of co-operation" between Rover and Power Jets. However he certainly appreciated the possibility of friction between the firms and in a discussion with Power Jets and MAP officials in April 1940 he stated that he required "complete frankness between the engineers concerned" and that some arrangement would have to be made over the rights to future inventions arising from the engine development "so that there would be no barrier to this".[57]

By May 1940 difficulties were building up and Tedder noted that he had been worried by the way things were going and that "Mr Whyte had gone to quite unreasonable lengths in trying to safeguard [Power Jets'] position". However, "in spite of much provocation" he intended to keep Power Jets alive and was still resolved not to let it be swallowed by two larger companies".[58] These remarks imply a deep unease with Power Jets on Tedder's part and it is worth noting just how early in the war the relationship between Power Jets and government officials became strained. To Power Jets, though, it appeared that

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Whittle and his colleagues had, in fact, independently initiated contacts with the Rover company shortly before, but these had foundered.

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Bonham Carter Papers, (n.36 above). W E P Johnson, 'Chronological Memorandum of Various Facts and Records, PJ - Rover - M.A.P.', 7 April 1942.

57
Ibid.

58
Ibid. Whittle also recalled a meeting at this time discussion over patents with Sir Wilfrid Freeman, then Tedder's superior and in overall charge of development and production who opened the discussion with "what shall we do about this bloody man Whyte?". John Golley, *'Whittle'* (n 3 above), p 144.

the Rover managing director S B Wilks "was fighting hard to get a commercial position to which he was not entitled" and was "very persistent" in refusing to agree to safeguards for Power Jets. The Power Jets position was that Rover would make their profit on the production contract and they were increasingly suspicious of any actions which seemed to show that the company was seeking to consolidate commercial rights for the developed engine in post-war markets.

W E P Johnson, the patent agent at Power Jets, and a friend and former RAF colleague of Whittle's, was intensely loyal to the inventor and displayed a deep personal resentment of any action from Rover or from the official side which appeared to prejudice Whittle's rights. His suspicions appear to have had a foundation but one must also consider whether more measured responses, even in the face of great provocation, might not have been more productive. By August 1940 Johnson put it to an MAP official that:

> the Rover people had not the shadow of an excuse for wanting commercial rights outside the Air Ministry contract ... they were therefore trying to get something to which they were in no sense entitled. I asked him how on earth he expected me to co-operate willingly with people who were trying to get something to which they had no right".[59]

In discussing the relationship between the companies it must also be understood that the Rover company was faced with an enormous task. The enlargement of the Whittle W.1 design meant that the W.2 was an unknown and unproven article. In spite of Power Jets' jealousy over all the details of the engine this proprietorial attitude seems, in retrospect, hard to justify since the W.2 was not even at prototype stage. G B R Fielden, one of Whittle's most able engineers, opined many years later that "the W.2 engine was not a mechanically complete design when the decision was made to put it into production" and that what Rovers got, in the main,

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Bonham Carter Papers, (n. 36 above). 'Chronological memorandum, 7.4.42',

was an aerodynamic design which was "not quite right".[60] Another Power Jets engineer, Jim Boal, who had a rare continuity of experience of working on the W.2 engine at Power Jets, then at Rover, and finally with Rolls-Royce, also considered that initially "there was no W.2 design".[61]

Thus the situation was that in 1940 the Whittle team contribution to the W.2 was an aerodynamic design, which covered the characteristics of the compressor, combustion chambers and the turbine, and a general mechanical scheme for the engine. The actual engineering solutions for the construction of W.2 had not been fully established, but were being developed by extrapolation from the successful W.U and W.1 in the light of test results with prototypes of the W.2 design which revealed a continual stream of new problems. Rover, as contractor, also had to accommodate input from Gloster engineers on aircraft installation requirements as well as reacting to continuously evolving thinking from Power Jets and from their own engineers on materials, performance improvements and manufacturing solutions. It is not surprising, given the magnitude of the development task, that a sense of ownership should also have arisen from the Rover side. The position over the engine, with regard to production at Rover, was therefore quite different to the more familiar situation where a complex, but developed, product is built under licence by another manufacturer. The Bristol air-cooled piston engines, for example, were manufactured under licence by Gnome-Rhone in France during the inter-war period. In such a case the licensee generally trusts the originator of the

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60
G B R Fielden, conversation with the author,at the British Standards Institution, 2 June 1981. "Rovers' were sold a pig in a poke, poor devils. The W.2 had not run. ... Absolutely bonkers". Fielden's recollections are of great value in that became intensely involved in the Power Jets engine development directly after leaving Cambridge with a 'First' in the Mechanical Sciences Tripos and subsequently had a distinguished career in engineering, retiring as Director of the British Standards Institution. Though highly appreciative of Whittle's talents and creativity he was able to assess the direction of the project in retrospect after considerable experience of managing engineering development. He also observed "Whittle wanted to control everything - you couldn't change a split-pin without asking him". G B R Fielden, conversation with the author at the Science Museum, April 1981.

61
Jim Boal, conversation with the author at meeting of the 'Reactionaries' (Power Jets re-union), Brownsover Hall, Lutterworth 16 May 1981.

design, is most anxious to obtain all the drawings and 'tacit knowledge' which will enable it to succeed, and is, in the early stages at least, most reluctant to deviate from the design and practice of the 'parent'.[62]

In the rather different circumstances which obtained between Power Jets and Rover, technical disputes could be regarded as almost inevitable, given the magnitude of the task and the fluid nature of the design, although they were perhaps exacerbated by being played out as a kind of three-cornered negotiation between Power Jets, MAP and the Rover company. However, the tension between them was increased immeasurably when Power Jets learned in 1942 that the Rover company was attempting a radical redesign of the engine.

The engine, in the form evolved by Power Jets had an odd feature which independent engineers were bound to question - a double reversal of airflow, with the gas following, in effect, an S-shaped path between compressor and turbine. The Whittle team had done this to make the engine as short as possible in order to overcome the possibility of the destructive "whirling" of the shaft coupling the turbine and compressor (swinging out of line like a skipping rope) and to reduce the effect of thermal expansion between the outer sheet metal combustion parts and the inner shaft.

The disadvantage was that the reverse flow arrangement imposed extremely complex shapes for the combustion chambers and associated gas trunking which required highly skilled and laborious sheet metal manufacturing operations. This high requirement for the most skilled type of sheet metal work must have caused serious concern about the possibility of manufacturing the engine in quantity.[63]

62
Harry Collins, in *Changing Order: Replication and Induction in Scientific Practice*, (Chicago, 1992) has explored the notion of tacit knowledge in relation to the repeatability of laboratory work. Engineering development and engineering production also offer many examples of the importance of tacit knowledge.

63
Parts which are machined or cut from solid by lathes or milling machines can be delegated

(continued...)

Another factor against the reverse flow arrangement was that the two 180 degree changes of direction of airflow caused internal air resistance and cost a significant amount of power. It appeared early on in W.2 development that the projected power would not easily be achieved and this performance deficit seriously undermined the military case for the aircraft.

The response of the Rover engineers was to re-arrange the layout to get rid of the reverse flow feature. The compressor and turbine were kept to the same pattern, but the double wall counter-flow combustion chambers were replaced by "straight through" cans which had the form of simple cones and were far easier to make. The only additional problem brought by this re-arrangement was the requirement to provide a third bearing to support the longer shaft in the middle, and the need to provide a sliding coupling to allow the shaft to adapt to the thermal expansion of the hotter outer engine parts. Both of these considerations were accommodated by an ingenious coupling devised by the Rover engineer supervising the project, Adrian Lombard.[64]

It now appears that Rover had, in this period, encouragement for the re-design from Major G P Bulman, then in charge of engine development (as Director of Engine Development at the MAP) and his deputy Major A A Ross. The design work and construction of this straight-through engine was carried out in secrecy, and news of the development was kept for some time from Power Jets and from

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63(...continued)
relatively easily to less skilled operatives once the procedures, gauges and tooling have been established. By contrast, forming and welding sheet metal, especially of the heat-resisting semi-stainless grades used in the Whittle engine, is a highly skilled industrial craft which could not, at that time, be mechanised or de-skilled.

64
Whittle later claimed that "for some time before and during the controversy, I had standing on my desk a wooden model of a shaft coupling which we were proposing to use in our own "straight-through" engine when we could get around to it". *Jet*, (n. 3 above), p 210. Unfortunately he has given no details of the coupling which would enable us to judge the fairness of this implied accusation of plagiarism.

the more junior MAP representatives at the firm.[65] This was because the Power Jets view that MAP were unfairly partial to Rover was also matched by a feeling at Rover that sections of the MAP were overly sympathetic to Power Jets and that great pressure would be brought to bear to make them desist from the straight-through arrangement which they genuinely felt to be superior.[66]

The Rover company first officially presented the design (known as the B.26) at a meeting on Rover premises in February 1942 where it was described as a "re-arranged assembly for ease of production" and, to the subsequent fury of Power Jets personnel as "the first serious attempt to productionise the design".[67] Whittle took the view that a "straight through" engine was under consideration by Power Jets anyway, but that time could not be spared from development of the proven layout in order that jet fighters should reach the RAF as early as possible and, in any event, Rover had no remit to do development work.[68] The re-design seemed to bear out all their suspicions about Rover's intentions "to gain a commercial position to which they are not entitled" and W E P Johnson set out the grievances

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65
One strand of 'pro-Rover' official opinion can be glimpsed in this extract from a minute on the proposed Gas Turbine Collaboration Committee arguing that each firm should be responsible for its own development. "In the development of the W.2B engine Wing Commander Whittle has been regarded as qualified to speak 'ex cathedra'. Any suggestion that the Rover Co. should be given licence to embody their own views even in details of a purely mechanical nature has been accepted without enthusiasm. It is now clear that Wing Commander Whittle himself is far less assured of his own aerodynamic features and is therefore anxious to obtain help from anyone and is looking especially to Rolls-Royce. DDGEPD to DSR, Minute of 28 September 1941, PRO AVIA 46/237.

66
David S Brooks, *Vikings at Waterloo; the wartime work on the Whittle jet engine by the Rover Company*, (Rolls-Royce Heritage Trust, Derby, 1997), p.56.

67
Ministry of Aircraft Production, 'Rover W.2.B. Thrust Power Units for F.9/40. Extracts from Summary of discussion and principal decisions at Conference held on 11.12.42'. Document attached to W E P Johnson, 'The Rover Independent Development', 7 April 1942, Bonham Carter Papers, (n. 36 above).

68
"The policy vis-a-vis Rover has slowly but surely changed. They have gradually assumed the position of design and research authorities, though they show at every turn their technical ability to justify such a position". W E P Johnson, 'Chronological memorandum, 7.4.42', Bonham Carter Papers, (n. 36 above).

of the company in a long memorandum entitled "The Rover Independent Development".[69] Apart from the criticisms of Rover from a technical point of view it made explicit his own views about the bad faith of MAP officials. A relatively small extract from the paper shows its general tenor. He noted that:

> it seems to be fairly clear that in the middle of February this engine must have been well on the way to completion and it is inconceivable that Major Ross was not aware of the fact. If he was aware of it, then he has shown a measure of duplicity not only in his attitude at the meeting itself, but also in his Minutes which seems to be so incredible in an experienced Government Servant that I hesitate to express it, let alone accept it. ... I believe the incident to demonstrate clearly that there is collusion between a Dept. and Rover, to defeat the objects of Collaboration, a secondary effect of which will be to enable Rover to build up prestige and weight as designers and originators, such as will stand them in good stead after the War. There can in my opinion be no doubt whatever as to the collusion.[70]

Whittle and his team made vehement representations to MAP about the Rover straight-through engine and Whittle explicitly took up with MAP the direct attack on the judgement of government servants that Johnson was suggesting in internal company papers, asking for a full enquiry to examine, among other things, "the qualifications, judgement, and experience, of the Civil Servants who have had such a powerful influence on the project" and offering to step down from the jet project "if my judgement and experience in such matters are believed to be inept".[71] The eventual outcome of the dispute was that Rover was allowed to continue with the straight-through engine "but that this should not be

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69
W E P Johnson, ibid.

70
"The matters complained of clearly show a fundamental disloyalty of Rover to their obligations and of certain Officials to their own Ministry's policy. ... It is obvious that to me that Rover have a very well prepared position to fall back on, namely the documents quoted herewith, or an ambiguous interpretation. The real impropriety is an ethical one and the Department is the guilty party as I see it. Broadly and nationally these inexperienced and inexpert people should not be wasting their capacity on such matters. W E P Johnson, 'The Rover Independent Development', Bonham Carter papers, (n. 36 above).

71
Whittle to Air Marshall Linnell, letter of 12 April 1942, quoted in *Jet*, (n. 3, above).

at the expense of the W.2B production programme".[72] Major G P Bulman, for his part, later recorded the view that "Whittle was his own worst enemy, quick to invest every discussion with the venom of suspicion". [73]

Whatever the merits of Power Jets' moral case, it has to be noted that the Rover B.26 was a rational solution and, moreover, it became the eventual successor to the Whittle layout. When Rolls-Royce eventually took over the Rover production plant (of which more below) they manufactured only enough reverse flow Whittle W.2.Bs (under the name 'Welland') to equip twenty Gloster Meteor Mk 1 aircraft before converting to the more aerodynamically efficient straight-through engine, based on Lombard's Rover B.26, and called the RB 37 Derwent I in Rolls-Royce terminology.[74] Lombard remained the supervising engineer on the project so there was absolute continuity from the Rover straight-through proposal to the highly successful Rolls-Royce Derwent (of which 500 were made) and which raised the speed of the Meteor from 415 to 470 mph. Adrian Lombard went on to become the most eminent director of engineering at Rolls-Royce in the post-war period.

There is an almost tragic quality of hubris about this episode, epitomised by Johnson's conclusions and policy recommendation:

> I am certain that if it is possible to put the whole position clearly to responsible and impartial officials, a radical revision of affairs must follow. We should, however, make it clear that our feelings are as much against certain Officials as against Rover, for these parties are, on the evidence, indistinguishable. It is our duty to badger the MAP,

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72
Meeting at Clitheroe 21 May 1942, Whittle, *Jet*, (n. 3 above), pp 214-215.

73
" ... scavenging through letters and minutes of meetings for odd words or phrases which he could pick on to suggest that they were deliberately ambiguous and revealing of a sinister influence behind the scenes determined to 'do him down' lest his jet become damaging to the piston aero engine". G P Bulman, unpublished autobiography, MS in the library of the Royal Aeronautical Society, London.

74
In fact the first fifteen examples of the next mark of Meteor (Mk III) were also fitted temporarily with Wellands until Derwents were available.

at the risk of unpopularity, into seeing the way it is heading.[75]

There seems little doubt that the emotional temperature of the whole project at Power Jets was extraordinarily high and rather different, for example, to the milieu at Rolls-Royce, where technology was being pushed just as far and as fast. Thus L L Whyte, who was a real asset, and the only member of the team with the stature and managerial expertise to hold his own with MAP officials, fell out with Whittle and resigned as Chairman and Managing Director of Power Jets in July 1941. He recorded merely that "difficulties had accumulated. ... Early in that month my association with Whittle, which had lasted nearly six years, came to an end. There were too many difficulties between us, and I was not sorry to leave Power Jets".[76]

Whyte was a loss, for in spite of earlier friction with officials he had the 'savoir faire' to represent Power Jets to MAP and to Rover. In his place Williams and Tinling became joint managing directors although, in G B R Fielden's view, they were "worthy, straightforward", but "not even amateurs" and thus Whittle had "no one to lean on".[77] Williams, Tinling and Johnson, while intensely loyal to him, echoed and amplified Whittle's own suspicion and jealousy about outside intervention, intellectual ownership, modifications by Rover and so on, rather than moderating his reaction. Their continual interventions with MAP after Whyte had gone were almost certainly unhelpful to Whittle's cause. Fielden recalled that "there was a general xenophobic feeling at Power Jets" and, on the

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75
Bonham Carter papers, (n. 36, above), W E P Johnson, 'The Rover Independent Development'.

76
L L Whyte, *'Focus'* (n. 23 above), pp 147-153. In this period Whittle also fell out with Isaac Lubbock, of the Shell combustion laboratories in Fulham, who had developed a combustion chamber which solved the problems that had been encountered up to then in getting stable combustion because Lubbock patented the "Shell" combustion chamber for is company. For Lubbock's side, his assistant Geoffrey Gollen, asserted that "Whyte was pure poison". Jules Lubbock, conversation with author, 25 November 1982. Jules Lubbock remained in close touch with his father's assistant, Geoffrey Gollen.

77
G B R Fielden, (n. 60 above). He remarked; "if only Power Jets had had a commercial managerial man".

basis of this reading of both official and company papers, the senior management came to be seen as suspicious, resentful, 'prickly' and became increasingly unpopular with officials.[78]

The senior management of the company was not a good psychological mix, and it also held an exaggerated view of the company's potential and bargaining strength. Perhaps too there was a naivety and an insufficient awareness of the danger they faced for even as these controversies with MAP were running Ralph Dudley Williams looked forward to the time when "the Management would be able to say we are practically inheriting the Rolls-Royce position as the leading aero engine manufacturers of the day".[79]

Because Power Jets had not evolved over years in contact with Government departments it had not developed the mechanisms, habits and the experience for dealing with them and, from the point of view of some officials, Power Jets was a problem. Many public servants approached the venture in an open-minded spirit, accepting that a new engine must be the product of unusual minds, although others were concerned by the continually deferred W.2 programme, the poor relationship between Power Jets and the Rover company as well as the combative approach of Power Jets towards MAP.

There was, after all, the example of the de Havilland jet engine - promising, powerful and actually overtaking the stalled Whittle programme so that de Havilland engines replaced Power Jets ones for the Meteor's first flight on 5 March 1943. De Havilland had started to study of the gas turbine in early 1941

78
Whittle, *Jet*, (n. 3 above) p.238, gives details of a meeting with Sir Wilfrid Freeman on 11 December 1942, then Chief Executive at MAP, at which Freeman "seemed to be antagonistic to the Board of Directors", suggested that Williams and Tinling had ceased to have any useful function, and "went so far as to say he would have them called up [for military service]". Johnson too was mentioned in connection with call-up.

79
Bonham Carter papers, (n. 36, above), Ralph Dudley Williams to Sir Maurice Bonham Carter, 21 February 1942.

at the request of MAP when Tizard "harassed with the vicissitudes of Whittle, cast around for some more normal character to tackle the design of a jet engine".[80] In under two years the de Havilland team, led by the freelance engine designer Frank Halford achieved a functioning engine capable of 1700 lbs thrust. At this time the Rover-built engines were restricted to 1000 lbs thrust and, additionally, on account of impeller bursting problems, were restricted to taxying trials only. De Havilland had received, it is true, unrestricted access to all the Power Jets data and considerable help from the RAE but it must also be noted that Power Jets itself had received a huge amount of assistance from the RAE which had seconded some of its best compressor and turbine specialists to the project and subordinated work on its own axial flow F2 engine.

Although the straight-through engine was put to one side by Rover following the fracas between Power Jets and MAP a stream of difficulties and complaints continued to emanate from Power Jets. Moreover, the results obtained with the basic W.2.B over the next ten months were poor. Against this background of disappointing engineering development Power Jets kept up a continual campaign of argument with MAP. Much of this was concerned with the division of design responsibility between Power Jets and Rover and with Power Jets' unresolvable claim for a formula which would recognise them as the ultimate design authority. This was problematic, since the design was continually evolving, and since creative engineers (as Lombard and his Rover colleagues clearly were) would be bound to have personal or original views on possible solutions.

MAP attempted to resolve these disputes by drafting "terms of reference" which were intended to regulate affairs between Rover and Power Jets. The growing exasperation of F J Linnell, Controller of Research and Development (CRD) at MAP, and in overall control of the jet engine programme, can be glimpsed from his letter enclosing these terms of reference and making the appeal that:

80
G P Bulman, unpublished autobiography, (n. 73, above).

> It is quite impossible to define with complete precision all the points which may arise. The Terms of Reference... must ... be used as a general guide and interpreted in a liberal sense on matters which are not explicitly covered ... A similar letter has been sent to Mr S B Wilks of Rovers.[81]

Linnell observed that the urgent need to produce a jet aircraft had "forced us into a position where we must attempt to manufacture the W.2B concurrently with the development and testing of experimental models", but reflected that this process "lends itself to misunderstandings as regards responsibilities" and that success would depend on "the fullest possible collaboration".[82] He also proposed a Technical Committee set up by MAP to rule on modifications and points at issue between the firms. Meanwhile Williams wrote to Bulman a long historical summary of past grievances. Bulman replied:

> Thank you for your letter of July 23rd. ... Fortunately my many other correspondents do not regale me with such lengthy epistles, though their matter is frequently of equal moment. Following our frank and to me very happy and most useful talk on July 20th, I think no further purpose would be served in further inquest on the past, with so much for all of us to do now. ... I attach a copy of the working procedure for the MAP Technical Committee which has been approved by CRD who is not prepared to have any further discussion either on the terms of reference on this particular document.[83]

Williams continued to object that the proposed procedure "was a great disappointment to us. I fear that 'row' you asked for when we last met is not long in coming. May we see you soon and get it over?".[84] Bulman replied, one senses, wearily:

81
Bonham Carter Papers, (n. 36 above), F J Linnell to J C B Tinling, 22 June 1942.

82
Ibid., 'Methods of Procedure for Producing the Whittle W.2B Engine', attachment to letter F J Linnell to J C B Tinling, 22 June 1941.

83
Ibid. R D Williams to G P Bulman, DED, MAP, 23 July 1942 and reply of 31 July. In fact a technical committee to regulate affairs between Rover and Power Jets had first been proposed in 1940. The narrative prepared for the Official History noted that it might have helped in 1940 but when the idea was revived in 1942 "as a last effort to persuade Power Jets and Rover to work together" it was too late. PRO CAB 102/393.

84
Ibid, letter from R D Williams to Major Bulman, 5 August 1942.

> The Terms of Reference ... have been laid down by C R D after immense expenditure of time and discussion. ... There is nothing I can see to be usefully added ... in relation to the actual progress of development and production of the W.2B engine, which is our sole objective, and not argumentation about the past, of which there has been more than enough already.[85]

We have seen that there were factions within MAP with respect to Power Jets although the company's actions progressively distanced its supporters. Whittle's admitted brilliance had won support from Tedder (before he left to become deputy commander of the RAF in the Middle East from December 1940), from Tizard, Pye and, perhaps, from Linnell. Bulman though, as the most important commissioning agent for RAF engines in the interwar period, was a strong supporter of the established companies, particularly Rolls-Royce and Bristol, and was quite sceptical about Power Jets. This polarisation also reflected a division of responsibility within MAP for the jet. Bulman, as DED, was responsible for engines actually commissioned for production for service, while Power Jets came under the direction of the DSR (Director of Scientific Research), through Harold Roxbee Cox as DDSR (later Director, Special Projects) - a situation that reflected the experimental nature of the jet and the original sponsorship of it by the Engine Sub-Committee of the ARC and by DSR. But by late 1942 the stock of goodwill within MAP towards Power Jets was largely exhausted. Whittle himself succumbed to two nervous breakdowns and it also seems that, while hospitalised, he was given electro-convulsive shock treatment.[86] However unfair this may seem, some officials must certainly have

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85
Ibid. G P Bulman to R D Williams, 14 August 1942. "Para 4a does not introduce any alteration in the existing procedure as between yourselves and R D E in the evolution of new ideas and/or the trial of experimental features in your engines in your works. The document is clearly intended primarily to clarify the situation affecting our mutual relations with the Rover Co, but not to modify them".

86
Lord Kings Norton, (formerly Harold Roxbee Cox), personal communication, 1986. He recalled visiting Whittle in hospital who said, pointing at his head, "they are giving me electric shocks". Kings Norton went to the chief medical officer of the RAF to have the treatment stopped, encountering the argument that it was needed to get Whittle back to normal. According to his own recollection, Kings Norton replied that "he never was normal". I am grateful to my colleague Timothy Boon at the Science Museum for pointing out that this is a very early use of

(continued...)

considered his nervous troubles as evidence of unfitness to control the jet programme and Fielden has suggested that "most of the officials regarded Whittle virtually as a nutcase".[87] Whyte described the episode more poetically, recalling:

> Unbroken tension and excitement, with its result in nerves and illness. At one critical stage Whittle himself could stand it no longer and as he lay in bed day after day the whole enterprise was shaken by the appalling doubt: had too much been gambled on one man and had that man taken on too much?"[88]

The disillusionment with the jet programme is reflected in a note from Air Vice Marshall F J Linnell, as Controller of Research and Development (CRD) at MAP, in November 1942 to Sir Henry Tizard, in which he expressed disappointment with jet progress and anticipated that the F9/40 aircraft fitted W.2B power units, then achieving 1450 lbs thrust, would be "of such inferior performance in climb ... and of so little superiority in speed" as to be unacceptable and "useless for operations by the time it is introduced".[89]

86(...continued)
electroconvulsive therapy and evidence of the urgent desire in the RAF for the jet engine to succeed. The technique was developed by Ugo Cerletti and first tried in Rome in 1938. It was described in an Italian medical journal in the same year.

87
Conversation with G B R Fielden (n. 60 above).

88
"From 1939 to 1941 the tension was never relaxed for a moment. We would leave board or committee meetings after exhausting battles with civil servants or with collaborating firms to return at once to engine tests at Lutterworth ... and frequently finish with night duty listening to the German bombers, as for example on the night of the first mass raid on Coventry, only twelve miles away. ... and this against the fall of France, the rally under Churchill, the Battle of Britain, and the risks of an invasion". L L Whyte, *'Focus'*, (n. 23 above), p 146.

89
PRO AVIA 46/237, letter from CRD to Sir Henry Tizard 9 November 1942, 'Sources for Jet Engine Narrative'. This file is unusually valuable since it contains selected, but uninterpreted, transcriptions of reports, memoranda and minutes on the jet engine programme which were marshalled for the official historians, and which do not appear to have survived in their original form.

Tizard agreed that the jet position was disappointing but although "the gamble of preparing for the production of the W.2B engine on a large scale has not quite come off" he felt that "even with all the mistakes, human and otherwise" it had been justified.[90] Shortly afterwards Linnell summarised the problems that had befallen the jet project for Air Marshall Sir Wilfrid Freeman, then Chief Executive at the MAP. He observed that the piston-engined Typhoon aircraft (designed by Hawkers but produced at Glosters) and the W.2B had taught that "bitter experience has proved that the only sound way to introduce a new design is for the design firm to be charged with the initial production". The major causes of the troubles with the W.2B he attributed to this mistake, to the attempt to produce a completely undeveloped design and to "undue optimism".[91]

Linnell recommended that Rolls-Royce should take over Power Jets with their factory at Whetstone and run it as the jet section of Rolls-Royce, while Rovers should "finish out the salvage of the W.2B engine from which I should hope to build between 150-200 training and development engines". Freeman then advised Cripps that he had ordered the production of W.2B engines to be stopped at 200 examples and the Meteor aircraft run would be cut short at about fifty. "Fifty [aircraft] should be about right" he noted, in a comment which certainly shows how little faith there was in potential reliability, "as I imagine we will run through the engines pretty quickly".[92]

Sir Wilfrid Freeman then proposed to Whittle a take-over of Power Jets by Rolls-Royce in December 1942 but did not force it through. The reason for this is not entirely clear but possibly resulted from Whittle's wish to be Chief Engineer of a future integrated scheme and Freeman's view that "he could not

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90
PRO AVIA 46/237, Tizard to CRD, reply of 13 November 1942.

91
Ibid. CRD to CE, 29 November 1942.

92
Ibid. CE to Minister, 30 November 1942.

very well put Rolls-Royce under [Whittle's] orders".[93] Perhaps of more significance was the absence of any administrative or financial mechanism open to MAP for forcing the acquisition of one private company by another.[94] Instead, Rolls-Royce took over the Rover production facility at Barnoldswick from early 1943, leaving Power Jets to carry on research and development of continuation engines to the basic Whittle design as an independent concern.

Bringing Rolls-Royce into the project quickly transformed the outlook for the Whittle engine. Ernest Hives, at the head of the company, nurtured a company culture with an exceptional attitude to engineering quality and a ruthless approach to research and development. His tough pragmatic view is captured in his letter to Linnell in March 1943 which promised to treat the jet "as just another aero engine" and not as a piece of scientific apparatus. "We do not look upon the turbine engine as a new secret weapon, it is just another way of pushing an aeroplane along, except that at the present time it is not as good as the conventional engine". He also noted for their next meeting that;

> I shall be bringing with me a report which will give the performance of the F.9/40 with various stages of progress of the [jet engine] and the dates at which we think these will be available. We want it to be understood that these are Rolls estimates, and therefore have to be taken seriously. ... We are satisfied that we are going to make a success of it ... the progress will be in keeping with our reputation".[95]

Rolls-Royce did in fact develop the W.2B to become a reliable unit but, as we have seen, it was quickly replaced by a development of the Rover-originated

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93
Whittle, *Jet*, (n. 3 above), pp 237-242, recalled from this meeting "a further harangue, in which he still had not explicitly stated that Power Jets were to be handed over to Rolls-Royce, though he had again inferred it".

94
PRO AVIA 46/245, 'Research Establishments, Omnibus Narrative File'. In the light of these discussions Rolls-Royce did attempt to negotiate the acquisition of Power Jets but agreement could not be reached over the valuation of Power Jets assets.

95
PRO AVIA 46/237, Ernest Hives to CRD, 27 March 1943. If this seems arrogant we should note Lord Kings Norton's recollection that Hives "believed in Rolls-Royce like some people believe in God". (n. 86 above).

straight-through variant.

The Nationalisation of Power Jets

The take-over of the Rover gas turbine programme by Rolls-Royce transformed the outlook for the series production of the Whittle engine, but the position of Power Jets still remained an irritant within MAP.

Bulman remained among the most formidable opponents and objected to the company having "the autonomy of a private firm, whilst being entirely supported on both current and capital accounts by M.A.P", arguing that, in its relationship with the producer firms, Power Jets was, in effect, functioning like a government research establishment and it should therefore be brought within the Engine Department of the RAE.[96] Friction was also caused by Whittle's unquenchable desire to build about twelve prototype engines a year in the new factory that had been provided for Power Jets at Whetstone with MAP funds.[97] This kind of prototyping was unlike anything done in government establishments and added to the anomalous position of the company. But in addition to the dissatisfaction within MAP, there was added internal company criticism of the management which was expressed by workers at Power Jets to Sir Stafford Cripps when he visited the Whetstone factory in 1943.[98]

96
PRO CAB 102/393, 'Gas Turbine Narrative' paras 194-195. This narrative, by Cynthia Keppel, was one of those prepared for Postan's official history (n. 2 above), and contains additional material. Bulman also instigated an enquiry into the salaries and expenses of Power Jets employees, although this found no irregularities

97
Ibid. Paras 194-195 attribute this policy to "Whittle's original champion, Sir Henry Tizard, now AMDP".

98
Ibid, para 196. G B R Fielden's recollection of the Minister's visit was that "Cripps must have realised straight away what the situation was - the management structure *non est*". Tinling appeared out of his depth and dried up giving the vote of thanks; the works manager "with surprising naivety" called for a response to Cripps' speech and a shop steward said that the

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The question of the ongoing Treasury finance for Power Jets was also on Cripps' mind and he initiated discussions as to how the benefit of this public expenditure could be secured for the nation. His own view was that:

> since substantially the whole cost of developing the gas turbine engine had been defrayed by the Government, arrangements ought to be made to secure the benefits of this development as Government property. Power Jets were entitled to be rewarded for having worked on the original idea and for having backed it when the Air Ministry were lukewarm about it, but for this and nothing more".[99]

The outcome of these discussions was a proposal for the nationalisation of Power Jets. This action was certainly problematic in view of the anxiety about upsetting the fragile jet programme in any way and feelings over the moral and commercial rights of Whittle and his original associates in the venture. Indeed, it seems unlikely that so final a step would have been taken at all, were it not for the constellation of forces pushing in this direction, and, in particular, the fact that the nationalisation was seen as being able to satisfy two quite different policy aims. As we have seen, for some MAP officials the administrative relationship with Power Jets appeared deeply unsatisfactory and the attitude to Power Jets of the 'hard line' faction within the Ministry can be seen in a noted from Sir Lindsay Scott, successor to Linnell as CRD whose expressed the view a little later that:

> we poured money into that company far in excess of its own capital until it became merely an inadequately organised and controlled organ of public policy and nationalisation, effected at the cost of relatively heavy compensation to private interests, became inevitable.[100]

98(...continued)
Power Jets management was no good "which was true". G B R Fielden, (n. 60 above). As a result an investigation into Power Jets management was conducted by Eric Mensforth, Chief Production Adviser at MAP and by the MAP regional controller which recommended that the management be strengthened.

99
PRO AVIA 46/245, 'Research Establishments; Omnibus Narrative File'.

100
PRO AVIA 65/1731, Sir Lindsay Scott to Secretary and C.E., Minute of 13 July 1945.

Stafford Cripps was concerned about the ethical situation regarding Power Jets and public investment in the engine, but he seems, in reaching the final decision to nationalise the company, to have been also swayed by his strong desire to create new institutions to advance the technological base of the whole British aircraft industry. Thus his thoughts on Power Jets crystallised into the view the view that an equivalent to the projected new National Aeronautical Establishment (to be discussed in the next chapter) was needed for the new gas turbine engine. Evidence that his thinking on this was indeed strategic, and not simply an expedient solution to the continuing problem of Power Jets, may also be adduced from the fact that, some time before nationalisation was proposed, he sought advice on the best structure and role for a jet engine research centre from the foremost independent internal combustion engine consultant, Harry Ricardo.[101]

The odd position of the Power Jets company offered a vehicle for an analogous establishment in the new jet engine field. It was clearly a creative concern, but was not set up for quantity production. Cripps seems to have held a genuine respect for Whittle and to have believed that a new organisation could be a vehicle for his abilities. Thus the decision to convert Power Jets into a research establishment is entirely consistent with Cripps' other initiatives for fostering new establishments for education and for research to support the aviation industry in the post-war era.

Discussions about the valuation of Power Jets assets ensued between MAP and the company but agreement could not be reached and on 26 November 1943 Cripps wrote to Bonham Carter that there was "no basis between us for

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101
H R Ricardo, 'Suggestions as to the Proposed Aero-Engine Research Laboratory' 18 August 1943, Science Museum archives. Ricardo was the most important consulting engineer for piston engines in the interwar period and had a strong influence on the direction of development through his membership of the Engine Sub-Committee of the Aeronautical Research Committee. His company also did a considerable amount of work during the war on the fuel control system (the 'barostat') for the Whittle jet.

acquiring the assets of the company". He proposed therefore to consider "the other alternative" but significantly, added that "we urgently need the plant for general experimental purposes".[102] A subsequent letter from Sam Brown, an undersecretary in MAP and head of the Capital Finance Department, reinforces this reading of a clear desire in the mind of Cripps to set up a research centre to for the new jet industry.

> The Minister reached the definite opinion that the national interests demanded the setting up of a Government-owned centre of gas turbine technology. The present stringency of building labour and resources generally renders it quite impossible for the Government now to construct a suitable new establishment. In these circumstances the Minister was forced to the conclusion that he had no option but to exercise his rights, which are not, I think, in dispute, to retake possession of the facilities occupied by the Company at Whetstone, but constructed wholly at the Government's expense, and which are now and always have been the property of the Crown.[103]

The decision came, understandably, as a brutal blow to the directors of Power Jets, and the terms that were put left no room for argument. Cripps stated that:

> if there was no quick agreement on the sum to be paid, [he] would take the alternative course of taking over possession of all the plant operated by the Company and directing all the labour to a new Government Company, leaving Power Jets in possession of its paper assets, such as patents, etc., and nothing else.[104]

As Schlaiffer succinctly put it, "the government's chief argument in driving so hard a bargain was that without the government financing after July 1, 1939, which amounted ... to about £1,300,000, or over sixty times the private investment, the company could not possibly have succeeded in producing a

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102
Sir Stafford Cripps to Sir Maurice Bonham Carter, 26 November 1943, quoted in *Jet*, (n. 3 above) p 265.

103
Sam Brown (MAP) to Tinling, 6 January 1944, quoted in *Jet*, (n. 3 above) p. 267.

104
Ibid, p 265.

useable product and must necessarily have been liquidated".[105] There was also the substantial investment in Rover, amounting to some £1.5m which had produced almost no visible return in terms of useable engines and although this expenditure was independent of Power Jets finance it seems likely that it would have influenced MAP thinking on compensation.[106]

Williams and Tinling received each approximately £46,786 for their 'A stock' while Whittle had waived his financial interest. The actual investors of cash or services (the holders of the B stock) received just over three times their initial investment and the total cost to the government of the acquisition was £135,500.[107]

The investors in the company found themselves in the curious position of having their hopes raised by press announcements of the successful development of the jet aircraft while, almost simultaneously, learning from the directors that MAP had taken steps to nationalise the company. Lawyers for a dissident shareholder began an action against the directors of Power Jets for accepting the government terms, putting the powerful argument that investors had waited patiently for nearly eight years for a return on their investments and that the directors had agreed to this sale "just at a time when the genius of Group Captain Whittle had

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105
Schlaiffer and Heron, (n. 38 above), pp 346-348. From 1 July 1939 all Power Jets expenditure had been met by the State. In equivalent 2002 prices this government expenditure at Power Jets equates to about £35m with a further £40m (2002 equivalent) spent at Rovers.

106
Use of Government Funds by Power Jets Limited

Year	Revenue	Machinery	Buildings	Total
1939	£ 12,000	...	...	£12,000
1940	72,000	£ 1500	...	73,500
1941	160,000	21,000	£ 10,000	191,000
1942	270,000	93,000	160,000	523,000
1943	370,000	98,000	30,000	498,000
Total	£884,000	£213,500	£200,000	£1,297,500

After Schlaiffer and Heron, (n. 38 above).

107
Schlaiffer and Heron, (n. 38 above).

given a phenomenal and almost unlimited value to the Company's Undertaking and assets including its patent rights".[108]

However, in reality the company's negotiating position was weak and was set out for shareholders by the directors.

> The facilities occupied by your company had been provided largely by the government. The proposed utilisation for a Government-owned centre of gas turbine technology would necessitate the Ministry re-taking possession of the facilities and the continuance of the development [of the jet engine] being carried on by the Ministry; the staff being if necessary removed from the Company under appropriate war-time powers. The result ... would be that your company would perforce remain inactive until the cessation of hostilities and restoration of more normal conditions enabled it to take up once more the development and commercial exploitation of the invention. ...
>
> While your Directors would have liked to have been able to get better terms and have tried their best to do so, they are satisfied that this is the best the Minister will offer and, if not accepted, the Minister will re-take possession of all the important facilities now enjoyed by the Company, operate the patents for the service of the Crown as well as he thinks fit and the shareholders may ultimately find that all, or the greater part, of their money has been lost.[109]

Although the directors of Power Jets were obliged to recognise *force majeure* in these dealings with the MAP the nationalisation was understandably a bitter experience. Williams subsequently stood for Parliament and much later said "I went into politics because I was so annoyed with Sir Stafford Cripps that I wanted to wipe the floor with him".[110]

108
Bonham Carter papers, (n. 36 above). Nordon & Co, acting for Mrs Emily Gladys Leney, letter of 5 May 1944.

109
Ibid. Draft letter to the Shareholders of Power Jets Limited, 10 February 1944.

110
"Unfortunately he died and had himself cremated, so I couldn't even piss on his grave". Sir Rolf Dudley-Williams, personal communication (n. 21, above). As discussed in note ??20 above, R D Williams changed his name to Rolph Dudley-Williams when embarking on a parliamentary career after the war and was knighted in 1964.

Whittle was placed in an extraordinary position - converted into a national icon at the same time that his company was taken from him. It was, L L Whyte observed "Greek tragedy in the modern world: the hero publicly acclaimed at the very moment when his deeper ambition is frustrated".[111] On 6 January 1944 the jet engine programme was publicly announced with Whittle credited as the inventor - the same day that the directors of Power Jets were informed that the company was to be nationalised.

Whittle himself believed that he "triggered off the train of events which led to this result" for in April 1943 he wrote to Cripps arguing that the whole gas turbine industry should be nationalised.[112] Edgerton has also given weight to the influence of Whittle's propagandising efforts for nationalisation.[113] However, it seems unlikely, on the basis of reading here of company and other papers, that Whittle's intervention had any decisive influence on the outcome.

One side effect of nationalisation was to solve at a stroke the almost impossible tangle of rights over intellectual and moral ownership of much that had been done, resulting partly from the dissemination of Whittle's ideas through the Gas Turbine Collaboration Committee and on the patent question, discussion of

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111
L L Whyte, (n. 23 above), p 148.

112
Whittle wrote to Cripps: "With the exception of Power Jets ... not one of the firms has taken any speculative risk and is not therefore entitled, even from the most capitalistic standpoint, to benefit financially, other than from the profit allowed in Government contracts. In my view there is a very strong case for complete nationalisation viewed from any political standpoint". He also pointed out that the state had expended some £2m on gas turbine development and was likely to be the principle customer for jet engines while the only private capital was the £23,000 subscribed by shareholders in Power Jets, that all the companies had collaborated in the interchange of technical information and that it would be virtually impossible to sort out patent rights and commercial ownership of particular features at the end of the war. "The circumstances are therefore quite unprecedented and the case for nationalisation seems to me to be overwhelmingly strong". Whittle, (n. 3 above) pp 262-263.

113
D E H Edgerton, *State Intervention in British Manufacturing Industry*, PhD thesis, Imperial College, London, 1986.

which had been postponed until after the war. Lord Kings Norton (the government scientist who, as Harold Roxbee Cox, ran the wartime gas turbine programme for the MAP) did not consider these that these secondary considerations influenced Cripps. Although he felt that Power Jets was very badly treated, in effect by Cripps, he made the reservation that "I don't think it was wilful - because he was too good a man".[114]

The Establishment of Power Jets (R&D) Ltd

The nationalisation of Power Jets was not simply a matter of state acquisition of a company, for it included another rather novel element - the merger into the new organisation of all the government scientists in the Engine Experimental Department of the Royal Aircraft Establishment (RAE) at Farnborough who were working on gas turbines.[115] This action underlines the seriousness of Cripps's attempt to create a powerful national research centre for the emerging gas turbine industry, for Farnborough was a national institution with a proud history and a record of success in aeronautical affairs, especially in response to the challenge of the Second World War. To change the status of these government scientists who were active in this new and promising field seems, in the context of the times, almost as radical as the actual nationalisation of Power Jets. It is another example of the asymmetry in the existing historiography of the jet that the creation of Power Jets (R&D) Ltd has been criticised frequently from the perspective of Whittle and other Power Jets personnel but it is far less well known that the merger was also resented by senior RAE staff working on gas turbines at Farnborough including Hayne Constant, as head of the turbine section, and Sir William Hawthorne, both of whom had been engaged in close

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114
Lord Kings Norton (Harold Roxbee Cox), conversation with the author, 14 May 1995.

115
PRO AVIA 46/245. An arrangement described in one of the official narratives as: "A very interesting experiment in the administration of scientific development by a Government Department".

liaison with Power Jets. Hawthorne, in fact, described it from the RAE perspective as "a great tragedy".[116]

Power Jets (R&D) Ltd

Power Jets (R&D) Ltd was formally established as a government-owned company on 28 April 1944 but although direct government control was intended "to cut a number of Gordian knots in personal relationships" the ending of Power Jets' independence did not fully resolve the problems which continued to exist both between Power Jets and on the one hand, the aero engine industry and, on the other, MAP officials.[117]

Bulman, who now was planning the new National Aeronautical Establishment (NAE), which will be discussed in the next chapter, cast doubt on the need for an ongoing research and development role for of Power Jets, since "a major objective [of the NAE] is to bring together aerodynamic and powerplant research". His opposition certainly reflected the poor opinion of Power Jets which he formed while he was in overall charge of engine development and he questioned "whether Power Jets was to continue as the chosen instrument for turbine R&D", when logically it should be absorbed into the NAE; which was beginning to be established on airfields near Bedford.[118]

116
"In April-May 1944 a great tragedy, in my view, happened to the R.A.E., because the Turbine Division, the major part of their establishment concerned with future aircraft propulsion, was wrenched from the R.A.E. to join with the existing Power Jets Ltd. ... The decision was not welcomed by Farren (Director of the R.A.E.) Constant or myself". Sir William Hawthorne, 'Aircraft Propulsion from the Back Room', Sixty-Sixth Wilbur and Orville Wright Memorial Lecture, Royal Aeronautical Society, 1 December 1977, (advance copy, Science Museum archives).

117
Schlaiffer, (n. 38 above), p 370.

118
PRO AVIA 15/2091, note by George Bulman, DCRF, 25 May 1944. Bulman moved in 1944 from Director of Engine Development (DED) at MAP to become Director for the Construction

(continued...)

Cripps however, did not accept this advice and this note to Power Jets from an aide shows the sincerity of the intentions he had declared earlier during the nationalisation to secure the talent in the company as a national resource:

> I am directed by the Minister of Aircraft Production to refer to his decision that you should act as the recognised national establishment for furthering, ... the advancement of knowledge on gas turbine engines. ... The Minister feels that this decision involves the installation at Whetstone, and not in the new National Establishment ... the equipment ... which will be required exclusively for the testing of gas turbine engines.[119]

This action certainly demonstrates that for Cripps, at least, the nationalisation of Power Jets had not been a punitive act and the genuine commitment to build something worthwhile on the bones of the Whittle concern is visible from the resources that were brought to the company. The new board, strengthened in accordance with Sir Eric Mensforth's recommendations, was an extremely powerful assembly, comprising Sir William Stanier (the distinguished chief engineer to the LMS railway, then serving as Scientific Adviser to the Minister of Aircraft Production), Harry Ricardo (the most eminent British engineering consultant on internal combustion engines), and from MAP, Sam Brown, head of the Capital Finance Department and Edwin Plowden.[120] Williams and Tinling continued as directors while Roxbee Cox, who had managed to get the trust of

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118(...continued)
of Research Facilities (DCRF) where he became responsible, among others, for the construction of the National Aeronautical Establishment, at Bedford, and for the dismantling and exploitation of the Volkenrode site.

119
Ibid. L H Curzon, MAP, to Power Jets R&D, November 1944. Curzon also wrote to the ARC noting that Cripps had "modified in one respect his acceptance in principle of your Committee's report" on the creation of a National Aeronautical Establishment and advised that he was directing Power Jets Limited to act as "the recognised National Establishment for furthering ... the advancement of knowledge on gas turbine engines".

120
Plowden was at the time Director General of Materials Production (DGMP) in the MAP and resigned his Power Jets directorship in March 1945 when he was appointed MAP Chief Executive. Mensforth's investigation into the management of Power Jets is alluded to in note 98 above.

all the factions in the industry and the Ministry in a unique way, became Chairman and Managing Director.[121]

Power Jets R&D Ltd was now a sizeable facility and occupied, at Whetstone, a factory of 80,000 square feet (8000 square metres) and expansion to 120,000 square feet was planned. It was well equipped with machine tools and capital plant and the research equipment included a 6000 hp steam turbine driving a compressor to produce the powerful air supply needed to test components for jet engines. The supply of three wind tunnels for testing 'cascades' of turbine or compressor blades was in train, as well as the manufacture of a supersonic tunnel.[122] The former RAE turbine facilities at Pyestock near Farnborough were also kept on and these included a 4000 hp electrically driven compressor. The company had a flight test section at Bruntingthorpe airfield, near Whetstone, with two Lancasters and a Wellington bomber, adapted as 'flying test beds' to carry jet engines aloft for airborne tests, and two Meteor jet-engined fighters. Over the first year of operation the staffing of the establishment rose from 1086 to 1327 employees, while the cost of the first year's experimental work, given in the first annual report in April 1945, was estimated at £600,000.[123]

These figures and resources make it clear that, overall, MAP initially acted fully in the spirit of Cripps' directive that Power Jets (R&D) Ltd should become "the recognised national establishment for gas turbine engines".[124] Power Jets was not nationalised to smother it to death stealthily although the role envisaged for the

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121
'Notes on the Organisation, Duties and Facilities of Power Jets, (Research and Development) Limited', Power Jets (R&D) Ltd, 12 March 1945, Science Museum archives.

122
Annual Report, 28 April 1945, Power Jets (R&D) Ltd, Science Museum archives.

123
First Annual Report, Power Jets (Research and Development) Limited, 28th April 1945, Science Museum archives.

124
Sir Stafford Cripps, MAP, to Harold Roxbee Cox, 27 April 1944, copy in 'Notes on the Organisation, Duties and Facilities of Power Jets' (n. 121 above).

government-owned company did not fully materialise and it eventually disappeared.

Power Jets (R&D) Limited becomes the National Gas Turbine Establishment

The life of the company was short. In early 1946 moves were made for putting turbine research under the same kind of government research establishment structure as that used for aerodynamics, radar, telecommunications and so on.[125] Whittle's continuing plan to build complete engines also contributed to wider industry opposition to cooperation with the new Power Jets structure. Whittle's notion was that Power jets would develop engines up to production standard, manufacturing a large enough trial batch to standardise the design which would then be handed over to the producer company.

This model of design and development was strongly resisted by the aero engine industry, and particularly by Rolls-Royce and de Havilland. Their opposition has usually been interpreted in terms of resentment of unfair competition and they had certainly threatened not to collaborate with Power Jets if this model was followed.[126] However, these major engine builders could clearly not place themselves under the direction of an outside design body - particularly Whittle's firm. Rolls-Royce had rescued the engine from the Power Jets-Rover debacle and had, throughout the war, followed their own engineering judgement.[127] De

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125
The comment in the official history that "Sir Stafford Cripps, the chief architect of the existing arrangement, had left the Ministry" is significant. Postan (n. 2 above), p 232.

126
Postan, ibid.

127
PRO CAB 102/51. The rueful acceptance, from the official side, of the attitude and the achievements of Rolls-Royce can be read in the assessment that "Rolls-Royce ... never failed to show their peculiar mixture of engineering ability and intransigence". D A Parry, 'The Production of Reciprocating Aero Engines 1935-1945'.

Havilland, as we have seen had also independently produced a highly effective jet design.

Whittle's plans were completely unrealistic by this time for the mainstream engine companies had begun to push ahead with their own designs. Rolls-Royce showed that they had mastered the design and development of Whittle-type centrifugal engines by building a new, large jet engine, the Nene, which ran in October 1944, just six months after the project was initiated, achieving 5000 lbs thrust - making it the highest powered jet at the time in the world.[128] The company had successfully resisted the notion of over-riding control of the programme by Whittle in 1943 and it was not credible that they would now accept it in 1945 when their own understanding of the gas turbine had increased enormously.[129] G B R Fielden felt that Whittle could have retained a useful role in the industry if he had gone to a "Ricardo type" consultancy but that "the idea of Power Jets at the centre of a spider's web in the post-war jet industry was a total illusion".[130]

Thus, in spite of nationalisation, Power Jets (R&D) Ltd was still "an elaborate organisation with an elaborate relationship with the Ministry of Aircraft Production" and the process for bringing programmes into being was

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128
The Nene is of interest also in that it was made available to the USSR in 1946 when the Labour government supplied 25 examples in what Bill Gunston, *Rolls-Royce Aero Engines*, (PSL 1987) called "a misguided gesture of goodwill" - an action which has usually been attributed to Cripps. The engine was copied by the Klimov design bureau and put into production as the VK-1 to power, among others, the MiG 15 fighter. Over 39,000 examples of the engine were produced.

129
This is not to imply that Whittle's qualities were not respected at Rolls-Royce. Ernest Hives did offer him a job in this period but they were unable to agree over terms. Lord Kings Norton, (n. 85 above).

130
Alternatively, he considered that Whittle could have teamed up with an established engine builder but instead "stayed in cloud cuckoo land and wanted to be all things to all men in the jet business. ... So bonkers the mind boggles". G B R Fielden, (n. 60 above).

characterised as "somewhat complicated and even mysterious".[131] It was also suggested that "the dilemma of public financial backing without public administrative control" was a continuing concern.[132] Power Jets (R&D) Ltd was formally converted to the National Gas Turbine Establishment on 1 July 1946 and though sixteen Power Jets engineers resigned, provoking a question in Parliament, the residue of Whittle's company passed from public view without further protest or comment.

131
PRO AVIA 46/245.

132
Postan, (n. 2 above), p 232.

Conclusions

We can see in the Whittle story a taxing problem for historical study. Even his contemporaries, and those closest to the jet programme were divided - often bitterly - over his potential and capacity.[133] One problem which complicates the analysis is that the Whittle story came to be deeply bound up with national myth. Although the Short aircraft company had been nationalised during the war as a response to poor production performance and management, the action proved remarkably uncontentious.[134] The case of Whittle was rather different because the jet engine became part of a new and emerging national identity. Thus even as the administrative arrangements for nationalisation were being confirmed, the achievement of jet flight was being trumpeted as a symbol of superior British technique. For example, news of the jet was the headline and lead story in the *Daily Express* early in 1944 ("Britain has fighter with no propeller"), with a portrait and profile of the inventor.[135] Whittle was given full credit for the invention - and in fact was exploited by Government agencies for public relations purposes. Little hint of the tensions within the programme reached the public until the release of his book *Jet* in 1953.

In this aspect of its manipulation the Whittle jet story joined, but surpassed, other claims, in the latter part of the war, for superior national technique, such

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133
Thus Lord Kings Norton completely disagreed with "the belief among the 'brass hats' that Whittle did not understand production, and no consideration was given to giving him what he wanted [but] he was brilliant - he could have done anything". More poignantly, he remarked "I was on Whittle's side throughout, but I wasn't strong enough to get him what he wanted" and also "Whittle and I have always been friends, but I was the instrument of authority and he disagreed with authority". Lord Kings Norton, (n.114 above).

134
Peter Howlett, 'The Thin End of the Wedge?', in R Millward and J Singleton, (eds.), *The Political Economy of Nationalisation in Britain, 1920-1950*, (Cambridge, 1995), pp 237-256. Howlett records some short-term attacks on Cripps in the Commons and the House of Lords but these were not sustained when it became generally accepted that the action was necessary on production grounds.

135
"All tests passed - speed is colossal". The Daily Express, 7 January 1944.

as the discovery of penicillin, 'asdic' submarine detection and developments in radar - revelations which had been used to boost national morale in the interests of the prosecution of the war and war production. The Whittle story, falling as it did towards the end of the war in Europe, became extended beyond this more limited aim and became an intrinsic part of the self-re-invention of Britain in the post-war era.

Partly in the service of this heroic myth, it has always been argued that the officials gave too little support to Power Jets and withdrew it too soon. This argument is another strand in the declinist analysis of recent British history which characterises its public servants and opinion formers as classicists with a remote disdain for technology.[136] But the striking point about the Whittle venture is that officials repeatedly gave the inventor the benefit of the doubt, in spite of his own personal problems and the increasingly difficult relationship with his company and colleagues. It can be argued that, contrary to the received view, British officials during the Second World War were particularly open to inventors with potential 'war-winning schemes' and the acceptance of proposals, both built and unbuilt, ranging from the Barnes Wallis bouncing bomb, Pluto (petroleum supply 'pipeline under the ocean') and indestructible floating island airfields made of "Pyecrete" (a frozen mixture of ice and sawdust) could be taken to show that their attitude was rather open-minded.

Certainly the messianic inventor can exercise great power and we have noted that even as hard-headed an airman as Lord Tedder fell under the spell of the early Whittle engine and promoted it as "a real war winner". The physical surroundings of the early test he witnessed were completely antithetical, say, to the ordered workshop environment of Rolls-Royce, and may well have added to

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136
There is plenty of material available for selection by those inclined to make such a case. Thus Harold Nicholson on the jet engine, 7 January 1944: "In the evening we here a talk about a new aeroplane which runs on compressed air. I do not understand a word of it. The inventor says a few very modest words at the end". *Diaries and Letters 1939-1945*, (London, Collins, 1967), p. 343.

the magical power of the occasion. Tedder noted that the test rig "was pure unadulterated Heath Robinson ... in what looked like, and I believe was, a derelict motor garage" he saw "a typical Emett design" but was impressed by the glowing combustion chamber and "the blazing blue jet flame roaring out into the open".[137]

From the perspective of this study the problems of the Whittle project were a too ready faith in invention and individual brilliance, and an insufficient attention to development and management - virtually the opposite of the faults which Whittle and his supporters have ascribed to wartime control.

137
Tedder, (n. 53 above). There is a compelling parallel here with the collector's search for art: "That is why collectors ... want to climb those vertiginous loft building stairs on Howard Street that go up five flights without a single turn or bend ... to wind up with their hearts ricocheting around in their rib cages ... from the exertion mainly but also from the anticipation that just beyond this door at the top ... in this loft ... lie *the real goods* ... paintings, sculptures that are indisputably part of the new movement, the new *ecole*, the new wave ... something unshrinkable, chipsy, pure cong, bourgeois-proof". (From Tom Wolfe, *The Painted Word*, (New York, 1975), p.23.

Jet Counterfactuals

We should, though, also consider the long-term effect of Power Jets and what might have occurred if Whittle had not obtained official support. In such a case intelligence reports of German jet developments in 1942 would, one assumes, have energised a crash programme in which the work of the RAE, where a sophisticated axial flow compressor had been developed, would have been put together with a major aero engine company, such as Rolls-Royce.[138] A viable engine would certainly have resulted, for a type not unlike this hypothetical motor was, in fact, produced as the Metrovick F2 Beryl during the war arising out of the partnership between RAE and Metropolitan-Vickers.[139]

However, in the absence of a Power Jets/government relationship it seems unlikely that so high a degree of administrative attention would have been focused on the jet programme. The "spoon-feeding" of Power Jets, the drawn out negotiations, and the personality of the inventor himself, combined to underpin the idea of the jet engine as something exceptional and extraordinarily hard to engineer. Having engineered it the British state came to regard it as a great prize, to be nurtured for strategic and economic reasons. As a propagandist for the jet, Whittle certainly succeeded and without him there would also have been fewer specially designated posts within MAP to nursemaid

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138
Generalised reports of German jet engine work had reached British intelligence from 1939. However, in May 1942, photo-reconnaissance following a bombing raid of the Heinkel works near Rostock showed a Heinkel 280 twin-jet fighter prototype. Constance Babington-Smith, *Evidence in Camera*, (Chatto and Windus, London, 1958), p 280. In November 1942 an Air Intelligence report on German jet aircraft work had been prepared (PRO AIR 20/290) showing the considerable extent of the work. This is discussed in F H Hinsley, E E Thomas, C F G Ransom and the late R C Knight, *British Intelligence in the Second World War*, Vol III, Part 1, (HMSO, London, 1984), p. 334.

139
The successor design to this, the Sapphire, was passed to Armstrong-Siddeley when Metrovick opted to leave the aero gas turbine field at the end of the war. It first ran in 1948 and was also licence-built in large numbers by the Wright corporation. The Avon, built by Rolls-Royce in 1948 can also be viewed as the implementation of the 'government' axial flow line in compressors by a major maker.

the gas turbine, probably no National Gas Turbine Establishment, and perhaps a less developed national sense of the jet engine as a triumph of British endeavour and technique. In the absence of this overt commitment there would also have been less likelihood of British companies winning a substantial share of global business jet engine business.

The counterfactual experimental question "what if there had been no support for the Whittle jet engine" could also be approached from the alternative proposition "what if there had been no war to provoke the development of the jet engine?". In such a case, it seems likely that the gas turbine would have been deferred by ten or fifteen years and, in the civil field, the new, high altitude pressurised airliners, such as the Lockheed Constellation would have had a longer life with their turbo-supercharged piston engines before the extension of services round the world prepared the ground for another jump in performance, comfort and speed, with a new turbine powerplant. In this case seems highly probable that the successful commercial development of such a powerplant (as opposed to its 'invention') would have been in the USA for a study of the 1920s and 1930s in American aviation shows a growing technical lead in the civil field and a growing ability for the industry to capitalise development.

As touched on in chapter one the American aviation industry in the 1930s was undergoing a step-change in the capability of the whole air transport system. It appears unlikely, in the absence of a major war, that in Britain finance would have been found to support a major new development like the jet and we have already reviewed the quite modest private finance available to Whittle prior to 1939.

It is also not generally realised that in the USA several gas turbine projects were under way in the late 1930s, none of which, it appears, derived from any knowledge of Whittle's experiments. Northrop was fostering research on a turboprop arrangement, anticipating a simpler, lighter engine with less vibration.

Lockheed had initiated studies for a pure jet design and were aiming at a 600 mph aircraft, flying at 50,000 feet.[140] There was also turbine research at the engine builders Pratt & Whitney while the turbo-supercharger department of General Electric, which was developing these devices for piston engines, was under the direction of Stanford Moss, an engineer who, as an engineering student, had been an enthusiastic exponent of the gas turbine and published his doctoral thesis on it in 1903.[141] In fact for these turbo-superchargers General Electric solved the materials and manufacturing problems of turbine blades capable of standing the heat of the piston engine exhaust gas, and partly for this reason, subsequently made a success of the Whittle engine when this was passed to them in 1941. (For a while during the war General Electric compressor impellers were shipped to Power Jets because British-made ones were bursting at full speed).[142] However, the point made here is that it hardly needed the Whittle engine to provoke interest at GE in the gas turbine. To answer the question posed at the beginning of this section, there is a powerful supposition that if re-armament in Britain had not brought government support to Whittle the practical aircraft gas turbine would have been realised in the USA as part of the broad sweep of improving aeronautical technologies.

The handling of the jet programme in Britain can also be usefully compared with development of the engine in Germany for there, events initially showed a remarkable parallel to those in Britain. A young German physicist and inventor, Hans von Ohain, began work on a jet engine from 1934. Thus in both Britain and Germany the gas turbine work was launched by a lone inventor, outside the

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140
Schlaiffer, (n. 38 above), pp. 440-479.

141
Sanford Moss, 'Gas Turbines and Turbosuperchargers', *Transactions of the American Society of Mechanical Engineers*, July 1944, pp 351-370. Moss commented "like most of the other inventors, the author at first thought he was alone in the gas-turbine field".

142
The existence of the Whittle jet was disclosed in general terms to the USA by the Tizard mission in 1940. In October 1941 a complete, dismantled, engine of W.1 type (the W.1.X) and a full set of drawings for the W.2B were shipped to the General Electric's plant in Lynn, Massachusetts, by air, accompanied by two Power Jets engineers.

mainstream of the aero engine establishment. Ernst Heinkel, a mercurial industrialist and self-propagandist took up von Ohain and an experimental jet-powered Heinkel aircraft made a rather marginal demonstration flight in 1939. However, Heinkel was an airframe company and the German air ministry was not greatly interested in an individualistic 'sport' development. Helmut Schelp, the visionary official at the air ministry who did most to stimulate the jet programme then approached the more established engineering-based companies BMW, Daimler-Benz and Junkers.[143]

BMW and Junkers agreed to take up the gas turbine and were given the latest results of axial flow compressor research emanating from Professor Albert Betz and W. Encke at the AVA aerodynamics research institute at Göttingen (in effect, the German equivalent to RAE Farnborough). Moreover these two firms were "very rigidly directed by the *Reichsluftfahrtministerium*".[144]

Thus the greatest weight of support went to established companies, with the original inventor being sidelined. The parallel in Britain would have been if Rolls-Royce and, say Bristol or de Havilland were given the bulk of the development funds and instructions to incorporate the RAE ideas on compressor design. In fact, as we have seen, the reverse happened. The analytical work of the RAE was put at the service of Whittle's company which also got the lion's share of attention and development finance, until a crisis was reached in 1943. The independent RAE work on axial flow compressors got rather low priority, going forward not with an aviation company, but with a steam turbine concern

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143
Heinkel and von Ohain were able to continue the work throughout the war but the main emphasis swung to the BMW and Junkers projects. The Heinkel-Hirth turbojet, considered as a long-range programme, was still incomplete at the end of the war.

144
Postan, (n 2, above) pp 187-190. These events are also covered by Edward W Constant (n. 5 above) and see also *50 Jahre Turbostrahlflug*, proceedings of DGLR Symposium, 26 and 27 October 1989. Hans von Ohain and Anselm Franz have also described respectively the Ohain/Heinkel and Junkers work in; Walter Boyne and Donald S Lopez (eds) *The Jet Age*, (Washington, NASM, 1979).

unused to aviation requirements.[145]

After 1943, as we have seen, MAP felt impelled to bring Rolls-Royce fully into the gas turbine programme, although Tizard's initiative in 1941 to broaden it to other companies was perhaps the first implicit acceptance of the fact that Power Jets was inadequate. Also, it should be noted, in 1941 a rather unique type of inter-firm communication was set up, known as the Gas Turbine Collaboration Committee (GTCC) to involve all the companies that were working on the new engine. The original suggestion was credited to Ernest Hives, of Rolls-Royce (who apocryphally remarked that "as we are giving so much information to the Americans we might as well give it to each other").[146] Roxbee-Cox was also a keen advocate for such a body and although the normal practice for engine procurement within the Air Ministry and MAP relied, in effect, on competitive development between firms it was accepted, for the jet that the problems were so new and various that a forum would be helpful and Linnell, as CRD, took the view that it would be worthwhile if it brought "the various factions within speaking distance of each other".[147] In fact the committee worked well and Roxbee Cox secured the cooperation of all the firms, arguing that they were ushering in a new age and that it was up to them "not to fumble the job". The greatest issue between firms - the question of patenting new ideas - was "banished from the agenda" on the assumption that it would ultimately be solved and the Committee served as a really valuable agency for the exchange of information on aerodynamic or mechanical problems and their solutions which were new to all the participants. The GTCC certainly made a powerful

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145
In the event, the Metrovick-RAE effort produced a highly creditable result and the F.2 engine flew in a Gloster F.9/40 Meteor prototype in November 1943. Little has been written about this engine but see R R Whyte, *Engineering Progress through Development*, (London, 1978). As noted above, the Metrovick work formed the basis for the successful post-war Armstrong-Siddeley Sapphire.

146
Keppel, (n. 96 above), para 117.

147
Postan, (n. 2 above) pp 205-206. Also 'Gas Turbine Narrative' (n. 96 above), paras 117-121.

contribution to the speed with which de Havilland and Rolls-Royce picked up gas turbine work and to the quality of their engines.[148]

On the basis of this study, therefore, it is argued that Whittle got exceptional backing until the programme ran deeply into trouble. Even then, Whittle's personal conviction, the charm to which his collaborators have attested, and, it must be said, his great talent, secured tremendous indulgence from officials, even though doubts were rife as to whether Power Jets could mature into the type of organisation which was going to be able to bring the engine into production and to serve as the ultimate design authority for it. This forbearance almost certainly delayed development and makes an interesting contrast with German policy for the conduct of the jet engine programme.

From these perspectives, it is argued that the official handling of the jet programme in Britain was a mixed achievement. Government officials and advisers picked up the project during re-armament, nurtured it through all the bitter technical and personal wartime disputes, and Britain thus ended the war with a substantial gas turbine industry nurtured by a government research establishment and an informed cadre of officials within MAP and the Ministry of Supply. However, this study shows the MAP to have been too supportive to the inventor and too slow to transfer control and industrial support away from Power Jets to the mainstream industry. Nevertheless, if survival in the market can be taken as an indicator of success it has to be acknowledged that British jet engines in the post-war period had a significant technical superiority over their competitors, while British aero engine production has now maintained technological parity and a major presence in international markets for over fifty years.

148
Schlaiffer (n. 38 above) pp. 490-492, attributed much of the British lead in turbojets by the end of the war to the policy of collaboration and to the GTCC. By contrast, American efforts were intentionally compartmentalised and the Westinghouse team were deliberately excluded from knowledge of the Whittle work being taken up at General Electric.

Chapter 4: New Resources and New Institutions

Introduction

The long-range planning within the Ministry of Aircraft Production (MAP) for the conversion to post-war production has been discussed in chapter two and it was argued that these plans were well considered and ambitious although one might query whether the aspirations behind much of the planning could ever, realistically, have achieved what was hoped for them.

In fact, the new institutions which arose out of the war-time planning in aeronautics were concrete evidence for the seriousness of these intentions. Much was achieved and the efforts did go some way to shifting the centre of gravity of industrial R&D in Britain. These various initiatives could not have been accomplished under normal conditions and the particular importance of air power to British strategic conceptions in the Second World War and the consequent great importance and power of the MAP during the war were indispensable pre-conditions. Indeed, it is surprising how much was done and how little comment these initiatives have aroused either in the historiography or among commentators on public affairs at the time.

This chapter therefore examines the creation of important new institutions which have had little attention in the historiography but were directly intended to advance the British aeronautical industry. These are the creation of the new College of Aeronautics at Cranfield and the planning and partial realisation of an ambitious new National Aeronautical Experimental Establishment at Bedford.

The systematic exploitation of German aeronautical research work in the post-war period and the recruitment of a substantial number of German aerodynamics, electronics and control specialists for the RAE and other establishments can also be regarded as an aspect of these institutional changes and is examined here. This episode has had remarkably little study in the British context and it has been widely assumed that all the worthwhile scientific spoils

from Germany went to the USA. Thus Bill Gunston, a writer well regarded by the industry itself and the former Technical Editor of Flight magazine asserted, as we shall see quite erroneously, that, in post-war Britain, designers struggled to create advanced aircraft without proper equipment because "all the transonic windtunnels found in Germany were pinched by our allies".[1]

In fact Britain was well equipped with advanced research equipment in the post-war era, much of it designed and built here, but also supplemented by a substantial haul of German material. This study shows that, contrary to the usual perception, a major, and highly selective, effort was mounted to bring German equipment and German personnel to Britain to augment the work of research organisations and aircraft companies after the war. The programmes made an important contribution to the resources available to the postwar British aircraft industry.

The College of Aeronautics

The College of Aeronautics at Cranfield (today Cranfield University) is, arguably, one of the striking successes of post-war British scientific and technological education. It has been, however, an anomaly in the British higher eduction sector set up as the only science and technology institution with a purely post-graduate intake, and until the 1960s with a remit solely to cover aeronautical subjects.[2] For these reasons, perhaps, it has had little attention in studies of education for the postwar period and it does not feature at all in Sanderson's otherwise comprehensive review of British higher education in

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1
Bill Gunston, *Bombers of the West*, (Ian Allan, 1973).

2
Cranfield diversified into other areas of engineering and technology from 1960 and after a brief spell as the Cranfield Institute of Technology became Cranfield University on 31 December 1969. As a purely post-graduate college, Cranfield initially awarded its own College of Aeronautics Diploma (DCAe) - a respected qualification in the industry. It subsequently also acquired the unusual power (for so new and small an institution) to award its own doctoral degrees.

relation to industry, perhaps because of its unusual status.[3] Neither has Barnett, in a passage excoriating the "petty scope of wartime plans for technical and higher education" noted the establishment of this important institution.[4] His general position has been challenged by David Edgerton, but without mention of the case of the College of Aeronautics although it has made, in its special field, a material contribution to the creation of a British 'technocratic elite' that has been studied by Edgerton.[5]

Nevertheless, Cranfield has proved important, with a substantial research programme, a contribution to the research and development of the industry, a large output of students with doctoral and higher qualifications, and a strong representation of former students at senior level in the industry.

It has been noted in the preceding chapter that MAP officials were uneasy about the skill and managerial resources within British aircraft companies. In particular, the limited diffusion of competence in basic design and the centralisation of design ability in a few master practitioners gave particular cause for concern.

The initiative to attack this problem in a radical way appears to have initially come from Sir Roy Fedden, the former chief engineer of the Engine Department of the Bristol Aeroplane Company. Fedden was an exceptional character - a

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3
Michael Sanderson, *The Universities and British Industry, 1850-1970*, (London, Routledge, 1972). For example, although *Flight*, 13 May 1943, p. 508, proclaimed the "Need for a University of Aeronautics"and followed the progress of the college, there is no mention at all of its formation and start-up in more general journals such as *Political Quarterly*, or the *Journal of Public Administration*.

4
Corelli Barnett, *The Audit of War*, (London, 1986). Barnett discusses training and education under the rubric 'The Lost Victory", pp. 276-304, but has little to say about higher level technical education, except to observe that "it was not until 1960 that Britain was to create her first colleges of advanced technology, some 120 years after Germany". This position has been challenged by David Edgerton in *Science, Technology and the British Industrial Decline*, (Cambridge, 1996) although the specific example of Cranfield is not mentioned.

5
David Edgerton, *Science, Technology and the British industrial 'decline', 1870-1970*, (Cambridge, 1996), pp. 15-28.

'gentleman engineer' with a private school background in the days when this was rare in design and production. For several decades he had driven the engine work of the Bristol company, devising successive generations of the highly respected Bristol radial engines. His extraordinarily single-minded (many said ruthless) approach both to engineering design and to industrial management successfully accomplished the taxing development of the high power Bristol sleeve-valve engines which powered a large proportion of British combat aircraft in the Second World War.[6] However, his style brought him into increasing conflict with the Bristol board which dismissed him in September 1942.[7]

Colonel Llewellyn, the Minister of Aircraft Production, wished to utilise Fedden's experience for the war effort and then created a special post within the MAP as 'Special Technical Advisor to the Minister' (STAM). He took up this post just as Stafford Cripps replaced Llewellyn as the new Minister.[8]

One the first tasks was to lead the 'Fedden Mission to America', partly to select American aircraft for the RAF, but also to review American production techniques and to suggest where these might be adopted by the British aircraft industry. To Fedden "the whole standard of training of aeronautical engineers

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6
Something of Fedden's powerful character and reputation can be glimpsed from the recollections of his development engineers at Bristol in the 1930s. Stanley Mansell recalled "it was just about possible to cope if one never let up for an instant, if one had the innate capability not to tire or to start making mistakes even at the end of perhaps 24 hours non-stop, and if one never ran into any kind of bad luck". Fedden tried to be sociable and charming, Mansell recalled, "but it was hard work for him. It conflicted with his wish to get on with the job". Bill Gunston, *By Jupiter: the Life of Sir Roy Fedden*, (Royal Aeronautical Society, London, 1978). This work has been re-published in expanded form as Fedden - the life of Sir Roy Fedden, (Rolls-Royce Heritage Trust, Derby, 1998).

7
The background to his dismissal has always been obscure. However it appears that Colonel Llewellyn, as Minister of Aircraft Production, tried hard through 1942 to bring about a reconciliation between Fedden and the Bristol management which foundered on the intransigence of the family members of the Bristol board. Sir Roy Fedden papers, Royal Air Force Museum Archives.

8
The two appeared to hit it off. Fedden called Cripps "absolutely splendid" while Cripps told Fedden "You have the reputation of being a stormy petrel. That does not bother me in the least. I like people who are prepared to shoulder responsibility". Bill Gunston, 'By Jupiter' (n. 5 above).

was so impressive" that he went beyond his remit to study it, contrasted the large number of apprentice-trained artisans in England given limited theoretical training, with the very high number of university educated engineers in the USA and observing that in the USA some 14,000 engineers graduated annually, of which 10% were aeronautical engineers. On his return he recommended that the MAP establish a major university as "the main seat of learning in aeronautics". Fedden was clearly considering a new institution for he noted that space necessary for wind tunnels would be required and that the college should be adjacent to an airfield.[9]

Fedden had the opportunity to propagandise for these ideas for, in addition to his regular meetings with Cripps, he frequently accompanied him on industrial visits and argued for this new initiative which would "bridge the gap between the academic approach of the universities and the hard practical needs of industry for all-round engineers with ... a sense of vision, dedicated enthusiasm and high moral fibre".[10] The proposal clearly resonated with Cripps' technocratic and dirigiste approach and he asked for comments on the proposed new college "generously equipped and endowed ... for advanced studies" from a range of organisations including the Royal Aircraft Establishment, the National Physical Laboratory, the RAF, and the Royal Navy, but particularly from the Aeronautical Research Committee, writing to Sir Brian Melvill Jones, the eminent Cambridge aerodynamicist and Chairman of the ARC in May 1943.[11]

The ARC collated the responses from its members, who were agreed on the need for a new, independent institution. Professor W J Duncan, for example,

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9
The Fedden Mission to America, *Final Report*, Section 6, Education and Research, (Ministry of Aircraft Production, June 1943), Science Museum Archives.

10
Gunston, 'By Jupiter', (n.5 above), p. 123. "I want you to create something unique" was the charge Fedden recalled receiving from Cripps.

11
Sir R. Stafford Cripps to Prof. Sir Melvill Jones, 6 May 1943, ARC 6707, T.4231. "The project which I have been considering is the establishment of a School of Aeronautical Science". David Owen, 'Note on a Proposed School of Aeronautical Science', ARC 6737, T.4236). The comments of the ARC are in the ARC ledger pages for 15 and 22 June 1943 (RAE Library).

argued that "the School must not be strangled at birth by the deathly hand of the civil service. It must be as free from bureaucratic control as the Universities and the report to the Minister unanimously recommended the establishment of "a single central and comprehensive postgraduate school of Aeronautical Science financed by the State".[12] The School should, it argued, provide high level scientific and technical training in aeronautics and should fit selected students "for leadership in industry, civil aviation, the Services, the research institutions and the universities".[13] A central post-graduate centre for aeronautics, rather than expanded facilities across existing university engineering departments, was much preferred on the grounds that it would otherwise be impracticable to provide "practical experience of the technique of flight experiments and ... laboratory methods on the very large scale on which they will be carried out".[14] There is also a suggestion, in the Cranfield 'folk memory' that the idea of a new and separate institution received a boost from Churchill who was said to have averred that "the universities had failed the country" in the light of growing evidence of German achievements in jet aircraft and V weapons.[15]

The progress of ensuing attempts by MAP to create the College of Aeronautics is interesting in that it makes a striking lesson about the limits of political power in a complex governmental structure - even for a man such as Cripps with a strong and directed view of what he wished to achieve. The difficulties that were encountered, from many directions, are all the more surprising in view of

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12
W J Duncan, 'Post-war Higher Education in Aeronautical Engineering', ARC note T.4244, 1 June 1943. W J Duncan had been a research aerodynamicist at the NPL and joined the RAE at the outbreak of war. He became the first Professor of Aerodynamics at the new college in December 1945 and was also important in the recovery of research equipment from Germany.

13
Aeronautical Research Committee, 'Proposed Central Postgraduate School of Aeronautical Science; Report to the Minister of Aircraft Production', (3rd draft), 31 July 1943. The report also recommended that the School should have university standing and have academic freedom in the same way.

14
B. Melvill Jones, 'Note on a Post-Graduate School of Aeronautical Engineering', Aeronautical Research Committee (ARC), 10 June 1943, and Prof. W J Duncan, 'Post-War Higher Education in Aeronautical Engineering', ARC, 1 June 1943, (Science Museum Archives).

15
The recollection comes from Geoffrey Lilley, who joined the teaching staff in 1946, via Professor Ian Poll, personal communication, December 1996.

the prestige of the British aircraft industry in the latter part of the war, the common view that British aeronautical production was a great national asset for the future, and the obvious reliance of the RAF on good equipment.

In August 1943 Cripps began to approach Cabinet colleagues about the proposed college, including Sir Archibald Sinclair at the head of the Air Ministry, arguing that "the creation of a post-graduate School of Aeronautical Science ... is, I believe, essential to the future of British Aviation".[16] Lord Hankey (then Chairman of the Inter-Departmental Committee on Education and Training) replied quickly and positively to Cripps' proposals, with the perceptive observation that "I have been troubled in mind lately by the fact that so many of our wonderful aircraft and their engines owe their origins to a few men of flair and genius", but he noted ominously that setting such a college up "is not all going to be plain sailing" and suggested a joint MAP/Air Ministry committee.[17]

In spite of the promised boost to the technical calibre of the aircraft industry, the Air Ministry seemed either lukewarm, or perhaps positively obstructive, suggesting further consultation and noting, with perhaps excessive solicitude, that the Treasury "have strong views on the matter" and "are by no means happy with [the] proposals". This could, perhaps, be attributed to mistrust between MAP and the Air Ministry, although this had moderated considerably since Lord Beaverbrook's period as Minister for Aircraft Production in 1940 and 1941.[18] It may also have been a factor that Sinclair was thought to be "not

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16
PRO AIR 19/389, 'College of Aeronautics, - Proposal for Establishment', letter of 26 August 1943. Cripps enclosed the ARC report and his own draft paper on the college. "We can maintain pre-eminence in military aviation, and achieve it in civil aviation, only by technical advance and this will depend on a standard of higher engineering education and research such as can only be achieved by a central organisation created and fostered by the state".

17
Ibid. Hankey's assessment that a new approach would be needed in aeronautical design rather parallels Fedden's arguments that "the excellent family of military aircraft which have been doing such outstanding work in the hands of the Allied Air Forces ... cannot be repeated in modern form with the same method of artistry that created them initially 7 or 8 years ago". Lord Hankey was also, in 1943, Chairman of the Scientific Advisory Committee, the Engineering Advisory Committee and the Technical Personnel Committee.

18
W P Howlett, *The Competition between the Supply Departments and the Allocation of Scarce*

particularly decisive".[19]

Cripps wrote repeatedly to Sinclair urging that "I am most anxious to get ahead with this project". Sinclair stalled, suggesting "soundings from London University authorities" and noting that the Treasury objected to "a cut-and-dried plan". Sinclair retailed the opinion that Cripps' proposals should be re-drafted in such a way as to present "a case for consideration in principle" leaving the exact form of the facility to be determined by a future committee on which relevant government departments and outside interests would sit. Cripps became more emphatic, arguing that "we cannot wait until another Committee has deliberated" and writing to Sir John Anderson (as Lord President of the Council) that "I do not feel I can wait indefinitely if I am to discharge my responsibility for the organisation and efficiency of the aircraft industry. ... All I want is the general approval to go ahead under the chairmanship of someone like Sir Roy Fedden to get ahead ... with a detailed practical plan".[20]

This proposal was agreed. Fedden set to work with his customary energy but the objections continued.[21] Some critics argued for an "elastic ideal plan" on the grounds that expenditure on research "is subject to an unusually large degree to the law of diminishing returns. A good man can do much with comparatively slender resources". A few thousands spent in existing universities, it was

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Resources in the Second World War, PhD thesis, Cambridge, July 1988, pp. 92-94.

19
Reginald Maudling, *Memoirs*, (London, 1978), p. 34. Maudling served in the Air Ministry during the war working in the office of the Principal Private Secretary. He characterised Sinclair's minutes as being of the type "A is of the utmost importance, but, on the other hand, let us not neglect B" and added that "in fact this worked pretty well",

20
PRO AIR 19/389. Letters of 6 and 16 September 1943. R H Melville, Private Secretary to Sir Archibald Sinclair also noted "the Minister of Aircraft Production keeps pressing for a reply and now states that all the Ministers to whom he sent his document are in agreement ... except yourself". Cripps to Sir John Anderson, letter of 16 September 1943.

21
Ibid. Note of LP(43) 59th meeting. The Lord President's Committee, with Attlee in the Chair considered the proposals on 29 September 1943 and approved Cripps' suggestion that Sir Roy Fedden would chair a committee to prepare a detailed scheme.

suggested, might achieve as much as many millions on a big scheme.[22] Even the aircraft industry had reservations about the school and, at a meeting with the MAP Reconstruction Committee in September 1943, SBAC representatives indicated that they were not keen on a School of Aeronautical Science, giving their view that "shop-trained engineers ... were more valuable than the University product who had not been through the shops" and, in apparent disregard of the various British reports emphasising the resource of trained engineering designers and sophisticated production facilities in American companies, doggedly asserted that "craftsmanship in engineering design was one of our strong points competing with America" and that design was a creative process - "an art, rather than a science".[23]

By February 1944 it was reported that "the older and more conservative firms with large resources of their own for technical education were inclined to hang back, but the younger and more vigorous firms were strongly in support. ... The [existing] universities entertained some misgivings about the effects ... on their interests".[24]

The Treasury continued to be doubtful, questioning the claimed economic benefit of a college and pressing the wisdom of "a more modest scheme". It is interesting, in view of Cripps' forecast, noted in the previous chapter, that "industries such as coal and cotton" would prove inadequate to sustain Britain in the post-war era, to note that in these discussions Sir Alan Barlow, for the Treasury, queried whether an investment in textile research might not be more

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22
Ibid. G P Thomson (SAAM) to Secretary of State for Air.

23
PRO AVIA 15/1915. Meeting of MAP Reconstruction Committee at IC House, Millbank, with members of the SBAC to discuss post-war questions, 16 September 1943,. Comments such as these make it hard to dismiss entirely Corelli Barnett's strictures against the cult of "the practical man" aired in *The Audit of War* (n. 5 above). It is certainly remarkable that the industry ignored the example of CalTech, which had been consciously promoted to make California a centre of the US aircraft industry with the construction of wind tunnels and experimental facilities in the 1930s and which had been so clearly effective in the development of the new modern airliners like the Douglas DC 2 and Lockheed Electra.

24
PRO AIR 19/389.

productive than putting funds to the new college. The ARC replied that "these views take too narrow a view of the possible development of civilian air transport". If aviation was expected merely to replace sea passenger travel the market was small but "it is far more likely that the air will create its own traffic - much as the railways did a hundred years ago. ... The importance of the civil aviation industry may turn out to be as great as that of shipbuilding at the present time".[25]

The decisive point in these discussions came when R A Butler who, as Minister for Education, had been brought into the discussion through the interdepartmental committee requested by Cripps. Butler agreed that "existing facilities for post-graduate training were wholly inadequate", that he would welcome the establishment of a college and that he would be "prepared to take responsibility for it".[26]

Surprisingly, this agreement still was barely sufficient to impel the proposal to a conclusion. The Air Ministry offered to vacate the RAF station at Abingdon for the college but quickly back-tracked, on the objections of an Air Ministry official, H H Balfour, who argued that Abingdon "was one of our permanent peace-time stations of which we have not got too many". Cripps replied that "it is precisely because it is a peace-time station and has permanent buildings that the Committee recommended its use ... it seems to me out of the question that ... you should now seek to go back on this decision". However, he did not manage to reverse the decision.[27]

The reasons for the remarkably lukewarm attitude of the RAF and the Air

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25
Ibid. The costs of an entirely new college were estimated by Fedden's committee to be £2.65m capital with an annual running cost of £360,000. These sums could be trimmed, it was expected, to £400,000 start-up capital and £200,000 annual income by taking over an existing RAF station.

26
Ibid. War Cabinet, The Lord President's Committee, 22 September 1944.

27
Ibid. Cripps to H H Balfour, Air Member for Supply and Organisation (AMSO), letter of 25 September 1944.

Ministry remain mysterious. No suggestion has been found that, for instance, the RAF saw the college as a threat to its own training programmes, but it did appear to feel self-sufficient with its two year course at the RAF School of Aeronautical Engineering at Henlow ("roughly equivalent to a University engineering degree") and the dispatch of selected officers subsequently to Cambridge or the Imperial College.[28] This attitude should perhaps be seen in the context of the RAF's period of great prestige and confidence - perhaps even arrogance - resulting from its prominent and highly publicised role in the British war effort - an attitude which we have previously noted with respect to competition for design capacity for civil aircraft. The RAF was winning the War.[29]

After considerable procrastination, the advantages of a new college did become apparent and, looking forward to a post-war period when the MAP might disappear, Sir Archibald Sinclair mused, in an internal Air Ministry note, that "If this [the Air Ministry] is to be the great Air Department of the future, we shall be the principal beneficiaries of the scheme and I suppose that it is not unlikely that when the Ministry of Aircraft Production falls out, the responsibility will devolve upon [us]".[30] He proposed honouring the original commitment to Abingdon or placating Cripps with another station and Cranfield in Bedfordshire was then offered. This was attractive as plans for the new National Aeronautical Experimental Establishment were now crystallising nearby on Bedford.

28
In the responses sought by the ARC to the proposed college in June 1943 Air Commodore H Gordon-Dean gave details of the RAF's own programmes and merely noted of the proposed college "I would be grateful if you would keep me in touch with the progress of your Committee's activities". By contrast C S Wright, Director of Scientific Research at the Admiralty replied that "the formation of a School of Aeronautics would meet with the enthusiastic support of the Admiralty". (ARC T.4260 and T.4246).

29
A useful glimpse of RAF attitudes can be gleaned from Lord Portal (as Chief of Air Staff) writing after D-Day that "the constant application of heavy bomber power" to the land battle "when its only purpose is to save casualties" would lead to the demoralisation of the army. Tedder replied that the Army, "having been drugged with bombs, it is going to be a difficult process to cure the drug addict". Lord Tedder, *With Prejudice*, (London, 1966), pp. 605-606).

30
PRO AIR 19/389, Air Ministry minute of 22 September 1944.

The Air Ministry, however, again attempted to renege, advising Sinclair that Cranfield housed an OTU (operational training unit) of Mosquito crews which were used as night fighters to support RAF bombers and it was argued that when the offer had been made in December 1944, "the official estimate for planning purposes was that the war with Germany would be over by the 31 December. ... This prospect has receded". It was important, the Air Ministry argued, not to disturb the flow of trained aircrew from the night fighter training unit at Cranfield while operations against Germany continued.[31]

Even an offer of temporary accommodation at Cranfield was tempered by a warning from the Air Ministry that it might wish to reclaim the site in 1948 and it seems likely that the wrangling would have continued without issue indefinitely had not R A Butler written to Sinclair with his typical subtlety that "although your Ministry has already offered to find us temporary houseroom at Cranfield ... I have also had an offer [from the Admiralty] to find us temporary accommodation at Manadon [Plymouth] where the Naval Engineering College from Keyham is being established". Butler suggested that the Portsmouth site offered certain advantages in that accommodation and instructional equipment was already in place and went on to ask for Air Ministry advice on flying facilities from the nearby Harrobeer field "which I believe is now used only for transport planes".[32]

Butler's ploy clearly worked for Sinclair's Parliamentary Secretary noted to him that "the light in which we should view the Admiralty offer ... is necessarily darkened by the suspicion that their Lordships may not have acted in a spirit of entirely disinterested beneficence". The Air Ministry feared that a College of Aeronautics sited at Manadon would run a risk of being "unduly influenced by the Navy" with its neighbouring Engineering College. "We should prefer" the Air Ministry noted, "the present arrangements to locate the College in the

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31
Ibid. PS to Sof S, 30 December 1944.

32
Ibid. Letter of 8 February 1945 from R A Butler to Sir Archibald Sinclair.

Bedford area to stand".[33]

Meanwhile Butler let the Air Ministry know of his intention to visit Manadon even though the interdepartmental committee had by then recommended Cranfield "not only on a temporary but on a permanent basis". Butler forwarded this report to Sinclair but his secretary then added (an especially light touch!) that "the letter should not be taken as a definite request to make Cranfield available ... Mr Butler's letter is for information only at this stage".[34]

Decisively out-manoeuvred, the Air Ministry then did cede Cranfield for the new project without further objection as a permanent home. Air Chief Marshall Sir Edgar Ludlow-Hewitt was appointed as Chairman of the Board of Governors and attacked the project with great energy.[35] In the wake of the German surrender he was quick to see the potential of the equipment in German aeronautical establishments for help in fitting out the College and in August 1945 Ellen Wilkinson, from the Ministry of Education, wrote to Viscount Stansgate, at the Air Ministry, noting that "Sir Edgar Ludlow-Hewitt ... has just been out to Germany, and tells me that it would be possible to secure a great deal of the technical equipment required for the College from German sources. I understand that the British Air Forces of Occupation with their disarmament staff are able and willing to collect this equipment for the College". Stansgate gave the necessary authorization. Ellen Wilkinson kept up the pressure from the Ministry of Education, writing again in March 1946 to him that "I am a little

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33
Ibid. As a desperate gambit the Air Ministry noted that "Harrowbeer is partly situated on common land, and while we cannot of course air to Mr Butler any suspicions of the Admiralty we may have, it is reasonable to argue that in view of the political pressure which will be brought to bear to evacuate common land, his tenure of Harrowbeer may be uncertain on that account".

34
Ibid. Visit to Manadon on 19 March. Letter to Sinclair, Air Ministry, 27 March 1945.

35
Sir Edgar Ludlow-Hewitt was noted for the contribution he made in stepping up and improving RAF aircrew training in the pre-war period. Sir John Slessor's verdict on him was "A great Air Force officer and a fine airman in every sense of the word ... one of the few senior Air Force Commanders of the Kaiser's war ... deeply knowledgeable not only of the higher direction of air forces but also, to an exceptional degree for a man of his age, of the technique of airmanship, Sir John Slessor, *The Central Blue*, (Cassell, London, 1956), pp. 114, 208-209.

anxious about the progress being made ... My purpose in writing to you is simply to enlist your personal interest in securing that everything possible is done to enable the College to open by the date proposed". By hand she also wrote "Dear Wedgie, Do buck them up. It is as essential for your crowd as ours that this job gets done in time. Really it has hung about rather long". Ever yours, Ellen".[36]

The Cranfield College of Aeronautics opened on time in October 1946. It has earned a first class reputation and has certainly fulfilled its mission to be a major part of the educational underpinning of the British aerospace sector. During the post-war era it has consistently maintained a position as the largest post-graduate aeronautical department in Britain and although today it has expanded into Cranfield University, with many other specialisms, the aeronautical school within it remains an important element with one of the biggest academic aeronautical research programmes in the world.[37]

The National Aeronautical Establishment, Bedford

Another important contemporary proposal, which had links with the proposal for a new College, was for a major new research facility, a 'National Aeronautical Experimental Establishment' which was conceived on a most ambitious scale. At the same time that Cripps sought help from the Aeronautical Research Committee (ARC) over the new College of Aeronautics he also asked it for a study on the facilities which would be required for research and development by the industry within the next fifteen years.[38]

36
PRO AIR 19/389.

37
In 1996 the College of Aeronautics, within Cranfield University, had about 270 post-graduate students and a throughput of approximately 80 Ph.D. students per year.

38
PRO AVIA 15/2361, 'Full Scale Flight Research, Proposed Establishment for'). Attempts to create a major new centre dated back to 1939, when David Pye, as Director of Scientific Research (DSR) at the Air Ministry, proposed new a flight research centre, arguing that fundamental research at Farnborough had been displaced by the need to deal with short-term

As with aeronautical education, the effect of contacts with America during the war again persuaded British engineers and scientists that the scale of research effort here was too small and once again, Roy Fedden's 'Mission to America' report took a propagandist line, observing that there were some thirty "good sized tunnels" in use in America, with a further ten under design or construction. Drawings and photographs of American wind tunnel facilities were included in his report, which argued for the need for increased research equipment in Britain and warned that facilities of the type seen in America would place them "far ahead of [a country] in which aircraft designers and engineers must of necessity design as an art rather than an applied science".[39]

The ARC committee, under the chairmanship of Melvill Jones, produced a bold document proposing a radical enlargement of research and development facilities. Aviation "was entering an era in which revolutionary changes are inevitable" it argued, and that now "apparatus of very large size is essential".[40] The development of the jet engine and the discovery that aircraft could fly at speeds approaching that of sound heralded a new, more scientific, age in aeronautics which would require far more sophisticated equipment.

One important requirement was a five mile runway ("the great length is required to enable aircraft of new and untried types to take off and land again without turning") but there were also to be some nine "new national wind tunnels" including four low speed (i.e. up to about 400 mph) tunnels with large working sections of 16 by 12 ft., three transonic tunnels (600-700 mph) and a supersonic

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problems associated with re-armament.

39
The Fedden Mission to America, Final Report, (Ministry of Aircraft Production, 1943), Section 6, Part D, Ch 1., 6D-1.01 - 6D-6.04. The influence Fedden had in the aeronautical community was not purely mediated by the report; he was in frequent personal contact with almost all senior figures involved in aeronautical research and development.

40
Aeronautical Research Committee paper; 'National Requirements for Aeronautical Research and Development', 23 March 1944, DSIR 23/13337. David Pye was also a member. For a brief account of the ARC, its history, role and influence, see Andrew Nahum, 'Two-stroke or Turbine? The Aeronautical Research Committee and British Aero Engine Development in World War II', *Technology and Culture*, April 1997, Vol 38, pp 312-354.

(Mach 2) 4 ft. tunnel.[41] The low speed tunnels were expected to need about 4000 h.p. to drive them and the high speed and supersonic tunnels about 40,000 h.p. There were also envisaged extensive engine test facilities and materials laboratories. In aggregate, the wind tunnels and test equipment would need about 200,000 hp - a demand that would require an electrical supply from the National Grid capable of providing 150,000 kW or 180,000 kW at peak - equivalent to the demand of a medium-sized town. The establishment was costed by the ARC at around £18 million - nearly £500m in today's prices.[42]

Like the College of Aeronautics Cripps responded to these proposals with enthusiasm, asking George Bulman, then Director of Engine Development (and scourge of Whittle) to take on the job of constructing it and offering "a prospect of rendering the country the greatest service". The new research centre, Cripps stressed, was "of vital importance for the country's future".[43]

In spite of the enormous anticipated cost of these facilities the plans were inserted into the national programme with surprising ease, in contrast to the much harder fought struggle to establish the new College of Aeronautics at Cranfield which was only expected to cost £2.65 million, (or £400,000 if based on an existing RAF airfield site). It appears that education was a more

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41
It should be appreciated that tunnels of this type are substantial civil engineering structures. The working section of 16 x 12 ft. for the low-speed tunnels required a circuit some 400 ft. (120 m) long to return the air, substantially build to resist a pressure that could be as high as six times that of the atmosphere.

42
PRO DSIR 23/13337, Aeronautical Research Committee, 'National Requirements for Aeronautical Research and Development', (The file contains A.R.C. Report 7500 of the same title, dated March 1944). The five mile runway would have been the longest in Europe. In the USA the almost limitless landing grounds provided by the dry salt pans of the Mojave desert (subsequently Edwards Air Force Base) did prove of great utility post-war for test-flying experimental high speed types.

43
George Bulman, unpublished autobiography, ms deposited with the library of the Royal Aeronautical Society, p. 506. "The scheme would demand the undivided attention of one individual to steer this great project through all the quicksands and shoals of Departmental policies, and especially through the Treasury which would undoubtedly seek to delay it and whittle down the expenditure". Bulman accepted the job of Director for Construction of Research Facilities (DCRF) and, although he suspected that the move had been partly prompted by the failure of the Napier Sabre engine programme, he accepted Cripps' assurances that this was not so "because he was one of the most honest men [he] had ever met".

contentious subject than national research and development efforts and one where many more special interests sought to be represented. Even the Treasury, which had balked at the costs of the College, gave authority in December 1944 for planning for the new establishment to proceed.[44]

Nevertheless, the actual location of the proposed 'National Establishment' still required extensive inter-departmental negotiation. Farnborough would be the most economical centre on which to base the new investment. However, the War Office resolutely opposed expansion of the existing aeronautical establishment, maintaining that the proposed new runway would bisect the Aldershot army training area.[45]

Considerations of flying weather and local topography then identified four possible areas, based around Reading/Oxford, Luton/Bedford, Coventry/Leicester and Hitchin/Cambridge but the Board of Trade and the Ministry of Labour, with responsibilities for the location of industry and for the minimisation of post-war unemployment, insistently pushed to have the Establishment located in one of the "difficult areas", strongly urging the selection of South Wales. It is a measure of the pervasiveness of the war-time 'command' mentality that the Ministry of Labour particularly commended the airfield at St Athan, on the South Wales coast, on the basis that "hostels were already established there".[46] However W S Farren, from his experience as Director of the RAE, displayed a more humane and intelligent attitude to location declaring that "research is done by men and not by wind tunnels. It

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44
PRO AVIA 15/2091. Major Bulman noted on 12 December 1944 "we have now received the authority of the Chancellor of the Exchequer to proceed with the planning and design of the new Establishment on the Bedford site". The initial approval in principle came from the Lord President's Committee in June 1944.

45
Ibid. In fact, much of this Army activity was transferred to Salisbury Plain in the post-war era.

46
PRO AVIA 15/2091, minute of 19 July 1944, minutes of Inter-Departmental Meeting, 25 July 1944. The new Establishment was expected to employ some 2000 skilled industrial workers and 1600 scientists. Douglas Jay, for the Board of Trade, strongly opposed the Oxford area on the grounds that labour resources were already insufficient for the Nuffield and Pressed Steel organisations; "it would be an embarrassment to the Board in resisting industrial approaches if a Government Department insinuated a fairly large labour demand into the area".

must be possible for the majority of the staff to live in a good town where there are the normal amenities people need for a reasonable life and good educational facilities for children. ... these rule out a site in the wilds".[47]

The Air Ministry and MAP senior staff fought also to make the facility accessible by quick train service from London, and deployed arguments against locating experimental flying in northern areas of industrial haze and poor weather.[48] In addition, choice of site was constrained by the need to installing a connection to the National Grid with a high capacity electricity supply at a cost of £1m per mile. For all these reasons Bedford, where two existing airfields could be joined up, eventually was chosen[49] A month later, in October 1944, he announced that "the question has been fully discussed with Ministries concerned. Having regard to their views and to such considerations as good flying weather, easy access to London, Oxford and Cambridge ... I have decided that the most suitable location ... is in the neighbourhood of Bedford". Cripps also displayed his wider vision by noting that "the opportunities of the site should provide for an architectural layout adequate to the needs of the Establishment" - a provision that he also had demanded for the new College of Aeronautics.[50]

Plans for the new establishment were laid out on the site on the basis of the 1944 ARC report although it was never fully completed to the almost grandiose

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47
PRO AVIA 15/2091, W S Farren, paper on site for the National Aeronautical Establishment, July 1944.

48
Ibid. Bulman noted that "we are virtually left with the single obstacle of Mr Jay,and it has been separately hinted to me that his President may not support him at Ministerial level". Most of the proposed sites were also opposed by Miss Champ of the Department of Town and Country Planning on the grounds that they did not wish to see growth in existing towns or new communities, although Sir H E C Beaver, from the Ministry of Works pointed out pithily that the Government was committed to a large housing programme and that "new houses will be built somewhere".

49
Ibid. "I want the decision as to the siting of the new ARC establishment to be finalised by the end of this month please without fail". Minister to CRD, 8 September 1944. This note, like many of Cripps' most emphatic ones is in bold red ink. These directives were said by initiates in the MAP to be "written in blood".

50
Ibid. Minister's statement of 9 October 1944.

scale that had been envisaged. Only part of the planned complement of 'national wind tunnels' were built and the runway was completed at three, rather than five, miles. Although it opened under the title of the 'National Aeronautical Establishment' Bedford was, from the outset, administered under the Ministry of Supply as a branch of the RAE at Farnborough and by the autumn of 1945 it was becoming accepted that Farnborough would not be displaced as the main research centre.[51]

The downgrading of what had been an exceptionally ambitious programme, was caused, in part, by the natural reduction in defence expenditure as the war came to an end, and although Bedford had been promoted as a national facility for the whole aviation sector, and particularly for the civil aircraft projects, it was inevitably seen primarily as a defence facility for purposes of financial planning.

As the screw began to tighten for government expenditure at the end of the war W S Farren advocated an initiative from the MAP "to persuade the Treasury to take a statesman-like view of our problems", but internally MAP officials conceded that the programme "comes at an awkward moment for us. ... From now onwards the Treasury will turn a more critical eye than before on any proposals for expansion. ... We must expect them to be running a full-blown economy campaign in about two years time".[52]

By August 1945 the Treasury noted to the MAP, on the subject of the staffing and administration at Farnborough and Bedford, that "for some time past we have been growing increasingly alarmed at your constant demands for additional scientific staff". The time had arrived when this "fairly free hand" allowed during the war was no longer possible. Approval had so far been given for acquisition of the Bedford site at a cost of £190,000, but came with a strong warning that the new establishment should be planned in relatively self-contained

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51
PRO AVIA 15/3691, 'R.A.E. Reorganisation', minute by Air Marshal Coryton, CRD, MAP, 16 October 1945. "The RAE [Farnborough] will certainly remain our principal aeronautical establishment for many years to come".

52
Ibid. Minute of PAS (E), 4 May 1945.

stages, so that "if the economy axe falls" while the project as a whole was incomplete, what has been built would still form a functional unit which would be "capable of standing on its own feet".[53]

In fact the vote of credit for all aeronautical research and development in 1945 totalled just over £4.5 million, a sum that was insufficient to also provide for the completion of Bedford to the scale as first conceived, although it did certainly become an important research facility with a suite of wind tunnels and other equipment.[54] But although Bedford was opened under the title of the 'National Aeronautical Establishment', it was effectively operated as a section of RAE, staffed and run from Farnborough, and never really developed a separate identity.[55] By 1947 it was accepted that the two sites would continue in existence and that Farnborough would remain the major national centre.[56] By 1955 the MoS came to the view that there was not "a homogeneous job" for Bedford that would justify separation and that "morale at Bedford would lose by separation from Farnborough ... being part of a large and successful organisation is beneficial. It was also accepted that the name should also be changed to R.A.E. (Bedford).[57]

53
Ibid. F C Newton, Treasury, to A L Cadman, MAP, 17 August 1945, , and minute by R E Bone, PS8, MAP, 5 September 1945; "the Treasury have been very disturbed by the continued growth in R&D staff".

54
These included a supersonic tunnel of eight foot working section and another of 3 foot section, both using drive motors and fans taken from the Herman Göring research institute at Volkenrode, although it appears that the aerodynamic design for the tunnels had been developed at Farnborough during the war.

55
Although RAE Bedford certainly pursued some research programmes of its own, a study of, for example, the Concorde programme implies that the origination of the aircraft concept, creative direction and initial wind tunnel testing took place at Farnborough. Bedford would then take over the proposed aircraft and wing shapes for high speed test in their powerful tunnels.

56
PRO AVIA 15/2091, Second Secretary MoS, minute of 30 July 1947. "The growth of G.P. [guided projectile] work has strengthened the case for saying that both Farnborough and Bedford are necessary if we are to cope with the liabilities ahead of us".

57
Aeronautical Research Council, T.4963, copy of letter from E T Jones, P.D.S.R. (A), MoS to Secretary, A.R.C., 12 April 1955.

Although post-war economies did contribute to the curtailment of the bold initial plans the sense derived from the public records is that the real check to the major strategic plan for creating a major national aeronautical centre at Bedford was the departure of Stafford Cripps from the MAP.[58] His vision and ambition for the industry had launched the scheme and like the College of Aeronautics, it was pushed along by an energetic stream of his letters, minutes and exhortation. Following his departure the development of the facility was subsumed into the normal channels and agencies which administered the scientific civil service. As the previous chapter showed, a similar fate befell another of his initiatives, the formation of Power Jets (R&D) Ltd as a national jet engine research facility.

The Exploitation of German Aeronautical Science

The exploitation of Germany's scientific research and its scientists by the USA, particularly with regard to Werner von Braun and the other rocket experts from the V2 programme who were taken to the USA by the American Army in 1946, has received considerable attention, both at a scholarly and a popular level.

There have also been broader studies of the American programmes which came under the project names 'Overcast' and 'Paperclip' which brought many German scientists to the USA. Of these studies the most comprehensive and analytical must be that by the American historian John Gimbel which puts 'Paperclip' into the context of the whole intelligence-gathering operation mounted in Germany at the end of the war and its translation into a kind of undeclared programme to extract "intellectual reparations".[59]

58
Following the Labour election victory on 26 July 1945 Cripps became Chancellor of the Board of Trade. Colin Cooke, in *The Life of Richard Stafford Cripps*, (London, Hodder and Stoughton, 1957), covers his time at MAP rather briefly. He deals with Cripps' role in putting MAP programmes on a more realistic basis and his exhortatory visits to the factories but does not refer to Cripps' strategic initiatives for the post-war industry and his far-reaching influence on it.

59
John Gimbel, *Science, Technology and Reparations; Exploitation and Plunder in Postwar Germany*, (Stanford, 1990).

By contrast, the British effort after the war to utilise German science and technology has received surprisingly little study although Tom Bower characterises UK efforts as amateurish and piecemeal.[60] Even a recent (1996) work on technology transfer out of Germany after 1945 largely neglects Britain.[61] This is a considerable lacuna in the study of the post-war period in Europe and the section here will focus, in particular, the use made in Britain of German aerodynamics and aeronautical science.[62]

It is suggested here that the British initiatives for the utilisation of German science were carefully targeted, ambitious and probably at the limit of what was practical in the immediate post-war environment. The effect of influx of German technique certainly should certainly be analysed in the context of British post-war aviation since it appears to have had a significant influence on research in the Government establishments and on the complexion of the British industry.[63]

First Impressions

As the Allied forces entered Germany, a variety of intelligence gathering operations and missions were put in hand to investigate German technique and

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60
Tom Bower, *The Paperclip Conspiracy*, (London, 1988). Bower makes the curious judgement that the British programme was characterised by excessive scrupulousness with respect to scientists with Nazi associations, vagueness about objectives and 'lost opportunities', while at the same time he castigates the Americans for being too greedy and too ready to whitewash the record of 'desirable aliens'. See also Clarence G Lasby, *Project Paperclip*, (New York, 1971).

61
Technology Transfer out of Germany after 1945, ed. Matthias Judt and Burghard Ciesla. (Harwood, Amsterdam, 1996).

62
There is a need for a far wider study of these events, which is beyond the scope of study for this author, taking in the use made of the whole range of scientific and technical material brought to Britain including German industrial chemistry, plastics and synthetic materials, textile handling, photography, film developments and much more.

63
Bower has contended that the UK failed to exploit the German lead in rocketry intelligently (The Paperclip Conspiracy, n. 59 above) but it is noteworthy that twelve scientists from the Trauern research centre were brought to the new Rocket Projectile Establishment at Westcott in Buckinghamshire. PRO AVIA 40 at the PRO contains more than five thousand engineering drawings for the V2 and the Wasserfall anti-aircraft missile that had been acquired for Westcott.

the apparent lead in many areas of weaponry. The initial British attitude to much of the German research that was uncovered was equivocal. The proliferation of surprising secret weapons and new kinds of aircraft had done almost nothing to slow the Allied advance and Sir Roy Fedden, leading one mission, contrasted this profusion of projects with "the simple, but sound, British aeronautical programme ... pursued with very little interruption throughout the war, but accompanied all the time by intelligent improvisation until there was really very little in the way of development to come".[64] But if the policy directing the German effort seemed diffuse, the actual technique of production was of excellent quality in most centres although not, in the opinion of the investigators, superior to British methods.[65]

On 7 June 1945, a month after the German surrender, Air Marshal Sir Alec Coryton at MAP invited members of the aircraft, industry to survey a cross-section of the corresponding German Industries under the leadership of W. S. Farren, Director of the RAE. The Farren Mission included eight industry designers and managers, the Director of Technical Development (DTD) at MAP and A K Cairncross, representing the Director-General of Programmes, Planning and Statistics at MAP. It left on 9 July, returning just over two weeks later. The Mission observed that there had been no central direction of the industry in Germany and "no O.R. [operational research] as we know it". There was also no organised resident German air ministry representative at the firms

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64
Sir Roy Fedden, 'Final Report - The Fedden Mission to Germany', MAP, June 1945, (Science Museum archives). Fedden's principal brief was to select equipment to equip the new College of Aeronautics. At Magdeburg Fedden photographed a pile of newly-made Junkers jet engines smashed in an Allied (piston-engined) bomber raid and wrote across the back of the print "The toll of the orthodox".

65
Both Britain and Germany suffered, in terms of economy of scale, from generally smaller plants and shorter production runs relative to the USA, although Britain had probably gone further in training and incorporating new labour into the aircraft plants whereas in Germany the power of the master craftsman or *Meister* in engineering shops seemed little diminished. Although in Germany much airframe manufacture was improvised and dispersed Hans-Joachim Braun has argued that engine manufacture tended to rely on established German high skill craft technique and multi-purpose tooling. The introduction of single purpose ('mass production') tooling was relatively slow and where engine manufacture was dispersed productivity was generally poor. Hans-Joachim Braun, 'Aero-Engine Production in the Third Reich', *History of Technology*, 14 (1992), 1-15.

equivalent to the British post of Resident Technical Officer (RTO). It also noted that "the firms were forbidden to make contact with the Service [and] considered that the inability of the designers to obtain first-hand knowledge of ... performance of aircraft under operational conditions was a serious hindrance. ... This lack of direct contact with the Service may well have been one of the contributory causes of the violent changes in Air Staff requirements".[66]

Thus the Farren Mission was able to take comfort from failures which Britain had avoided, and claimed that "when U.K. personnel reached Germany after the war, the surveys supported a view that the MAP had been successful".

What certainly was different, in the German case, was the sophisticated level of the aeronautical research effort and the quality of the associated equipment in the firms where, it was noted, research and development departments in the firms were well organised and staffed with "relatively young men of experience, energy, and enthusiasm". Farren observed that although "their methods did not differ greatly from [ours] ... their resources were greater".[67]

It also began to be appreciated by British investigators that jet aircraft like the Messerschmitt Me 262 which were entering service by the end of the war would have proved a grave embarrassment if they had been made available only a little earlier and in sufficient numbers.[68] In addition there were other innovations such as rocket interceptor fighters, anti-aircraft rockets, the V1 and V2 missiles, and radio-controlled anti-shipping glider-bombs and although these could scarcely, in

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PRO AVIA 10/411, 'Farren Mission to Germany'.

67
Ibid. Sir Alec Cairncross has also left his recollections of the mission recalling that "the Farren Mission was greatly impressed by the lavish scale on which the German government had supported research and development, employing in 1945 5000 workers [in a private firm] in five separate establishments, and stressed the contrast with regarded as the parsimony of the British government in financing research and development in aviation". A K Cairncross, *Planning in Wartime*, (Oxford 1991), pp. 137-140.

68
PRO AIR 8/784, minute of 24 January 1945. The threat of the new Messerschmitt jet fighters was serious enough for Lord Portal to predict that "if Germany has not been beaten before July 1945 she will have dominance in the air over Germany and above the armies during good flying weather".

most cases, be regarded as mature and practical weapons systems they nevertheless pointed to a huge German lead in the technology of high-speed flight, propulsion, guidance and control as well as the research facilities for the mechanical and aerodynamic analysis of aero structures in a new high-speed aerodynamic regime. As the British missions moved through the parts of Germany to which they had access the scale and quality of the advanced research being done began to astonish them.[69] In a rider to his defence of the pragmatic British production programme, Sir Roy Fedden observed that the Allied victory had been won by "obsolete types, from which every ounce of development had been wrung". American commentators reached a similar conclusion, suggesting that the air war had been won with brawn, not brain: "we choked them with the weight of our planes".[70]

Perhaps this should not have been so surprising for before the war Germany had hosted visits for British aeronautical engineers, including Roy Fedden, who visited frequently, Sir Harry Ricardo, and a delegation from Rolls-Royce which toured a range of companies and research establishments. These tours always impressed with the scale and quality of the facilities and no doubt were offered to persuade British opinion that to challenge Germany in the air would be fruitless.[71] Nevertheless, when re-visited in 1945, the scale on which Germany's

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69
Gunston, 'By Jupiter', (n.5 above), p. 130.

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Gunston, 'By Jupiter', (n. 5 above)), p.130 and Senator Albert D Thomas, quoted in Judt and Ciesla, (n. 62 above), p 101.

71
The subject of these various high level missions into Germany before the war and German intentions in facilitating them is a curious one which has not been explored. It is interesting to note that Tizard wrote to Lord Swinton, Secretary of State for Air , in 1936 about one such: "H R Ricardo, of whom I expect you have heard, has just returned from Germany where he has been shown German engine developments. I think that it would be helpful to you if you had a talk with him. His news is very reassuring in some ways". (PRO AIR 2/1866, 'Committee for the Scientific Survey of Air Offence'. The facilities given to the Rolls-Royce mission in 1937 are particularly intriguing, since these were top-level engineers who could see the significance of what they were shown. The three Rolls-Royce men were A G Elliot, Chief Designer, H J Swift, General Manager, Production, and J Ellor, the R-R supercharger expert. They saw, among other things, the Daimler-Benz, Junkers and BMW aero engine works and were provided with a Junkers Ju 52 aircraft. They were deeply impressed with the scale of organisation and the provision of enclosed 'silent' test beds with instrumentation grouped outside, noting that the facilities of plant, buildings, equipment and personnel for research and development was

government defence research establishments had moved ahead was startling. The first challenge to British investigators appeared to be the exploitation of the plant and physical resources found in the British area of control in Germany.

The Hermann Goering Research Institute, Volkenrode

Six important research facilities fell inside the British Zone of Occupation. They were:

Luftfarhrt Forschungs Anstalt (LFA) Volkenrode
Aerodynamische Versuchs Anstalt (AVA) Göttingen
Kaiser Wilhem Institut (KWI) Göttingen
Dispersal Wind Tunnels from AVA, Reyershausen
Rocket Research Station and liquid oxygen plant, Trauen
Focke-Wulf structural testing laboratory, Detmold.

Many of these facilities, such as the AVA at Göttingen (equivalent in some senses to the RAE at Farnborough), were well known before the war. However, the greatest surprise, as well as the greatest prize, was found in the immense Hermann Goering Research Institute at Volkenrode, near Brunswick.[72] The institute had been conceived on a vast scale by British standards and was equipped particularly to deal with the new problems of high-speed flight. It was hidden in a forest and extraordinary care had been taken to conceal it from Allied photo-reconnaissance flights. No large roads led there, the power lines had been buried underground, and the whole site was elaborately camouflaged.[73]

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superior to anything we have seen in this country". They also noted the open layout of factory sites with buildings widely spaced "evidently planned [to make] air attack extremely difficult". Report reproduced in *The Archive,* (journal of the Rolls-Royce Heritage Trust), Vol 2, Issue 2 No. 6, 1984 and subsequent issues.

72
PRO AVIA 9/88, 'Visits to Volkenrode'. Paper on file: 'MAP Interest in German Research Establishments', 3 January 1946. This notes "of these, by far the most important is Volkenrode".

73
Ibid. Sir Arthur Woodburn, as Parliamentary Secretary for the MAP, visited Volkenrode in January 1946 and recorded that "the Herman Goering wind tunnel was covered by a special cement platform covered with tons of earth in which shrubs, grass and even trees were planted. ... the fact that all this ... was planned and prepared long before the war and so carefully

Ben Lockspeiser, as Director of Scientific Research in MAP (DSR), went to appraise the site in May 1945 when the British army advised that there were "some wind tunnels in a large forest" and was amazed to find "the finest aeronautical establishment he had ever seen".[74] His report to the Minister for Aircraft Production revealed the contemporary excitement at the discovery.

> It is concealed and dispersed in a large forest. ... Its aerodynamic, supersonic and high speed equipment is far ahead of anything in this country, and as far as my knowledge goes, ahead of American equipment also. ... in several directions the equipment is unsurpassed anywhere".[75]

W S Farren, thinking clearly of his own facilities at Farnborough, observed independently that Volkenrode had "a magnificence ... that beggars the imagination of anyone who has seen similar institutions in the UK".[76]

Initially the site was under the control of Colonel Donald Putt of the US army which had discovered it shortly before but, as noted, it fell inside the British Zone and was shortly to be handed over to the British Army. Putt, in fact, was the officer in charge of the American intelligence operation 'Lusty' and was subsequently a major proponent of the American 'Paperclip' programme to

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hidden [is] itself a silent indictment of the Nazi preparations for war".

74
Ben Lockspeiser, introductory remarks as Chairman on 9 October 1946, to; R. Smelt, 'A Critical Review of German Research on High-Speed Air Flow', *Journal of the Royal Aeronautical Society*, 50, (1946), p 900.

75
PRO AVIA 15/2216. Ben Lockspeiser, DSR to Minister (through CRD and DTD), 11 May 1945. Lockspeiser noted that the establishment "consisted of seven independent institutes, each under a professor and reporting directly to Berlin, which covered aerodynamics, gas dynamics (supersonics), strength of materials, engines, special engines (rockets and gas turbines), weapons and theoretical ballistics. The head of the aerodynamics institute acts as administrative head for the whole. The scientific staff number about 150 and the total number of people employed was about 1000. ... It had very large funds at its disposal from 71/2 to 8 million marks yearly, (and received, in addition, 1-11/2 million marks a year from industry for wind tunnel work)".

76
AVIA 10/113, quoted in Bower (n. 60 above).

bring German scientists to the USA.[77] Lockspeiser considered that Britain ought, without delay, put the site back into use or, in view of the possible political difficulties of allowing the installation to remain intact in Germany, transfer the most valuable equipment to the new National Aeronautical Establishment being established at Bedford. The scale and sophistication of the equipment made such an impression on Lockspeiser that he judged that exploiting the Volkenrode facility meant that:

> we should bridge over the gap of some five to ten years which I see no means of doing by any other method. ... The equipment ... is such that we cannot expect to be able to build its parallel within a number of years and the knowledge possessed by its scientists is such that it will fill in gaps which otherwise would take us similarly many years to fill in from our own resources and researches. It would, in our view, be difficult to exaggerate the importance to this country of exploiting these facilities to the full".[78]

Lockspeiser's reports from Germany also reflected the difference in approach between the USA and Britain in acquiring this intellectual booty. The British model was that the material would be acquired by government agencies such as the RAE or other research establishments and then be put at the disposal of firms for assistance with specific research contracts under security conditions. The American approach, although more ambitious and far-reaching seemed looser and at odds with this British 'government-rationing' attitude. Lockspeiser observed that "a large part of the scientific service provided by America for this kind of investigation is in the hands of industrial representatives who have been placed in uniform and there is no doubt a great temptation in the way of

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77
C G Lasby, *Project Paperclip*, (n. 60 above), p 28-29. According to Lasby, Putt was one of the most vocal and influential advocates for the transfer of German scientists to the USA. "Lusty" was just one of a large number of the intelligence missions intended to investigate and exploit German science after the surrender. These also included ALSOS (the mission to investigate the state of German atomic research), CIOS (Combined Allied Intelligence Sub-Committee) and BIOS (British Intelligence Objectives Sub-Committee).

78
PRO AVIA 15/2216. Herman Goering Research Institute at Volkenrode (Luftfahrtforschungsanstalt Herman Goring - LFA), Ben Lockspeiser, DSR to Minister (through CRD and DTD), 11 May 1945.

individuals to profit their employers".[79]

Lockspeiser was correct about the attitude of the Americans, although it is not clear whether the American 'industrial representatives' regarded this as a temptation or simply a normal duty.[80] In fact, he visited Volkenrode at the same time as the noted aerodynamicist Theodore von Karman, who had arrived from CalTech as part of the 'Lusty' operation.[81] George Schairer, the head of the Boeing aerodynamics department and a member of this group, wrote home from Volkenrode to his deputy at the Boeing company within a day of Lockspeiser's own note to the MAP, giving his colleagues important details of the German research into the use of swept back wings for high speed flight.[82] This information was incorporated into Boeing engineering policy so quickly that the XB-47 bomber project, then under development, was delayed while this new aerodynamic theory could be incorporated. As subsequent sections will show, Boeing's readiness to incorporate this new thinking led, within a few years, to a

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79
Ibid.

80
Gimbel, 'Science, Technology and Reparations' (n. 59 above), p viii, quotes an interesting contemporary German opinion that this technological booty represented a subsidy from the foreign taxpayer to the capitalist in the guise of costs of the Occupation; "the foreign capitalist receives his German competitors' secrets and enriches himself by them, but he does not re-imburse his country ... with the result that the foreign taxpayer is the primary sufferer".

81
Clive Irving, *Wide-Body, the Making of the 747*, (London, 1993); 75-94.

82
Schairer wrote "the Germans have been doing extensive work on high speed aerodynamics. This has led to one very important discovery. Sweepback or sweepforward has a large effect on critical Mach No." and he gave sample calculations to illustrate the theory. G S Schairer to Benedict Cohn, 10 May 1945, reproduced in facsimile in *50 Jahre Turbostrahlflug*, DGLR-Symposium [Proceedings], Munich, 26 & 27 October 1989. The fact that Schairer wrote "Censored" on the cover of his letter and signed this statement himself could indicate a desire to avoid US government control although one account attributes his action to a desire to "avoid delay".

Schairer and Cohn would have immediately realised that the swept back wing allows a subsonic aircraft to approach the speed of sound without suffering the effects of buffeting and trim change (pitching up or down) - the so-called compressibility phenomena which had been encountered by the increasingly powerful Allied service aircraft used in the war. Schairer's Boeing colleagues absorbed the importance of his note and immediately began wind-tunnel tests. By September the experimental XB-47 bomber project had been converted to use a 30 degree sweptback wing, although this meant delaying it behind their rivals. Boeing won the contract and the aircraft became the B-47 bomber.

generation of transport aircraft with a significant speed advantage over British (and other American) rivals.[83]

Lockspeiser also asked for a ruling to stop the records of scientific establishments being moved and for them to be microfilmed "for the benefit of all". In fact, some 3 million documents, many of them from Volkenrode, were taken by US agencies.[84] Sir Roy Fedden told his biographer some years later that he had two loaded trucks with equipment collected for the new College of Aeronautics taken away from him by American forces at gun-point. He also alleged that American investigators with whom he had examined wind tunnel models of swept wing aircraft at Volkenrode went back secretly by night and took them away.[85]

The initial report from Volkenrode by Lockspeiser was among the first to air "the problem of the German scientists". He mused "what is to be done with them? They are, in my opinion, primarily scientists with an almost pathetic eagerness to continue as scientists working for us or anybody else. If they are deprived of their equipment they would inevitably drift to other countries. ... I suggest that those who are really first class ... should be brought over here to work under supervision".[86]

83
Clive Irving, 'Wide-Body', (n. 81 above).

84
Michael Gorn, *The Universal Man, Theodore von Karman's Life in Aeronautics*, Washington 1992; 105-106. Much of this haul, weighing some 1500 tons, was air-freighted back to the USA, to form the nucleus of the Armed Services Technical Information Center.

85
Bill Gunston, personal communication, 1997 (also see n. 6 above). Gunston recalled Fedden saying "it was the law of the jungle out there". It is possible that Fedden had encountered in this case an American unit of the Allied army 'T-Forces' which had armoured infantry and anti-tank weaponry in order to gather material in target areas immediately resistance ceased. In general Anglo-American co-operation was good and apart from these intelligence related issues Fedden specifically noted the generosity and helpfulness to the Mission of the U.S. Army. ('Fedden Mission to Germany', (n. 64 above).

86
PRO AVIA 15/2216. Ben Lockspeiser to Minister, 11 May 1945. Colonel Putt, although concerned about the possibility of the German scientists becoming "allergic to further enquiry ... by a succession of unrelated investigators", confirmed that when interviewed by visitors they were "quite anxious to be revealing ... and they get a square meal with the G.I.s".

In July 1945 Sir Frank Tribe at MAP proposed a scheme to dismantle and remove the plant and equipment to Britain, suggesting that "this would eventually constitute once-for-all delivery to us on reparation account". He also noted that the plan could have the incidental result of collecting together at Volkenrode a few of the best German aeronautical scientists and technicians, observing that "I believe the Americans have not yet taken them all!". The most suitable could then, he suggested, be transferred to the RAE or UK aircraft design firms, "if and when Government policy here permits".[87]

This proposal had interesting links with earlier discussions in Britain as to how a resurgence of German air power might be prevented and Tribe observed that "our feeling is that the UK government will eventually be driven to the conclusion that no effective plan for preventing the export of German scientists to foreign countries, or, in the long run, controlling their activities in Germany beyond a certain point, will be successfully evolved, and that therefore it would be desirable to have the best of those who might be particularly dangerous from the point of view of war potential (e.g. aeronautical scientists) under American or British control while at the same time gaining substantial advantage to our own war potential".[88]

For a time the MAP considered an alternative strategy of operating and administrating the establishment on its existing site. R V Jones, then Deputy Controller of Research and Development (DCRD) at the MAP, listed 17 aircraft projects of interest, including rocket-powered and swept-wing types and suggested that the aircraft should be completed by their designers and staff "to the point at which the Germans fly them and prove them to be airworthy"

87
Ibid. It should be noted that the policy of "denial" of German scientists to other powers was initially pursued by both US and UK governments out of a genuine fear of a revival of German power through defence research conducted in other countries. It was not initially directed against the Soviet Union and it was only, from about 1947 that it took on this complexion. This shift coincided with a general perception in the US State Department that the current policies were by then "flogging a dead Nazi horse". Gimbel, 'Science, Technology and Reparations', (n 59 above).

88
AVIA 15/2216. Tribe's paper also noted "I am sending a copy of this letter to Barlow at the Treasury because of the reparation issues involved".

before taking them to England for further study.[89] He also proposed that "the maximum concentration of MAP will be in Volkenrode and we hope that we shall be able to consider that station as our MAP headquarters in Germany".[90]

However, this course was rejected because it was considered both politically too sensitive to utilise the site and because this would also have had the effect of preserving an element of German war potential. The problems of managing work there must also have seemed insuperable. The decision was taken, therefore, to remove the research papers and records to Britain and to dismantle the research plant and equipment for use in Britain.

Operation Surgeon

The resources assembled to dismantle Volkenrode were impressive. At a meeting at the Air Ministry on 12 July 1945, Sir Charles Ellington, as Assistant Chief of Air Staff (ACAS) observed that under the government's policy for war reparations only six months were available "in which to satisfy our requirements from places of scientific value in Germany such as Volkenrode". The task was to be a special operation and would be run largely by the RAF as MAP did not have the administrative or command organisation to undertake the task.[91]

This operation, code-named 'Surgeon' was assigned a commanding officer from the British Air Forces of Occupation (BAFO) and senior MAP officials including Major George Bulman, DCRF (Director of Construction of Research Facilities, MAP), the aerodynamicist W J Duncan, scientific and technical

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89
R V Jones D/C RD, MAP statement on Volkenrode to ACAS, Air Ministry, 6 July 1945, AVIA 15/2216. Jones ascribed the highest priority to a supersonic swept-wing jet-powered project, the DFS (Deutsches Forschungsintitut fur Segelflug) 346. This was intended for reconnaissance and was intended to achieve the then startling performance of 1250 mph (Mach 1.9) at 60,000 feet.

90
PRO AVIA 15/2216, R V Jones D/C RD, MAP statement on Volkenrode to ACAS, 6/7/47.

91
Ibid.

officers from MAP, a librarian, representatives from the aircraft and engine companies.

The operation consisted of two phases. Firstly, detailed information was to be collected from German scientists in the form of monographs on their research work, followed by the removal to UK of the equipment that would be of value. Initially, some 35 British scientists came out to Germany to clean up of the facility (it had become occupied by displaced persons and by troops), to run the wind tunnels and become familiar with the apparatus. This group also identified and located the former German scientific staff, where possible, and brought suitable individuals back to write technical monographs summarising the war-time research in their various fields. By October 1946, 180 scientists and technicians from Volkenrode and the Göttingen institutes had been located and employed to write these reports. From the Volkenrode staff alone some 250 monographs were commissioned, translated and reproduced by a printing department specially established there.[92]

The work was scheduled to begin on 15 January 1946 under the supervision of Major Bulman and, in the light of the section above on the establishment of the new National Aeronautical Establishment it is interesting to note the comment that "the Treasury have given approval to the special arrangements necessary for removing this valuable equipment, and they will look to the use of it to save some of the very large expenditure which is planned for Bedford".[93]

There was also a specialised dismantling team from the Ministry of Works - the agency which was responsible for the actual construction of government research facilities including the ambitious new aeronautical institute at Bedford.

92
PRO AVIA 12/82, 'Operation Surgeon - Memorandum No. 2', and Johanna Weber, interview with author, 1 June 1998. Dr Weber recalled that after the surrender "we were [working] in the fields with the farmers" until the British investigators came to find them.

93
PRO AVIA 9/88, 'MAP Interest in German Research Establishments'. It was noted to Sir Alec Coryton, Controller of Research and Development (CRD) that "Mr Gorrell Barnes of the Treasury is therefore accompanying you [to visit Volkenrode] to obtain a general picture of the equipment involved and the scale of the operation".

Two flights per week in each direction of transport aircraft were also scheduled to bring out documents and smaller equipment.[94]

The Ministry of Works engineers, who referred to themselves ironically as 'Operation Spanner-hammer' constituted a subset of the 'Surgeon' team. The intention to re-use the material for new British aeronautical facilities was facilitated by the fact that these were, in most cases, the same individuals responsible for the erection of heavy capital plant for British government research facilities including the RAE, Farnborough, the National Physical Laboratory, and the new Bedford site.[95] The bulk of the structure of the large wind tunnels formed substantial civil engineering structures which were relatively 'low tech' and not worth transporting. However, the 6000 hp Siemens electric motors and their control gear were precious and a number were shipped to England with their associated mercury arc rectifiers and compressors and were used in the construction of the '8 foot' and the '3 foot' supersonic tunnels that were built at Bedford. However one complete smaller supersonic tunnel was disassembled and transported to be rebuilt for projectile studies at the Armament Research Department at Fort Halstead near Sevenoaks. Also invaluable in Britain was the advanced ancillary optical equipment used for flow visualisation in the tunnels.[96]

94
PRO AVIA 15/2216. It was also noted that "at Göttingen there is ... equipment deposited by Sir Roy Fedden [for the College of Aeronautics]. This should be included in general plans".

95
Paul Fletcher, conversation with the author, March 1996. 'Superintending Engineer - Heavy Research Plant' for the Ministry of Works, Fletcher was concerned with the engineering of all the large government research installations in the UK and was in overall charge of the engineering side of the dismantling of Volkenrode and the transport of its equipment. He was also involved in the planning and layout of the Bedford site and the building of the wind tunnels, spinning tunnels and engine test facilities there so there was a close integration between these programmes.

96
For example, Schlieren interferometry equipment. The superb quality of the German optical and mechanical instrumentation can be seen in the case of kinetheodolites - calibrated camera devices used on ranges for tracking the trajectory, height and speed of projectiles and aircraft. In 1965 the RAE were still using and maintaining what effectively were German Askania instruments of pre-war manufacture. (Kinetheodolite planned maintenance manual, Workshops Department in conjunction with Instrumentation and Ranges Department, July 1966, Science Museum Technical File for Inv.1993-2547).

Much of the lighter and more delicate freight was flown back to Farnborough and a Douglas DC 3 and a Junkers Ju 52 aircraft were dedicated to this. In addition three or four Hudson aircraft brought a stream of personnel back and forth from England for study. These included both government and industry scientists, a considerable number RAF and service personnel and politicians such as Arthur Woodburn (Parliamentary Secretary for the MAP) who went to see the progress of 'Operation Surgeon in January 1946.[97]

John Wilmot, as Minister for the new Ministry of Supply also planned a visit. The plans for this are noteworthy in connection with the surmise in earlier sections of this study that the highly directed strategy of the MAP in the latter stages of the war towards the aircraft industry was weakened in an important degree by the departure of Stafford Cripps. It is certainly difficult, for instance, to imagine Cripps writing about the proposed visit to Volkenrode in the diffident terms in which Wilmot did to his colleague Herbert Morrison (as Lord President of Council), on 31 August 1945.

> I have been told that it is most important for any Ministers who have a responsibility for the future of research and development for the Armed Forces ... themselves to visit ... the enormous Hermann Goering Research Establishment. ... Do you think that you and I ... could make a trip over there? ... If you did not feel able to go I would not go myself.[98]

However, the momentum for the operation had been established and it ran to completion until almost everything useful and transportable had been taken although some equipment did still remain in situ at the end of the agreed period and was destroyed punitively.[99]

97
PRO AVIA 9/99. "Our purpose was to check up on the progress of the M.A.P. scheme for the exploitation of aeronautical scientific a material in the British Zone in Germany, described as Operation Surgeon".

98
PRO AVIA 9/88, Visits to Volkenrode, Notes by Parliamentary Secretary on visit to Germany, 9-14 January 1946.

99
Paul Fletcher, (n. 95 above).

Some idea of the scale of the operation can be gained from the provision of six road tractor units and low-loader trailers of 100 tons capacity which were used to take loads up to Hamburg for shipping. The total quantity of material identified for removal to the UK amounted to some 14,000 tons.[100] On some of the outbound flights the 'Surgeon' aircraft brought back to Germany half ton loads of Birmingham nails to build packing crates from trees felled in the surrounding forest and sawn in a sawmill set up by the Ministry of Works team.[101] The curious emotions that must have existed in the German civilians at the time can be judged by the fact that the British team had the willing assistance of the Siemens company's chief export packer and his assistance for the electrical equipment.[102] This equipment was delivered to several hangars at Great Storton airfield which marked one end of the proposed five mile runway at Bedford and from there delivered to the various research establishments controlled by the Ministry of Supply.[103]

100
PRO AVIA 12/82, 'Operation Surgeon, Memorandum No. 2'. The scale of this removal is all the more remarkable when it is recalled that this 'take' consisted of 'high tech' research equipment rather than general industrial plant. By 1 October 1946 approximately half the identified material had been shipped (7620 tons by sea and 144 tons of more delicate equipment by air) and it was reported that shipments were going out at a rate of 1800 tons a month. For the new College of Aeronautics at Cranfield alone, which was the junior partner in allocations, 400 tons of research equipment and machine tools were packed in Germany during October 1945 by Wing Commander Hereford. (John Harrington, Librarian, Cranfield University, personal communication, 1996).

101
Paul Fletcher (n. 95 above). Nails were unobtainable in Germany and were so sought after for construction that the MoW supply bought another advantage. The German vehicle drivers were given 28lb bags of nails for each trip to the docks at Hamburg as 'currency' to distribute. This largesse ensured there was no pilfering of equipment.

102
Ibid. Fletcher recalls the attitude among the Siemens men as "We have a good name and we want to see that it comes out tidily".

103
PRO AVIA 9/88, M.A.P. Interest in German Research Establishments, Note for CRD by E C Ashworth, PS 15, 3 January 1946 and paper 'Organisation of Operation SURGEON'. The Ministry of Aircraft Production was amalgamated with the Ministry of Supply during the course of this programme. "MAP have appointed a British scientific staff at Volkenrode and at other ... research stations. ... they are at the moment preparing inventories of all German equipment found in the Establishment for use by the Allocations Committee in London. This Committee under the Chairmanship of DCRD allocates the German research equipment concerned to Government Establishments, Aeronautical Establishments etc. in U.K. and the Dominions".

Emigration from Bizonia - The Employment of German Scientists

In July 1946 the decision was made by the British and American governments to fuse their respective zones of occupation in Germany into a single administrative area termed the "Bizone". (British officials, more playfully, tended to refer to the area as "Bizonia"). This fusion implied, or perhaps made more overt, a direct competition between the Anglo-American allies and the Soviet Union for the scientific and economic spoils of Germany and there was substantial, and exclusive, Anglo-American co-operation.[104]

However, there was inevitably still rivalry between the Britain and the USA, although this should not be overstated compared to that which existed in relation to the USSR and also France. Thus it is interesting to recall the claim by Bower, alluded to above, that British efforts were poorly focused and inconclusive since the study by Lasby, written from American sources, shows that American officials considered British plans to be very effective.[105] Colonel Putt wrote in November 1946 that "the Board of Trade handles all scientists coming here and has little interference from anyone. Once it is decided they want a man he is brought over and put to work. ... Whether he is lily-white [does] not worry them too much. If any man can be of assistance in realigning a segment of their economy which is out of adjustment, they try to get him".[106]

Putt had a strong personal commitment to the utilisation of German scientists for the United States and perhaps over-emphasised British efforts. In fact, British policy, like that in America, was initially ambivalent over the employment of

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104
PRO BT 211/46, 'Employment of German Technicians and German Reparation Labour Generally', March 1946. The secret and contentious nature of these arrangements is illustrated by the instruction on a telegram in the file from the British administration in Vienna to the Board of Trade: "This message will not be distributed outside British or US government departments or HQs or re-transmitted, even in code, without being paraphrased".

105
Bower, (n. 59 above) and Lasby, (n. 60 above).

106
Note from Colonel Putt to 'Hap' Arnold, Commanding General, AAF (Army Air Force), 4 November 1946, quoted in Lasby, (n. 60, above), p. 170.

"ex-enemy aliens". There was less concern about the acceptability of this where pure defence research was involved and scientists could be brought to establishments like the RAE, but the question of using a wider range of personnel to assist industry at large in Britain was the subject of some debate. However, Board of Trade officials were generally keen to utilise German developments as were British defence personnel actually serving in Germany. Similarly American military personnel in Germany were initially more enthusiastic than State Department officials at home. Indeed, it was the value put on German science by the military of both allies that led to mutual suspicion and competition between British and American officials actually on the ground in Germany, as glimpsed from Putt's remarks above. Both groups were excited by the new technologies they had found and both considered their own governments to be irresolute in forming plans to utilise German personnel. Both groups reported to their home administrations that the other ally was being less scrupulous than themselves about former Nazi affiliations among the candidates in order to urge greater urgency.[107]

In Britain the arguments for an expedient approach came quite quickly to dominate policy while some moral doubt still was felt in American government circles over the question and it was said that German scientists often migrated back to the British zone after tiring of waiting for US employment.[108]

Thus a cipher telegram from the Cabinet Offices to the British Embassy in Washington 14 February 1946 observed that:

107
PRO BT 211/46, G E Preston, minute of 27 September 1945. "Brigadier Spedding told me that the Americans are already busily removing technicians from Germany and offering, as an inducement in some cases, naturalisation".

108
There was some fragmentation of policy on both sides over the question. Although in February 1946 the American State Department were opposing immigration there were already 130 German scientists in the USA by the end of January 1945. With the onset of the Cold War the American position soon reversed; by 1948 the opposition within the State Department had been countered and the US then avidly sought specialists. See Lasby (n. 60 above).

750 Germans evacuated from the Russian zone and frozen in the American zone may be released to Russian zone if not designated. ... We have deferred from submitting a list of Germans solely because American policy is not yet determined. It would therefore be manifestly inequitable if our scrupulous regard for the proprieties should prejudice our chance of exploiting the Germans now detained.[109]

A further telegram advised the embassy that the British list would be ready for exchange by the first of February and that "we consider it not unreasonable to request crystallisation of American policy". It suggested that if this were not forthcoming in a month "we shall consider ourselves free to go ahead on a unilateral basis".[110]

There was now growing pressure from many areas of government and particularly the Board of Trade and the firms themselves to extend the exploitation of German technique beyond the purely military sphere.[111] This was a contentious issue and conflicted with what has been called "rigidly moral approach" of the post-war Labour government and the feeling that private industry and individual firms should not profit from the war-time sacrifice of Allied lives by gaining special access to the German work. Therefore, it was proposed, scientists and technicians brought to the UK would normally work for Trade Associations or research establishments since the work done there might be expected to augment the capability of a whole industrial sector, rather than enriching particular companies or groups of individuals.

109
PRO AVIA 15/3846, 'Panel to Consider Employment of German Scientists, Specialists and Technicians for Civil Industry in the United Kingdom'.

110
PRO AVIA 15/3846, telegram of 19 January 1946 to British Embassy, Washington. In fact MAP had noted that in early January 1946 "Air Vice Marshall Jones paid a special visit a few weeks ago to Volkenrode and Göttingen to disclose the broad policy in connection with the German scientists in the UK ... at Headquarters in London arrangements are now in hand for the preparation of the contracts and for the accommodation, programmes of work etc. for those Germans who elect to come to this country". (Note from PS15, PRO AVIA 9/88).

111
Sir William Palmer attempted to convert some political objections by arguing that "no matter how objectionable and undesirable ... Germans could help over the long term. ... The Americans were recruiting vigorously ... and we should be missing a valuable opportunity if we did not follow their example", minute of 28.9.45, PRO BT 211/46, Quoted in Bower, (n. 59 above).

Thus Stafford Cripps, for example, is said, initially to have suggested that employment for the Germans in non-military industries in the UK was only tolerable if they were "sucked dry of their knowledge in a short time".[112] However, Arthur Woodburn argued that "there is no possibility of getting these men to put all they have into our research if the arrangement is merely to suck them dry and throw them back into Germany".[113] The relaxation of this attitude resulted in the suggestion, which appears to have emanated from Cripps, that German technique could be disseminated through trade associations to prevent individual companies obtaining an advantage.

However Board of Trade officials were unhappy with such a policy. "This seems to me quite wrong", minuted George Preston at the Board of Trade. "It is the individual firms who design and make the goods, not the trade associations, and if we are to get any benefit from these German technicians, we must surely obtain them for particular firms. I recognise that this may cause some jealousy ... [but] it seems to me that if it is properly handled we have a chance of helping our export trade materially if we can pick up a relatively small number of the right people. ... The papers passed through the President [Cripps] when I was up in the Private Office last week. He ... was not happy at the suggestion that these technicians should be attached to particular firms". Preston went on to comment that there seemed little point in getting civil technicians over to work for trade associations or the government. "If we tried this on, the good ones ... would, I fear, either be persuaded to go to the United States or elsewhere or to remain at home".[114]

112
BT 64/2879, quoted in Bower (n. 60 above).

113
PRO AVIA 9/88. Arthur Woodburn, 15 January 1946, suggested that "there is no question that the ability and accumulated scientific knowledge of some of these scientists is so great that it is essential both for the demobilization of the German war potential and for the economic and speedy progress of our own work in jet turbines, etc. and that arrangements should be facilitated for the bringing of the required personnel to this country permanently. ... I understand so far there are objections to their families coming here but I fear objections of this kind will prove short-sighted in the ultimate interest of our research in vital fields.

114
Minute of L B Hughes to George Preston, 22 September 1945 and Preston's reply, BT 211/46. Board of Trade view, as understood by Preston, was that "it is our present policy to exploit German industry to the full, and in many cases the most effective way will be to get the

These doubts were intended to be reconciled by a scheme for civil industry administered by a panel chaired by Sir Horace Darwin, Director of the National Physical Laboratory. This was announced by Stafford Cripps in Parliament in December 1945, when he declared that "it is the Government's policy to secure from Germany a knowledge of scientific and technical developments that will be of benefit to this country". He remarked, perhaps disingenuously, that "although we were generally ahead there are certain fields in which the Germans held a temporary lead". Sir Charles Darwin was to examine the requirements of British industry and to scrutinise the credentials of those whose names were put forward. Another role of the Darwin panel was "to see fair play between the firms".[115]

Alongside the announcement of the scheme measures were devised to pre-empt objections from labour organisations. A brief drafted by the Board of Trade for issue by the Ministry of Labour offered arguments for employers to deploy. It suggested that "it is evident that there must be some industrial technique in which ... Germany has surpassed us. It is intended to bring certain German scientists, specialists and technicians ... into civil industry ... in order to gain the most up-to-date knowledge and perhaps save ourselves many years of research. The Americans and the Russians are exploiting the Germans in the same way". It also stressed that the inventions and discoveries would be available to industry as a whole and that "they will have no authority over British workpeople".[116]

German specialists over here to teach us their skill". BT 64/2879, minute of 10.9.45, quoted in Bower, (n. 59 above)..

115
PRO AVIA 15/3846. 'Panel to Consider Employment of German Scientists, Specialists and Technicians for Civil Industry in the United Kingdom'. The Darwin Panel nominees handled by the "German Division" at the Board of Trade was an extremely diverse list including specialists in cameras, lenses and optics, photographic film, fuel injection, but also oddities like the chief engineer for a fully-fashioned hosiery machine company and a designer of sugar and chocolate machinery.

116
PRO BT 211/47. The press release on the Darwin scheme, released in December 1945 also made these points and added that "during their stay the Germans will not be in any position of authority, and will, in no case, serve in any vacancy which could be filled by a British employee".

An elaborate system set up to prepare the ground in the firms and local areas, with the Board of Trade acting as go-between for the employers and the TUC.[117] In addition, Sir Walter Citrine, as General Secretary of the Trades Union Council (TUC), was extensively briefed by the Board of Trade which stated that "Germans would normally work in Government Establishments and Research Associations". Although "exceptionally they might find their way into individual firms Germans are, however, under a contract with H.M.G.". It added that:

> "the number of Germans who will serve in this country will not exceed one or two hundred ... no known pro-Nazis will be admitted ... only those Germans who have a real contribution to the national interest ... the results of their discoveries and inventions will be available to industry as a whole".[118]

Inevitably there was some negative publicity and officials noted that "the Beaverbrook press were running the story in a big way" with "uninformed press criticism" and that a story in the Daily Mail for 5 January 1946 reported that "a rumour-monger [sic] is sweeping Barrow .. the shipyard workers resent the arrival of former Nazis who are still pro-Nazi".[119]

However the British public displayed a remarkably sanguine view about the utilisation of German science and the superiority in many areas which this implied over UK technique. In December 1945 Stafford Cripps opened an exhibition of German industrial products at Millbank which showed something of Germany's war-time advances in science and industrial technique. It also sought to promote the BIOS reports (British Intelligence Objectives Sub-Committee) on German developments for British industrial use. These amounted to 1400 reports on a great range of industries and techniques compiled by some 10,000 investigators. Cripps urged British industry "to make the fullest and

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117
PRO BT 211/47, minute of 25 February 1946.

118
Ibid, paper of 9 January 1946.

119
The Germans referred to at Barrow-in-Furness were Helmuth Walter and his team which had produced a hydrogen peroxide submarine power plant to allow sustained high speed underwater running. The Admiralty had managed to install the Walter team at Vickers in advance of any general resolution of the policy doubts over placing the Germans in specific companies.

speediest use of the knowledge gathered ... there was no time to waste". Among the wonders promised were "powdered white of egg which whips better than the real thing, a bath enamel you can hit with a hammer without chipping, the perfect baby food ... and, for women of all ages 'lizard' shoes and handbags, flexible, durable, dyed in rich shades and made out of haddock skin".[120]

The Daily Graphic reported that "we so often have occasion to criticise the obstructiveness of the Board of Trade that it is a considerable satisfaction to be able to compliment its President, Sir Stafford Cripps, on the apparent thoroughness of his investigations into German trade methods". The exhibition was intended to tour Cardiff, Birmingham, Manchester, Leeds, Nottingham, Newcastle, Glasgow, Belfast and Bristol.[121]

German High-Speed Aerodynamics and British Defence Science

However, the greatest concentration of British effort was in aeronautics. In November 1946 Arthur Woodburn for the Ministry of Supply (MoS) had announced that German scientists were to be employed at the RAE and at the recently created Guided Projectiles Establishment at Westcott. The press statement was careful to emphasise that the pay "will be comparable to that of British technicians ... but at a slightly lower figure". Any suggestion of feather-bedding former enemies was countered by the announcement that "the men will

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120
'To Brighten your Life', Sunday Pictorial, 24 November 1946. It is interesting to note, in the era before the Cold War, how openly this German technology was displayed in Britain. In October and November 1945 the Royal Aircraft Establishment put on a display of captured German aircraft and equipment which included not only service types like the piston-engined Focke-Wulf 190 and Messerschmitt 109, but also the Messerschmitt 262 jet fighter and secret types such as the twin jet-engined Arado 234 B-2 bomber which had not been used operationally before the fall of Germany. Jet engines, bombsights, communications gear as well as V1 and V2 missiles were also on display. A few months later three aircraft with most of the engines and other small equipment were moved to the Science Museum to form a popular exhibition entitled "German Aeronautical Developments".

121
BT 211/47.

be accommodated in Army huts".[122]

This 'Defence Scheme' eventually identified 124 individuals included guided missile experts, rocket engineers, aerodynamicists, flutter analysts, instrumentation engineers, an archivist, experts in servo mechanisms, control guidance, gas turbines, and, most curiously, two naval historians.[123] Of these scientists some had already been brought initially to Britain for interrogation, in effect as VIP prisoners of war. The aeronautical scientists were taken to the Beltane School at Wimbledon which had been requisitioned for the purpose as part of a separate operation known as 'Inkpot'. By late 1945 about 250 of the best German scientists and engineers had been brought there for interrogation.[124] and were subsequently offered employment on a special pay scale within Civil Service terms, graded as 'German Scientist I to V'. For example, Adolf Busemann, one of the foremost experts in the world on swept wings and supersonic flow was retained in Britain and worked at Farnborough and at the National Physical Laboratory but soon left to work in the USA.[125]

However, others such as the eminent Göttingen aerodynamicist Dietrich Kuchemann were offered employment freely while they still in Germany. Initially these contracts were for six months, and Kuchemann's associate, Dr Johanna Weber, who took up a similar offer to follow some months later, recalled that the short period of these initial contracts was a major factor in inducing German scientists to accept.[126]

122
Ibid, cuttings in file from The Times, Daily Mirror and The Telegraph, 1 November 1946, Daily Worker 8 November 1946.

123
PRO CAB 122/352.

124
Bower, 'Paperclip' (n. 60 above), pp 149, 171.

125
Karl Doetsch attributed his desire to leave to the fact that intellectually Busemann felt isolated at NPL and that "there was no one of his calibre" there. Karl Doetsch, conversation with the author, 5 October 1998.

126
Johanna Weber, interview with the author, 1 July 1998.

Apart from the lucky find of Volkenrode the British search had not been hit or miss - CIOS targets even specified minor Messerschmitt dispersal factories. There was also a specific search for personnel with particular skills such as those involved in work on flight control and stability on the new high speed aircraft. This brought Morien Morgan of the RAE to Germany to seek out Dr Karl Doetsch who had been working on the directional instability of the Messerschmitt Me 262 since the Gloster Meteor was similarly afflicted with this 'snaking' problem.[127]

The two schemes were the official channels for the employment of German specialists and they show that 124 German scientists and technicians were formally brought into the UK under the Defence Scheme while another 257 Darwin Panel nominees were listed in 1946, although it is not clear how many of this latter group came.[128]

It also appears that other Germans did come under less formal conditions. One example, which may not have been exceptional, is that of the engineer August Stepan who had worked on the Doblhoff tip-jet driven helicopter system in Austria. In 1947 he was given a contract by the Ministry of Supply and worked at the Fairey company on the Rotodyne passenger helicopter project until 1962. However he does not appear on the lists of Darwin Panel scientists so far found by this author or in the separate DCOS scheme for defence scientists and his case raises the question of how many others there may have been like him.[129]

127.
Doetsch was one of the German scientists offered employment at Farnborough and he and Dietrich Kuchemann were the only ones offered "German Scientist I" grade salary. Karl Doetsch, (n 125 above).

128
Although the intention to recruit under this scheme was announced early in 1946 and many individuals appear to have come to the UK in 1946 and 1947 the details of procedure, contract terms and so on were not formally defined until March 1948, and is detailed in PRO CAB 122/352. The Ministry of Supply paid for removal expenses of Germans and their families.

129
August Stepan, personal communication, 1990.

German High Speed Aerodynamics at RAE, Farnborough

As already noted, the British pattern for the utilisation of German science was to concentrate this material in the Government research establishments. The reports and personnel and equipment thus were located principally at RAE, Farnborough while the actual hardware initially went to the new Bedford research centre which, as we have seen, stayed under Farnborough control.

The presence of German personnel at Farnborough, in addition to the captured documents and reports, ensured that British transonic research made striking speed in the immediate post-war period.

It is also interesting to note that this absorbtion took place partly with the assistance of intermediaries who were at home in the German language, such as the aerodynamicist T R F Nonweiler. Nonweiler was the son of German-Jewish immigrants and acted as a security vetting officer for some of the German aerodynamics reports.[130] As many British aerodynamicists were competent in scientific German it would be tempting to cast the analysis of these events in terms of technology transfer, as it is generally understood, but more particularly, in terms of the transfer of "tacit knowledge", as analysed by Collins.[131] The essential elements in such a case, it might be argued, include a body of advanced technical and theoretical knowledge, complemented by subtle practical and experimental 'know-how' (in this case wind tunnel and modelling technique) mediated by key personnel.

However, an analysis along these lines would undervalue the state of British aerodynamics at the end of the Second World War and could also imply that it

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130
Conversation with Steve Thornton, Librarian at RAE Bedford, December 1996.

131
Collins argues for the importance of the human mediation of tacit knowledge in the case of the TEA carbon dioxide laser in one of his case studies by noting that "no scientist succeeded in building a TEA-laser where their informant was a 'middle man' who had not built a device himself". H M Collins, *Changing Order*, (Chicago, 1992), p. 55.

had developed in isolation from Continental work. In fact, aerodynamic research in Britain had been well integrated into developments in Germany and elsewhere during the 1920s and early 1930s. Senior RAE aerodynamicists were well informed about German research and a knowledge of technical German was considered almost essential in the field. In particular, Hermann Glauert, the outstanding theoretician at the RAE in the inter-war period, was at the forefront in spreading an appreciation of the work of Ludvig Prandtl and the 'Göttingen school' of aerodynamics in Britain.[132]

These contacts disappeared as German aerodynamics became incorporated into German war planning. Probably the last open international exchange took place in Italy at the Volta High Speed Conference in 1935, and there British, American, French Italian and German aerodynamicists gave papers on current thinking about future high-speed developments.[133] One commentator has concluded, from a study of the papers given at the conference and the citations in them, that Germany was pre-eminent in theoretical aerodynamics in 1935, with Britain only slightly behind. By contrast, the USA (excepting the special case of Theodore von Karman who, from 1930, in essence imported German aerodynamics to Cal Tech) was rather backward in theoretical high-speed aerodynamics although the National Advisory Committee on Aeronautics (NACA) was "widely recognised for the excellence of its empirical data and for little else".[134]

At this conference the aerodynamicist Adolf Busemann presented a paper on supersonic flight which mentioned the possibility of using swept wings in the

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132
In addition to his theoretical work, Glauert, who was fluent in German, with another RAE aerodynamicist, R McKinnon-Wood, had been sent in 1918 to study German wind tunnels. R McKinnon Wood, 'Recollections 1914-1939' Royal Aeronautical Society Centenary Journal 1866-1896, p 89.

133
The Volta High Speed Conference, held under the auspices of the Italian Academy of Science, was held in Rome from 30 September to 6 October 1936. Proceedings were published as *Convegno di Scienze Fisiche, Matematiche e Naturali*, Theme: High Speeds in Aviation, Reale Accademia D'Italia, Fondazione Allesandro Volta, Rome, 1935, (2nd ed. 1940).

134
Edward W Constant II, *The Origins of the Turbojet Revolution*, (Baltimore, 1980), p. 156.

transonic region.[135] This was almost the last opportunity for international exchange and following the Volta conference the German work became increasingly secret, while in Britain, the expansion of the Royal Air Force and the introduction of new types of aircraft absorbed a great proportion of the time and energy of government scientists at the RAE.

During the war the RAE did nevertheless manage to do some advanced work in high speed flight and in a notable investigation, began flight trials with a Spitfire which was dived at an angle of 45 degrees from a height of 40,000 feet, increasing the speed attempted in each flight until over Mach 0.9 was attained. At the same time a scale wind tunnel model was tested in parallel in the new high speed Farnborough tunnel. In this way an unusually good understanding for the time was developed into the interaction between the effects of compressible air flow at speeds approaching that of sound and the effects on the control and stability of the aircraft.[136]

There was also some advanced theoretical work undertaken at the RAE during the war including a study on a hypothetical supersonic biplane. This derived from an ingenious proposal also aired by Busemann at the 1935 Volta conference and relied on the interference between the shock waves reflected between the superimposed wings to cancel each other out and thus avoid the high drag (and power requirement) associated with supersonic flight.[137]

135
A Busemann, *Aerodynamischer Auftrieb bei Uberschallgeschwinigheit*, Volta proceedings (n 133, above) pp 328-360.

136
These unwanted control effects derive from the shock waves which may develop and interfere with the normal (subsonic) operation of wings and control surfaces. It was reported that R. Smelt, one of the RAE investigators, briefed the test pilot that, based on wind tunnel work, he would be unable to recover from a dive at a particular Mach number at 40,000 feet but "if he had patience" the Mach number would fall until the elevator became effective. (Quoted in chairman's introduction to R. Smelt, 'A Critical Review of German Research', (n 74, above).

137
M J Lighthill, 'A Note on Supersonic Biplanes', Aeronautical Research Committee Reports and Memoranda, R&M No 2002, 27 October 1944. W F Hilton, at the National Physical Laboratory, also published a paper 'Further Tests on a Faired Double Wedge Aerofoil' on 11 May 1944 (ARC Fluid Motion Panel 693) which noted interestingly "centre of pressure calculated by Busemann's method".

Thus although Busemann's swept wing proposals were not explored in Britain during the war and the extent to which German research on swept wings in the transonic regime had progressed came as a surprise in 1945, these studies were not received by a naive or theoretically unsophisticated audience. British aerodynamicists realised the point of this work virtually as soon as they saw the reports and analyses and they had the theoretical and mathematical equipment to be able to extend it and, as we have seen, began rapidly to incorporate the thinking into proposals for operational aircraft.

The case of the reception of German high speed aerodynamics in Britain does not therefore fall into the categories for technology transfer or for the communication of tacit knowledge that have been discussed by historians of technology. Rather, it represents a re-integration of a particular branch of theoretical aerodynamics which had been undergoing separate evolution since German science had "gone off the air" as it were, in the late 1930s.

Conclusions: the Utility of German Science

In numerical terms the number of specialists brought to Britain does not support the assertion, referred to above, that Britain was backward in exploiting German work in comparison to the USA and the official British total so far discovered of 381 German scientists should be compared with the declared total of 210 who emigrated to America under the auspices of Project Paperclip. [138] A more reasonable judgement is that the number of German scientists actually brought to Britain was probably in line with what the government and industrial research establishments could absorb.[139] The quality and the experience of the individuals

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138
Bower, (n. 60 above).

139
It is also part of Bower's curiously argued thesis (n. 60 above) to suggest that the German technicians who did come to the UK were poorly integrated into British companies. Max Bentele, a gas turbine engineer from the Heinkel-Hirth company came to the Parsons company to help develop a gas turbine tank engine in 1947 and has recorded "excellent cooperation with our British colleagues". Max Bentele, *Engine Revolutions*, Society of Automotive Engineers, 1991, 87-103.

recruited also shows that Britain sought out individuals in the top rank of German aerodynamics and aeronautical science and, as we noted with the case of Karl Doetsch, the intelligence evaluation and preparation was already in place to enable British investigators to locate them.

However, it is unlikely that a final judgement can ever be reached on the contribution to the British aeronautical industry of the various programmes to exploit German science. The value of the physical equipment as well as the intellectual contribution made by the personnel and the research documents brought to the UK is literally incalculable for various reasons. Thus one could, for example, put a notional value on the R&D work from which the Winter/Multhopp transonic aircraft design (discussed in the next chapter) sprang but this might not represent the cost which the RAE would have had to expend to get to the same point without them. In such cases it may be sufficient for other workers to know of a new possibility in broad detail in order to jump to it quite rapidly by their own efforts.

It should be noted that there were efforts made in the immediate aftermath of the Allied exploitation programmes to assess the value of what had been taken, both from the German side and on behalf of the British and American governments of occupation. Perhaps the major motivation behind this for German trade associations, but also Allied occupation bodies such as the Bizonal Economics Administration, was to establish the value of intellectual and other properties removes from Germany in order to establish a credit figure towards the reparations account. Establishing the value of this material proved extraordinarily difficult and the final assessment reached by the commission the established by the administration for this purpose came up with an estimate of ranging between $4.8 billion and $12 billion.[140]

Estimating the share of this which fell to Britain would be extraordinarily problematical and, moreover, would not represent its utility. Firstly, there is the

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John Gimbel, 'Science, Technology and Reparations', (n. 59 above), pp 153-166.

possibility, quite strong in many cases, that British manufacturers would have adopted types of plant, processes and designs that were in use in Germany anyway in time, and that there was a process of modernisation which had been deferred by the war. Another reason to suggest that the value to the recipient is lower than the value estimated by the loser is suggested by a 'housebreaker' analogy where the burglar never obtains the full cost of items taken away. In the case of German science the utility that patents, processes, scientific knowledge and so on would have had when stripped out of the milieu in which they developed must have been vastly reduced. Perhaps the only environments where this special knowledge could have been absorbed and transferred without high dilution could have been in defence establishments such as the RAE.

In some areas of British aviation technology, post-war development was practically untouched by a knowledge of German work. This was certainly true of the gas turbine development carried on at Rolls-Royce, De Havilland, Bristol and Armstrong-Siddeley which built exclusively on what had been done during the war in the firms. The German jet engines were analysed at Farnborough, by RAE scientists and by Power Jets (R&D) at Farnborough who concluded that there was little learn from them.[141] It is also noteworthy that only two German turbojet engineers were brought to Britain in the DCOS scheme and one of them, Dr Max Bentele, with high level experience of turbine blade design at Heinkel-Hirth was not used in the British jet aero engine programme but was despatched to a fairly low priority project for a gas turbine tank engine at C A

141
The German BMW and Junkers axial flow engines compared poorly in aerodynamic design of their compressors with the RAE-designed compressors which had been incorporated into the Metropolitan-Vickers F 2 'Beryl' engine while British mechanical design and turbine metallurgy had been brought to a higher level through the Whittle, Rover and Roll-Royce programmes. By contrast to the UK, France which had missed out on turbojet development during the war, considered the BMW design team to be a great prize. BMW was located in Munich, in the American zone, but the team and the chief engineer H. Oestrich, appear to have been "spirited away" from the American zone by French agents while awaiting travel to the USA. The team re-appeared in Switzerland in a new organisation, the *Atelier Technique Aeronautique Rickenbach.and the first French jet engines put into production by the nationalised SNECMA aero engine company bore the designation ATAR.*

Parsons, in Newcastle-on-Tyne.[142] This sparing use of German turbojet personnel argues again for a purposeful and highly selective British approach to German engineering and scientific personnel.

By contrast, the British jet engine teams were quick to appreciate the superior quality of German test facilities and instrumentation and the De Havilland team spent several weeks at the BMW high altitude test cell in Munich, completing over 70 hours of testing on the Goblin engine which provided information which could not then have been obtained anywhere else. The cell could be de-pressurised to simulate altitudes of up to 50,000 feet, while the inlet air speed could be regulated up to 550 mph and refrigerated to - 70 degrees C.[143] The team noted that the speed at which results were obtained was much better than if flight tests only were used and the information far more complete. The BMW test facility was removed to the USA but the practical experience of the utility of the installation certainly helped establish the need for test cells working on the same principle at NGTE.

Germany was, of course, closely identified with advances in rocketry and British liquid fuel rocket motors certainly owed much to the V2 engine concept. Much work was done on these, for rocket assisted take-off applications, for the abortive rocket fighter programmes and particularly for the Blue Steel and cancelled Blue Streak nuclear weapons.

By contrast, the solid fuel rocket technology which was used in many anti-aircraft and air-to-air weapons was a largely home-grown and successful British technology. Thus the Bristol Bloodhound missile, which emerged as an excellent ground to air defence system against high altitude hostile bombers relied largely on British technology for its solid fuel core motor and radar guidance, and not, for example on the German *Wassserfall* liquid fuel anti-aircraft missile which

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142
Max Bentele, *Engine Revolutions*, (Society of Automotive Engineers, Warrendale, PA, 1991), pp 16-103.

143
E S Moult, 'The Development of the Goblin Engine', *Journal of the Royal Aeronautical Society*, 51, 1947, pp 655-685.

had been studied with such interest by Allied investigators.[144] In cases such as these the fact that Germany had done a thing, or had begun a project, was perhaps sufficient stimulus for British research engineers to accept that it could be done and to successfully attempt it, but in their own way.

Nevertheless, it must be accepted that German aerodynamic work was important in Britain. "As far as the aerodynamics of swept wings were concerned there was no background in English at all" one RAE aerodynamicist recalled. In the 1950s British workers therefore referred to the specially written reports from Volkenrode and Göttingen and to the RAE series "Reports and Translations" (R&T's) which were translations of papers from various captured German archives.[145]

Perhaps most significant, in the long term, for British aeronautics was the employment at Farnborough of the Göttingen aerodynamicist Dietrich Küchemann and his collaborator Johanna Weber. Küchemann took British nationality in 1952, becoming head of the Supersonics Division of the Aerodynamics Department in 1957 and overall head of RAE aerodynamics in 1966.[146] Both Weber and Küchemann had a major impact on the Concorde programme but if any single person can be considered as the 'father' of the aerodynamic design of Concorde it is, in the opinion of this writer, Küchemann.

In this context Concorde is certainly an interesting case since it represented such an enormous technological and scientific effort. It might therefore be tempting

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144
The AVIA 40 class at the Public Record Office contains more than 5000 drawings on the Wasserfall missile and the V 2 which were collected in Germany for the Westcott rocket research establishment.

145
John Bagley, conversation with the author, May 1996.

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Küchemann had intended studying theoretical physics but, by the time he started his doctorate most of the outstanding physicists and mathematicians who had established Göttingen as an outstanding centre for physics had fld the Nazis. He therefore began working with the eminent aerodynamicist Ludvig Prandtl and, by 1945, was thought to be the foremost exponent of the aerodynamics of propulsion in Germany. He was elected a Fellow of the Royal Society in 1966. See P R Owen and E C Maskell, 'Dietrich Küchemann', *Biographical Memoirs of Fellows of the Royal Society*, Vol. 26, December 1980, pp. 305-326.

to regard the heritage of German scientific influence in both America and Britain as a kind of technological supremacism for in some respects Concorde can be regarded as the British equivalent of the American Apollo space programme.

However, this seems too simple a view for there is also the point that the Second World War marked a step change in the application of science to weapons systems.[147] While Britain had made notable use of scientific research in many areas, the new technologies and weapons systems demanded quite a new scale of expenditure and effort. Germany had been among the first to realise the returns that might be available from this intense application of science and research. Thus the effect on the Allies of their analysis of German science was as much moral as direct. Although in many cases the post-war programmes of the former allies did not build directly on the weapons and solutions that had been attempted in Germany, the scale and extent of research and the degree to which engineering science was applied to German war projects was eloquent.

147
Although Apollo and Concorde were not weapons systems they can certainly be regarded as first cousins to them and could not have been remotely possible, at the time they were created, without defence expenditure.

Chapter 5: The Royal Aircraft Establishment in the post-war period

Introduction

In recent years the growing academic study of aeronautical history has tended to emphasise the role of political and social factors on developments in the industry, in contrast to an earlier (though still active) genre deriving from the industry itself and from 'amateurs' of aviation, in which the principle and most interesting agents are seen as the designers, the pilots, and the firms. Both schools would benefit by being informed by the other. However, in the post-war era, there is a powerful third element contributing to the development of aircraft programmes which must be considered in order to reach an integrated understanding. This is the contribution of the research done by scientists and research engineers within government establishments which attained a special importance in the post-war decades.

The influence of the government's centralised direction of aeronautics has been touched on with respect to the development of new facilities and establishments in the latter part of the war, and in the pattern of utilisation of captured German personnel and results. However, it was the pre-existing and powerful Royal Aircraft Establishment (RAE) at Farnborough, which became the locus for this enhanced effort in the post-war period. These constituent parts of the British aviation ensemble made up, therefore, a kind of triad, with policy and projects being developed in a sometimes rather elusive way through long-range studies at Farnborough, preliminary project work in the firms, and contacts which were exchanged reciprocally between these centres with policy-makers, defence planners and RAF personnel. It is the aim of this chapter to tease out something of these relationships and to throw light on the extraordinary influence of the RAE in the period.

As the Cold War took on the character of a competitive contest of research and

development during the 1950s, the influence of the RAE grew enormously, in part because the new fields of jet propulsion, supersonic aerodynamics, guidance technology and electronics offered a series of step changes in weapons capability, each step both alluring and enormously expensive, and RAE advice became vital in guiding policy makers as to whether to pursue such leads. Another factor contributing to this influence was that intelligence about the Soviet Union's capability was so scanty that the best insight into the weapons that the Soviet Union might deploy derived from analyses of what systems the aeronautical scientists, particularly within the RAE, considered that it might just be possible to create.[1] (It is interesting to note that this pattern of is largely at the heart of weapons escalation since evaluators necessarily must 'aim off' and assume a precaution that an enemy might have more success than themselves in any particular line of development).

However, to return to the immediate post-war years, the RAE can be best regarded at that time as an institution that had, as its central role, the task of "technologising" the British aircraft industry and, in this period there is no doubt that the advanced projects were critically reliant on the RAE. In fact, it would have been impossible for the firms to have completed the design, testing and evaluation of the new post-war generation of high-speed jet aircraft without the RAE since they lacked the research equipment and wind tunnels required. In 1951, for example, the English Electric company was one of the first firms to build a trans-sonic wind tunnel as the design for its P.1 supersonic fighter started to advance. The firms also lacked specialist staff; "they always had their chief aerodynamicist," one RAE scientist recalled, "but to be honest, he was the

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1 "Direct penetration of the Russian research and development programme was impossible. We had never seen a single Russian equipment [sic] until it was in operational service or deliberately shown". Intelligence official's statement in minutes of Defence Research Policy Committee, 24 May 1955, PRO DEFE 10/40, quoted in Jon Agar and Brian Balmer, 'British Scientists and the Cold War: The Defence Research Policy Committee and information networks', 1947-1963, *Historical Studies in the Physical and Biological Sciences*, 28:2, 1998, p 209.

one aerodynamicist".[2] Another RAE member was more severe, recalling in the mid-1950s "some twenty design departments, all more or less inadequate".[3]

From the time of the war-time coalition government it had been accepted that these deficiencies would have to be addressed by government action, largely through the research establishments, and the early post-war years saw what was almost an inversion of the capitalist ethos with government scientists and civil servants often adopting a more "progressive" and explicitly technocratic posture than the firms were prepared to do. However, it was also a period in which the war-time consensus still prevailed and in which collaboration between the Services, the firms and the government research establishments in pursuit of common national purpose was the norm.

By 1962 the RAE employed 8500 people (of whom 1500 were "qualified scientists and engineers") at Farnborough and its other sites, making it the largest research establishment in Europe. Its facilities, too, were world class. For example, to model the flight of experimental anti-aircraft missiles RAE installed TRIDAC, possibly then the most powerful computer in the country. This analogue machine could simulate all phases of missile interception in its full six degrees of freedom in 15 seconds (the actual flight time), using 8000 thermionic valves and consuming as much electricity as a small town.[4] In the same period the RAE upgraded its pre-war high-speed wind tunnel, increasing

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C H E Warren, interview with the author, 1 June 1998. As an influential member of the Aero Department "Chew" Warren was involved in many of the advanced RAE aircraft proposals in the period covered. From 1960 he headed the Noise, Flutter and Vibration section in the Structures Department where he made a special study of the effects of the sonic boom over land, as part of the Concorde programme.

3
John Bagley, conversations with the author, 1997. John Bagley was a member of the Aero Department and worked for a long period with Dietrich Kuchemann. He came to the Science Museum in 1979 and preceded the author as Curator of Aeronautics.

4
Sir George Gardner, Director of Guided Weapons Research and Development, Lecture to Bedford Technical Society, 2 October 1957, Science Museum archives. At this time a digital machine would have needed about 7 minutes for a problem of this complexity.

the 8000 horsepower drive motors to 20,000 horsepower enabling it to run supersonically at a continuous airflow speed of 1000 mph. This was a piece of highly sophisticated scientific apparatus - in effect a laboratory instrument capable of fine measurement, but with the strength, mass and complexity of a substantial industrial plant. The facility was opened by Reginald Maudling in 1954 and thereafter was devoted largely to projects such as the development of the supersonic fighter to intercept Soviet atomic bombers and to the development Britain's own deterrent V-bomber force.

The organisation covered the complete spectrum of aeronautical technology including guided weapons research, armament, radio, instrumentation and navigation as well as maintaining its own chemistry, physics and materials section and all this expertise contributed to the emerging post-war generation of British jet aircraft. It was, wrote M J Lighthill as the then Director of the RAE, "a central reservoir of scientific and technical knowledge ... on which all British producers and users of aircraft are able to call".[5]

The account here cannot cover all the areas in which the RAE was active and therefore deals mainly with the aerodynamic and "project work" that contributed to specific aircraft or aircraft proposals . However, the main focus of this chapter is on the role of the RAE in the two decades from the end of the Second World War - the period of this study - during which, it is argued, its influence on national defence was at its peak. Certainly by 1970 the firms had become more independent and were forced into competing groups. They were, moreover, beginning to be required to pay for Government facilities and the establishments were themselves being encouraged to become more accountable and "the freedom was going out of research".[6] The industrial situation also

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M J Lighthill (subsequently Sir James Lighthill), 'The Royal Aircraft Establishment' in Sir John Cockroft *The Organisation of Research Establishments*, (Cambridge, 1965), pp 28-54.

6
Mike Dobson, former superintendent, RAE Bedford, personal communication, 28 March 1998.

changed radically during the post-war years and during the 1960s the aircraft firms were becoming transformed, bringing in more analytical talent and investing in research facilities.

The work of the RAE in this period underlines the thesis that the Cold War was, in a sense, a war - one of competitive innovation in weapons utilising the most advanced technology that the country could deploy and some of its best scientific and engineering personnel.[7] This was clearly a hugely expensive undertaking and has been analyzed from one perspective as a waste of human assets and national resources as well as a dangerous game of escalation which carried the risk of triggering conflict, particularly at crucial periods when new systems were about to be deployed. However, an alternative strategic and utilitarian view, which has been defended in the USA rather more robustly than in Britain, is that the effort was worthwhile because the threats were met. According to this view a third world war was averted not only by balance of terror but in the early period, when atomic war fighting was considered a possibility, by a balance of capability. The technical success of Western defence science in countering and meeting Soviet threats could be seen, therefore, on this view, be seen as a contribution to stability.

Perhaps the surprising feature of the work at the RAE in this period is that, in spite of all the pressing needs and perceived dangers implicit in this world order, the direction of the research performed there by its highly intelligent and motivated scientists was done with a remarkably light touch on the part of their superiors. Indeed, much influential work was done because RAE scientists themselves felt that it would be strategically significant or that it would be scientifically interesting.

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Thus Sir John Carroll, at the Defence Research Policy Committee in 1955 suggested that "the present armament race ... [is] a research and development race and not one for the provision of equipment". Quoted in Agar and Balmer, (n. 1 above). This point is also well made by Peter Nailor, 'The Ministry of Defence 1959-1970' in *Government and the Armed Forces in Britain 1856-1990*, Ed. Paul Smith, (Hambledon Press, London, 1996), pp 235-248.

There were various reasons for this comparative freedom. One was the prevailing sense throughout universities and research institutes, that lasted until the Thatcher era, that advanced research should not be shackled to closely too specific ends. Useful results would certainly accrue but, the argument went, who could say where? No one had foreseen, it used to be said, that Fleming's stray mould would lead to penicillin, and this perspective was underpinned by the administration of the Establishment since the Director was generally a government aeronautical scientist who had grown up in this system with its tradition of intellectual independence. Another reason for this comparative independence of the RAE scientists was that aircraft were entering a new aerodynamic realm as they approached the speed of sound. Up to 1945 the Air Staff had expected, for example, incremental progress in engine performance leading to improvements to the speed and height ceiling of aircraft; the main question was how rapidly these would come along in comparison to the progress of the enemy. With the approach to the speed of sound there was a genuine discontinuity of knowledge and the solutions were in the hands of the scientists while the experience within the aircraft companies did not extend to trans-sonic and supersonic flow or to the associated problems of stability, control, structural integrity and the prediction of performance in this regime.

Thus post-war British aeronautical work can be seen as being led as much by scientific research as by military requirements and by military assessments of threat. Furthermore, because of the centrality of new science to aviation the perception of threat would be very likely to derive from the aeronautical scientists' own appreciation of what the potential enemy might be able to achieve. However, it is important to note that in this new, uncertain, post-war era (uncertain both politically and aerodynamically) the development of military aircraft specifications was a much more fluid process than during the Second World War. Then, the mission could be defined reasonably closely on the basis of actual experience with losses, evaluation of success, and continual knowledge of enemy capabilities. In the Cold War era the nature of the threat was speculative as were the potential capabilities of the defensive and offensive

aircraft which might be produced to operate in the new trans-sonic and supersonic regimes.

The complement of aerodynamic staff at the RAE was drawn from the rather few universities which had aerodynamics courses (that run by Sir Brian Melvill Jones at Cambridge was one) as well as academically trained engineers and a considerable number of mathematicians of exceptionally high attainment who frequently came directly on completion of their undergraduate degrees. Thus, to a considerable degree the RAE developed its own cadre of aerodynamicists and its own style of research.[8] However, the work of the theoreticians, it must be noted, was supported by a large number of talented practical engineers and technicians and by well-equipped workshops in which prototypes, wind tunnel models and instrumentation of the highest quality were made. To support this the RAE ran its own craft apprentice scheme, although exceptional individuals recruited in this way could move into more directing positions in research programmes. Thus the early work on jet lift and the control of vertical take-off craft was done by a former craft apprentice, Dennis Higton, and his moving platform rig was the conceptual predecessor to the Rolls-Royce Flying Bedstead and, eventually leading to the reaction control system of the Harrier.

At the theoretical centre of the innovative work of the RAE was the Aerodynamics or "Aero" Department, whose members, according to one recollection, led "a god-like separate existence". and it was in the Aero Department that new concepts for aircraft and new directions for theoretical

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On completion of his degree during the Second World War, Sir John Charnley recalls being interviewed by C P Snow who was involved in the allocation of scientific manpower for the war effort and sent to Farnborough because of his interest in hydraulics and structures. Sir John Charnley, interview with the author, 28 May 1998. Sir John Charnley was, among other posts, Superintendent of the RAE Blind Landing Experimental Unit, Head of the Weapons Department, RAE and Chief Scientist to the RAF. C H E Warren recalls being allocated to the RAE on completion of his mathematics study at Cambridge with the winning proposition that "in the last war you'd have been sent to the trenches but we've been thrown out of France now. Have you heard of a place called Farnborough?". (n. 2 above).

research tended to arise.[9] Within this group there was a strong team spirit, perhaps engendered by the largely secret nature of the establishment's work and the consequent lack of opportunity to publish work competitively.[10] In this atmosphere scientists within the group were, to very high degree, self-directing and, in the Cold War climate there was a good chance that many of the ideas and suggestions emanating from this group could be tested in wind tunnel work and with research aircraft. Thus aerodynamicists have recalled being "in the fortunate position of never having to think about money for the things we were doing" and that "we never thought about cost - we never asked". It must certainly have been an almost idyllic time for aeronautical scientists with high theoretical capabilities and self-motivation. The perception of some of those who worked at the RAE in this period was that "it was absolutely marvellous" and that "we thought of the topics ourselves and found the answers; we had the perfect jobs". The RAE was also a highly integrated community in which the various groups knew what lines each was working on and collaborated. "We really were a team here. People had ideas, but passed them into the team; everyone was very co-operative".[11]

The Aerodynamics Department also contained an inner circle of perhaps six people, the Projects Division, (also referred to as Aero Projects) which played a leading part in devising proposals and considering what new types of aircraft could result from the latest aerodynamic research. Tom Sommerville, who was head of the group for a period, considered that the job was "to look one step

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9
Brian Kervell, former member of Structures Department, RAE, personal communication, 3 February 1997.

10
An ingenious mechanism did exist for peer review of secret work through the Aeronautical Research Council which had a fluid dynamics committee composed of security cleared aerodynamicists from the universities and other establishments at which, C H E Warren considered, the ARC would put forward ideas and comments on the work at RAE "but in a generous way" (n. 2 above).

11
Johanna Weber and C H E Warren, interview with the author, 1 June 1998.

ahead", because "aerodynamics always played a leading part" in advanced projects and that "we were able to integrate the thinking of all the [other] departments".[12] Within the Aero Department internal contact was ensured by bi-monthly meetings where the theoreticians and perhaps flight test practitioners would stimulate each other with problems, queries and proposals, often in the absence of any top-down directive or requirement. On these days the internal morning discussion was followed by an afternoon meeting with senior government and RAF personnel and, for example, the Vice Chief of Air Staff (VCAS) of the RAF would come to survey both the progress of practical short term experimental work on service types but also to meet the Director and senior staff and to learn what advanced ideas were in the air.

In this period the Air Staff targets for future aircraft were frequently "not in black and white" and were evolved and modified in discussion with Aero Projects or with specially formed multi-disciplinary teams such as the "Advanced Bomber Project Group". In addition, the Director of the RAE always took a close interest in the work of these groups and was able to represent it at higher policy levels both informally and through bodies such as the Air Warfare Committee at the Air Ministry. Senior RAE people also maintained a range of contacts in the services and in government, with a number of them, including Morien Morgan, Handel Davies, Sir James Lighthill and Sir John Charnley moving from the RAE into wider government roles.[13]

In the context of so much open-ended and self-directed research it is often hard to disentangle where aircraft developments actually originated and it is important

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12
Tom Sommerville, interview with the author, 16 October 1997. The group also acted as arbiters when several competing designs were produced by the industry.

13
For an understanding of British defence policy it seems important to give attention to role of informal and social contacts between the protagonists. I have attempted to show how essential these contacts were in a slightly earlier period to the establishment of the WW II radar chain and the concurrent development of high power interceptor engines in 'Two-stroke or Turbine: the Aeronautical Research Committee and British Aero Engine Developments in World War II', *Technology and Culture*, April 1997, pp 312-354.

to see Farnborough as part of a wider aeronautical community involving the RAF, the Air Staff, and civil servants in which ideas and possibilities could circulate and resonate. In this milieu aircraft requirements and projects developed in a "social" and even an informal way so that "Operational Requirements" (ORs) which were issued to the industry to invite design submissions for future aircraft had been refined by an interchange, which helped to define what might be attainable, between RAE experts, Ministry of Supply officials and RAF officers.

Of course the Air Staff could originate operational requirements for aircraft on the basis of strategic and combat needs in advance of the firms' ability to meet them and even in advance of the power of the RAE to predict whether the performance was attainable. This was certainly the case with the "medium bomber" requirement which was to result in the V-force, issued in 1946. However, in other cases, such as that of the supersonic fighter and also, later, with Concorde it seems clear that the impulse to initiate the projects came from Farnborough.

It is also noteworthy that RAE staff in this period recall considerable contact with RAF personnel at a practical and an experimental level, with, on occasion, uniformed RAF officers going into the wind tunnels to collaborate on programmes. There was also a very high degree of collaboration with the firms at all levels, from the Director and Deputy Director at the RAE to the research scientists on the particular projects who all liaised in a personal way with the appropriate contacts in the aircraft firms. Through this, the research flying and wind tunnel programmes at the RAE were completely integrated into the development programmes for the forthcoming service aircraft. Indeed, this had to be so for, as the case studies here will show, the companies in this period were simply not equipped to do the fundamental research to support the advanced programmes.

This disparity between the capability of the RAE in advanced areas and that of

the industry led, in 1947, to a proposal from the Ministry of Supply (MoS) that the RAE might be made responsible for the direct design and manufacture of military aircraft "with the object of producing better types" and "for the benefits of research to be passed on to operational aircraft as early as possible".[14] The main objective (which is significant in the light of the discussion below on the supersonic fighter and the atomic threat) appears to have been to obtain an advanced interceptor. The RAE discussed the idea internally and though reflecting on "the problems of getting the firms to do advanced work" - particularly the problem of aero-elastic distortion on highly swept-back wings - cautioned strongly against the proposal. Its view was that the existing co-operation between RAE specialists and the firms' designers had only been achieved "after years of striving to gain the industry's confidence". If the RAE were to become a competitor the effective partnership with the firms would be dissolved and "the whole structure of the aircraft industry would then lose its main scientific support - a disaster for which a single national factory, however efficient, would be poor recompense".[15]

In pursuit of its aim to nurture the capability of the industry, the RAE mounted numerous conferences and meetings in this period to pass on to the implications of its long-range research to the designers and the aerodynamicists from the aircraft firms. These would take the form of presentations, followed by discussion, from a range of RAE personnel including aerodynamicists, control and stability experts, structural and 'flutter' analysts and so on, to acquaint the firms of "what it would be like to design a supersonic aeroplane". Flutter was a particular province of the RAE, since the mathematics of the interaction

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14
PRO AVIA 13/666, 'Proposals for the RAE to take direct responsibility for the design and production of aircraft', March 1947. This idea recalls the role of Farnborough in the First World War, when as the Royal Aircraft Factory, it had a contentious, and eventually untenable, role as both a government manufacturer and as a design and research authority.

15
Ibid. These opinions were expressed by Morien Morgan, then Head of Aero Flight and P B Walker, Head of Structures, who became well known for his investigation of the Comet crashes.

between aerodynamic flow and the elastic or vibratory movements of the aircraft structure is particularly demanding. It was an area in which, during the 1950s, the firms appeared unable to cope, often leaving the final validation of a design, or the cure of a fault, to the RAE. Moreover, the theoretical solutions that came to be adopted by the industry for such analysis was established at Farnborough. The theoretical excellence of the RAE at this time was accompanied by a laconic, almost self-deprecating style and one mathematician, describing his presentation on the expected solutions for supersonic wing design to the industrial audience, recalled mildly that "I'd just done some sums really ... and drawn some graphs".[16]

RAE Contributions to the post-war British Aircraft Programme

The intention in this chapter is to study the exceptional degree of integration and exchange between government science and the aircraft firms in the period under review. This intimate relationship reflected, initially, the political philosophy of the post-war Labour government, although it continued substantially in the same path when the Conservative administration was returned to power under Churchill in 1951. The association certainly reflected the pattern of collaboration established by weapons development during the Second World War, but was also a response to the very high scientific and technical demands of the new post-war aircraft and systems which were evolving rapidly and competitively at a time of enormous changes in performance and capability. However, the role that RAE performed was not identical in each case, in some instances acting as initiator and champion for an idea, and at others acting more conventionally to provide the research underpinnings for a Service requirement. A study of some of the major projects which relied on substantial RAE involvement in this period

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16
C H E Warren, (n. 2 above). The major theoretical insights on flutter analysis at Farnborough were ascribed to E G (Ted) Broadbent, subsequently Visiting Professor in Mathematics at Imperial College.

gives an insight into the influence of the establishment and the way it affected British aviation in this period.

The P.1 Lightning Supersonic Fighter

In 1945 a study of the 'interception problem', prepared by Don Hallowes, an Aero Department mathematician, analyzed a new type of threat - the high altitude high-speed bomber made possible by the new and rapidly developing jet engine. Hallowes assessed the chances of intercepting hostile incoming bombers at a range of speeds from 300 mph up to 500 mph and various heights up to 50,000 feet. He hypothesised as the defence "a good conventional jet-propelled fighter such as might be flying in a few years' time" powered by the Rolls-Royce Nene which was then, at 5000 lbs thrust, the most powerful jet engine in the world, providing a top speed of 595 mph. Hallowes treated the problem as a series of exercises in three-dimensional geometry calculating the results of a large range of different defence conditions, such as radar range and fighter readiness, and their interaction with bombers at varying speeds and heights. From this he arrived at what he called "a pseudo-statistical approach" to answer the question "how fast and high must a bomber fly to avoid interception?" and reached the important conclusion that "in a large number of cases (70 to 90%) a bomber flying at 500 m.p.h. at 50,000 ft. would be free from the possibility of interception".[17]

This study is interesting because the performance parameters of such a bomber mirror almost exactly those selected by the Air Staff in the following year for the high altitude high speed "medium bomber" force called for in its Operational

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17
D M Hallowes, 'An Examination of the Interception Problem', RAE Report No. Aero 2035, April 1945. As well as enemy height and speed the analysis studied the interaction between a range of possible values for radar detection range, the distance between defending airfields, and the 'lost time' - the period elapsing between the first detection of the bomber and fighter take-off.

Requirement (OR) 229 issued in November 1946 that led to the Vulcan, Victor and Valiant 'V-force' aircraft.[18] However, the RAE, as we have seen, nurtured a culture in which the various groups knew what lines the others were working on and where ideas were shared. The RAE was essential to the development of the nuclear V-force bombers but, as Sir John Charnley recalled, "at the same time that you'd be thinking about that, you'd be thinking about how to beat it".[19]

To combat the high altitude, high subsonic speed bomber and make interception possible it was essential to restore the speed advantage of the fighter over the bomber, but this would require "a step into the unknown" - the design and production of a supersonic fighter.

Speeds approaching that of sound had been encountered in dives by late Second World War combat aircraft, often with disconcerting loss of control, buffeting and even structural failure. To analyze these problems, which came to be known as 'compressibility effects', the RAE pioneered high Mach number trials in Britain during the war by diving a Spitfire at increasing speeds up to Mach 0.9 while simultaneously conducting wind tunnel model experiments in parallel with these flights to help predict the control effects that would be encountered and to analyse the pilots' experiences.[20]

Bullets and artillery shells could be supersonic and stable in flight and the mathematics of fully supersonic flight was fairly simple and reasonably well

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18
Tracing the influence of work such as this is always difficult. However the circulation of the paper is recorded and included a large part of the scientific direction in the Ministry of Supply including the Controller of Research and Development (CRD) and the Director of Scientific Research (DSR). The operational research sections at the Air Ministry and in Fighter Command are also included. On the basis of the performance targets for the V-bomber force and the British supersonic interceptor it appears that Hallowes' study was highly influential.

19
Sir John Charnley, (n. 8 above).

20
W A Mair (ed.) 'Research on High Speed Aerodynamics at the Royal Aircraft Establishment from 1942 to 1945', R&M No 2222, ARC Monograph, 1946.

known. The greatest uncertainty was in the trans-sonic region where the aircraft had not quite reached the speed of sound (a Mach number of one), but where the local flow over convex shapes on the aircraft accelerated the flow to become supersonic in parts. This mixed flow was extremely complex aerodynamically and mathematically, and while some aircraft, such as the Spitfire, had approached the speed of sound with reasonably progressive control changes which a prepared pilot could cope with, other types had shown severe problems. No body of theory existed to explain this.

In the latter stages of the war some thought had been given to developing an experimental supersonic aircraft - the Miles M52, using a development of the Whittle W2/700 engine. This programme was cancelled, partly through doubts about the ability of the small Miles company to sustain an advanced programme, but mainly on advice from the RAE that the M52 wing was not thin enough to allow supersonic flight. Furthermore, the Allied discovery of the extensive work in Germany on swept wings in the trans-sonic regime suggested that the straight wing approach adopted for the M52 was mistaken.[21] In 1948, Hans Multhopp, one of the German aerodynamicists who came to Farnborough (formerly an aerodynamicist with Kurt Tank in the Focke-Wulf design office), proposed with M Winter, another German colleague, an experimental swept wing trans-sonic research aircraft. They calculated that the new Rolls-Royce Avon engine was just sufficient to give the aircraft a supersonic performance of Mach 1.24 at 36,000 feet "if equipment and instrumentation are restricted to only the most essential items". The other restriction was to keep the diameter of fuselage to the absolute minimum dictated by the Avon engine and to this end the pilot was to be located in a prone position in a compartment located, in effect, within the

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21
The cancellation of the Miles M52 has always been a contentious issue with British aircraft enthusiasts who have personalised the issue by blaming the then Director of Scientific Research at MAP, Sir Ben Lockspeiser, for setting back the British supersonic programme by years. However the interviews conducted by this author make it clear that the advice came from RAE aerodynamicists who also calculated that the thrust from the special W2/700 was inadequate. The critics point out that the American rocket-powered Bell X-1, the first supersonic aircraft, used straight wings but the clear flying weather of Nevada and the almost limitless desert runways provided a far better environment for early supersonic trials.

inlet duct. The wing was to be swept back at an angle of 55 degrees to delay compressibility effects while the tailplane ("a scheme which was developed some years ago for the Focke Wulf 183 fighter") was to be mounted high on the fin to keep it clear of the wing wake and to avoid the loss or alteration of pitch control which had been encountered in transonic flight.[22]

This aircraft, which the authors suggested could be regarded as "an experimental reduced scale model ... of an aircraft having possible practical applications" (i.e. a fighter) was not built but later, in 1948, another RAE paper by Owen, Nonweiler and Warren proposed a larger supersonic fighter which derived from it.[23] In general layout and wing plan form the proposed fighter followed closely the Winter/Multhopp design, including a version with a prone pilot position, although an alternative layout was sketched with a conventional pilot position above the intake and a radar scanner dish faired into the centre of the intake duct. However the Winter/Multhopp aircraft was only supersonic by dint of scrupulous streamlining and avoidance of all unnecessary structure. A practical fighter would need much more power to attain this performance and the new feature of this June 1948 proposal was the use of multiple engines staggered so that the thickest part of one lay over the thinner part of the other - the so-called 'hip and waist' arrangement. The earlier conclusions of Hallowes are implicit in the paper which noted that the success of bomber interception depended largely on the margin of speed of the fighter over the bomber and that, as bomber speeds increased, this margin was becoming progressively harder to maintain. The authors noted that instability in the transonic regime was expected from work up to date, including disturbance in pitch and a severe loss, or even reversal, of aileron effectiveness (control in roll). However, these

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22
M.Winter and H.Multhopp, 'Transonic Research Aircraft with "Avon" Turbine Jet Engine (A.J.65)', RAE Technical Note Aero. 1928, February 1948.

23
P R Owen, T R F Nonweiler and C H E Warren, 'Preliminary Note on the Design and Performance of a Possible Supersonic Fighter Aircraft', RAE Technical Note Aero 1960, June 1948. It is significant that Winter and Multhopp, as German scientists, were able to work on the research aircraft but not, at that time, on the fighter derivative.

problems, which might be tolerated in a research aircraft and mitigated by accelerating rapidly through the 'sound barrier' (not the RAE term), had to be solved for a practical fighter to give progressive control at all speeds.

By November 1948 the Advanced Fighter Project Group, which had been set up at the RAE, reported on work to date stressing the difficulty in predicting the nature of the threat (in terms of speed and altitude) for which "the fighter which must stop the bomber" should be designed. The task, they proposed was that of defending "this island against the attacks of enemy bombers similar to the long-range high altitude bombers we ourselves are developing" - aircraft capable of delivering bombs at 500 knots and from 50,000 feet.[24] Although the study noted that this was a "restrictive and possible unrealistic assumption" these were also the performance characteristics of the hypothetical intruder aircraft for the earlier RAE interception analysis.

The group considered that, although the state of knowledge on aerodynamics, stability and control was still developing, the main uncertainty centred around the structure. The operational supersonic fighter was required to be a large and complex aircraft weighing perhaps 30,000 lbs (at a time when the relatively simple 'first generation' jet fighters such as the De Havilland Vampire and Supermarine Swift weighed only 8000 to 10,000 lbs). The gamble of estimating strength and weights closely in the absence of "real guiding experience" or established design principles is shown by the structural challenge of providing enough stiffness to wings and tail surfaces to prevent flutter and aileron control reversal.[25] The catch here was that the forces would be higher than those met

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24
'Report of R.A.E. Advanced Fighter Project Group', RAE Report Aero 2300, November 1948.

25
One problem encountered as aircraft approached the speed of sound was that of the much higher aerodynamic loads encountered. Control reversal could occur because movement of the control surface could produce a force adequate to twist the wing or tailplane supporting it, giving a control effect in the opposite sense to that applied. Thus a major problem in the development of supersonic aircraft was to design in adequate stiffness and strength at acceptable weight.

hitherto although the surfaces were required to be much thinner and, for geometric reasons, the high degree of sweepback also would tend to compound the problems of twist and aero-elastic distortion. However, the price of a slightly 'safer' and more conservative design, increasing the structure weight by a factor of only 3% would reduce flight endurance from 55 minutes to 29 minutes - scarcely a useful fighter.[26]

The RAE admitted that the new fighter would be "unlike anything designed or built in this country before" and that there would be many entirely new design problems to solve, but it argued that "the requisite information, experience and design skill can only come from a direct attack on the problem". Indeed, in the light of these technical reservations the RAE took a bold and even propagandist role in weapons development policy, arguing that "a fully operational supersonic fighter would be an immeasurably valuable asset to the defences of this country" and actively promoting work on it in spite of the many uncertainties. It noted:

> The unknown factors are many and frightening but the prize may be immense. ... If we had unlimited time ... the obvious way to achieve this prize would be to tackle the problem slowly. ... It would, however, be a lengthy process. In view of this we would like to suggest, in all seriousness, that we take a short cut by proceeding forthwith with the design of a fully operational supersonic fighter on the lines sketched [out]. ... This would admittedly be an appalling gamble.[27]

The RAE suggested that "a first class design team from the Industry" be asked to proceed with the design of an operational supersonic fighter. In August 1948 the Ministry of Supply (MoS) issued Operational Requirement (OR) F.23/49

26
Report of R.A.E. Advanced Fighter Group, (n. 24 above) p 11. The RAE noted that "it may be extremely difficult, or even impossible, to keep the structure weight down to that assumed. ... It is hardly to be expected that on a type of structure having many new features such as very thick skin, less than half the usual ratio of thickness to chord, and large sweepback angle, a firm will achieve first time the same high structural efficiency [as for subsonic types]. ... This difference ... is unfortunate but time does not permit the repetition of the work".

27
Ibid.

based on this RAE thinking which asked for "a minimum top speed of Mach = 1.2 or higher" and a fantastic climb performance allowing six minutes from the moment the pilot presses "the first button" to reaching 50,000 feet. The MoS then began to pursue discussions with English Electric as the most likely company to build the aircraft and, by March 1949, confirmed to the company that it was to develop the concept as the English Electric P.1 - the prototype that was to lead to the Lightning fighter.[28] Thus the project, it should be noted, was set in train at virtually the same time as the trans-sonic Hawker Hunter (and long before the Hunter flew), with the intention of leap-frogging a generation of fighters.

It is important in studies of Cold War work to bear in mind that nuclear strategic thinking evolved continuously during the period and the P.1 interceptor programme must be understood in the context of its times. At the outset of the programme the atomic bomb constituted a new and terrifying weapon but, in the minds of defence planners, there was still some hope for defence. It appeared that technical constraints meant that the actual rate of production of bombs was quite low and the relative scarcity of atomic weapons suggested that an attack could be defeated by a really exceptional technological effort.[29] A glimpse of this thinking can be gathered from a paper on 'The Air Defence Problem' given to aircraft industry designers and RAE representatives in December 1953 which hypothesised what soon came to be seen as an unrealistically limited and strategic attack on Britain, suggesting that "the elimination of the United

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28
An 'Experimental Requirement' ER 103, issued in late 1947, preceded this. The advantages of English Electric were an industrial management that was more solid than that usually found in the aircraft companies and a design team led by Teddy Petter that had, largely through its own initiative, launched the Canberra jet bomber.

29
The initial post-war assumptions were that Britain would be able to make bombs at a rate of 15 a year from 1951 while the USSR was considered to be behind Britain in the essential technology, science and industrial resources (although PMS Blackett independently estimated that the USSR would be able to make 40 bombs a year from 1952). Also, in 1949, there was said to be "desperate anxiety" in the USA over the shortage of uranium which was a limiting factor in their production programme. Margaret Gowing, *Independence and Deterrence, Britain and Atomic Energy 1945-1952*, (London, 1974) vol I, pp 4, 167-168, 360.

Kingdom capital, ports and bomber bases would be a strong factor towards the success of Russian aims in Europe in the next war".[30] The initial development of the Lightning therefore took place in the context of a range of suggestions for fast-climbing manned rocket or hybrid rocket and gas turbine-powered fighters. Sir Charles Gardner (as Director of Guided Weapons Development, DGWD) also gave a glimpse of a certain optimism for defence when he noted that "the Million-fold increase in striking power of a single aircraft has transformed the defence problem from one in which an attrition of 5 or 10 percent could be worthwhile ... to one in which it is necessary to achieve an annihilation defence in which virtually every aircraft must be destroyed".[31]

One of the challenges for this study is to elucidate the contribution of government scientists at the establishments to the aircraft and equipment that was actually supplied. This has traditionally been hard because of the mythologising tendency in British historical accounts which conventionally emphasise individual contributions and efforts. This has been seen, for example, in the story of the Whittle jet, where the contribution of government scientists from the Engine Department of the RAE has been largely ignored.

Furthermore, it has been noted that much aviation history has been written by enthusiasts with a particular regard for the firms. Thus, in the case of the English Electric P.1 Lightning, Bill Gunston, one of the best-known British aviation historians, opined that the English Electric designer Teddy Petter and

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30
PRO AIR 64/167, paper by Air Commodore Grandy at the Designers' Convention, Ministry of Supply, 15th and 16th December 1953.

31
Sir Charles Gardner, DGWRD, 'The Future of Military Aviation', lecture to the Imperial Defence College, 19 June 1957, (Science Museum archives). The hybrid rocket/gas turbine interceptors developed to prototype stage as the Saunders-Roe SR.53 and Avro 177 were cancelled in the aftermath of the Sandys 1957 Defence White Paper. However it was by then becoming clear that the gas turbine engine, with reheat, as in the Lightning, could give impressive climb performance without the complication of mixed powerplants and dangerous chemical fuels.

his team "needed all their skill to create a supersonic aircraft which ... could form the basis for an operational fighter, in an environment devoid of practically any supersonic experience and with the most meagre facilities". Their success, he suggests, "was to some extent despite the advice of officials who caused endless trouble trying to make English Electric adopt a T-tail".[32] These 'officials' were actually the most talented and experienced aerodynamicists in the country, feeling their way, like those in the companies, into the new trans-sonic and supersonic regimes and it is clear that, rather than keeping them at arms' length, the companies were most eager to have RAE advice on their designs. Of course both government and company scientists made both good choices and bad. The initial English Electric 1948 project drawings mirrored closely the planform of the RAE study, including the ingenious 'hip and waist' engine arrangement (fig ? - line drawing). This became a distinctive and successful feature of the production aircraft although in the case of the T-tail English Electric became convinced that RAE advice was wrong. In this they proved to be correct and the low tail position eventually adopted proved far more effective in the nose high landing attitude.

This study demonstrates that the aerodynamic and structural facilities open to the industry were far from meagre; they were, in fact, enormous, and although largely concentrated at the Farnborough and Bedford sites of the RAE, any account of this period must stress the tremendous integration between the companies and the government establishments. Mike Dobson (subsequently Superintendent of RAE Bedford), who joined in 1954 as an aerodynamicist and worked initially on the P.1A, recalled a colleague who worked "for months and months in the 'three foot' wind tunnel. It was a long time before I realised that he was English Electric and not RAE. The attitude was ... RAE was part of UK

32
Bill Gunston, *Fighters of the Fifties*, (Cambridge, 1981), p 74.

Limited".[33] In this period there was a huge amount of work in the RAE tunnels on stability and control for the supersonic fighter and also on the aerodynamics of the engine intake. There was also deep involvement of the RAE in the flight test program and the Short S.B.5, built as a smaller model of the P.1 to evaluate its low speed handling, was flown extensively from 1954 to 1960 by Aero Flight, at RAE Bedford, in the service of the development of the interceptor.

The RAE also served as the point at which the contributions of the other government research establishments, and RAF fighter development experience, were integrated into the aircraft. This included, for example, tactical ideas as well as radar and infra-red research. The effect of these important elements of the interceptor can be seen in the arguments which began to surface from about 1953 for a collision course interception, rather than the usual turn by the fighter onto the tail of the bomber, as a way of getting the interception point back from the coast of Britain [34]

Thus at the Sixth Fighter Tactical Convention in 1952, described as "a family gathering of the Fighter World, for the free exchange of views on current and future problems of common interest" the view was advanced that "from the Communist point of view Korea can be classed as a second Spain ... a testing and proving ground for their equipment and crews against Western powers", and it was suggested that, in a wider conflict, the "immediate threat was ... of atomic attack on the UK by bombers at the beginning of a war"..[35] This marked

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33
Mike Dobson, (n. 6 above). The Aeroplane and Armaments Experimental Establishment (AAEE) at Boscombe Down, though primarily concerned with refining and accepting effectively finalised aircraft designs for squadron service also in this fluid period made a large contribution to the development of aircraft while still in the prototype stages.

34
'Designers' Convention' (n. 30 above).

35
PRO AIR 64/180. 'Report of the Sixth Fighter Tactical Convention, 1-4 July 1952 held at Central Fighter Establishment, West Raynham'.

an early interest in collision course attack and, a little later, Dr F E Jones of the RAE noted explicitly that "if the over-riding requirement was for interception at the earliest possible moment, and certainly before the coast, we may be forced to collision course intercept using guided weapons".[36]

This represented a change in the way in which the supersonic fighter would be used, but the RAE studies in terminal dynamics showed that the advantage of collision course interception was strikingly great. The need to destroy a bomber carrying an atomic weapon as far out from the coast is clear, but there were also aerodynamic and operational considerations. Firstly, the timing and positioning of the approaching fighter for the turn onto the tail of the bomber for a pursuit course attack was extremely critical. Furthermore, making this turn at a high rate caused the drag to build up and the fighter speed to decay. It was also a manoeuvre which, at supersonic speed, used a very large proportion of the fighter's fuel load and limited the number of targets which could be engaged.

The requirements of fighter interception also acted as a driver for all the establishments contributing to airborne interception (AI) radar as well as to guided missile development and the electronic guidance components for them. The Lightning, when it entered service in 1960, certainly vindicated the early RAE advocacy of the supersonic interceptor but although, like so many British aircraft, it arrived awfully late, the performance substantially exceeded the initial RAE predictions. It was, however, an aircraft that was predicated on the special air defence and quick reaction needs of Britain. In this role it was probably the most potent interceptor at the time in the world, but this specificity of role denied it really substantial export sales, although forty were sold to Saudi Arabia and a further fourteen to Kuwait.

36
'Designers' Convention', (n. 30 above).

The performance of the Lightning perhaps also says something about the complexion of British technology in this period. Lightning pilots recall a real thoroughbred with astonishing rate of climb (two and a half minutes to reach 40,000 feet), a speed, in later versions, of more than Mach 2, and flying qualities that were "beautiful" and "perfect". However, the promised integration of the computation aids and electronics - the aircraft radar, navigation system and attack sight - never reached the level of contemporary American semi-automatic systems. Interception was, a pilot recalled, "a real one-armed paper-hanging operation" imposing an extremely high work-load.[37] This deficiency was spotted early on by the RAE and it is noteworthy that, during the programme, the instrument experts at Farnborough reflected that the electronics industry was overloaded and that "the effects of lagging equipment development are becoming very apparent in current fighter development".[38] In terms of maintenance too the aircraft reflected, throughout its operational life, the initial RAE view of it as an experimental aircraft which could be converted to an "operational prototype", if flight development was a success, and it demanded a huge and continuous effort on the part of the RAF engineering ground services.

In strategic terms the fairly simple scenario for the overall air defence of Great Britain which had spawned the supersonic fighter also changed. The planning for the interception of a rather limited atomic attack proved unrealistic in the thermonuclear age and it became tacitly accepted that the UK would not be able to build and man enough supersonic fighters to defend the country against the likely scale of a Soviet bomber attack. In the light of this perception Duncan Sandys' 1957 Defence White Paper, surprisingly, served to preserve the Lightning programme for though Sandys is mainly remembered for prematurely anticipating the age of the missile and the end of manned military flying this

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37
Brian Carroll, former RAF Lightning pilot, personal communication, 25 June 1998.

38
PRO AVIA 65/369. Memorandum by A Stratton, Instruments and Photography Department, RAE, 5 December 1956,

view overlooks the main objective behind his strategic thinking. Sandys, with a rather remorseless pragmatism, held the position that Britain could not withstand a nuclear attack and that both conventional and nuclear war-fighting strategies were unrealistic. The overwhelming need therefore was to secure the credibility of the British deterrent and he saw that this would necessitate the move away from the manned nuclear V-force to intercontinental missiles.[39] In the interim, while the V-force continued to pose a viable threat, the Lightning force that was coming into service was to be devoted largely to bolstering this credibility and to "the defence of the deterrent" against a Soviet counter-force strike against V-bombers at their bases.[40]

The Lightning was certainly the most complex and potent fighter ever built by Britain alone and, from the perspective of Cold War history, it was a response, at the limits of what was technologically achievable, to the nuclear threat faced by specifically by Britain, which, for geographical reasons was different, and probably much more difficult technically, than either the Soviet or the American air defence problems. The programme was extraordinarily ambitious for a country the size of Britain and it could be argued that the influence of the RAE was to nudge defence policy towards an excessively technological aircraft, rather than to the more flexible fighters exemplified by, say, the French Mirage series with its great possibilities for extended and incremental development. Backing the Lightning to leapfrog a whole generation of fighters perhaps also caused Britain to forgo interim supersonic aircraft like the American F-100 Super Sabre or the F-104 Starfighter and also to forgo sales of fighter aircraft which fell to the Americans both in Europe and in Britain's 'natural' markets in

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39
T C G James, *Defence Policy and the Royal Air Force 1956-1963*, Ministry of Defence, 1987, Air Historical Branch archives. One senior civil servant likened Sandys, in pursuit of these policies, to "a programmed tank".

40
In fact the 1956 Defence White Paper (Command 969) had initiated the policy that close defence of vulnerable areas was outmoded and that the aim was to concentrate on defending the V-bomber bases using a guided weapon (the Bloodhound) to break up enemy formations before engagement by UK fighters. Discussed in Jack Gough, *Watching the Skies*, (London 1993), p 178.

the Commonwealth.[41]

Nevertheless, in the long term, the Lightning was the learning project which really established the English Electric team at Warton as the leading military aircraft group in Britain. Indeed, it is clear that the development of technological and analytical power in the British aircraft industry, looked for in the post-war years by defence planners and civil servants, did in fact occur. When C H E Warren returned from the USA in 1960 to head the Flutter, Vibration and Noise unit in the Structures Department at the RAE he found the firms much more capable. "In the old days the RAE had done the sums which worked out whether the aircraft would flutter - now the firms were doing the work and we were just monitoring it".[42]

The technical expertise of the group has been maintained during the mergers which established the British Aircraft Corporation and then British Aerospace and through the collaborative Jaguar, Tornado, and Eurofighter projects. Today, as the Military Aircraft and Structures Division of British Aerospace, the group which grew out of English Electric has become established as one of the largest and most capable military aircraft organisations in Europe.

The V-force Bombers

Advice from the RAE was also crucial in the development of the British post-war bomber V-bomber force, which formed the initial delivery system for

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"By 1950 we knew enough to design a supersonic aircraft as good or better than the F104. I've never understood why we were so slow to do it". Handel Davies, interview with the author, 15 April 1998. Handel Davies was Head of Aero Flight (J) in the immediate post-war period and, among other posts, was Scientific Adviser at the Air Ministry (1955-1956), Deputy Director of the RAE (1959-1963) and British chairman of the management boards for Concorde and Tornado.

42
C H E Warren (n. 2 above).

British nuclear weapons and which remained in service until 1970. However, its role in this programme was rather different to that in the case of the supersonic fighter discussed above. With the fighter, the RAE took a proactive and propagandist role and could even be said to have originated the concept, whereas the requirement for a long-range, high-speed bomber derived from strategic thinking within the Royal Air Force.

The experience of the Second World War had shown that massed formations of bombers, even with substantial capability for defensive fire, were highly vulnerable to fighter attack. By contrast, the survivability of unarmed, high-speed high altitude aircraft, such as photo-reconnaissance Spitfires and the unarmed Mosquito bombers had proved good. This practical experience complemented the mathematical analysis of interception at RAE, discussed above, and the provisional 1946 'medium bomber' Operational Requirement, as we have seen, asked for an aircraft with speeds in excess of 500 mph at 50,000 feet. It asked, moreover, for a radius of action of 2000 nautical miles, clearly indicating that a threat to Moscow and important cities in the Soviet Union was in mind.

The major factor driving the creation of a new type of aircraft at the limits of aeronautical science was knowledge of the atomic bomb and it is interesting to note that the Air Staff "jumped the gun" by issuing a specification for aircraft capable of delivering the bomb before the British government had not made a commitment to the production of atomic weapons. However, the GEN 75 committee of Ministers, convened to consider atomic matters, had already received unequivocal advice that "the United Kingdom should undertake the production of atomic bombs as soon as possible" while the Chiefs of Staff (Lords Alanbrooke, Cunningham and Portal) minuted the Prime Minister directly on 1 January 1946 that "we are convinced that the best method of defence against the atomic bomb is likely to be the deterrent effect" and that

"we must have a considerable number of bombs at our disposal".[43]

The Attlee government formally decided to proceed with the development of the atomic bomb in late July 1946. Thereafter the principle of deterrence for the United Kingdom by atomic bomb-carrying high-speed high altitude aircraft was firmly established by Lord Tedder, who followed Lord Portal as Chief of Air Staff in 1946 and was continued by his successor, Sir John Slessor (1950-1954).

The initial aircraft requirement, though making no reference to an atomic weapon, was clearly drafted with one in mind for it called for an aircraft capable of carrying a single 10,000 lb bomb, some sixty inches in diameter and twenty four feet long.[44] These dimensions were effectively those of the Los Alamos plutonium (Nagasaki) weapon, with a ballistic casing, that William Penney's team was to replicate in Britain.[45]

The process of procuring these high-performance aircraft was inevitably complex. A.V. Roe (Avro) and Handley Page, having built large numbers of heavy bombers during the war, were clearly front-runners, Shorts (which, as noted, had been nationalised during the war) and Vickers all became involved in production. Handley Page, in fact, anticipated the RAF need for a high speed jet bomber and had started an ambitious project with slender swept wings almost a year earlier, partly using German design experience which had been acquired by Handley Page designer Godfrey Lee during his membership of an Allied

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43
Humphrey Wynn, *The RAF Strategic Nuclear Deterrent Forces: their Origins, Roles and Deployment, 1946-1969*, (HMSO, London, 1994), pp 7-43.

44
"The RAF did not wait to hear whether Attlee's inner Cabinet had ratified the decision to 'go nuclear', before it started to lay plans as 'delivery vehicles' for nuclear bombs. as a result, three new V-bombers were being readied for deployment by the end of the 1950s". Solly Zuckerman, *Monkeys, Men and Missiles*, Collins, 1988, quoted in Wynn (ibid).

45
For an account of the British replication of the 'Fat Man' plutonium weapon, see Brian Cathcart, *Test of Greatness*, (London, 1994). OR1001, the procurement document for the atomic bomb, was issued on 9 August 1946.

technical intelligence mission to Germany.

The Avro team also understood that sweepback was needed for the high transsonic speeds required but did not consider it was possible to provide adequate strength for a wing of the span required without excessive structural weight. The Avro solution was to maintain the sweepback and reduce the span, but to restore the wing area by filling in the space between the swept-back wing and the fuselage, thus independently devising the delta wing. In this period, incidentally, the aerodynamic orientation of Avro was strengthened by the arrival of W S Farren who resigned his post as Director of the RAE to become chief designer at Avro.

Both these proposals Handley Page and Avro proposals were highly ambitious, unlike any preceding aircraft, and carried major risks. The RAE, functioning as independent design advisers for the Air Staff formed the 'Advanced Bomber Project Group' from the Aero and Structures Departments and noted that the very long range required and "operation at a Mach number of 0.87 and at a height of 50,000 ft means that designers are being asked to go right outside the realm of past experience into a region bristling with aerodynamic and structural unknowns". The group reflected that the drag coefficient of an aerofoil did not vary appreciably until a critical Mach number was reached (and thereafter rose steeply), but considered that experimental information on whether this critical Mach number could be deferred to a value of at least 0.87 was "as yet scanty and conflicting". Unless this could be achieved the requirement for range could not be met and the group noted that "present knowledge is ... grossly inadequate for the safe design of an advanced bomber".[46]

The RAE suggested that "we cannot put all our eggs in one basket" and advised pursuing several designs in order to spread the risk. Out of the large number of

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46
'Report of the R.A.E. Advanced Bomber Project Group', RAE Report Aero 2246, February 1948.

notional designs for tailed and tail-less bombers of varying sweepback considered, it suggested work on a tail-less delta and a tailed aircraft of about 45 degrees sweep. These were theoretical or 'paper' aircraft but they corresponded broadly to the Avro Vulcan and Handley Page Victor proposals. The RAE also proposed an intermediate design with less sweepback which presumably gave comfort to the Air Staff who were clearly nervous about the progress of procurement and, in fact, had sponsored the order from the MoS of a more conventional intermediate or 'insurance' type - the Short Sperrin, in case the firms were not able to solve the aerodynamic problems of the advanced types. However, the Air Staff considered this aircraft to be "unimaginative" and took a gloomy view of its likely performance "from our knowledge of the work of the firm".

This hiatus was exploited by George Edwards, chief designer of Vickers, who lobbied officials to assert that a bomber that almost approached the original performance requirements could be built to a faster time-scale and the Vickers proposal (subsequently named the Valiant) ousted the lacklustre Sperrin as the insurance aircraft. The relaxed specification called for a speed of 465 knots at 45,000 feet but, even so, the production of this aircraft was an industrial 'tour de force' and the first example arrived for squadron service in February 1955, whereas the Vulcan and Victor, which started almost a year earlier, did not reach operational squadrons until May 1957 and April 1958 respectively. Thus the development of the V-force operational procedures and the airborne dropping trials of inert versions of the first British atomic weapon (Blue Danube) took place with Valiants in 1955. The first live drops of British nuclear weapons were also performed by a Valiants, with a fission bomb being dropped in the 1956 'Buffalo' trial followed by a thermonuclear device in 1957 (the 'Grapple' trials). These aircraft were subsequently converted to air-to-air refuelling tankers as the better types arrived and were finally grounded as their fatigue life was approached in 1964.

The decision to order RAF nuclear bombers in triplicate was one of the most

notorious cases of the multiplication of British aviation projects which imposed a heavy financial burden on Britain in the Cold War years. It also represented a profligate use of British aircraft design skills, squeezing out, among other possibilities, better British civil airliners. The puzzle is that for the 'medium bomber' programme the RAE had encouraged both insurance aircraft as well as alternative designs for the eventual high performance front-line types. However, with regard to the supersonic interceptor it was remarkably single-minded, (asking for only one basic layout and one manufacturer), although this may have been because of a consciousness that it was proposing a large, risky and expensive step which was perhaps not so dear to the hearts of the Air Staff as the bomber. There was also some small latitude in the intercepter performance; it was a 'hot-rod' whose mission was short. By contrast, the bomber, to constitute a viable deterrent with a reasonable chance of survival, could not compromise on range, speed, or height over the target.

This habit of multiple procurement was also due in part to Second World War experience where it had proved impossible to predict which designs would be superior until they reached service (the superiority of the Avro Lancaster over the Handley Page Halifax and Short Stirling was often advanced as proof of this) creating a doctrine which was held dearly by the RAF. The RAF, furthermore, had ended the war with immense prestige and was used to getting what it wanted. It was not, of course, the role of the RAE to comment on procurement policy, but in the light of genuine uncertainty about the right structural and aerodynamic solutions for new aircraft the RAE were perhaps too ready to see a large number of alternative aircraft projects materialise as useful full-sized experiments. Handel Davies, referring to the trans-sonic fighter and bomber programmes suggested that "many of us thought at the time that it would be better to do a bit more experimental work on prototypes than to go ahead with three of each. ... I think we dithered a great deal on the merits of

delta or sweepback and shared the blame for the multiplication of projects".[47]

Throughout the development programme of the three V bombers there was again a major contribution of RAE aerodynamic work, and this also extended to the aerodynamics of the carriage of nuclear weapons and their release.[48] The RAE also contributed to the further development of the Vulcans and Victors to carry the Blue Steel powered "stand-off" missile and the finding that the partially recessed missile "has little effect on the drag coefficient of the aircraft" was important to establishing the viability of the development of this next phase of the British deterrent.[49]

RAE expertise of a different kind was needed in the service of the V-force when a Handley Page Victor on trials from Boscombe Down in August 1959 crashed unaccountably into the sea off the Pembrokeshire coast. More than 600,000 pieces of debris were recovered by trawling the sea bed (sixteen trawlers were involved) and the investigation was conducted by the Structures Department at Farnborough where the fragments were reassembled on a wooden framework. The investigation concluded that the loss of a pitot head through vibration had given a false indication of low airspeed causing the automatic system which protected against stall to push the aircraft nose down into a catastrophic supersonic dive.

47
Handel Davies (n 41 above). Apart from the single supersonic Lightning fighter programme there were several trans-sonic fighter programmes including the Supermarine Swift and Scimitar, the Hawker P1081 and Hunter, the Gloster Javelin and the De Havilland Sea Vixen which reached production, as well as a huge number of experimental projects including proposals for hybrid jet/rocket interceptors from three firms.

48
PRO AVIA 65/30, 'Speeding up Development, Production and Introduction into Service of Military Aircraft - Policy'. Thus in February 1958 the Ministry of Supply noted that Vulcan B. Mk 1 "had now been completed by the firm and handed over to the RAE. ... Trials are now in progress to clear Yellow Sun for carriage".

49
PRO AVIA 65/369 includes P Lee and K W Newby, 'Tests in the RAE 10 ft by 7 ft High Speed Tunnel of a Winged Bomb mounted under the Fuselage of the Avro Vulcan', RAE Tech Note 2365, May 1955.

The Comet Investigation

The Handley Page Victor investigation, conducted under the direction of P B Walker, Head of the Structures Department, recalled the earlier notable investigation at Farnborough into the unexplained crashes of two de Havilland Comet airliners over the Mediterranean in 1954. As the first jet airliner in the world to enter service, the Comet losses were seen as entailing a grave loss of national prestige. However, the extraordinary efforts made to elucidate the cause of the failures should not, however, be seen merely as industrial support for a flagship civil aircraft. Defence officials saw the Comet disasters as directly affecting international perceptions of the technical quality of British aircraft generally and thus also impacting on defence and deterrence. Writing in April 1954 Air Chief Marshall Sir John Baker, (as Controller of Aircraft, MoS) registered "the most urgent need ... to resolve and rectify the technical cause of the accidents ... [in the] interests of the integrity of the aircraft industry from both the national and strategic viewpoints".[50]

Therefore the unusual step was taken of asking the RAE to take charge of the investigation, (rather than the Accidents Investigation Branch of the Ministry of Civil Aviation, which had formal responsibility for enquiries of this type) This underlined the unitary nature, at the time, of both the British military and civil aviation programmes and also suggests how advanced, and perhaps even premature, the Comet was in terms of the deployment of the jet engine to a British airliner. However, the episode also points up the unique strength of the RAE, for only Farnborough, at the time, had the resources and expertise to construct a rig to repeatedly pressurise an entire Comet fuselage to simulate the cycle of take-off, climb and descent, while hydraulic jacks replicated the flight loads on the wings. After some 3000 "flights" a fatigue crack, originating at the corner of a window pushed out a section of the fuselage. This pattern of failure

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50
PRO AVIA 65/59, CA to DCAS, 21 April 1954, 'Comet Aircraft Production Policy'.

was confirmed by debris from the second crashed aircraft (BOAC Comet G-ALYP) then being recovered from sea bed off Elba.

The result of this investigation was the grounding of the Comet fleet pending structural modifications to the aircraft and to those of the next series, the Comet 2. Many of these were subsequently taken into RAF Transport Command, largely to protect de Havillands from financial failure under "a unique arrangement to which Treasury have agreed as a special measure".[51]

The Mach 2 Fighter

The supersonic interceptor and the V-bomber force represent two models for the way in which the RAE contributed to operational aircraft. However, this reasonably smooth progression from a project study, whether initiated by the firms or by the RAE, did not always occur. For example, following the initiation of the supersonic interceptor as a counter to bombers with high subsonic speed, the RAE then looked ahead to the possibility of the Soviet Union developing bombers with low supersonic performance (Mach 1.3), and proposed, as a countermeasure, a new design of fighter based on an RAE project for an aircraft capable of Mach 2.[52]

The RAE conducted an analysis of the utility of such a defensive fighter together with the Radar Research Establishment (RRE).[53] Their report suggested that the weapon was worth developing, in conjunction with more advanced

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51
PRO AVIA 65/59, 'Comet Aircraft Production Policy', memorandum of 16 March 1955.

52
C H E Warren, J Poole and D C Appleyard, 'An Investigation into an Aircraft to fly at a Mach Number of 2', RAE Report No. Aero 2462, June 1952.

53
'Defence against High Altitude Bombers by Mach 2 Fighters - a Joint R.A.E./R.R.E. Study', RAE Reports Aero 2513 and 2513A, June 1954.

airborne radar systems, and that such an aircraft "can achieve a kill line 30 miles out to sea" against a Mach 1.3 target. The system, it noted, could also cope with a Mach 2 target but "the kill line would shrink in very close to our coast line".[54]

However, the main argument for a Mach 2 fighter - that the Soviet Union might supplement their high subsonic speed bombers with some Mach 1.3 aircraft seemed rather implausible, even to its proponents, since it began to appear that designing a long-range Mach 1.3 bomber was no easier than designing a Mach 2 bomber. As the missile age dawned the perceived threat of such high altitude supersonic manned bombers receded while the Lightning proved capable of development to Mach 2 performance and some elements of the AI and ground control electronics permeated into the Lightning programme. The RAE Mach 2 fighter proposal proved to be a dead end with only two prototypes of the Bristol 188 built to test the wing layout.

However, the work was influential at least in that the Bristol 188 was built in stainless steel to cope with the expected kinetic heating. The expense and difficulty of this construction was to play an important part later in the decision at RAE to restrict the design speed of Concorde to about Mach 2 (where aluminium alloy structure would just suffice) and not to aim for a speed of Mach 3 or more, as was being contemplated in the USA.

The project also throws further light on the role of the RAE both as a kind of "advanced projects office" for the industry, and as a "booster" in policy-making circles for advanced aviation projects. Thus the same RAE Mach 2 thinking also gave rise to a research contract to the Avro company to develop a supersonic high altitude reconnaissance and bomber aircraft and the RAE helped to mediate between the company and the Ministry of Supply in the development of the new

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54
PRO AVIA 65/369. 'Joint RAE/RRE supersonic fighter working party'. The putative fighter was a straight wing Mach 2 aircraft to OR 329.

type.

Indeed, protagonists at the RAE for advanced aircraft like Morien Morgan co-operated (one could almost say colluded) with the companies to promote advances in aviation technology and when Avro sought government funding for the design and construction of a small-scale flight research variant of the supersonic bomber Morgan, (as Deputy Director) wrote to Avro that the RAE was preparing an appreciation of the Avro design "for official consumption, which I hope will help". He wrote also to the Ministry of Supply that "we are in full agreement with the reasons the firm give ... and consider that they have made an excellent case for this development".[55] A supersonic airliner version of the Avro bomber was also proposed but made little progress, due to its marginal payload, although Morien Morgan's real powers of advocacy were shortly to bear fruit with another supersonic airliner proposal - the narrow delta layout that led to Concorde.

Inventing Concorde

The RAE contribution to V-bomber development corresponded to the conventional role of a government research establishment in supporting a military programme. However, in initiating and promoting the supersonic airliner proposal which led to Concorde, the RAE followed a more inspirational and propagandist pattern. In some respects this activity, linking the latest theoretical aerodynamics to a possible future aircraft, recalled the role that the RAE had adopted for the supersonic fighter when it urged a development that

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J R Ewans, Chief Designer, A V Roe and Co., Limited, to Morien Morgan, 5 January 1956, and his reply of 13 January; Morien Morgan to Secretary, MoS, FAO PDSB(A). Letters with Avro company project brochures on Avro 730 Supersonic High Altitude Aircraft to Specification R.156.T, July 1955, and Avro 731 Research Model of Avro 730, ex-RAE Museum now Archives Department, RAF Museum AC/94/27/39,40 and 41.

was well in advance of what the aircraft industry, and even perhaps the Air Staff, were contemplating.

In the case of Concorde, RAE influence spread even more widely than this and into the political domain, largely through the efforts of Morien Morgan and his efforts in the creation of the Supersonic Transport Aircraft Committee. The establishment of a sense of the desirability of a supersonic airliner programme in British political and industrial consciousness thus illustrates the technocratic nature of decision-making in British aviation and the prestige of aeronautical scientists at the RAE, where supersonic passenger flight had been considered from the mid-1950, initially linked, as we have seen, to the Avro 730 supersonic bomber project. From 1955, the highly persuasive Morgan "did the missionary work to get the companies to take an interest in it" and persuaded all the chief designers who were prepared to co-operate to join the Supersonic Transport Aircraft Committee (STAC) which first met in November 1956.[56]

As interest in the supersonic airliner began to build, RAE aerodynamics research began to suggest a completely different supersonic configuration for the aircraft - the narrow delta. The understanding of the narrow delta is associated particularly with the RAE aerodynamicist Dietrich Küchemann who, as discussed in chapter four, was one of the German scientists offered employment in England by British investigators in Germany at the close of the war. He came to Farnborough in 1946 and his long-term professional associate, the mathematician and aerodynamicist Johanna Weber came, at his instigation, some months later in 1947.

Johanna Weber initiated the first interest in the aerodynamics of the narrow delta at the RAE with a survey paper in 1955 on all the available information on this type of wing and the configuration was first considered for its low 'wave

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56
Handel Davies, (n. 41 above).

drag' in supersonic flight.[57] Indeed, it appeared to be the only shape that would allow carriage of a reasonable civil payload. The solution to the supersonic end of the speed range thus began to become emerge, but it was still unclear whether it would it be possible for this supersonic, low-drag shape to queue and land at normal airliner speeds, using available runways. "The problems were the low speed problems of the high speed aeroplane - it seemed hopeless" C H E Warren recalled.[58]

The aerodynamicists considered by then that "we'd solved the classical aeroplane", but the narrow delta entailed a new type of flow and though, with its echoes of the schoolboy paper dart the configuration seems, with hindsight, an almost unsurprising choice for a high speed aircraft, the way in which it works amounted to a real paradigm shift in aerodynamic thinking.[59] In essence, at high angles of incidence, the airflow over each wing rolls up into two huge stable vortices. This contrasts with classical aerodynamics of straight wings, where orderly flow front to back was the desired state and wandering, unstable vortices over the upper surface of the wing were associated with stalling and loss of lift.

Soon it began to emerge from this research that the vortex flow of the narrow delta could offer the combination of both very high speeds and the possibility of flying slowly (and landing) in a 'nose high' flight attitude. Thus speed could be

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57
J Weber, 'Some Effects of Flow Separation on Slender Delta Wings', RAE Technical Note Aero 2425, 1955.

58
C H E Warren, Handel Davies and Sir John Charnley, meeting with the author, 14 May 1998.

59
The concept of paradigm shift, explicitly extended from the work of Thomas Kuhn by Edward W Constant to comprehend technological development, has been touched on with reference to the Whittle jet. Interestingly, adherents of the concept of the paradigm shift stress the importance of individuals like Frank Whittle outside the mainstream of a particular professional group but, in the case of the vortex flow for Concorde-like wings, the new theory arose and was promoted among the established aerodynamics practitioners of the RAE (and, in parallel, incidentally, at the French aerodynamics establishment ONERA).

reduced but lift could be maintained, it seemed, without the complicated flaps and leading edge devices, on which conventional airliners depended, by progressively raising the nose and increasing the angle of incidence of the wing. This discovery of the greatly extended range of 'non-linear lift' was at the core of the RAE advocacy of the narrow delta.

Once it was shown theoretically that this slender supersonic shape should also be able to fly slowly doubts still existed. Though low speed lift was assured by the pair of large stable vortices rotating over the upper wing, how stable where they in the ultra-slow landing regime? In a side gust, might they not be liable to slide off one wing or the other and take some seconds to regenerate? American wind tunnel studies had predicted that this form of aircraft might be prey to 'Dutch roll' - a spiral instability with the aircraft rolling and swinging in a corkscrew motion about the direction of flight.

But as the theoretical solution of the narrow delta began to emerge for the civil supersonic mission it was adopted with tremendous enthusiasm by the community of Farnborough aerodynamicists. One, in particular, W E Gray, believed that Farnborough and Britain had a mission to develop the supersonic aircraft and he also considered that the Dutch roll danger was exaggerated. Gray was an extraordinary character whose research effort was entirely "self propelled". He had been a pilot, awarded the DFC in the First World War, and was often seen cycling round Farnborough in his old leather flying cap. He had a talent for cheap, pragmatic experiments and made it his mission to investigate this roll phenomenon experimentally. Gray's private programmes often cut across the intentions and plans of other departments and sometimes section heads and senior officers would refuse to see him to avoid being badgered for research facilities, flight time or resources. Gray, who was an expert rose grower, usually managed to detain his quarry by finding a moment to present a bunch of his own blooms.

Gray initiated one of his typically ingenious and cheap research programmes to

test the claimed instability of narrow deltas, building and launching simple balsa models with a variety of shapes across the 24 foot wind tunnel. The models began their glide in still air and, as they crossed the tunnel nozzle, encountered the tunnel flow from the side, simulating the kind of side gust the airliner might encounter on a landing approach. The aim was to see whether the disturbance damped itself out or was self-sustaining. The mathematician Jean Ross, who had just joined the RAE, was assigned to help with these trials and recalled "I was his ball girl", retrieving the models from across the wind tunnel.[60]

However, Gray went almost too far with his next sally. He argued that "the national good [and] the RAE's good name" turned on flying a narrow delta supersonic shape without delay and advocated building a range of cheap wooden manned gliders which he volunteered to fly "and so permit the Captains of Industry to keep their white robes unblemished".[61] His criticism of RAE direction and "the massive slow-motion approach" of the Ministry of Supply got him into trouble but the view that Jean Ross held of his particular style was that "you could be amused or you could be cross, or you could respect him. I think most people respected him". Indeed, the conjunction of Germanic theoretical and mathematical training, as exemplified by Kuchemann and Weber, with Gray's pragmatic English empiricism, which bordered on the eccentric, is one of the most fascinating conjunctions in the generation of the Concorde project.

As confidence in the solution built within the RAE on the high speed and low speed behaviour the Establishment again mounted, from the late 1950s, a series of conferences and "selling" visits to the firms explaining the thinking behind the narrow delta, its aerodynamic, performance and control characteristics. Thus the initial "project design" for the SST can certainly be attributed to the RAE

60
Jean Ross, conversation with the author, 23 May 1994.

61
W E Gray, 'The Case for Flying a Narrow Delta Glider in April 1959', RAE Tech Memo Aero 618. The model experiments are described in 'Dynamic Tests on Free-flying Models of Slender Wings Subjected to Side-gusts', RAE Technical Note Aero 2983 (1958).

and not to any particular firm. This parentage is revealed by the remarkable similarity of the shapes proposed independently for the aircraft by separate design teams at Bristol, Handley Page and English Electric, all of which showed a similar planform and the distinctive ogee (wine glass) shape that came to typify Concorde.

Conclusion

A central point about the RAE which needs to be touched on again concerns its crucial role in the integration of defence science and technology, for it was largely through the work at Farnborough and Bedford that all the then new and developing technologies for trans-sonic and supersonic flight came to be integrated into military aircraft. For example, work on pilot physiology, done by the RAF Institute of Aviation Medicine, would drive pressure flying suit design, but the suit itself had to interface with the aircraft systems and thus Mechanical Engineering Division of the RAE assessed techniques for providing the suit with the compressed air it needed from the compressor stage of the jet engine.[62] To take another example, the work on weapons, missiles, and guidance done at RAE and elsewhere also had to be integrated into the aircraft. This included the aerodynamic effects on performance and handling of the aircraft while the ordnance was attached and establishing safe separation on firing. Guidance and the integration of missile and aircraft electronics also fell to the RAE in this period, while 'terminal dynamics' - the complex three-dimensional theoretical treatment of interception, pitting the fighter/missile ensemble against the hypothetical enemy bomber was very much an RAE speciality.

The strength of the RAE was that "presented with any aircraft-like problem, the

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62
A typical example of this kind of work is represented by G R Allen and M D Chamberlain, 'The Operation of Anti-G Suits with Air taken from the Turbine Engine Compressor', RAE Tech. Note Mech. Eng. 128, July 1952.

RAE could pull together a high quality group over a range of subjects".[63] Even as late as 1963 the RAE was itself pioneering a new integrated navigation and attack (nav-attack) system for the TSR2 tactical strike aircraft without any lead contractor from industry - a phenomenon which reflected both on the strength of the RAE and the thinness of the UK defence electronics sector.[64]

The work reviewed here is necessarily only a sample of the huge output of research work carried out by the RAE in the period under review but hopefully, it is enough to show its far-reaching influence on British aircraft and on the character of the post-war aviation enterprise. Even an RAE programme with the apparently innocuous purpose of developing a blind landing system for poor visibility was tied in to the British posture on nuclear deterrence since "the point about the blind landing was to get the V force from their base airfields to their dispersal airfields where their weapons were stored".[65] This dispersal capability was needed to establish a credible deterrent capability for the V-force in the event of an imminent Soviet attack and it is an intriguing thought that part of the effect of the experimental transmissions from the RAE Blind Landing Unit at Martlesham in Suffolk was to acquaint Soviet signals analysts with the capability of the force for all-weather operation.

The competitive development of aircraft and aircraft systems at the frontiers of knowledge illustrates the special Cold War phenomenon of science at war which, it is argued, put a special stamp on the post-war British aircraft effort. However, this chapter is not a critique of this orientation, or of the procurement policy of the UK for aircraft, but an attempt to show how the science and the operational analysis of the RAE contributed to policy and was part of a larger

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63
Sir John Charnley, (n. 8 above).

64
Handel Davies and Sir John Charnley, (n. 58 above).

65
Sir John Charnley, personal communication, (20 May 1998).

political and decision-making milieu. In addition, the concentration on the preliminary, aerodynamic design of new aircraft should not be taken to imply that the firms did not contribute a huge amount to the designs, as they began to take shape. The RAE aerodynamicists would themselves be at pains to point this out, being essentially modest, cautioning that "a lot of things go into an aeroplane" and stressing the contribution to the actual aircraft of "the immensely practical people from industry".[66]

Finally, we should perhaps remember the large national and international role that the RAE played in aeronautics. The work done there circulated within the aeronautical community of the NATO countries but the RAE also fuelled the post-war British university expansion in aerodynamics with high-level teaching staff for aerodynamics and aviation subjects.[67] Internationally it also contributed, for example, chief scientists to Lockheed and Martin-Marietta. It is also interesting to note that from 1971 Dietrich Kuchemann, then head of the Aero Department, promoted the initiative to set up powerful new transonic wind tunnels with NATO partners through his promotion of the European Large Wind Tunnels Group. Thus through the Cold War the RAE served as the main and enduring core of European aerodynamic knowledge and was instrumental in returning some of this expertise to Germany, as part of the larger Europe.

66
C H E Warren, (n. 2 above).

67
Austin Mair became Director of the Fluid Motion Laboratory, University of Manchester, and then Professor of Aeronautical Engineering at Cambridge (1952); Paul Owen, Director of the Engineering Research Laboratory at Manchester (1963) and then held the Zaharoff Chair of Aviation, Imperial College (1984); Alec Young held the Chair of Aeronautical Engineering at Queen Mary College, London (1954-1978); Alan Thom at Oxford and Sir Alfred Pugsley became Professor of Engineering Science at Bristol (1945-1968).

Chapter 6

Planning in Detail - Post-war Projects: the Vickers V1000, Aero Engine Development, the V-force Programme

Introduction

The contention that British aircraft production suffered from a multiplicity of projects, and from the maintenance of too many separate companies during the twenty years following the Second World War, has become accepted as something of a truism among commentators on the industry. This account certainly endorses that view, but here the intention is to use case studies of individual programmes to examine this phenomenon and to investigate the character of the post-war direction of aeronautical research, development, and procurement. The chapter therefore looks quite deeply into a number of specific projects, both to examine the process by which these projects became established and sustained, and to gain some insight into the nature of the relationship between the administration and the industry.

Perhaps cavalierly, to some, this account does not dwell on distinctions in attitudes towards the aviation industry between the various post-war Labour and Conservative administrations. Certainly several historians have sought to analyse what was distinctive about the post-war Attlee administration and the explicitly technocratic 1964 Wilson government, with respect to their attitudes to advanced industry, contrasting both with earlier socialist attitudes to industry and with a certain implied Conservative laissez-faire posture.[1]

Rather less appears to have been written about evolving Conservative policies with respect to technology. However, the term 'laissez-faire' hardly applies to multi-million pound programmes closely administered by government

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See, for example H Mercer, N Rollings and J D Tomlinson (eds), *Labour Governments and Private Industry*, (Edinburgh, 1992), N Tiratsoo (ed) *The Attlee Years*, (London, 1991), and R Coopey, S Fielding and N Tiratsoo, *The Wilson Governments*, (London 1993).

departments and it appears, from the perspective of this study, that pro-aviation Conservatives such as Peter Thorneycroft, Aubrey Jones and Julian Amery were just as technocratic (and, in principle, as *dirigiste*) as their Labour counterparts while Conservative and Labour aviation sceptics were equally sceptical. Governments of both parties, it could be said, were content with a kind of aeronautical 'Butskellism', a fairly pragmatic and consensual form of tinkering, although both were capable, now and again, of more resolute action, as with the determination of the Conservative administration to use the TSR 2 strike bomber contract, awarded in January 1959, to force the long overdue consolidation of aircraft companies, and the Labour government's later cancellation of that project in 1965 (actually a move that was also expected by many close to the programme in the event of a Conservative victory).

However, the direction of the industry, for the first part of the period at least, was carried forward by officials, acting rather in the 'Crippsian' spirit of encouragement to the industry and with an intention to achieve integration between civil and military projects in the interests of the national economy. The studies here will throw light on the extent to which the structure inherited and adapted from war-time systems and institutions could achieve this.

As argued in the preceding chapter, the aircraft sector, for some twenty years after the war, can be regarded as an ensemble which comprised a highly centralised government research capability, a large number of aircraft and engine firms, a government procurement agency in the Ministry of Supply which implemented the requirements formulated for the RAF by the Air Staff and, in principle, the civil air lines. There was, in addition, an extended and a rather diffuse defence community, also touched on in the previous chapter. This included bodies like the Air Warfare Committee, the Defence Research Policy Committee, supplemented by lines of communication between all the groups mentioned above, and often relying on personal links formed during the Second World War.

This system was placed under enormous pressure to produce aircraft and weapons of the highest achievable technical quality in response to the emergence of the Cold War, in the light of a growing realisation of the offensive threat posed by Soviet nuclear capability, and in response to the continuing conviction that Britain should retain 'Great Power' status with a global reach. These requirements, it is argued, stretched the capability of this system to the utmost, and the final project case study in this chapter looks at the major load (or major distortion) imposed on the industry by the V-bomber project. Amongst various effects, this defence effort determined both the character of the firms and the way they interacted with government. The scale of the defence effort also severely prejudiced the attention that could be devoted to civil aircraft development. It is appropriate therefore, in this section, to both to review the technological challenges of weapons development to British aviation in this period, the way they were met, and the effects that they had on the industry.

Case studies in Procurement

The Vickers V1000

When the Vickers V1000 long-range transport was cancelled in 1955 it marked, for the aircraft industry's supporters, a pivotal moment in the development of British civil aviation. George Edwards, the Vickers chief designer declared in *The Times* that "Britain had abandoned the struggle to get into the front position on long-range aircraft. ... large turbojet aircraft were going to dominate first class travel on the North Atlantic. ... it is a national decision that we shall regret for many years".[2] A few years later, the Parliamentary Secretary to the Ministry of Aviation was quoted as describing the cancellation as "a terrible

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2
The Times, 12 November 1955.

tragedy".[3]

From the point of view of this study the episode can be regarded as a test of the whole post-war strategic approach to civil aircraft development. The Ministry of Supply had the responsibility to nurture saleable designs and it had as allies, the RAF and the airline corporations who were, at least in principle, pulling in the same direction in order to get the maximum value for Britain from the money spent on development.

For that reason the V1000 appeared, at the outset, a highly attractive project. The RAF wanted a high-speed jet transport to replace the piston-engined Hastings and in 1951 issued a specification for an aircraft, to be ready in 1956, for the movement of troops or light equipment and, in particular, to be used for overseas deployment of a V-bomber squadron, carrying equipment and support personnel. The point was explicitly made that in order to produce the aircraft in time and to economise on development "the Air Staff has decided that it is to be based on an existing design. It will also be an advantage if it can be drawn up as a common operational requirement with the Minister of Civil Aviation".[4]

The main elements of this specification included a range of 3000 miles and cabin pressurisation - qualities that would also suit it for the developing long distance civil routes. All the current large British types were considered, including an adaptation of the next version of the Comet airliner - the Comet III. This was thought to represent the least departure from an already known type. and considerable airline experience would have been accumulated with it by the time the RAF took their versions.

A point raised against the Comet by the RAF was that it was considered too

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3
Flight, 13 July, 1959, p 59.

4
PRO AVIA 65/19, 'Long Range Jet Aircraft, Policy and Financial Questions, Specification C 132 V1000', (Appendix to Spec O.R. 315).

small to airfreight aero engines. BOAC, who were also involved in the discussions thought that the Comet would not be capable of further development and so also supported a project that would bring forward a successor to it for international routes - a larger, faster jet aircraft.

Also considered were transport adaptations of all three British V-bombers. The first choice was the Handley Page design (the Victor) which was currently being built. This had an extremely sophisticated aerodynamic design, promising very high speeds, but the prototype had not yet flown. By contrast, the technically less ambitious Vickers Valiant bomber was already flying and this seemed, therefore, to be the best basis for the relatively speedy production of the future RAF transport and civil airliner. The choice of a transport version of the Victor or Avro Vulcan was also opposed on the grounds that it would "eat into bomber production".[5]

By May 1952 Sir Hew Kilner of Vickers was pressing for "an immediate order for a prototype of the Valiant transport" without which, he alleged, Vickers would have to discharge design staff (a canny threat in view of oft-stated MoS concerns to retain skilled industry groups) and MoS officials began to consider how to obtain Treasury finance for the Vickers transport in advance of a finalised Operational Requirement (OR). The Valiant conversion was promised as a 120 seat aircraft, against the 80 seats for the Comet III, and also offered higher speed. The Air Staff objective, it was noted, was to make Bomber Command mobile and to do this, "it must be possible to transport personnel and equipment as fast as the bombers operate".[6] No justification seems to have been developed for this tactically novel and quite surprising proposition except for the RAF's observation that, if slower aircraft were purchased supporting staff and ground crew "would either have to start earlier or arrive later" than the

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5
Ibid. This was an ominous sign and we shall see below that problems with bomber production were in train.

6
Ibid.

bomber force when deployed overseas. This was a quite indulgent specification for a transport aircraft, but MoS officials accepted readily that "it is quite clear that the [RAF] must have a Valiant Transport with Conway engines".[7]

However, the Treasury, as we shall see again, was independently capable of asking perceptive technical and strategic questions, querying whether "it is really necessary that military transport should fly at over 500 mph" and suggesting that if the airline Corporations preferred the Comet the RAF should have the same types since "it is not at all certain that we can afford to develop and produce two types of high speed transport".[8]

By October 1953, the Treasury noted that the aircraft "is really an entirely new aircraft and departs considerably from the Valiant bomber" and, sidelining the MoS, queried directly with the Air Ministry the RAF insistence, "of which they would admit no relaxation", on a performance comparable to the V bombers. Why could the RAF not make use of an enlarged version of the Bristol Britannia aircraft - a turboprop aircraft, faster than the previous piston-engined generation but slower than a pure jet airliner, recently developed, also at Government expense, as a civil transport aircraft for the emerging airline market?

As noted, the requirements of the RAF were also intended to assist development of another commercial jet airliner, in addition to the Comet, and the MoS observed that "if the country is to export aircraft in the way that is done with shipping it must obviously have to offer more than one prototype from one firm". The delicate path MoS officials trod in all these project negotiations was highlighted by the internal warning that, when deploying arguments to the Treasury to attack the suitability of the Comet III for the RAF ("only ... a very

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7
Ibid. 'Notes on draft O.R. 14 June 1952'. The emerging draft operational requirement proposed "in a cold war the large scale transfer of troops ... in a hot war to accompany the Valiant bombers and provide the radar countermeasures essential for the security of the force".

8
Ibid. Minute from D F Hubbock, (Treasury), 12 July 1952.

inadequate interim aircraft for military purposes"), it was important that "we must, of course, take care not to damage the case for the Comet III for BOAC".[9]

In August 1952 the Air Staff completed the Operational Requirement for the aircraft (O.R. 315) which set out the detailed performance targets. Meanwhile, BOAC had become more equivocal about purchasing a new jet aircraft but the MoS agreed to go ahead with the development, with the weak proviso that despite the uncertainty of the civil interest "it would also be advantageous if the aircraft were designed to be basically suitable for adaptation to civilian use".[10] The lukewarm attitude of BOAC may have been a result of performance assessments for the emerging V1000, but may also have been a bargaining tactic, for the Corporation tended to lean on the difficulties and expense of operating British aircraft when negotiating prices and subsidies. This apart, the project seemed an ideal marriage of the two functions. In design terms the Vickers Valiant was not a large step into the unknown - indeed it had been commissioned as an "insurance" design in case the more advanced Avro Vulcan and Handley Page Victor met development problems and it did in fact reach service several years before them. The conversion of this reasonably conservative bomber did not appear to problematic and this was the basis on which Vickers had first bid for the job.

It seems remarkable, in the light of the rhetoric of the war-time reconstruction arguments developed in the MAP, and the subsequent claims by MAP and MoS to be uniquely capable of the centralised strategic direction needed to make the best use of British aeronautical R&D, that this commitment to commonality between the civil airliner and RAF transport was put in such vague terms. Indeed, it was the Treasury, rather than the MoS, which continued to put most

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9
Ibid.

10
PRO AVIA 19/811, 'History of the Vickers 1000'.

stress on the need to integrate civil and military requirements.

This period of collaboration with the firms to develop new products was distinguished by a quite open-handed financial attitude on the part of the MoS. The essential emotion seems to have been that MoS officials had the experience and technical knowledge to deal with the firms, and that this encouraging and accommodating approach was essential for extracting advanced technical performance from the industry. Much ingenuity was expended by MoS officials to defend programmes and overspends from Treasury attack.

Thus, as the V1000 study gathered way at Vickers, the MoS obtained Treasury permission for a preliminary provision of £50,000 but an official noted that "I think that the firm should tell us immediately if they find that the £50,000 ceiling is impeding progress". This must certainly have been viewed by Vickers as a hint that control would not be rigorous and the firm responded in appropriate vein that "too rigid a limitation on expenditure would involve delay in meeting the production order". It was hardly surprising that by January 1953, it was noted by J E Adamson that "Vickers have exhausted the £50,000 and are writing to request further financial cover. Is there any reason why we should not ask for Treasury authority to order the first prototype?". In fact, in September the Treasury approved spending (up to £600,000) on a prototype although it detected that "the aircraft is really an entirely new aircraft".[11] Assembly then started in February 1953 though the Treasury quickly detected that the programme was sliding and that "no more than six aircraft would be available by March 1958".[12]

11
Ibid. The close Treasury reading of the project papers is shown in the observation that "the idea of using the outer ... Valiant wings now seems to have gone and the aircraft now appearing on the drawing board is an entirely new aircraft of 194,000 lbs all up weight". (The Valiant itself had a gross weight of only 140,000 lbs in comparison, showing the weight growth during V1000 design).

12
PRO AVIA 65/19, US (Air), 23 September 1952, J E Adamson, A.S. Air, 2, minute of 1 January 1953.

This inability of the industry to develop and build the new generation of sophisticated aircraft fast enough, both in terms the design and delivery of the prototypes, and subsequent series production programme will be discussed again with reference to the Vulcan and Victor V bombers. However, a major asset, for MoS officials, was that the aircraft was to have Rolls-Royce Conway engines (in the event to prove another source of delay) and therefore would be the product of the Ministry's two most trusted producers, although, by February 1954 Vickers' estimated cost to completion had risen over a year from £1.925m to £2.913m leading even the normally supportive MoS officials to comment that "a jump of 50% is good going, even in these times", and that "the change is more surprising in that the firm has been one of our better estimators" noting that there had been no changes in the requirements for the aircraft.[13]

The firm now surprised officials by asking for a new test rig to test the wing at a cost of £0.628M, confirming how far the design must have come from the cost effective conversion of an existing bomber and prompting, to this writer, the question as to why all these costs came as a continual stream of surprises, given the claimed proven expertise of the MoS in dealing with the firms. Certainly it had been accepted that the aircraft needed a new fuselage, since, in the original bomber, the spar system of the wing passed through the fuselage and cut into the internal volume. This was not a problem for the carriage of bombs but it did not provide the continuous tubular cabin space needed in an airliner. The new wing, though, with 30% more area, was required in order to achieve the take-off performance specified, and the whole ensemble now dictated a new undercarriage. Thus so much would be new that the whole basis of the original tender - the low-risk conversion of an existing type - was specious. One could even speculate that Vickers were attempting to get funding for a new civil airliner development piecemeal - tugging the leash as it were - for increasing funding when sufficient monies had already been committed to make it unattractive for the MoS to turn back.

13
Ibid. Memos of 4 February and 9 March 1954.

By 14 June 1952 RAF had revised their procurement and were asking for a total of only 28 aircraft of which twelve were to be Bristol Britannias and the remaining fourteen Vickers V1000. These were desperately small orders, given the huge design and start-up costs for both, really providing no help to either type as economic production propositions and shows how, between them the MoS, the RAF and the industry effectively squandered the subsidies that were being paid for weapons R&D and aircraft start-up projects in the period.[14]

Numerous delays occurred. According to the programme the prototype should have flown in December 1954, but in October 1955, when cancellation was discussed in the Cabinet, the project had over-run the budget four-fold and it was only three quarters finished. The weight had increased and it was now outgrowing the thrust of its Rolls-Royce Conway engines. It was unable to meet the take-off requirements written into the OR which called for an ability to clear 50 feet from a 2000 yard take-off run in tropical conditions and would only be able to do so with the provision of various "hot-rod" modifications that the RAF considered undesirable, or possibly the provision of two extra engines, although internally N H Wilkinson in MoS quipped that "a V1000 with six Conways sounds elephantine - and white at that".[15]

The Air Ministry had lost patience and proposed cancellation since "the aircraft is marginal as regards meeting the specification and it is late. ... This is the second time that Vickers have let us down within twelve months and the firm ought to be left in no doubt as to the Air Ministry's opinion". Although the Air Ministry view was that "those concerned in the Ministry of Supply ... might

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14
Ibid. Minute of 14 June 1952 and 2 June 55, discussing whether the military requirement justifies the enormous development costs, now estimated at £6m plus a share of the Rolls-Royce Conway development (£7m).

15
PRO AVIA 19/811. Memorandum of May 1955. Vickers were also considering the use of either reheat, water/methanol injection or flap blowing, or a combination of these, in order to achieve the take-off performance required and it was observed that "the Air Ministry had already accepted a lower safety standard for take-offs than normally demanded (and considerably less than for civil standards)".

have been more cautious in accepting the firm's estimate" an attempt was made to rescue the project with the firm belatedly proposing last-ditch tactics to the MoS to save the aircraft by reviving the prospect that the transport should "definitely be coupled with the development of a civil aeroplane". Vickers claimed that it would be competitive with the emerging Boeing 707 and held out the prospect of it being certificated and released for airline use in mid 1960.

But patience also was exhausted within MoS which seemed no longer prepared to act as a buffer between Vickers and the Treasury. Reginald Maudling, as Minister of Supply, said "he was very concerned about this project and doubted whether the UK could afford it. ... The cancellation of the V1000 will undoubtedly be resisted by Vickers, but the effect will probably be salutary".[16] Maudling asked to be briefed on the extent to which the V1000 failed to meet RAF needs with regard to the performance and delivery time. He also requested a note on the DC 8 and Boeing 707, particularly with regard to the extra flexibility of these aircraft, compared to the V.1000, the dates by which they would be expected on the transatlantic run, and whether they would be true non-stop transatlantic aircraft. "The Minister wanted answers to the points George Edwards has been making in the press" and to be able to "hit back" should a debate occur in the House of Commons.[17]

The brief showed that the considerable weight growth and failure to achieve take-off performance suggested that the V1000 "would be at the limit of development at the beginning of its life".[18] The parity with the Boeing 707 publicly claimed by George Edwards was also, for aerodynamic reasons, unattainable, and it is inconceivable that Vickers could not have known this. The V1000 was going to be slower and the main reason was that as an 'insurance'

16
PRO AVIA 65/19, report of meeting 12 June 1955.

17
Ibid. Minute of 29 November 1955 from PS to Minister.

18
Ibid. PS to Minister 29 November 1955.

bomber design, the Valiant had relatively less wing sweep - the critical feature in allowing aircraft to cruise at very high subsonic speeds. By contrast, Boeing had already tackled the tricky aeroelastic problems of high wing sweep. Furthermore, their 707 prototype had flown in the previous July while advance orders for the Boeing 707 and Douglas DC 8 were already valued at over £200m. The Vickers claim therefore, that they could beat Boeing into production with their as yet untried and uncompleted aircraft looked completely unconvincing, and, in view of the inferiority in flight speed, the only real selling point that Vickers might have offered would have been be an earlier introduction into service.[19] The numerous delays in the programme gave no confidence that this could be achieved. Certainly BOAC showed even less interest in the Vickers aircraft at this late stage. The Corporation declared that it could not afford it and that "even if they could find the money they would not want to buy an aircraft like the V1000".[20]

Raising the proposed cancellation with Cabinet colleagues in October 1955 Reginald Maudling, as Minister of Supply, reviewed the position on British airliner development succinctly. "According to present plans the V.1000 would be inferior to what is expected of American machines although it might be ready a little earlier. We have considered whether, by any reasonable modification of the design, we could make the aircraft fully competitive but ... the chance of success would be small and the time needed would mean the loss of any advantage of early delivery". Noting that there was "a real danger of having a white elephant on our hands" Maudling pointed out that in pulling out of a short-term attempt to meet the Boeing challenge with the V.1000 in 1960 it might also have to be accepted that Britain would not be able to produce a

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Edward's astonishing retrospective gloss on the cancellation of the still unflown V1000 was that it occurred "at a time when the 707 only existed in its prototype form with a sub-standard body and a sub-standard range". Arthur Reed, *Britain's aircraft industry : what went right? What went wrong?*, (London, 1973), p.4.

20
PRO AVIA 19/811, Reginald Maudling, Minister of Supply, Paper to the Cabinet on the cancellation of the V1000, 13 October 1955.

competitive jet in 1965 that would be good enough to take on the American jet aircraft of the 1960 vintage. He looked forward to design studies that would indicate "whether we can produce a competitive jet in 1965 or whether we have got to surrender this particular field to the Americans until we can re-enter it with a true supersonic aeroplane, not before 1970".[21]

R A Butler, as Chancellor of the Exchequer wrote to Maudling on 21 October 1955 "I am sure you have reached the right conclusion and that the V.1000 should be allowed to die. I note that nearly £2 1/2m has so far been spent and I hope it will be given the coup de grace as soon as possible". For the future, Butler agreed that the principal aircraft firms should prepare design studies for a transatlantic aeroplane to be available in about 1965. "In view of the enormous cost of these things, I hope that such an airframe would be capable of a military application".[22]

The conclusion drawn here from Maudling's summing up of the V.1000 affair is that the long-range planning conducted by the Ministry of Supply for this new airliner had been inadequate for the scale and cost of the venture. An 'expert' Ministry, established in the mould conceived by Stafford Cripps, tasked with the long-range planning and wellbeing of a major strategic asset and export industry had demonstrated poor control - one might say gullibility - in the administration of the contract with Vickers. It seemed, rather, to have accepted, in its relations

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21
Ibid. Apart from the dangerous appeal to 'leapfrogging' American technology with a supersonic aircraft, Maudling's paper was, for 1955, a remarkably sanguine reflection on the prospects for the British industry. "Behind this all, of course", he observed, "there is the basic question of whether it is right for us to try and compete with the American aircraft industry across the whole board".

22
Ibid. With respect to the general progress of British ambitions for civil aviation Jacqueline McGlade, 'U.S. Cold War Aid and the British Aerospace Industry', Business History Conference, Glasgow, 1997, has, in an interesting study, argued that the substantial orders for British military aircraft, placed by the USA as Cold War re-armament aid between 1951 and 1957 caused the UK to "reverse its preference for civil aircraft development". I argue that these purchases, running at $200m to $300m per year merely reinforced the entrenched trend which was already strongly favouring military procurement over civil work.

with industry, an increasingly vague promotional role. We can recall the arguments deployed by MoS officials in the immediate post-war era when it was claimed that

> the rapid pace of aeronautical progress makes it especially difficult to ensure that each new aircraft design derives full benefit from the latest advances. To achieve this calls for an up to date knowledge, an appreciation of future research trends and the power to deploy research and development. ... The MoS must remain fully in the picture".[23]

By contrast, this episode could be said to have marked the beginning of the end for the belief that MoS officials could continue as the supreme planning 'intelligence' which could juggle the requirements of the RAF, of BOAC and other airlines, while considering also export potential, the strategic retention of design skills and some responsibility for regional employment policy.

But beyond that, there was the failure to identify the major thrust in air transport - the long-haul jet - and to plan for it, in spite of the fact that the efforts of Boeing and Douglas in this field were not a surprise - they were, as one would expect, the subject of intense interest and comment in the global industry. The V.1000 had certainly not represented a considered plan. The civil side of the project had come about accidentally as the result of the RAF transport requirement and when it failed there was nothing else in train. Vickers, for their part had squandered an opportunity to advance a marketable civil aircraft on the strength of the military development finance, even allowing the first year of the programme following the issue of the operational requirement to elapse without producing a design. To this author, the episode speaks of the lack of an entrepreneurial culture within an aviation industry that had been conditioned through its wartime years under the direction of the MAP

23
PRO AVIA 55/30, Report of the Committee on Ordering Procedure, 1947.

and subsequently the MoS. However, Dennis Healey, the Minister of Defence responsible for cancelling the TSR 2 strike aircraft ten years later, took harsher view, suggesting that the manufacturers "tended to get the government on the hook by giving cost estimates and delivery dates which were far too optimistic and then were quite content when the aircraft was cancelled".[24]

The Napier Nomad and other engine developments

It might perhaps be argued that the procurement pattern for the Vickers V1000 was necessarily a special case. There was, after all, an initial strategic argument for the aircraft, while the business of procurement of civil airliners for the national carriers was a complex and highly charged affair. However, procurement of aircraft and equipment in almost all cases reflected a Byzantine interplay between government departments, the RAF, the national airlines and the firms.

The case of Napier Nomad engine, and some other engines considered here, is instructive since it illustrates this well. In fact, the Nomad engine was strategically and commercially irrelevant, and yet it consumed a striking amount of administrative effort during its cancellation. The history of the project also demonstrates the power and the influence of the 'aviation lobby' at this time, and throws light on the way in which this influence was deployed.

The project had its origins at the end of the Second World War with the proposal, emanating from the Ministry of Aircraft Production for an extreme long range patrol engine for Imperial maritime surveillance. It appears that the specification was tailored specifically to give the Napier company some R&D work for it had good experience in diesels but had not then taken up the gas turbine, due to the major problems it had experienced during the war in

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24
P Pagnamenta and R J Overy, *All Our Working Lives*, (London, 1984) p. 69.

bringing the Sabre engine into service.[25]

The project was also framed at a time when it seemed that the new jet engine was inherently extravagant in fuel and best suited to high power short endurance military roles. The Nomad, in contrast, was a 'turbo-compound'; a complicated and ingenious hybrid of two-stroke piston-engine diesel with gas turbine and compressor offering a 'compound' engine in which the piston engine element and the gas turbine (turbocharger) were geared together. This allowed the output to be optimised at any height or power requirement, offering extreme economy. (Shaft power could be drawn from both the piston engine component and the turbine, in differing proportions, depending on speed, load, height and so on).

This engine was of great theoretical and engineering interest but after eight years of government funded research,it was clear that the engine was still far from reaching service reliability and in August 1953 Air Commodore 'Rod' Banks, Principal Director of Engine Research and Development at the Ministry of Supply minuted "I have come to the conclusion that the development of the Nomad engine must be discontinued and our support should cease". This was to take effect in two months and it was noted that the engine had already been placed on "special category" (effectively a stay of execution) a year before to avoid heavy redundancy charges from Napier. The Napier company "had taken an inordinately long time to bring the engine to its present state of development", time was running out and it "still requires very considerable effort over the next three years".[26]

Rumours of cancellation soon reached the firm which quickly deployed the

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Napiers had taken a licence pre-war for the German Junkers aeronautical diesel and was then developing from it the compact high power 'Deltic' diesel for motor torpedo boats. This engine was also to have great propaganda value in the 'dieselisation' of British railways.

26
PRO AVIA 65/25, 'Development of Napier Nomad Engine, Finance and Policy Considerations', minute of 31 August 1953, F R Banks, PD Eng RD.

threat of "throwing the market away to the Americans" and an alliance of interests between Napiers and Blackburn aircraft company emerged to lobby for the merits of a Nomad-engined version of the Blackburn Beverley military transport aircraft.

The firms' case was that civil aviation was a pyramid, with 'Blue Ribbon' airlines at the top and 'air tramping' at the bottom, for which the Nomad-Beverley would be ideal and giving up the Nomad would be "throwing the market away to the Americans". MoS officials almost as ready as the firms to raise the American spectre and one of them mused whether there was any chance of persuading the Treasury to "carry" Nomad development outside the Defence Budget if it were kept within a maximum of £500,000 per year. "I doubt it myself although we could possibly use the argument that if we drop ... [it] ... British ... freighter aircraft will be dependent on American engines or, worse still, we shall have to buy entire American aircraft".[27]

The spectre of having to buy from America was routinely advanced at the onset of cancellation discussions although, in the civil field, the British airlines much preferred American equipment and frequently argued to be allowed to buy developed aircraft such as the Lockheed Constellation, rather than to act as virtual development engineering partners with British manufacturers to help them refine their products.

Blackburns could deploy, as a director, Sir John Slessor, former Marshal of the Royal Air Force, who quickly made representations to the Chancellor of the Exchequer, the Minister of Defence and to the Minister of Supply. His shameless intervention expatiated on the technical success of British V-bombers, fighters, the Viscount, the Brittania and the Comet, (comparable to the "crack ocean greyhound" liners of an earlier age) but argued "My Dear Chancellor" ... that "we must not allow the virtues and glamour" of these great aircraft to blind

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27
PRO AVIA 65/25, Deputy Secretary (C) to U.S. (Air) 30 September 1953.

us to the fact that our air power and export trade will rest on the merchantmen, the freighter and the tramp". What was needed were "big loads at low operating costs". The Duke of Edinburgh too was recruited on the side of this lobby by Sir George Nelson of English Electric (now the owners of Napier) and he passed on Nelson's memorandum to ministers. Meanwhile Sir Conrad Collier, also of English Electric came in person to the MoS to present the case that "any dropping of the Nomad ... would be a National calamity".[28]

These events show the complex power relationship which surrounded British aeronautical development at the time and the almost fantastic amount of lobbying and political activity elicited by one of the least significant aero engine projects. Sir John Slessor, who marshalled these bamboozling arguments, certainly traded on his distinction in the RAF. Ministry of Supply officials however noted that the Beverley aircraft was "extremely expensive" for air freighting (especially in a post-war world awash with ex-military DC-3 Dakotas) and, if fitted with Nomads, even more so.

Banks, though styled 'Director' apparently could not command action in such cases and officials considered what was to be said to Napiers "if they get tough", showing some ingenuity by suggesting that "before we finally kill the Nomad" there would be a good deal of advantage in allowing Napiers to visit Canada and the USA "thereby testing Blackburn's assertion that operators overseas have already expressed keen interest in the Nomad version of our 'Universal' [the Beverley freighter]" and allowing American business to convey the message they were reluctant to drive home themselves.[29] Meanwhile Slessor cast doubt on the competence of MoS officials by writing to Duncan Sandys, as

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PRO AVIA 65/25. That the Duke of Edinburgh was prepared to become involved in a rather minor policy matter of this kind may seem surprising to us today, his intervention requiring Duncan Sandys, as then Minister of Supply, to reply that cancellation had been decided on "only after prolonged and careful consideration". He included "for your confidential information" the sums being spent overall on aero engine development.

29
Ibid, Minute of US (Air) 19 September 1953.

Minister of Supply, that "I hope you will ... support my suggestion for an impartial enquiry".[30]

Within the MoS it was now agreed that the Nomad was "the least important and least promising of the runners" among engine projects and one for which there was no longer any military requirement. As a final stratagem Napier offered to keep the Nomad going at their own expense, if the MoS agreed to support the Eland and Oryx (two gas turbine projects) "at a greatly intensified rate of development". This was clearly a specious proposal and officials noted that for the sake of keeping the Nomad alive we would be diverting money away from "the four more efficient firms whose programmes are regarded as essential".[31]

There was now enough resolve in the department to secure a final decision. Still, one is left wondering at the political and institutional dynamic which allowed these same officials who rationally analyzed the shortcomings of the Nomad programme to spend £3.58m on it out of a total aero engine R&D budget of £22.7 in the financial year 1952/53. In other words the Department acceded to the expenditure of 15% of its entire engine development budget on a device which they knew to be both devoid of a convincing defence function and which was performing poorly according to development criteria. (This was almost 3% of the entire R&D allocation of £121m to the MoS from the defence budget for developments of all kinds). Nevertheless, the MoS continued to support the Nomad in 1953/54 with a further £2.8m and it was only in July 1954, virtually a full year after Banks had recommended that the project be cancelled, that Duncan Sandys confirmed this unequivocally.

30
Ibid. Sir John Slessor to Duncan Sandys, Minister of Supply, 15 September 1953, It should be recalled that, due to Britain's financial problems all foreign travel and expenditure of foreign exchange was rigorously controlled by the Treasury.

31
Ibid. R.Bullock Air 2(a) 11 March 1954, The "four more efficient firms" were Rolls-Royce, Bristol, de Havilland and Armstrong-Siddeley.

Banks, in spite of his excellent engineering judgement and his comparatively resolute judgement in this case, shared the luxurious approach to development and the reluctance to prioritise between projects which permeated MoS in the post-war era. A familiar pattern was that money was spread across a large number of projects (some of quite marginal importance, as we have seen), while front runners, from good producers and of importance to the RAF, during the course of a year, to be dangerously underfunded and were presented to the Treasury as specially deserving cases. Thus the Treasury proposed allocating £121m to R&D for the 1954/55 but added a proviso that the Rolls-Royce RB 106 supersonic engine project "would not be used as a lever to obtain more money for R&D". But Banks "while recognising the overall need for economy" argued that "we cannot afford to rely upon one project alone to meet the thrust required for the supersonic fighter". Four large turbojet projects, which overlapped substantially in performance characteristics, all needed to be carried forward together. Of the de Havilland Gyron, Rolls-Royce RB 106, the Bristol Olympus, and the Rolls-Royce Conway, he asserted, "not one is more important than the other. They are all of vital importance to the consistent development of the aircraft concerned".[32] Thus, in the interests of 'insurance' the MoS was prepared to fund (actually five) high technology engine projects of roughly comparable power, from separate manufacturers and consume over several years about one quarter of its total allocation for aeronautical R&D. Much later, in retirement, Banks commented, with remarkable insouciance, that "the government" had been wrong to keep weaker companies going and "there were far too many airframe and engine firms. ... the government should have taken a stronger line".[33]

32
PRO AVIA 65/12, 'Gas Turbine Engines, Research and Development'. Minutes of July 1953 and 3 November 1953. Banks asserted "I think it quite wrong and most unsafe from this Country's standpoint to reduce R&D expenditure. ... Such expenditure should be increased at this critical point in our technical progression". He added that "the Americans might be pleased to have some of [the engines] when available".

33
Rod Banks, quoted in Arthur Reed, (n. 19 above). There was also a less-discussed Armstrong-Siddeley large engine project running alongside the four cited.

In the period the separate requirements of civil and military R&D were, as we have seen, frequently intermingled and the late-war policy justification for this seemed highly plausible. Britain could only afford so much high technology R&D. The most efficient course would be to re-purpose the cutting edge weapons research to create superior civil products. The real result of this was to allow a serious lack of clarity over the sums disbursed by the MoS for engine R&D. In some cases the firms sought to combine civil and military requirements in order, naturally enough, to perform civil R&D out of allocations defence work. However, MoS officials were also quite prepared, on occasion, to assist in this process, acting in effect, to protect the firms against a more rigorous view of accountability being imposed by the Treasury.

An example of this method of administration can be seen with the Rolls-Royce Dart turboprop which powered the Vickers Viscount airliner. The Ministry had sponsored the Dart to power the Vickers Viscount 700 series and the combination proved highly successful. Vickers subsequently began design work, at the company's own expense, to enlarge the aircraft to form the 800 series Viscount. However, the further development of the power of the Dart, to suit it for the new Viscount, continued to be paid for by the MoS. Some MoS officials began to consider this anomalous and advanced the idea that Rolls-Royce "should be conditioned to the idea" of MoS stopping the contract.[34]

> The policy of sponsoring civil aircraft had crystallised so that now we expect industry to bear some part of the risks by sharing in the cost of development. The Viscount is now launched with 100% of its development finances paid for by MoS and further 'stretch' ... is being done PV. It is therefore to avoid the anomaly that Rolls-Royce are stretching the Dart entirely at the expense of [Ministry] R&D funds, without risk to themselves, to standards being set by Vickers. ... This matter becomes one of principle".[35]

34
PRO AVIA 65/17, 'Aero Engine R&D, Rolls-Royce Dart Finance and Policy'. "Vickers are enlarging the Viscount as a Private Venture and the RDA 5 [Dart] has emerged as a new engine with a standard presumably being set by Vickers".

35
PRO AVIA 65/17, J E Adamson, AS/Air 2 to PD Eng RG, 22 August 1953.

Although Banks took the firm's side and asked for finance to take the engine to flight test other MoS officials also could see that the broadcast industrial subsidy they were providing to the aircraft industry was a liability in its dealings with the Treasury and R H W Bullock advised, with reference to the Dart, that "the non-defence element in our estimate for 1954/55 is going to come under very heavy fire from the Treasury". However, his solution was scarcely resolute and he submitted that it would be of great assistance "if we can offer a slight sop to them in the shape of the approaching termination of support for one existing engine" to offset the new engine programmes, although Banks' replacement, R H Weir, reluctantly agreed support for long enough to allow Rolls-Royce to clear the new propeller reduction gear - "an Achilles heel of an otherwise successful engine".[36]

The upshot was a compromise apparently satisfactory to officials and to the company that help for the Dart would continue and, in return, Rolls-Royce would themselves "carry" development of the Nene fighter engine. The lack of clarity in this bargain, whereby government continued support for a successful civil engine which had first run over seven years before and which was in operational service in many parts of the world, while the company purported to finance themselves a purely military fighter engine, is manifest and it is hard to perceive whose interests were really served by arrangements of this kind. However, such understandings were common in the period under review, perhaps allowing officials the flexibility to conceal some programmes or to get others started in an undeclared way. Similar lack of clarity was evident in V-bomber force engine policy, when in mid-1956 the suggestion was aired (against a background of increasing airframe and engine costs) that worthwhile economies of scale might be had if the second series of the Bristol Olympus-powered Vulcan bomber was redesigned to use the Rolls-Royce Conway, as developed for the Mark II Handley Page Victor. Bristol countered with the proposition that they would carry on development of the Olympus for the Mark

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36
PRO AVIA 65/12, R H W Bullock to PD Eng RD, 11 January 1954 and reply of 8 February.

II Vulcans on the basis that "the cost to the Ministry would be no greater than if the Conway had powered both Victor 2 and the Vulcan II". The Ministry then agreed to pay Bristol a price "which would have been paid for an equal number of comparable engines" and also advanced £1m to Bristol against tooling, as a special measure "because of Bristol's financial position at the time".[37]

In defence of the contemporary development and procurement pattern it could perhaps be argued that the aero engine makers were at the time making the transition from Whittle-type centrifugal flow engines to more efficient and powerful axial flow types and virtually every new design generation produced a striking increase in power. Aero engines, perhaps, constituted a field in which a certain amount of experimental duplication could be encouraged, especially in view of the still experimental nature of the gas turbine engine. However, in the direction of aircraft procurement the situation was little different and, during the 1950s, the MoS administered an array of projects in almost every corner of aeronautics for a large variety of roles and missions while, as discussed earlier, officials tended to see themselves often as protagonists for the firms rather than judicious controllers of the procurement process, with the Treasury cast rather in the spoiling role. The attitudes of that time are well illustrated by the attempt to develop a fast-climbing rocket fighter to counter the Soviet bomber threat. In the event, the Lightning proved able to achieve this kind of rapid climb interception, but in the meantime the Air Staff, sponsored three competitive projects for this from Bristol, Avro and Saunders-Roe (although they conceded that they had preferred the Avro proposal from the outset). As financial controls began to bite the Assistant Chief of Air Staff (ACAS) commented ruefully that "it is clear that if we have a rocket interceptor at all, the Treasury will allow us to build only one design".[38]

37
PRO AVIA 65/55, 'Vulcan Aircraft Production Policy'.

38
PRO AVIA 65/43, ACAS(OR) to DGTD, 11 March 1953.

Deterrence and the V-Force Programme

Any study of the UK aircraft industry in this period must take account of the immense load imposed by the British resolve to develop an independent nuclear deterrent and the aircraft capable of delivering it. The performance targets for speed, height, load and range required the deployment of the most advanced aerodynamics and structural techniques which were at the limit of what was achievable. The programme has been discussed from this perspective in the preceding chapter on the RAE. It is examined here from the strategic aspect because these considerations underpinned the perceived necessity to build and deploy a nuclear deterrent force - a programme which imposed the greatest workload on the industry in the period. The progress of the programme also helps us to a view of the manner and effectiveness of MoS control over a programme which was a clear national priority.

David Edgerton has described the post-war British aviation industry as, essentially, a defence industry.[39] However, the purpose of this brief study of the manned bomber deterrent is to show just how great a load this programme was - a programme which surpassed in complexity and expense all other British aviation activities in the period. The design and industrial production effort was equally demanding and for that reason is considered again here. With a total production of over 410 large, hugely expensive and technically sophisticated four-engined aircraft, this was, in terms of value and complexity, the single most important aircraft programme in Britain between 1945 and 1965 when the last Vulcan was delivered.[40]

39
David Edgerton, *England and the Aeroplane*, (Manchester 1991), pp. 88-89.

40
The total number of V-bombers built is far higher than the front-line strength mainly because they were delivered in three phases. First came the Vickers Valiant, followed by the Mark I Victors and Vulcans and then the more capable Mk II versions. The only other aircraft programme to rival the total V-bomber project in numbers was the turboprop Vickers Viscount of which some 459 examples were built. This was, of course, the UK's most successful civil aircraft programme. However, this 360 mph 72,500 lbs weight turboprop aircraft in no way compared in complexity, and dependence on advanced knowledge, to the high subsonic speed

The early post-war decision to build a long-range jet bomber programme has also been touched on in chapter five. Defence planners do not seem to have considered, at the time, that the transition from the massed high-explosive and incendiary attacks of the Second World War, to atomic attack constituted a step-change in human affairs. In a crude sense, the atomic attacks on Japan were seen to have done, in an instant, what the massed Allied bomber forces had done to cities like Hamburg and Dresden over a rather longer period.[41] Furthermore, the actual radius of destruction of an atom bomb, against substantially built Western and Soviet cities, was reckoned in hundreds of yards rather than miles. "An A-bomb could wipe out a factory or a neighbourhood, but hardly an entire city. A target might escape altogether if the bomber missed by ... half a mile".[42]

Nevertheless it soon became apparent, from 1952 onward, that the hydrogen bomb changed this entirely and that a nuclear war would be far more terrible than any before, not survivable for a small country like Britain. However, Britain had, through incremental steps, set out on the path of becoming a thermonuclear power. Thus in 1954 the Defence Review expected the Russian strength, by 1958 or 1959, to be about 850 jet bombers and 40 airfields.

> We cannot be sure what priority the Americans will accord to these targets. ... Since the very survival of Britain would depend on the promptness and thoroughness of the counter-attack it is essential that we should ourselves possess and control a bomber force capable of performing this vital task. ... The Secretary of State for Air said that the threat of air attack had greatly increased with the hydrogen bomb

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turbojet bombers of about 216,000 lbs (98,00 kg) flying at about 600 mph.

41
Donald MacKenzie, in *Inventing Accuracy* (MIT Press, Cambridge, Massachusetts, 1990) p. 100, also sees the immediate American post-war view of atomic weapons as an incremental improvement to the mass air attack with conventional weapons.

42
Norman Friedman, *The Fifty Year War; Conflict and Strategy in the Cold War*, (London, 2000), p 35. Friedman cites the relationship that the zone of physical destruction (blast destruction) from a bomb is proportional to the cube root of its power.

and could now be considered mortal.[43]

The appraisal suggested that "it is essential that the Russian Air Staff should at no time believe that the threat ... is a manageable one" and anticipated that suggestion that the Soviet government would be willing to accept the loss of "some of their cities". According to the thinking at that time:

> for the deterrent to be effective they must be convinced that the United States and the United Kingdom would ... smash their offensive power. ... The long-range bomber with nuclear weapons is incomparably the most important weapon in warfare today. On the basis merely of military effect for money expended it is far and away a better investment than other ... forces. The Chiefs of Staff have recommended that in the economic situation in which we find ourselves it is in certain conventional weapons that risks must be taken, not in nuclear weapons and the means of their delivery.[44]

On the basis of this thinking, Britain began committing, from the mid-1950s, about £125m a year to the deterrent. This amounted to about 10% of the overall defence budget and defence planners suggested this was "a not an unreasonable proportion of our defence effort to spend on the prevention of global war" and that "the salient fact about the V-bomber force is that, in relation to its power and to the defence budget as a whole, it costs so little".[45] From the perspective of this study, of course, the essential point about this cost is that the commitment of about 1% of GDP to this particular aeronautical project constituted an enormous load, and an enormous distortion for the industry.

As the force came into being it became apparent that Britain's possession of a

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43
PRO AIR 19/653, 'Swinton Committee - Main Papers and Minutes', note referring to proceedings of Defence of Defence Policy Committee, DP (54) 5th Meeting, 6 July 1954.

44
Ibid. Air Ministry paper, 30th June 1954. (Original emphasis).

45
PRO AVIA 19/822, 'Production - Bombers', extract from minutes of Defence Board, 30 October 1958, and brief by ACAS for meeting of Secretary of State for Air and Prime Minister 30 May 1957. This writer has not found evidence that the proposition that a British deterrent contributed to "prevention of global war" was seriously debated within government (although it was, of course, challenged vocally outside it by bodies like CND).

smaller, but semi-independent, deterrent force put the nation in a unique position compared to the USA and the Soviet Union and some theory of deterrence began to emerge within British defence circles. However, this strategic thinking, it must be said, appears to have been of a remarkably pragmatic and quite simple kind. Thus it is surprising, in a period when theorists in the USA were developing elaborate protocols to try and predict the progress of nuclear exchanges, or the effect of weapons development and deployment on stability, to find a British official musing over the Delphic proposition that; "the nub of the question is the answer to the question what constitutes a viable deterrent?" and continuing with the "assumption" that "the Russians would regard a known UK ability to strike 75 targets successfully as an effective deterrent".[46] Relatively coarse calculations of 75% aircraft serviceable at any time and a 50% loss rate en route to the targets produced a size requirement for the force of some 200 front-line aircraft. The slightness of this crude and non-statistical calculation is certainly surprising, both in view of the sophisticated use of operational research by the RAF in the war, and the highly developed (some would say arcane) use of game theory in the USA in the period for the development of strategy for nuclear deterrence.[47]

However, Britain's situation was very different to the 'semi-symmetrical' nuclear postures of the USA and the Soviet Union and had to take account of its particular circumstances. In the pre-missile era, Britain considered the first Soviet attack might well fall in Europe and it was argued that "the first retaliatory strike ... must come from UK bases" which would be able to react

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46
Ibid. Note by ACAS (P), 27 May 1957. This also observes that the British calculations assume one strike will achieve destruction of a target but "the Americans assume seven strikes per target".

47
See, for example, Herman Kahn, *On Thermonuclear War*, (Princeton, 1960) or Barry H Steiner, *Bernard Brodie and the Foundations of American Nuclear Strategy*, (Kansas 1991).

six hours before the US mainland.[48] But alongside the Anglo-American and NATO commitment there was the conviction that "we must be prepared to 'go it alone' in defence of purely British interests". In May 1958 an Air Ministry paper noted:

> The (believed) rocket threat to London during Musketeer [the Suez operation] was countered by SACEUR's reply [Supreme Allied Commander, Europe] that Russia would immediately be destroyed in retaliation by the American bomber forces. We cannot guarantee such support in future. We must have a large enough deterrent force to show our Allies that we can, if necessary, take a relatively independent line.

Tellingly, it concluded "not only have we to convince Russia that we have a worthwhile deterrent force. We also have to convince our Allies".[49] However, a credible deterrent relied, as has been discussed in above, on a continuous maintenance of relative technical quality vis-a-vis the Soviet Union's own aeronautical developments. Thus, by 1957, it was clear that the Mark I Victor and Vulcan bombers would have poor survivability, from about 1963 onwards, in the light of a developing Soviet anti-aircraft missile capability and the improving ability of Soviet manned fighters to intercept them at their operational height. The effectiveness of the deterrent, it was judged, would therefore depend on a further technological and industrial effort - increasing the proportion of the improved Mark II Vulcans and Victors since these both flew higher and were constructed to carry the new air-launched 'Blue Steel' nuclear missile, designed to reduce the depth of the V-force incursion into Soviet air defence area and the time spent there.

By mid-1957 the calculation was that these enhancements were necessary to allow the force to reach a sufficient number of "the total of 312 cities in the

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48
PRO AIR 19/822, 'Arguments in Support of a Minimum Size of V-Bomber Force', 24 May 1957.

49
Ibid. 'The Deterrent', paper of 24 May 1957.

U.S.S.R. with a population of 100,000 and over".[50] This estimation led to the argument prepared by the Air Staff, and deployed by Duncan Sandys, as Minister of Defence, that "in order to exercise any serious deterrent influence upon the Kremlin" a large part of the current order for Mark I aircraft should be converted to Mark II types to provide a front-line force of 120 Mark IIs (an extra 95 of these aircraft) although "there could be no arithmetical proof that this was the right figure".[51] The additional cost was to be £75m and Sandys suggested that the expenditure was small in relation to the amount already spent on the bomber programme and, spread over five years, would cost on average £15 million a year "which is about one per cent of this year's defence budget".[52]

Blue Steel, the Mach 2 'stand-off' missile with a range of 100 miles, (referred to in contemporary discussions as the "powered bomb"), was an additional financial burden on the programme for the deterrent and, in itself, a major industrial and technical effort which used A V Roe for the missile, de Havilland and Armstrong Siddeley for the rocket engines and Elliott Brothers for the guidance system. There was also a major input from the RAE as design authority for crucial elements of the system and as technical adviser. Thus in 1959, Blue Steel expenditure for the next financial year was budgeted at £23m, about 25% of the cost of providing the V-force aircraft, with this proportion expected to rise to 50% in 1964/65.[53]

There were also additional political and economic elements in the calculation of the size and composition of the V-force and Sandys noted that, since its nuclear

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50
Ibid. 'Distribution of Russian Targets', paper of 24 May 1957.

51
Ibid. Minister of Defence in Defence Committee, extract from minutes of meeting of 2 August 1957,

52
Ibid. 'The Strategic Bomber Force', Memorandum by the Minister of Defence, 27 May 1957.

53
Ibid. Memorandum on the costings of the deterrent, 10 August 1959.

deterrent was one of the main justifications advanced for the reduction in the contribution of conventional forces to NATO, Britain should not hesitate to order an increased proportion of the improved Mk II aircraft "which, at comparatively small cost, will so greatly increase our military power and influence".[54] In fact, the actual size of the force posed a ticklish problem since NATO had been told that the British target was 240 front-line V-bombers, although this was looking increasingly unachievable for both production and financial reasons. It was admitted that West German politicians were expressing misgivings about British cuts in conventional weapons and that "our failure to be specific about the strength of our bomber force was causing increasing embarrassment in our relations with N.A.T.O".[55]

There appears, also, to have been some intentional ambiguity in British intentions for the use of strategic weapons, for though the V-bomber forces had not been assigned to NATO, the Supreme Allied Commander, Europe (SACEUR) "had been assured" that its primary task was to support the Allied forces under his command and "retardation operations in support of SACEUR".[56] 'Retardation' implied nuclear attacks on force concentrations and 'choke points' in the event of a westward thrust by conventional Warsaw Pact forces and necessarily conflicted with the over-riding British purpose for the independent nuclear weapon (in the event of the failure of deterrence), affirmed by Harold Macmillan as Prime Minister in July 1958 as being "to make sure that, in a nuclear war, sufficient attention is given to certain Soviet targets

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54
Ibid.

55
Ibid. 'Size of the Bomber Force', Extract from Minutes of Prime Minister's meeting GEN.570/2. 30th May 1957.

56
Ibid. Defence Board paper, 'The V-Bomber Force and the Powered Bomb', Memorandum by the Secretary of State for Air, 29 October, 1958.

which are of greater importance to us than to the United States".[57] This still implied pre-emptive counterforce or 'blunting' attacks on the UK-facing (western) Soviet bomber bases in the event of Soviet aggression on land, although the prospects of achieving success in this were receding.[58] More realistically, the UK force was intended:

> to enable us, by threatening to use our independent nuclear power, to secure United States co-operation in a situation in which their interests were less immediately threatened than our own [and] to retain ... our right to have a voice in the final issue of peace and war.[59]

However, by January 1957, when Harold Macmillan replaced Anthony Eden as Prime Minister there was a growing sense that UK defence expenditure was unsustainable. As Chancellor of the Exchequer, Peter Thorneycroft warned of an expected budget deficit of £500m while, at the same time the defence budget stood at £1550m. Macmillan believed that the manpower and skills locked up in the conscription army, and the defence budget consuming 10% of GNP, was preventing a resurgence of the economy. Furthermore "Suez showed that we had not the ability ... or the strength of will to carry through an operation of relatively minor scale, and that we were exceedingly vulnerable economically as

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57
Ibid. Note by Secretary of State for Air : "On 16 July 1958 the P.M. listed the reasons for the force".

58
Ibid. 'Arguments in Support of Minimum Size of V-bomber Force', 24 May 1957. In the event of a Soviet attack on NATO ground forces Air Staff argued that "the first retaliatory strike must come from British bases. ... Our immediate action would probably be an air strike against Russian long-range bomber bases, of which there are some 130". (Note 40 Russian bases had been expected in the 1954 Defence Review). At the Witness Seminar on the 1957 Duncan Sandys White Paper, organised by the Institute of Contemporary British History in July 1988, Sir Richard Powell (Deputy Secretary and then Permanent Secretary in the Ministry of Defence), and the defence historian T C G James, recalled that the V-force was numerically too small to be used against counter-force targets. This view probably reflects a consensus reached at a slightly later date. In American policy there was also a tension between the use of nuclear force for blunting, retardation and destruction; see Norman Friedman, *The Fifty Year War*, (London, 2000), pp 136-143.

59
Ibid.

pressure on the pound brought [Suez] to an abrupt conclusion".[60]

This was the background against which Sandys had been appointed Minister of Defence. "Something drastic had to be done" to release manpower and reduce the financial burden.[61] The review conducted by Sandys culminated in the 1957 Defence White Paper.[62] The main targets were the conventional forces of all kinds - anything which did not lend credibility to the deterrent - although the review did also lead to pressure to reduce the V-force numbers. The defence programmes were "imposing a severe strain on the economy" and planning staff were asked to consider how far the V-bomber force could be reduced since "we should never, in practice ... challenge the Soviet Union alone". Against this, the Air Staff argued on the operational grounds that reductions in the number of aircraft in an attacking bomber force multiplied the effectiveness of the fighter defence and would lead to a disproportionate penalty in aircraft losses and the efficacy of the force. A force of 144 front-line aircraft was expected to succeed in attacking 40 targets in Russia while a force of 104 would, it was judged, reach only 23, causing the Assistant Chief of Air Staff (P) to brief the Secretary of State for Air and the Chief of Air Staff that "Further tampering and tinkering with the size ... of the force in the interests of economy dressed as strategy may well mean the reduction of the force to impotence and the waste of our investment".[63]

The force was then stabilised at 144 front-line aircraft (of which 104 were the Mark II Victors and Vulcans) and the development of the Blue Steel stand-off

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60
Sir Richard Powell, (Dep. Sec. Ministry of Defence 1950-59), Witness Seminar, 'The Move to the Sandys White Paper', Institute of Contemporary British History, July 1988.

61
Ibid.

62
The Defence White Paper of 1957, (Cmnd. 124).

63
PRO AIR 19/822, Note of Defence Committee meeting of 6 August 1957, and 'Brief for Secretary of State for Air and Chief of the Air Staff, for Defence Board', 30 October 1958.

bomb continued. The revised calculation of UK potential for deterrence now considered that the force would be able to attack between 30 and 40 major cities with an estimated total of 8 million people killed in such an attack. The scale of material destruction, it was believed "would be comparable with the general devastation wrought by German forces ... in World War II". It was observed, though, that "there is no mathematical proof that this is the right number" for the composition of the force and that "the Russians did not surrender to Germany".[64]

While these theoretical and strategic discussions about the amount to commit to deterrence continued there was a pressing practical problem with the actual production and deployment of the aircraft in sufficient numbers. Thus, in May 1957, the Air Ministry repeated their persistent criticism that production was going far too slowly and that "the remarkable thing about the V-bomber force is that while it has nominally received top priority in the Government's defence policy for years ... it is still so very small".[65] The point was made that in 1954 the annual review to NATO "we declared that ... by December 1957, we would have a force of 208 V-bombers". In 1956 the expected achievable deployment was scaled back to 128, but by May 1957 the problem had to be faced that NATO were not aware that for production reasons the build-up had again slipped so that by December there would be no more than 80 aircraft in the front line.[66]

The slow build-up of the force was of concern throughout the life of the

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64
Ibid. "However, it does not follow that they would readily court a repetition of destruction on [this] scale".

65
PRO AIR 19/822, Brief for Secretary of State for Air and Chief of the Air Staff for meeting with prime Minister, 30th May 1957. (The Deterrent and the Defence Budget: Memorandum by the Chancellor of the Exchequer, GEN.570/6).

66
PRO AIR 19/822, 'Chronology of build-up of the V-force: brief for meeting with the P.M.', 30 May 1957.

programme, with new targets continually being set when the previous ones were not met. In January 1958, MoS officials noted that although adequate jigs existed at Avro to build three Vulcan aircraft a month there was insufficient labour to build more than two and that since there had been no significant reduction of labour over the past years "one can only draw the conclusion that the firm has been consistently understaffed on labour" and that "it is now considered impossible to meet the Shackleton or Vulcan programmes for 1956/57".[67] The final Handley Page Victor was handed over in 1963, and the last Vulcan in 1965, thus completing a smaller force than initially ordered some eight years after the date originally set for full deployment.

Alongside the V1000 affair this failure to keep the V-bomber production on track shows again the problems besetting a centralised 'expert Ministry' in peacetime procuring aircraft and engines across the civil and military spectrum. This was a programme that was at the core of Britain's defence strategy. It was the most expensive and the largest aircraft programme in existence in Britain at the time and it is unlikely that Ministry staff failed to detect the ongoing production problems at the firms. In addition to its central control the Ministry maintained a network of Resident Technical Officers (RTOs) - engineer civil servants located at the firms to monitor progress and to interface with the projects. There is also a suspicion of cynicism on the part of the firms with regard to the promised production schedules and delivery dates and that "the Ministry was paying and the firms weren't losing anything but reputation, perhaps. The firm knows that once the Ministry is committed (really committed) there is not much you can do except wait for them to deliver".[68] However, Sir Richard Powell, as Permanent Secretary in the Ministry of Defence in this period took an alternative view about the problems of delivery.

67
'Vulcan Aircraft Production Policy', PRO AVIA 65/55, memorandum of 3 January 1958.

68
Frank Armstrong,, former Deputy Director, NGTE, conversation with the author, 20 November 2001.

Every project was grossly undermanned and took twice, three times, four times what ... the industrialists and the designers said they were going to take. All these projects were definitely undermanned. That's why everything took so much longer and cost so much more. It was not deliberate - it was just wildly optimistic and overambitious. Excessive optimism followed up by disappointment.[69]

The Rolls-Royce Conway - attempt at synergy

A final engine case study of another episode, which comes out of the V-force programme, further illustrates the inherent tensions in the MoS mission. The RAF were keen, as we saw above, to maximise the height achievable by V-bomber aircraft to increase their survivability over the Soviet Union and a proposal to upgrade the Rolls-Royce Conway engines for the improved Mk II Handley Page Victor aircraft emerged in conversations between senior RAF personnel and Rolls-Royce engineers. Rolls-Royce held out the prospect that further development would yield an engine with superior thrust, range and height performance. The new 'Stage 4' Conways, uprated from about 17,250 to 20,000 lbs thrust would also allow loaded Victors to take off in 2000 yards, rather than 3000, thus increasing the number of dispersal airfields they could use and the survivability of the force in the event of a Soviet 'counter force' attack.

The Air Staff were keen to foster this, while the Ministry of Supply was sympathetic since the emerging civil Vickers VC 10 airliner was also to use the Conway and Aubrey Jones, as Minister, began to push for extra funds, outside the defence allocation, on the basis of this synergy. However, Jones' personal enthusiasm was not appreciated by the Air Ministry which viewed his initiative as premature, suggesting that; "it is particularly unfortunate that the Minister of Supply should have attempted to force our hand by disclosing these ideas to the Treasury. ... I think you would agree that we should not be manoeuvred into a

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Sir Richard Powell, conversation with the author, 14 February 2002.

premature approach".[70]

To the Treasury it seemed evident that the provision of better engines "as a relatively straightforward way" to improve the efficacy of the V-force should be funded from the agreed total defence budget of £1620m.[71] Meanwhile Aubrey Jones' well-meaning and apparently logical 'Crippsian' initiative to link defence R&D with a marketable civil development also quickly ran into difficulties when the Treasury suggested BOAC should pay more towards development of the improved engine, noting "the striking contrast" between "the substantial all-round improvements" in VC10 performance and the limited value placed on it by BOAC, "judged by their readiness to pay a higher price for improved aircraft".[72] The Treasury considered BOAC's offer of £3500 per aircraft inadequate, suggesting that it equated to attracting just one extra tourist passenger per transatlantic flight for a year and "should the Corporation not be expected to pay a full economic price including a reasonable share of the development cost of the Stage 4?".[73]

The MoS, attempting to hold the ring between these interests, and in receipt of strong objections from BOAC, replied that "the little calculation you suggest ... is, I am afraid, too great a simplification. It certainly cannot be assumed that BOAC would carry an extra passenger on every trip made by VC10 aircraft". More persuasively, MoS argued that asking BOAC to contribute to development was invidious because, after completion of the programme, Rolls-Royce would

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PRO AIR 19/822, DCAS to Secretary of State, Air Ministry, 20 April 1959.

71
PRO AIR 19/822, "I am puzzled by the difficulty that has arisen. ... should have thought room would have been found for it within the ceiling. But it is for you and not me to assess priorities in the defence programme". Derick Heathcoat Amory to Harold Watkinson, Minister of Defence, 20 November 1959.

72
PRO AIR 19/822, DCAS to Secretary of State for Air, 20 April 1959.

73
PRO AIR 19/822, 'Production - Bombers', Treasury minute of 19 May 1959.

be able to sell improved engines to BOAC competitors without a development surcharge.[74]

The programme was expected to cost between £15m and £18m with £6.1m attributable to the civil side. Rolls-Royce, pleading declining profits, asked for government support for all this, while the Treasury reminded MoS that the Minister of Transport and Civil Aviation (Harold Watkinson) had made it clear in Parliament that there would be no Government money in the VC10. It noted that "while the statement was not without its ambiguities" they did not wish to give Rolls-Royce any reason to believe that government finance would be available towards the VC10 engines. Nevertheless, the appeal of an "integrated programme" gathered strength and Aubrey Jones, writing to Harold Watkinson, as Minister of Transport and Civil Aviation suggested that "if the military requirement can be justified, that might pay for its development. This would be preferable to putting Government money into the civil development".[75] Eventually, this integrated programme for Conway development was accepted, although without Jones' covert civil subsidy, and the programme costs were split between the Air vote (from the Ministry of Transport and Civil Aviation) the military R&D vote, and with Rolls-Royce making a contribution towards the specifically civil element in the programme.

The final outcome was depressing and again suggests that the appealing post-war concept of using the MoS to harmonise the interests of the manufacturers, the Services and civil operators set what was a perhaps an impossible task. The cost estimates for the VC 10 grew, while BOAC cut back the numbers it was prepared to take. Vickers, now merging with Bristol, English Electric and

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PRO AIR 19/822. G V Hole, MoS, to D R Serpell, Treasury, 30 June 1959.

75
PRO AVIA 65/737, letter of 29 May 1957, Bligh of Treasury to Leitch, MoS. PRO AIR 19/822, letters of 14 April, 8, 19 May 1959. F J Doggett for the MoS suggested that Rolls-Royce needed support, but David Serpell, at the Treasury replied that "I have seen Rolls-Royce's latest Report and doubt whether you should rely heavily on the statement that their profits are declining".

Hunting to form the British Aircraft Corporation (BAC), twice appealed to the government for launch aid which reached over £10m. Production reached only 54 aircraft and both Rolls-Royce and Vickers/BAC lost money on the aircraft (Vickers put their loss at some £20m). Functionally, the VC10 turned out to be an excellent aeroplane with high rates of utilisation and high load factors. Nevertheless only eight were sold to non-UK airlines and, in Vickers' view, the export prospects for the aircraft were fatally weakened by BOAC attacks on the aircraft and the corporation's approach to government for a £30m subsidy to cover expected operating losses.[76]

The tussle over the question of allocations between defence and civil budgets for the Conway are illuminating, for this area was viewed with particular unease by the Treasury on account of the lack of transparency in the transactions. Thus Denis Haviland, then Undersecretary (Air) in the MoS reported that a meeting at the Treasury with David Serpell during this period was:

> ... enlivened periodically by a fairly severe attack on the way in which the Ministry [of Supply] handles its research programme and the way in which Mr Serpell had the transfer of certain items from the military to the civil budget 'put across' him at the time of the Estimates last year. ... His conclusions were that the Treasury control over the research programme was quite inadequate; that the control exercised ... [by the MoS] was also inadequate.[77]

The Treasury solution was for a financial ceiling covering all aeronautical research, and military and civil interests should be obliged to reach agreement within the allocation. However, MoS considered this amounted to a Treasury policy of "divide and conquer", anticipating "a scramble for marginal money at all times of financial pressure. It is out of this scramble that the Treasury would

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76
Charles Gardner, *British Aircraft Corporation: a history*, (London, 1981), pp 84-90.

77
PRO AVIA 65/1084, 'Future of the Aircraft Industry', D L Haviland, (U.S. (Air)A), 3 July 1958 to PS/Secretary.

hope to see 'unnecessary' projects brought to light for them to cancel".[78]

Encounters such as this were not, in themselves definitive, and seem to have been taken in good part by the protagonists, but they are indicative of a growing perception, in government circles, that there were problems in the 'machinery of administration' arising from the various roles of the Ministry of Supply and its location between the aircraft industry supplier and the users. There may have been no general prescription for a new administrative structure but there was, by the late 1950s a sense that the MoS had become "the fifth wheel on the car which wasn't really necessary".[79]

Towards a new relationship: Sandys and Plowden

In 1957, Reginald Maudling stood down as Minister of Supply and, apparently, recommended the abolition of the department to the Prime Minister, Harold Macmillan.[80] In this context it is interesting that a few months earlier, in relation to the projected overspend for the defence R&D vote, Maudling showed the untenable position of the Supply minister in a note to Macmillan, as then Chancellor of the Exchequer.

> When it comes to cutting out projects I face the difficulty that the Minister of Supply cannot make excisions from his military R&D programme without the agreement of the Defence Departments. To this extent, while I am responsible for the size of the estimates, I do not have control over them.[81]

78
Loc. cit.

79
Sir Richard Powell (n. 69 above).

80
Aubrey Jones, *Britain's Economy: the roots of stagnation*, (Cambridge, 1985), p. 71.

81
PRO AVIA 65/1084, 'Future of the Aircraft Industry', Minister of Supply to Chancellor of the Exchequer, letter of 12 September 1956.

Aubrey Jones then accepted the post of Minister of Supply (the last there was to be), though "little realising how ... I was to be dragged behind the grinding wheels of Mr Sandys' chariot".[82] The 1957 Defence White Paper, touched on above in connection with the V force, was devised by Duncan Sandys solely with the problems of deterrence and expense in mind. Nevertheless, there was an industrial consequence in the new arrangements since Sandys, as Minister of Defence, was now made the major determinant of the defence programme. This "first step on the road towards a unification of the defence structure"[83] was intended to lessen the competition between three powerful service and effectively heralded a more direct relationship between the service users and industry and a weakening of the importance of the MoS.

Traditionally, the aircraft companies, and their historians, have dated the travails of the industry from the publication of Sandys' White Paper calling it "the biggest shock ever ... to be administered to the aircraft industry".[84] From the perspective of this study the White Paper was also the seismic triggering jolt which unlocked the tectonic strains that had been growing over years in the relationship between the government and the industry. Thus, even before the document was published, there are signs that a transition point had been reached. Officials were, early in 1957, reflecting that "it is healthy, as well as inevitable, that the industry, swollen by rumours of wars, should now suffer some deflation" and were reviving earlier rationalisation initiatives that had stalled in 1953.[85]

82
Aubrey Jones, 'Britain's Economy' (n. 80 above), p. 72.

83
Ibid.

84
Charles Gardner, 'British Aircraft Corporation', (n 76 above), p. 19.

85
PRO AVIA 65/736, 'Size and Shape of the Aircraft Industry, Including Relationships with the M.O.S. (now Aviation)', Second draft of paper by Peter Humphreys-Davies, Deputy Secretary, MoS, 15 February 1957.

This time, the analysis was more resolute. Stiffened, perhaps, by repeated disappointments, a new attitude - even a new emotion - developed among MoS officials who abandoned their former liberality and adopted a ruthless assessment of the fate of the firms in a resolve to implement an effective remodelling of the industry. Thus one asked, in terms unthinkable a decade earlier;

> Why are Bristols so important? I suggest their most notable achievement since the war is the amount of government R.&D. money they have absorbed to achieve so little. My guess is that the total now exceeds £150m. We shall only get value for money out of Bristols if they have to fight for existence in a competitive world".[86]

Now officials contemplated with equanimity the demise of firms that the department had earlier been anxious to protect. Thus Armstrong Siddeley "will now collapse at the end of the Sapphire and Mamba lines, ... de Havilland [engines] ... seems likely to decline to a minor status" while the disappearance of the relatively minor airframe firms "would not be disastrous".[87]

The Sandys analysis that missiles would soon perform the task of nuclear delivery, and such air defence as was possible or necessary, turned out to be highly premature. Nevertheless, the policy served to secure the termination of many aircraft and engine contracts in the interests of a contraction that was already perceived to be required. Ironically, as Hayward points out, orderly 'short step' developments, with excellent export potential such as a supersonic Hawker Hunter, with a reheated Rolls-Royce engine, was also cancelled.[88] What survived was the highly ambitious TSR 2 strike bomber project which was used by Aubrey Jones at the MoS to induce a measure of consolidation on the industry by bringing Vickers and English Electric together as the principal

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86
PRO AVIA 65/736, Minute of 29 March 1957, US/LGW to Dep. Sec (C).

87
Ibid.

88
Keith Hayward, *The British Aircraft Industry*, (Manchester 1989), pp. 69-70.

partners in the British Aircraft Corporation (BAC).

Whether this project was a suitable tool for these policy aims is an intriguing question. Over its life TSR2 displayed, in effect, the 'mission creep' problem - a growth in the specification and performance that was promised or specified, leading ultimately to an unaffordable product. The industry's apologists tended to blame the Air Staff and claimed that "the final TSR 2 requirement had everything built into it that military imagination could devise and quite a lot that was not strictly essential".[89] However, the industry, and the government research establishments, almost certainly were complicit in the upward creep of performance targets (as we saw with the Vulcan engine programme in the previous chapter) because this, in a sense, was their *raison d'etre*.[90] From the point of view of this study, the process of performance and cost escalation should be regarded as a socio-cultural one, in which defence priorities (or wishes) can be too easily communicated to the supplier firms and where the firms reciprocally aim to tempt their patrons with something much better, if more funding (usually modest compared to that already committed) can be found. The argument here is that the post-war MoS actually represented an inversion of the ethos of the war-time MAP which, for clarity and control, established a separation between the user/specifier and the production system. By contrast, the way in the MoS had operated its contracts had established a milieu in which this kind of contact and negotiation could occur. The progress of the TSR 2 development also suggests that a similar process of 'positive feedback' in technological expectations continued under the Ministry of Aviation.

89
Charles Gardner, *British Aircraft Corporation*, (n. 76 above), p. 69.

90
This creative desire can explain why new developments are sometimes pursued even in apparent defiance of rational business strategy. David Noble has observed, in the machine tool industry, that development engineers, and even the heads of companies, are often more interested in performance than in profit. David F Noble, *Forces of Production*, (New York, 1984) p. 9.

The responsibility of the MoS for aviation came to an end in 1959 with the formation of a new Ministry of Aviation with Duncan Sandys as Minister. Sandys was said to be a supporter of the supersonic transport (Concorde) project now being canvassed by RAE and industry[91] and by an irony, his own defence policies appear to have pushed the RAE scientists (the early protagonists) to become committed propagandists for the supersonic transport since "the RAE swung behind the civil supersonic transport when most of the military projects disappeared".[92]

The enthusiasm for the supersonic transport was continued by Peter Thorneycroft, Sandys successor as Minister of Aviation, who seemed still, like all the Ministers responsible for the industry since Cripps, to be acting fully in the spirit of his late war agenda for reconstruction. To the Cabinet Thorneycroft noted in 1961 that: "I am deeply concerned as to the future of the aircraft industry, for which the Government have accepted a substantial measure of responsibility". Among other proposals for investment in the industry Thorneycroft anticipated "whether we like it or not" the almost certain introduction of supersonic air travel and noted that, although the USA had started investigating an all-steel Mach 3 aircraft, British design research was advanced on an aluminium alloy Mach 2 design. "My technical advisers firmly believe that Britain has an opportunity here of gaining the leadership we so narrowly missed with the Comet".[93]

91
Geoffrey Owen, *From Empire to Europe: The Decline and Revival of British Industry since the Second World War,* (London, 1999), p. 309.

92
John Bagley, conversation with the author 1997. He recollected that, for a time after the Sandys White Paper, "all our swept wing stuff at one time was being carried on the Armstrong-Whitworth freighter - the only peg left to hang it on".

93
CAB 129/106. 'The Future of the Aircraft Industry', Memorandum by the Minister of Aviation, October 1961. "Whether we like it or not, the 1970s will almost certainly see the introduction of supersonic travel. ... The Americans are thinking of an all-steel aircraft capable of Mach 3 but this is an extremely ambitious project, even for them". The phrase about Comet Thorneycroft used strongly suggests the imprint of Morien Morgan, Deputy Director of the RAE and moving force behind the programme, as discussed in chapter five.

Hayward suggests of this time that "the strongest impression of the period is that, having engineered the regrouping, and having reintroduced launch aid, the government had no coherent idea of what to do with the industry".[94] This is fair, but really had also been true throughout the entire post-war period. The Cold War defence programmes clearly had their own imperatives. For the rest, civil servants and Ministers had been required to simulate an entrepreneurial and commercial instinct. It is the contention here that this promotional role, combined with an explicitly protectionist agenda, served to delay the emergence of an entrepreneurial culture in the firms.

The election of the Wilson government in October 1964 brought a new step in the adjustment of the government-industry relationship. Dennis Healey, as Minister of Defence, was perhaps constitutionally less indulgent to the aircraft industry. Healey claimed that "the previous government had cancelled thirty major aircraft projects in about ten years at a cost to the taxpayer of £250 million without ever actually getting an aircraft off the ground".[95] The cancellation of TSR 2 followed in April 1965, while a committee of enquiry under Sir Edwin (subsequently Lord) Plowden was set up.

Plowden was not particularly radical, the recommendations including a flexible form of nationalisation or government shareholding - a type of "mixture of public and private enterprise [that] has not been much tried in this country" but was deemed to work well in Italy, a substantial size reduction, a merger of the

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94
Hayward, 'British Aircraft Industry' (n. 88, above), p. 84.

95
Pagnamenta and Overy, *All Our Working Lives*, (n. 24 above), p. 69. Sir Richard Powell considered, with regard to the proliferation of aircraft projects "no one ever tackled that problem seriously until Healey". (n. 69 above).

two airframe groups and exploring partnerships with Europe.[96] To American diplomatic observers the Plowden Report appeared to based:

> to great extent on untested assumptions, loose general analysis and inadequate statistical base. Report will lack rigorous analysis and economic-military back up data which should be essential in major report of this kind.[97]

However, Plowden could perhaps be viewed less as a searching enquiry than a process for formally legitimising the growing perceptions about the industry that had been germinating within civil service departments and government. The "melodramatic" reaction of the industry, calling the report "entirely negative and defeatist" has been described by Edgerton who, drawing on Tony Benn's diaries, finds evidence of Tory as well as industry hostility.[98] According to the reading here a readjustment was inevitable under governments of either party. Thus although Aubrey Jones issued a minority report within Plowden arguing, particularly, that a government shareholding would reduce the progress of the industry towards a more commercial outlook, his judgement on the industry was not that far removed from Healey's. Jones considered that "the aircraft industry had not presented a pretty picture - ignorance of markets, laxity of costs, and greed for public money"[99] while previously in 1957, as part of the impulse towards spending reduction that prompted the Sandys White Paper, the Macmillan cabinet called for an 'informal' enquiry to consider the future of the

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96
Report of the Committee of Inquiry into the Aircraft Industry, Cmnd 2853, December 1965, pp 82-97.

97
National Archives and Records Administration, RG 59, Records of the US Department of State, Central Files, 1964-66, AV 12-7 US. Telegram From the Embassy in the United Kingdom to the Department of State, London, October 22, 1965, 1937Z. The Embassy also suggested that release of the American Department of Defense report into the US supersonic transport, though perhaps useful to British and French in terms Concorde project, might "dramatize what seem to be major deficiencies in Plowden Report".

98
David Edgerton, 'The White Heat Revisited; the British Government and Technology in the 1960s, *Twentieth Century British History*, No 1, 1986.

99
Aubrey Jones, 'Roots of Stagnation' (n. 80 above), p. 80.

aircraft industry, commissioning, the Chancellor of the Exchequer (then Peter Thorneycroft) to establish a working party. The report had noted that for civil work the industry;

> has grown up largely at government expense. Generous financial help was in fact given. ... This took the form of payment of all costs of development for a wide range of interim or conventional types of civil aircraft. ... Later, more advanced aircraft using gas turbine engines were developed largely at the Government's expense.

Companies were now being induced to take over "much or all of the cost and risk of development". Newer, stronger units were needed and continuing government civil R&D support should be conditional on the industry progressively taking over this expenditure.[100]

Neither Padmore's earlier study nor Plowden seemed to recognise the contribution of the government's own structures to the outcomes of aircraft programmes. But though few striking changes emerged directly as a result of these studies under Conservative and Labour administrations, the Plowden report does mark the development of a new realism as evidenced, perhaps, by the establishment of the post of Chief Economist at the Ministry of Aviation in 1965 to provide advice within the department and to keep in touch with economic organisations in other parts of government. This is not to imply that a clear path for the management of the aerospace sector by government had been discerned by the mid-1960s. The ensuing administrative changes, taking us beyond the period of this study, make that eminently clear. In 1959, as we have seen, responsibility for the supply of military aircraft had been switched to the Ministry of Aviation, then to the Ministry of Technology in 1967 and to the Ministry of Aviation Supply in 1970. Other punctuation marks include the bankruptcy and protective nationalisation of Rolls-Royce by the Conservative Heath government, the Concorde programme, the nationalisation of the British

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100
The Future of the Aircraft Industry: Aeronautical Research and Development, First Report by the Aircraft Industry Working Party, 14th April 1958 (Chairman, Sir Thomas Padmore, Treasury).

Aircraft Corporation and Hawker-Siddeley Aviation to form British Aerospace by the Labour government under Harold Wilson in 1976, with both Rolls-Royce and British Aerospace being privatised under the Thatcher government in the 1980s.

With regard to military procurement, in 1971, following the report by Sir Derek Rayner, the supply of military aircraft was made the responsibility of the Ministry of Defence, with the creation of a dedicated Procurement Executive within the MoD. In a sense, the creation of this partly autonomous agency, with to an extent, a 'Chinese wall' between it and other defence policy functions, recalls the greater administrative focus that was achieved by the creation of the Ministry of Aircraft production in 1940. Responsibility for civil aircraft programmes and launch aid (renamed launch investment) now rested with the Department of Industry which established the definite aim of recovering its investment, and a share of profit, from sales.

These do seem to be steps on a path to greater clarity of direction of aerospace projects. Certainly in recent years the international performance of Rolls-Royce and the British contribution to Airbus appear to have vindicated the evolving mechanism of administration, the increased realism of the industry, but perhaps most importantly, the growing maturity of the technology. However aerospace programmes can still continue to run into overspends and argument. This should be no surprise for as John Jewkes argued in 1978, one of the important meanings of the 'high' in 'high technology' is "exceptionally high-risk technology".[101]

101
John Jewkes, *A Return to Free Market Economics?*, (London, 1978), p. 120.

Chapter 7: Conclusions

Preamble

The history of relations between government and the post-war aircraft industry can be seen in terms of a gradual movement from the system developed for the totally directed war economy, with the government as the sole customer, to a more autonomous industry competing in the global aerospace market. The administration of the industry over the period studied reflects this evolution and thus the post-war decades show a continuation, in a gradually attenuating form, of the pattern of administration and control developed during the war at MAP. However, by the end of the period covered by this study a transition is occurring in the structure of the industry and in the pattern of its administration by government.

It has been noted, in preceding chapters, that the great achievement of MAP lay in guiding production during the war when it was largely following the precepts set down for it in 1940 for the separation of procurement and production from the Air Ministry. This clarity of purpose allowed the British aircraft industry to achieve remarkable feats of production and also to attain high technical quality. The success attained in this role, and the confidence this engendered, it is argued, underpinned the case that was made in the late-war era, for a pivotal post-war role for the combined MAP and MoS in the exploitation of the aircraft industry in the national interest and the development of aircraft of all types.

The job, therefore, that the MoS was expected to do in the post-war world, was far broader and more complex than that performed by the MAP in the war and it is argued, on the basis of the studies considered here, that this wider 'industry ministry' task introduced a confusing multiplicity of roles and compromised what was simple, clear and effective about MAP. Ironically, this expansion of its mission led almost inexorably back to the problematic situation that Churchill had identified in 1940 in which he judged that the users and specifiers of aircraft would interfere with production if all these interests were too closely associated.

Thus the MoS came into being under the post-war Labour government embodying the aspirations of Stafford Cripps for an agency that would represent the interests of "a progressive active government" in industrial policy, with over-arching responsibility for both *military* and civil procurement, a brief to promote a hoped-for move into the emerging world civil airliner market, and a responsibility for a general overseeing role for the aircraft industry which implied an industrial support function. This study shows that, interestingly, this essential role was not challenged by successive Conservative administrations and MoS continued, in essence, to follow the path that had been set out for it as the war ended. This implicit or institutional departmental policy continued until the financial pressures imposed by aviation programmes became increasingly exposed to question, and when a growing lack of confidence in the capacity of the government/industry ensemble to develop genuinely exportable and profitable products came to the fore in both Conservative and Labour thinking.

Discussion

How effective, therefore, was the Ministry of Supply in the role assigned to it for guiding industry in this "joint endeavour with us" to compete head on with the USA and to gain a sizeable share of the world civil airliner market?[1] Certainly if the long-range strategic role anticipated in late Second World War policy discussions had been implemented in an effective way, we would expect to see more evidence of the MoS taking an entrepreneurial and considered look at the world aviation market for potential numbers of aircraft sales, together with studies of sectors and niches for particular types and sizes of aircraft. In the case of the Vickers V1000, for example, there is no hint of this and MoS seems to have had a largely reactive role, buffeted by the demands of the RAF and the assertions of Vickers. In effect MoS acted here, in part, like a fairly

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1
PRO AVIA 65/59, 'Comet Aircraft Production Policy', note by Sir James Helmore, January 1955.

uncritical bank.

The degree to which aircraft manufacture features in the manufacturing economy of a nation owes less to competitive advantage than to accidents of history and, in particular, its defence policies and its experience of warfare. In the post-war period a major element of the remit for the MoS was to utilise the national investment that had been made in military aircraft production facilities to also promote civil aircraft production. In fact British firms had tentatively begun tentatively to try and emulate the new American high speed, all metal airliners during the 1930s but re-armament put a stop to this. As we have seen in chapter two, the intention to re-enter the civil airliner market after the Second World War became a major feature of British aeronautical policy.

However, post-war defence objectives and Cold War re-armament squeezed British civil aircraft programmes just as pre-war rearmament had done. Nevertheless, there were many civil projects in this period but few viable entrepreneurial schemes of adequate scale that reflected sensitivity to the airline needs or to international markets. Thus in 1965, fully twenty years after this intention to compete internationally in airliner production was made an explicit objective, Plowden noted that "the effort to establish a self-supporting British civil aircraft industry has not yet succeeded".[2] At a slightly later date British representation in the Airbus consortium, on which the British share of European civil airframe work now rests, came about from an independent deal arranged by Hawker Siddeley Aviation, and not from a considered strategic move developed within the MoS or its successor ministries.

Moreover, in its purely military procurement role the success achieved under MoS direction was equivocal. The key indicator in this must be the production of the V-bomber force, judged to be the UK's main defence priority, but finally delivered years after the target date. Nevertheless it should be noted that, during

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2
Report of the Committee of Inquiry into the Aircraft Industry, Cmnd. 2853, 1965, p. 20.

the period under review, the industry was certainly not backward technologically. The Royal Aircraft Establishment, (RAE) administered by the MoS was pre-eminent in European aviation research while the annual Farnborough air show there was always a national media event. The advanced research of government scientists at RAE and elsewhere, stimulated by Cold War apprehensions also resonated with the ambitions of industry engineers. Thus the 'defiant modernism' of post-war Britain was sustained by impressive, but spasmodic, technological aviation feats such as the vertical take-off 'Flying Bedstead' trials (1954), the 1,132 mph world speed record by the Fairey Delta FD 2 (1956), and the eventual deployment of the Lightning fighter and the V-force bombers, with Concorde as a final act in what had been a succession of *coups de theatre.* These patchy, disconnected, often brilliant, but literally incoherent acts of technological bravura certainly sustained the nation's 'high tech' self image but, on the military side there were too few consistent programmes with their own long-term logic and the possibility of convincing military export sales which would have helped the industry resist the cuts of the late 1950s and early 1960s.[3]

The task of the post-war Ministry of Supply differed profoundly from that performed by the war-time MAP in a number of ways. The analysis of these suggests that war-time supply ministry proved to be an inappropriate model for the peacetime direction of the industry. Firstly, war-time production had swept away a huge number of perturbations and left officials and government with simplified (though not simple) choices. Post-war planning and direction turned out to be a very different matter. It was not simply that the number of tasks increased and that the role that the Ministry was asked to perform widened. The task of planning in the post-war era was more difficult than wartime production for in spite of the enormous centralisation of the post-war aircraft sector and its dependence on government funding there was nevertheless a return to a type of

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3
It is significant that after the Fairey Delta FD 2 world speed record it was taken to France for further trials since the attitude to supersonic booms there was more relaxed. No further UK military developments flowed from the FD 2 but these experimental trials in France have been widely credited with accelerating the development of the highly successful series of Mirage fighters from Dassault.

mixed economy. There thus were more 'cross-currents' in the post-war world and more connectivity between different groups, firms and institutions. Although many of the participants, such as the airlines, were state controlled, this did not lead to a simplification of the situation since they answered to different masters and, in the case of the airlines, were charged with a duty to act in their own commercial interests. In trying to meet its obligations to national security and to also promote the industry, the Ministry of Supply was caught up in an almost irresolvable cats' cradle of tensions. The result was that, in the post-war decades, decisions were taken in a febrile and over-politicised milieu in which industrialists, politicians and public servants interacted and with these public servants, in particular, burdened by a multiplicity of conflicting considerations.

Another factor was that the post-war MoS differed in composition from the MAP in a rather profound way which, perhaps, politicians such as Cripps had not anticipated. The special war-time recruitment of economists, managers and technical experts had been essential for planning aircraft production during the suspension of the market. However, the impressive assembly of managerial and economic talent which was assembled to run the war-time aircraft programme at MAP had been an exceptional response, analogous to the allocation of academic scientists to projects such as radar, or artists to camouflage and deception projects. When peace came there was an inevitable demobilisation. The concentration of expertise had been special to the war and could not have been sustained in a peacetime Ministry.

A third difference between the war and the peace was that British war-time aircraft production had taken place against a backdrop of a certain 'design maturity' of aircraft types. Although British aircraft and engines improved throughout the war this was an incremental process, accepting as much new technology as could be fed into the production programmes without incurring loss of output. Thus it has been noted in chapter two that the MAP's greatest success lay in managing relatively consistent long-run production tasks – for example, Lancaster and Spitfire aircraft, Rolls-Royce and Bristol engines - even though these had been allowed to continually evolve in a controlled way in search of increasing performance.

By contrast MAP's performance in managing advanced technology projects was perhaps less impressive and the case of the Whittle jet has been adduced in support of this contention. Other war-time programmes with a substantial element of new engineering development were often disappointing and, as with the Whittle jet, the complex Napier Sabre piston engine also went badly off course with, in each case, the associated new aircraft (Gloster Meteor and Hawker Typhoon) also trailing in development. Step changes in performance were rare and, when attempted, proved hard to manage, and were usually late.

The post-war era was one of rapid technological change forced partly by the performance competition imposed by the Cold War, by the introduction of the jet engine, and by the discovery that speeds approaching or beyond the speed of sound was possible. In this period, with successive step changes in aviation technology occurring, many programmes were more akin to the troublesome, speculative, advanced technology programmes that had been epitomised in the war by the Whittle jet rather than programmes where maximising output for large, fairly consistent production runs was the key. These Cold War programmes were, in fact, intensive development exercises rather than pure feats of production, and production itself and speed of deployment, as in the case of the V-bombers, could be slow. In this environment, it is argued, the war-time expertise acquired by the MAP was of reduced applicability.

We have also seen that, even as the war ended, some officials within MAP were concerned to see the development of greater initiative on the part of the firms and wished to see moves that would "stir the industry from its lethargy". However, it is suggested here that in attempting to administer strategic plans for the future of the sector and juggling the needs of the RAF and the airlines, the MoS actually delayed the development of an international perspective in the firms and the evolution of a competitive entrepreneurial culture. The existence of the MoS really ensured that the major focus of the aviation industry was on securing government contracts rather than foreign customers. Thus in the early 1950s the companies were highly averse to accepting risk on civil airliner projects. For example, during the production of the de Havilland Comet in 1952 (a time of great optimism for the jetliner and before the accidents) the company

resisted a partnership with government through the Export Credit Guarantee Department under the terms of which government risk would decrease as sales were made, and argued for total government underwriting of any unsold aircraft which they proposed should be passed to the RAF. Vickers too asked for the same provision.[4]

Although this attitude came to be gradually modified over the period of this study the bankruptcy of Rolls-Royce in 1971 can also be taken as evidence for the influence of MoS procedures in delaying the development of a more entrepreneurial stance in British companies. Although this event took place outside the period studied here, the programme to develop and sell a new large engine (the RB 211) in America, for the emerging generation of wide-body civil jets, started in the mid-1960s. Thus it appears that a major reason for Rolls-Royce being driven into receivership was that it had committed to the development of a new, far larger and more complex engine than it had built before, under a tightly drawn international contract with the Lockheed aircraft company, rather than under the more indulgent conditions which had previously tended to obtain in its dealings with the MoS where programme delays and cost over-runs were not fatal.[5]

The wartime reconstruction plans dissolved quite soon in the post-war milieu into a system which combined powerful elements of Ministry direction with some free market incentives but where a kind of competitive lobbying and influence broking were highly important. In this period, it can be argued, the British aviation and engine companies were only partially in the aviation business - they were also, crucially, in the business of winning development contracts from government. Indeed, it could be argued that a real business ethic

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4
PRO AVIA 65/59, L J Dunnett, US (Air), minute of 4 March 1952. "The attitude of de Havilland, though much as I expected, puts the whole question of the export of civil aircraft into its proper perspective. However much people like Lord Douglas of Kirtleside and Peter Masefield may assert that it is the easiest thing in the world to produce large numbers of civil aircraft, what they totally fail to appreciate is the problem of who is to carry the financial risk involved. This problem has come up in an acute form in the case of Vickers".

5
Andrew Nahum, 'Sir David Huddie', obituary, *The Independent*, 16 June 1998.

did not really exist at the time; the concerns were not so much businesses as agencies which retained elements of the war-time relationship with the sponsoring department. Thus Sir George Edwards perhaps revealed more than his typically pithy remark intended, when he said to Rolls-Royce managers, following the 1971 bankruptcy that "you've forgotten how to walk the corridors of power".[6]

This attitude can be viewed against the performance of Sir George Edwards' own company, Vickers, over the development of the V 1000 airliner which was analysed in chapter six, for it is apparent that the American companies approached civil aircraft development in a different way. The Boeing KC-135 military tanker/transport aircraft, for example, was developed under a defence contract but was subsequently used by Boeing as a springboard for a self-funded further design effort to produce the 707 airliner with the substantial investment of $15m of Boeing money. By contrast the V1000 proceeded principally with MoS funding and the company did not emulate Boeing and accelerate development by making a substantial investment of its own. The Vickers airliner also was based on a government-funded military aircraft (the Valiant bomber) but there was a substantial difference in the speed and energy with which Boeing tackled the design and engineering of their new airliner. Although Sir George Edwards claimed that the cancellation of the Vickers V1000 was the "one single significant point" in the post-war history of the British aviation and that it occurred "at a time when the 707 only existed in its prototype form with a sub-standard body and a sub-standard range" this Boeing 707 prototype (company designation Model 367-80) had been flying for some 17 months.[7] Although it had started at almost the same date, by this time the V 1000 prototype only existed as a partially completed fuselage and a set of wings which had not been fitted.

6
Sir David Huddie, conversation with the author, 29 October 1997.

7
Sir George Edwards, quoted in Arthur Reed, *Britain's Aircraft Industry: What went right? What went wrong?, (London, 1973)*, p.4.

Boeing's Model 367-80 design project commenced on 20 May 1952 and the prototype flew on 15 July 1954. The 'substandard cabin' on the prototype, to which Edwards referred, had four abreast two-plus-two seating, with a width of 132 inches, based on the popular Stratocruiser, but was enlarged to 148 inches to accommodate three-plus-three seating and also to exceed the cabin width of the emerging rival Douglas DC-8. In spite of this major change the first aircraft with the revised fuselage began test flights from 20 December 1957 and the type entered commercial service in October 1958. The MoS assessment at the time of cancellation was that Vickers would only have been able to deliver 6 V1000s by that date.

End Words

The model of a supply ministry, responsible for all the research and production of the aircraft industry sector, both for civil use and defence, proved to be inappropriate to the post-war world. The strains in this system became increasingly apparent throughout the 1950s although it was not evident how the situation should be tackled. Within the MoS the problem was seen largely in terms of the size and structure of the industry and the need for some form of rationalisation became a recurring theme within the MoS from about 1950, although the means and the will to do this were not to hand. As we have seen, the 1957 Defence White Paper started a major shift, although Duncan Sandys, as Minister of Defence, was not concerned with industrial policy, but solely with the cost of British defence and the problems of deterrence. Nevertheless, the White Paper served to extinguish a large number of projects which were sustaining the industry in its diffuse form. Following the post-Sandys cuts, the contract for the TSR2 bomber, as the sole remaining substantial aircraft project was used as a lever to force some amalgamation on the UK industry.[8]

8
The TSR2 contract was awarded to Vickers and English Electric in January 1959, setting the companies on the road to merger as the British Aircraft Corporation in 1960. (then known by the designation OR 339).

If this implies the judgement of hindsight it is necessary to recall the proposition in the introductory chapter which suggested that these events be viewed as an 'experiment in administration'. There was no existing model for the peacetime government administration of a high technology industry which required investment decisions beyond the capacity and experience of the commercial sector to finance, while the passage of the industry from a position of close administrative and technological dependence on government agencies was inevitably a process that took time. So to did the development of patterns and structures for government direction and collaboration with the industry.

It is important, therefore, to stress again the evolutionary nature of arrangements in this period and the essentiality of history to an understanding the structure of the industry, its capacity, its relationship with government and its ethos. Thus we have seen that the Second World War brought huge expansion to a far smaller pre-war industry, and provided an administrative system that allowed it to work at the limit of its capacity, manufacturing technologically successful weapons in firms which, in many cases, had a rather low technological base. Government planning, through MAP, supplied an essential component of management to this programme while government research thorough the RAE and other establishments, supplied a major proportion of the underpinning R&D.

Although very different to the contemporary American system this British pattern of procurement – collaborative, highly centralised and bureaucratically planned – was a rational strategy for extracting maximal war production in the British context. The British institutions and the relationship between British companies and government were distinct and specific to the re-armament and the war, and the political and social organisation at the time. They cannot be criticised for being insufficiently 'American' but the post-war era saw a progressive weakening of this integration of government and the firms. Thus, in 1965, Plowden found that the average profit in the aircraft industry was only 5.9% on capital employed and well below that for British industry in general which ranged between 11.3 and 13.5%. To Plowden this seemed to indicate a failure in the commercial approach of the firms. However, this profit figure is

another indicator of the transitional nature of the post-war aircraft industry and should be viewed against the earlier context of the war-time profits allowed by MAP which, as we saw in chapter two, could range from between 2.05 and 4.4%. During the post-war period under review here many projects were set up effectively as risk-free development contracts and so the war-time spirit of profit limitation was considered appropriate.

Those economists who had been most closely involved in MAP planning also, after a time, repudiated the most literal application of the system in the post-war era. Sir Alec Cairncross was careful to explain that the success of MAP was obtained in the highly specific circumstances of wartime when the market was suspended and with the government as the sole customer for industrial output, recalling that "we were virtually a communist economy".[9] Ely Devons, as former head of the statistical section, and 'chief planner' at MAP also attacked the use of planning culture in altered circumstances of post-war aircraft procurement while his predecessor at MAP and founder of the statistical section, John Jewkes, wrote the polemical book *Ordeal by Planning*, asserting in one chapter "the moral sickness of the planned society".[10]

However, the inescapable reality, for large defence projects, is that the state is inevitably interwoven into planning and finance. In major civil projects the long payback period takes these developments beyond the scope of the capital markets and no nations have remained in the aircraft industry without strategic government finance. To sell their products engine and airframe manufacturers now function, in effect, as financiers for their airline customers and this role requires enormous sophistication and resolution on the part of the industry and its government partners. During the period studied here these commercial instincts and strategies were still in gestation.

9
Sir Alec Cairncross, 'The Ministry of Supply in War and Peace, 1939-73', conference at the Business History Unit, London School of Economics, 14 December 1992.

10
Ely Devons, 'The Aircraft Industry', in D Burn (ed.), The Structure of British Industry,(Cambridge, 1958): 69-70. John Jewkes, Ordeal by Planning, (London, 1948).

In the case of defence projects government must devise the specification and the 'mission' and hence the degree of technological risk or 'boldness'. Therefore some 'planning' role is inescapable. However, the state must, it has come to be recognised, exercise some kind of self-denying ordinance - it has to accept a role as customer, through its procurement departments, although, at the same time, through its research contracts and its own intramural research establishments, it is continually upping the technological stakes and the potential of future systems.

In the case of defence procurement it has become evident that a too easy exchange between these functions can lead to a continual growth in performance specification and cost during the life of a project; a too rigid separation could deliver producible and perhaps economical aircraft which were outclassed upon introduction. As we saw with the TSR 2 and with the Vulcan engine programme in the previous chapter the industry, the government research establishments, and the RAF were complicit, with the manufacturers, in the upward creep of performance targets because this, in a sense, was their *raison d'etre*.[11] From the point of view of this study, the process of performance and cost escalation should be regarded as a socio-cultural one, in which defence priorities (or wishes) can be too easily communicated to the supplier firms and where the firms reciprocally aim to tempt their patrons with something much better, if more funding (usually modest compared to that already committed) can be found. The argument here is that the post-war MoS actually represented an inversion of the ethos of the war-time MAP which, for clarity and control, established a separation between the user/specifier and the production system

Interestingly in recent years, for military aircraft at any rate, something recalling the separation of production from the service and specification functions has been, in a form, restored and today Ministry of Defence operates a kind of 'Chinese Wall' between the sections responsible for these functions.

11
This creative desire can explain why new developments are sometimes pursued even in apparent defiance of rational business strategy. David Noble has observed, in the machine tool industry, that development engineers, and even the heads of companies, are often more interested in performance than in profit. David F Noble, *Forces of Production*, (New York, 1984) p. 9.

In 1998, reflecting on the changes to the structure of the industry and its relationship to government Handel Davies, as a former Director-General of Scientific Research (Air) in the MoS and subsequently Deputy Controller of Aircraft (R&D) in the Ministry of Aviation, considered that "we wasted twenty years in sorting out the industry" with the Plowden report in 1965, marking the turning point towards a more rational relationship between government and the aircraft industry.[12] But these years were spent, in a sense experimentally, attempting to manage this putative major national industrial asset, and following the direction developed by Stafford Cripps in the late war as part of the reconstruction policy. This system had, in the 1950s, tremendous institutional inertia and the authority that derived from war-time patterns and war-time successes. Thus it necessarily took some years for it to become apparent that the combining of the central control of procurement and production with a strategic industry management task had set up tensions which were proving irreconcilable.

Perhaps another lesson from a study of the post-war industry concerns human hopes, timescales and industrial lifecycles - for these hopes were not misplaced but they were perhaps premature. It proved impossible to fulfil the Crippsian vision for transforming the wartime British aircraft building capacity into a powerful economic asset within the lifetime of the post-war Labour government, or indeed during the tenure of many administrations after that. But today, the British aerospace industry is in a powerful position, as the second largest (or second equal, with France) aircraft industry in the world, with Rolls-Royce having developed a really striking position of competitiveness vis-a-vis American aero engine builders. The British aircraft industry did eventually achieve a position of maturity and capability. At the end of the war optimists hoped that Britain would reach this position in five to six years; in fact the process took between five and six decades.

12
Handel Davies, conversation with the author, 15 April 1998. Handel Davies was an aerodynamicist and Deputy Director of RAE between 1959 and 1963. He became Technical Director of the British Aircraft Corporation in 1969.

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