

**BRITAIN 1939 – 1945:  
THE ECONOMIC COST OF STRATEGIC  
BOMBING**



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ABSTRACT

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The strategic air offensive against Germany during World War II formed a major part of Britain's wartime military effort and it has subsequently attracted the attention of historians. Despite the attention, historians have paid little attention to the impact of the strategic air offensive on Britain. This thesis attempts to redress this situation by providing an examination of the economic impact on Britain of the offensive. The work puts the economic cost of the offensive into its historical context by describing the strategic air offensive and its intellectual underpinnings. Following this preliminary step, the economic costs are described and quantified across a range of activities using accrual accounting methods. The areas of activity examined include the expansion of the aircraft industry, the cost of individual aircraft types, the cost of constructing airfields, the manufacture and delivery of armaments, petrol and oil, and the recruitment, training and maintenance of the necessary manpower. The findings are that the strategic air offensive cost Britain £2.78 billion, equating to an average cost of £2,911.00 for every operational sortie flown by Bomber Command or £5,914.00 for every Germany civilian killed by aerial bombing. The conclusion reached is the damage inflicted upon Germany by the strategic air offensive imposed a very heavy financial burden on Britain that she could not afford and this burden was a major contributor to Britain's post-war impoverishment.

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## ABBREVIATIONS

AAEE	Aeroplane and Armaments Experimental Establishment
AOC-in-C	Air Officer Commanding in Chief
AS	Anti-Submarine
BBSU	British Bombing Survey Unit
BCATP	British Commonwealth Air Training Plan
CAS	Chief of the Air Staff
CBRM	California Bearing Ratio Method
CFC	Central Flying Control
CIGS	Chief of the Imperial General Staff
C-in-C	Commander in Chief
CNS	Chief of the Naval Staff
CRD	Civilian Repair Depots
EATS	Empire Air Training Scheme
FCO	Flying Control Organisation
FCS	Flying Control Staff
HC	High Capacity
HCU	Heavy Conversion Unit
HE	High Explosive
HMS	His Majesty's Ship
hp	Horse Power
ID	Identification
kW	Kilowatt
LMF	Lack of Moral Fibre
MAP	Ministry of Aircraft Production
MP	Member of Parliament
MPH	Miles Per Hour
NOCOP	No copies to be made
OTU	Operational Training Unit
POL	Petrol Oil and Lubricant
PRO	Public Record Office
RAE	Royal Aircraft Establishment
RAF	Royal Air Force
RAAF	Royal Australian Air Force
RCAF	Royal Canadian Air Force
RN	Royal Navy
RNAS	Royal Naval Air Service
RNZAF	Royal New Zealand Air Force
SAA	Small Arms Ammunition
SAE	Society of American Engineers
SAP	Semi-Armour Piercing
SHAEF	Supreme Headquarters Allied Expeditionary Force
SIGINT	Signals Intelligence

TI	Target Indicator
UK	United Kingdom
US	United States
USA	United States of America
USAAC	United States Army Air Corps
USAAF	United States Army Air Force
USAF	United States Air Force
USSBS	United States Strategic Bombing Survey
WAAF	Women's Auxiliary Air Force

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## *Introduction*

In August 1943, the Prime Minister of Britain, Sir Winston Churchill, advised Clement Atlee, the Deputy Prime Minister, that when dealing with the Royal Air Force (RAF) he should be aware that:

In this case, as in other matters, you will find the whole Air Ministry headed by the Secretary of State for Air will hold together. They consider themselves the salt of the earth and that nothing should be denied them. They are so accustomed to having everything for which they ask that they have forgotten any other services exist in the whole world<sup>1</sup>.

Churchill's advice to Atlee was an early, if somewhat indirect, acknowledgement of the wealth and resources that Britain had committed to conducting air war during World War II. To date, the historical record lacks a well-researched estimate of the financial cost Britain incurred in carrying on an air war between 1939 and 1945. The reasons for this are many, but the most significant is that the wartime accounts are partial and only deal with direct government expenditure. This thesis begins the process of addressing the gap in the historical record by providing an estimate of the financial cost for one part of Britain's air war, the strategic air offensive against Germany.

The strategic air offensive against Germany is the most logical starting point for any estimate of the financial cost of Britain's air war in World War II. The offensive was the longest and largest single air campaign undertaken by Britain

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1 PRO CAB 120/291, NOCOP Minute Prime Minister to Deputy Prime Minister, 6th August 1943.

during the war and it consumed by far the greatest proportion of the resources dedicated to fighting in or from the air. The analysis of the financial cost of the strategic air offensive provided below is a first step in calculating just how much it cost the people of Britain to fight an air war during World War II.

The air war conducted between 1939 and 1945 required a massive expansion of the British aircraft industry, which increased domestic production from 893 aircraft in 1935 to 26,461 aircraft in 1944<sup>2</sup>, a massive 2,963% increase in less than nine years. If this increase in production is measured in terms of the structure weight of the aircraft produced, the increase is an even more massive 10,916%, with production increasing from 1.91 million lbs in 1935 to 208.5 million lbs in 1944<sup>3</sup>. Yet, this extraordinary increase in aircraft production and the British aircraft industry is only one part of the story.

In order to conduct the air war Britain also had to recruit and train over a million men and women to serve in the RAF. Of these men and women, somewhere between 100,000 and 150,000 personnel were required to operate Bomber Command, whilst untold thousands may have been assigned to roles in other organisations closely supporting Bomber Command. The Air Ministry had to pay for the feeding, clothing and accommodating of these men and women. There were further costs as well. Both the aircraft built for Bomber Command and the

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2 Central Statistical Office, *Statistical Digest of the War*, Tables 130-131, Aircraft Production by Main Groups, HMSO, London, 1951, pp.152.

3 Central Statistical Office, *Statistical Digest of the War*, Table 131, Aircraft Production by Structure Weight, HMSO, London, 1951, pp.153.

people who worked within it needed large bases to operate from. Britain had to build these airfields, with their paved runways and taxiways, their hangars, workshops and accommodation. She had to manufacture the bombs and the other ordnance required to inflict injury on the enemy. Finally, she had to find and import the fuel to power all of these aircraft, men and munitions to their targets in Germany and Europe. In February 1944, the Secretary of State for Air, Sir Archibald Sinclair, told the House of Commons that the largest share of the resources dedicated to the air war went to Bomber Command<sup>4</sup>. With very few exceptions, Bomber Command was to be the RAF's main effort throughout World War II and identifying the size of the resources devoted to it is, as has already been said above, the subject matter of this thesis. Given the size of the resources dedicated to the strategic air offensive, it is the contention of this thesis that the economic cost of the strategic air offensive may have contributed to the problems faced by the British economy as it attempted to return to civilian production after World War II.

The seriousness of Britain's economic problems became obvious after the election of the Labour government in 1945. The situation was so bad that in March 1946, Canada quietly cancelled British debts of £101 (\$CAN425) million after Britain had failed to meet her commitments for the Empire Air Training Scheme (EATS)<sup>5</sup>. By the 20<sup>th</sup> January 1947, a British government White Paper

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<sup>4</sup> Sir A. Sinclair, 396, *H.C.Deb.5s*, 29 Feb 44, Column 1275

<sup>5</sup> Rachel L Heide, 'The British Commonwealth Air Training Plan: How Canada's Contribution to the Second World War Affects Us Today', [www.vac-acc.gc.ca/general/sub.cfm?source=history/secondWar/bcatp/page4](http://www.vac-acc.gc.ca/general/sub.cfm?source=history/secondWar/bcatp/page4), 10<sup>th</sup> January 2004

was issued acknowledging the ‘extremely serious’ position of the post-war economy<sup>6</sup>. By March of 1947, Britain the critical state of the British economy forced the new government to inform the United States in a blue diplomatic note that she was incapable of continuing support to Greece and she would be unable to assist the United States in supporting Turkey<sup>7</sup>. The British blue note may have helped prompt the Truman administration to establish the Truman Doctrine and develop the Marshall Plan<sup>8</sup>. Britain’s financial plight drew attention to the fact that her economy had suffered significant damage during the war, perhaps just as much as Germany’s, and that both countries were in danger of economic collapse raising the threat that they would bring the whole of Western Europe’s economy down with them.

Alan Sked and Colin Cook estimate that between 1939 and 1945 Britain lost approximately £7 billion from her national wealth<sup>9</sup>. During that period, total British government spending had amounted to £28.7 billion of which £22.8 billion (79.4 percent) was spent on defence<sup>10</sup>. The analysis in this thesis shows that Bomber Command’s share of the expenditure was at least £2.78 billion. This amount equated to 9.4 percent of total British government spending during World War II and 12.1 percent of her spending on defence during that time.

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6 R.J. Donovan, *The Second Victory: The Marshall Plan and the Post War Revival of Europe*, Madison Books, Boston, 1987, p.21

7 Donovan, *Second Victory*, p.22

8 Donovan, *Second Victory*, p.23

9 A. Sked and C. Cook, *Post-War Britain: a Political History*, Pelican Books, Harmondsworth, 1979, p.27

However, £2.78 billion was equivalent to 46.77 percent of total British government expenditure outside of defence which underlines the size of the government's expenditure on the strategic air offensive against Germany.

The significance of this expenditure also lies in the unfortunate fact that unlike a dockyard, which can manufacture different types of ship or a harbour, which takes both civilian and military vessels, the factories and airfields built for the strategic air offensive were single use assets. In 1945, the aircraft factories, bomber airfields and all of the personnel and services created to operate and sustain them, began the process of decommissioning, closing and scrapping. They were not to contribute to the future economic welfare of the country and subsequently a large proportion of the investment made by Britain in the industries required to supply the strategic air offensive became absolute losses, and as such, they were a significant contribution to the impoverishment of the country.

In analysing the financial costs incurred by Britain in conducting the strategic air offensive, it is important to keep in mind the fact that the wartime accounts put together by the British Treasury were compiled using cash accounting techniques. Such an approach only details the amount of cash spent on an activity and not the opportunity costs associated with the activity. In order to obtain a clearer picture

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10 Central Statistical Office, *Statistical Digest of the War*, Table 173, Central Government Expenditure (Exchequer Issues), p.195.

of the true costs of the strategic air offensive, I have made extensive use of modern accounting practice, particularly the accrual accounting method.

The reason for using an accrual method is that it provides a better evaluation of the total costs incurred in an activity than does the older cost accounting method, which the British Treasury and business used prior to the 1990s. The cash accounting method that was previously used focussed attention on the movement of money into and out of the accounts controlled by business or government entities. It more easily allowed managers and officials to ignore the total cost of an activity; and it encouraged cross-subsidisation<sup>11</sup>. Cross-subsidisation leads to a risk of underestimating the true cost of an activity. It is a contention of this thesis that the financial cost of the strategic air offensive was much higher than previously shown.

Assessing the cost of the strategic air offensive has been difficult due to the lack of consolidated data and the way in which the government accounted for expenditure. This thesis is one of the first works to address the subject of real cost and it does so by conducting a partial cost-benefit analysis of the strategic air offensive using tools from economics and accounting<sup>12</sup>. The tools used to arrive

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11 Cross-subsidisation is where money from one area of an enterprise is used to subsidise the operation of another area. For example; the lowering of the price of electricity supplied to domestic users by charging commercial users a higher price.

12 The cost-benefit analysis being conducted here is concerned solely with the financial costs of the strategic air offensive and not its military or political benefits. The aim of the thesis is to arrive at an estimate of cost only and not to become involved in the arguments over whether the strategic air offensive was worthwhile as a military campaign.

at the cost-benefit analysis include the use of direct and indirect costing methods of evaluating total financial costs incurred. This approach gives a clearer picture of the total financial value of the cost of strategic bombing on Britain. Before looking at the usefulness of this approach, it is necessary to clearly state that the thesis uses the term 'cost' in an economic sense only. 'Costs' is used here as a measure of the strictly financial value of the direct and indirect inputs required to support Bomber Command in the strategic air offensive. Direct cost refers to the price paid for goods and services, whilst indirect costs include the cash value of such things as the loss of shipping tankers used to carry high-octane fuel or the value of agricultural production displaced by Bomber Command's airfields.

The benefit of using this approach is that it provides a more accurate evaluation of the economic impact on Britain of strategic bombing. The cash accounting system used to assemble the British National Accounts did not clearly identify all the costs of an activity and, as has already been pointed out, it encourages cross-subsidisation, which makes it very difficult to identify the real costs of an activity. In the area of British aircraft production, Treasury did not factor in the cost of additional infrastructure or services supplied to manufacturers by the government. Indeed, the manufacturers' prices were unilaterally reduced by Treasury to take into account the grants, loans, goods and some services supplied to the manufacturer at government expense. This had the effect of making British aircraft appear cheaper than they actually were. The accuracy of the costings

were further reduced by the habit of the time which ignored the value of inputs such as transport, government supplied fuel and storage facilities. The overall effect was that the cost of the strategic air offensive is markedly lowered.

This thesis will provide an estimate of the financial cost to Britain of the strategic air offensive that will show that it was much higher than previously thought. The argument propounded here is that the resources consumed by the strategic air offensive against Germany imposed a financial cost on Britain that, whilst fully justified in political and military terms, would adversely affect her standing as an economic power in the post-war period. The importance of identifying the size of the expenditure involved is that it allows a comparison between the economic damage inflicted on both Germany and Britain by the strategic air offensive. The result is a more effective comparison of the usefulness of strategic bombing as an economical means of conducting war. It is worth stating at the outset that the importance of the study does not lie in producing another list of figures showing the size of the resources required to conduct the strategic air offensive. The real importance lies in the potential distortion of the British economy that the size of the investment in strategic bombing may have caused. This distortion may help in explaining Britain's poor economic performance in the decades following the end of the war.

In analysing the financial cost of the strategic air offensive, the first step is to describe the conduct of the strategic air offensive. This is the point of Chapter

One, 'The Strategic Air Offensive 1939 to 1945'. Chapter One provides a chronological description of the offensive so that the expenditure made by the British government is seen within the historical context of wartime military operations. The description covers the three stages covering of the offensive consisting of the initial period extending from September 1939 until February 1942; the period of increasing weight of attack from February 1942 until June 1944; and the Crescendo of the campaign between June 1944 and May 1945. The purpose of the chapter is to outline the conduct of the strategic air offensive and to lay out before the reader the military situation to which Britain was responding.

Following this description of the offensive, Chapter Two, 'Air Mindedness and the Development of a British Theory of Air Warfare', examines the intellectual underpinnings of Britain's strategic air offensive against Germany. The chronology extends from the late Victorian period, when imaginative writers such as H.G. Wells began to produce books and articles describing the joys and horrors of aircraft flight, to the end of World War II. Based on the analysis of documents on British air power theory, which finds little evidence of a critical evaluation of strategic bombing, chapter two will argue that the mood created by writers like Wells had a much greater effect on British thinking on air power than the more rigorous military thinking portrayed by men such as Douhet and Mitchell. The evidence supports the belief that British thinking on air power was more of a blind faith in the effectiveness of technology than any rigorously reasoned theory.

The analysis of British thinking during the period 1900 to 1945 shows a notable lack of rigour in the consideration of the effectiveness of strategic bombing. The government, Parliament, Air Ministry and the RAF, the aircraft industry and the public all assumed that bombing by aircraft would result in a catastrophic outcome for civilised life in cities. The reasons for these assumptions were manifold, however the desire of the Air Ministry and the RAF to bolster their position and their prospects of increased government funding appear to have led to an over-emphasis on the dangers of letting potential enemies become more powerful in the air.

The claims that there was a lack of rigor in the evaluation of strategic bombing is supported by the behaviour of the RAF during the 1930s, when evidence showing that bombing may be more difficult than expected was deliberately ignored or downplayed. When the air exercises demonstrated that bomber formations would suffer severe casualties during attacks on London, the umpires reversed the results on the basis that the bombers were attacking and the fighters were not. These early indications of the vulnerability of bombers, which came before radar, should have induced some reassessment of the viability of bomber attacks, however, there are no indications that such a reassessment occurred. The result was that as Britain faced the growing threat of war in the late 1930s, an unfounded fear of strategic bombing unduly influenced the government and reinforced the appeal of appeasement. In 1941, Sir Winston Churchill levelled such an accusation, charging that the Air Ministry and Air Staff had undermined the determination of

the pre-war governments to resist Nazi expansion 'by the pictures they painted of the destruction that would be wrought by air raids'<sup>13</sup>.

Amongst the leading advocates of the effectiveness of air power were the aircraft manufacturers who hoped to build the advanced bombers necessary to conduct the proposed strategic air offensives. The way in which the British aircraft industry developed and the effectiveness of its operations from 1920 till 1945 are examined in Chapter Three, 'The British Aircraft Industry'. The comparative analysis of the technological and commercial activities of the British aircraft industry clearly showed that Britain's interwar aircraft industry was a large and vibrant industry that dominated the world by insinuating itself into the fabric of foreign aircraft industries.

The analysis conducted in Chapter Three demonstrates that Britain's aircraft industry relied on an aggressive programme of developing joint ventures within overseas markets rather than attempting to export domestically-produced aircraft and aircraft components to these markets. Any attempt to build their businesses through simple exporting would have failed in the face of the trade barriers erected by foreign governments to protect their own nascent aircraft industries. The British aircraft firms used licensing agreements and joint ventures with foreign governments and aircraft companies to get around these barriers.

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13 PRO CAB 120/300, Minute Churchill to CAS, 7th October 1941. In the original minute draft Churchill had originally used the word 'terrified' but replaced it with depressed.

What appears to have made the British attractive to foreigners was the promise of technological transfer. The British aircraft firms' willingness to enter joint ventures or to license foreign companies to produce British designed aircraft made them attractive to foreign governments wishing to quickly create their own aircraft industries for reasons of national security or prestige. The commercial benefit to the British aircraft companies was that they collected royalties on these technologies and techniques or made profits through their joint venture arrangements. The only apparent loser in the arrangement appears to have been the British taxpayer who funded the aeronautical research and design that the firms were then exporting for profit.

The analysis of the interwar British aircraft industry shows that it was strong, technologically proficient and commercially and politically astute. This is contrary to the more widely accepted view of the industry as being technically backward, relative to the American industry, and commercially dependent upon Air Ministry orders. This latter view arises from basing the analysis of the British aircraft industry on the measurement of domestic production without taking into account, as this thesis does, the wider international commercial activities of Britain's aircraft firms. The final part of Chapter Three focuses on the extent of government financing needed to fund the extension of factories and plant in the aircraft industry to meet the demands of war. Estimating the extent of this funding is essential to establishing the true costs of aircraft used by Britain in the strategic air offensive, as the British government reduced the price paid to reflect

the extent of their investment in expanding the manufacturing capability of the individual firms involved.

Chapter Four, 'The Aircraft of the Strategic Air Offensive', deals with the costing of the fifteen aircraft types that Bomber Command used during World War II. It describes the various aircraft and identifies the cost of their production before combining all of these to produce an overall figure. The most important finding made in this analysis was that the price paid by the British government for British aircraft and aircraft components was substantially below that paid by the British or American governments for equivalent American products. The best example of this price differential is shown by a comparison of the prices paid for a Merlin engines manufactured by the American company Packard as against that paid for one made by Rolls Royce. The Packard variant of the engine was more than twice as expensive as the Rolls Royce version. My analysis of the discrepancy suggests that the American price represented the true cost of production plus profit, whereas the British price had deductions made to offset government loans and investment in plant and equipment for Rolls Royce.

The suspicion that the cost of British aircraft production was consistently underestimated is further supported by comparing the price of similar American and British aircraft types. For example, Boeing's B-17 and the A.V. Roe's Lancaster were similar aircraft but the price of the B-17 was more than twice that of its British counterpart. This discrepancy cannot be explained by profiteering or a lack of efficiency on the part of Boeing. Most likely it is due to the price of the

Boeing aircraft being a more realistic appraisal of the true cost of production.

This is further evidence that the cost of British aircraft has been consistently understated making them appear cheaper than they were. From the analysis here, it appears that the price data in the MAP price books is not dependable when it comes to evaluating the true cost of an aircraft and the evaluation of the government's investment in factories and plant. The analysis in Chapter Three offers essential data which will assist in correcting this problem.

The aircraft, which Britain built at such great cost, were part of a wider production campaign in infrastructure, petroleum and armaments. In Chapter Five, entitled 'Airfields', the construction of airfields is described and the cost identified. The construction effort required to provide Bomber Command with enough all-weather airfields stands as one of the greatest works of civil engineering in British history. In size and scope the airfield construction programme of World War II rivals the building of the canals, railways and roads that now cover the nation. The fundamental differences between Bomber Command's airfields and Britain's canals, railways and roads is that the former were built in a period of five years and, with a handful of exceptions, were only ever used during the strategic air offensive. The cost to provide Bomber Command with airfields is estimated here as being at least £193.95 million, which is little short of the £212.7 million that Britain spent on providing factories and plant for bomber production. This makes the provision of airfields one of the more expensive undertakings during World War II.

Construction of so many airfields in such a small space as the British Isles provided did not just involve a massive effort but it imposed a level of logistical complexity. In constructing airfields sites had to be surveyed, land cleared and levelled, drainage and conduits for communication systems laid, tarmac and concrete laid and buildings constructed. The job of building these airfields required the recruitment of a large workforce, and the movement by road of enormous quantities of soil, fill and cement to and from the work sites. It also included detailed surveying to ensure that the maximum number of usable airfields were crammed into the available usable space. In this thesis, for the first time, the indirect costs of building airfields are included in the calculations. Amongst the most notable of these indirect costs are the opportunity costs of the value of the crops lost as airfields covered arable land. The work in this chapter provides an insight into the wider economic impact of Bomber Command's operations and adds to an understanding of just how expensive it was to conduct the bomber offensive.

Another area of major expenses was that of petroleum production, which is the subject covered by Chapter Six, titled 'Petrol, Oil and Lubricants'. This chapter describes the extensive programme of works undertaken to provide Britain and the Allies with supplies of high-octane petrol and other petroleum products. The chapter examines Britain's unsuccessful attempts to develop her own high-grade petroleum industry and it describes how America underwrote the lion's share of the cost required to provide petroleum products to the Allied war effort. In assessing the costs of petroleum to the strategic air offensive, the analysis in this

chapter is unique, in that it takes into account indirect costs of the loss of petroleum and tankers at sea. The chapter covers an area of endeavour that has received little attention in the history of the offensive and attempts to show that ensuring access to high-grade fuels was a major cost to Britain and the United States.

Chapter Seven, 'Armaments', analyses the cost of the bombs and pyrotechnics dropped by Bomber Command during World War II. Surprisingly, this is a subject which does not seem to have received much attention in the history of the strategic bombing campaign. The most important finding in this area is that the historical record indicates that there were substantial on-going problems with failure rates in British aerial bombs. The indications are that many aerial bombs actually blew up prematurely, that is in the air, and many others failed to detonate after hitting the ground. The significance of this finding is that the failure of a bomb negates the entire effort that went into getting it to its target. That is all of the investment in factories, plant, airfields armaments factories, fuel and manpower is lost if the bomb does not function. In Chapter Seven, the evidence suggests that a high proportion of bombs failed. It is hoped that the preliminary findings on the failure rates in this chapter will prompt further research into the subject of aerial armaments used during World War II, as it is important to evaluate the impact of faulty weapons, particularly fuses, on the effectiveness of British strategic bombing.

The final chapter, 'Manning the Offensive', describes and analyses the cost of manpower in the strategic air offensive. It focuses on identifying the costs associated with the individual activities including recruitment, selection, training, accommodation and feeding and clothing the people who served in Bomber Command during the war. The analysis also identifies the size of Bomber Command during the war and confirms the number of aircrew as having served in it as being approximately 125,000, the figure which has been widely accepted. The analysis of cost in this area shows that manpower was the second highest cost after the cost of buying aircraft and investing in the aircraft industry. However, the costs identified here are conservative and it is likely that manpower may have been the highest cost, especially as no account could be made of those personnel serving in other RAF commands who were fully committed to directly supporting the strategic air offensive.

My analysis of the cost of the strategic air offensive is a continuation of the historical examination that began in the years immediately following the end of the war. A detailed survey of this history prefaces the analysis in each chapter. However, it is important, briefly, to discuss some of the more important sources which I have used in the study overall. Of these works, the foundation stone was the Statistical Digest of the War, compiled by the Central Statistical Office of the War Cabinet Secretariat. The information collected in the 193 tables is the most reliable available on Britain's economic and industrial activity during World War II and it is essential to any study of British economic history during this period.

The next most important work is Sir Arthur Harris's official despatch on Bomber Command's operations<sup>14</sup>. Harris's despatch is a very important source for this thesis. It is an official report written by Harris's staff at High Wycombe and it covers all aspects of the strategic air offensive against Germany from the point of view of those who conducted that offensive<sup>15</sup>. The *Despatch on War Operations* has its limitations, amongst which is a complete disregard for everything that occurred within Bomber Command prior to Harris's taking command in February 1942. The effect of this is that much of the history of the strategic air offensive appears to accept that the initial period of the strategic air offensive, that is the period before February 1942, is not really part of the offensive. A major purpose of this thesis is to show that the strategic air offensive described by Harris could only have occurred in 1942, when all of the resources such as aircraft, aerodromes and men, became available.

Sir Arthur Harris also wrote the third important source used here. In 1947, Harris published his unofficial record of the campaign, *Bomber Offensive*<sup>16</sup>. The book was one of a number written by senior officers of the RAF or by others closely involved with the strategic air offensive. The importance of Harris's book is that it set much of the tone for the other books written by authors who were prominent actors in the drama of the air offensive. Harris's own Senior Staff Officer at

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14 Sir A. Harris, *Despatch on War Operations 23rd February 1942 to 8th May 1945*, Frank Cass and HMSO, London, 1995

15 H. Probert, *Bomber Harris His Life and Times: The Biography of marshal of the Royal Air Force Sir Arthur Harris, The Wartime Chief of Bomber Command*, Greenhill Books, London, 2001, pp.353-354,

16 Sir A. Harris, *Bomber Offensive*, Greenhill Books, London, 1998

Bomber Command, Sir Robert Saundby, produced a history of strategic bombing<sup>17</sup>, while Sir John Slessor<sup>18</sup> and Lord Tedder<sup>19</sup> produced memoirs<sup>20</sup>. Sir Winston Churchill, P.M.S. Blackett<sup>21</sup>, G. Bulman<sup>22</sup>, Sir Alex Cairncross<sup>23</sup>, Ely Devons<sup>24</sup>, Roy Fedden<sup>25</sup> and Solly Zuckerman<sup>26</sup> also produced works that dealt in part with the air offensive. Many of these authors, particularly those such as Harris, Saundby, Tedder and Zuckerman, expressed strong and often contrary opinions on the way in which the RAF conducted the strategic air offensive. They have continued the wartime debates and disputes in their post war writings. In light of this debate, it is necessary to be careful to be aware of their potential biases when using these sources. This qualification aside, these sources are important in any work on the strategic air offensive against Germany

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- 17 R. Saundby, *Air Bombardment: The Story of its Development*, Chatto and Windus, London, 1961
  - 18 Sir John Slessor, Marshal of the Royal Air Force who served as the Air Officer Commanding 5 Group Bomber (Apr 1941 to May 42), the Air Officer Commanding in Chief Coastal Command (Feb 43 to Jan 44) and Deputy Air Commander in Chief Mediterranean Allied Air Forces (Jan 44 to Apr 45). See [www.rafweb.org/Biographies/Slessor.htm](http://www.rafweb.org/Biographies/Slessor.htm)
  - 19 Lord Arthur Tedder, Marshal of the Royal Air Force who served as Air Officer Commanding in Chief RAF Middle East (Jun 41 to Feb 42), Air C-in-C Mediterranean Air Command and Mediterranean Allied Air forces (Feb 42 to Jan 44) and Air C-in-C and Deputy Supreme Allied Commander, SHAEF (Jan 44 to Jan 46). See [www.rafweb.org/Biographies/Tedder.htm](http://www.rafweb.org/Biographies/Tedder.htm)
  - 20 Sir John Slessor, *The Central Blue: Recollections and Reflections*, Cassell, London, 1956; Lord Tedder, *With Prejudice: The War Memoirs of Marshal of the Royal Air Force Lord Tedder*, Cassell and Company, London, 1966
  - 21 P.M.S. Blackett, *Fear, War, and the Bomb: Military and Political Consequences of Atomic Energy*, Whittlesea House, McGraw Hill, New York, 1948
  - 22 G. Bulman, *An Account of Partnership-Industry, Government and The Aero-engine*, Rolls Royce Heritage Trust, Derby, 2002
  - 23 Sir A. Cairncross, *Planning In Wartime: Aircraft Production In Britain, Germany And The USA*, Macmillan, London, 1991
  - 24 E. Devons, *Planning in Practice: Essays in Aircraft Planning in War-Time*, Cambridge University Press, 1950
  - 25 Sir R. Fedden, *Britain's Air Survival: An Appraisal and Strategy for Success*, Cassell and Co., London, 1957

A further group of works of high significance are the official histories, of which William Hornby's excellent *Factories and Plant* provides the best detail on the economic activity underpinning the strategic air offensive<sup>27</sup>. In describing the provision of factories and plant by the British Government to private industry, Hornby ranges across all of the industrial sectors of interest to this thesis. The other official histories, W.K. Hancock's and M. Gowing's *British War Production*, Richard Sayers, *Financial Policy 1939-45*<sup>28</sup> and Peter Inman's, *Labour in the Munitions Industries*<sup>29</sup> and *The Design and Development of Weapons*, co-authored by M. Postan, D. Hay and J.D. Scott<sup>30</sup>, all provide some detail. The lack of footnotes is a drawback in all of these histories but they are essential reading for anyone working on the British wartime economy.

The next most important official history was the official history of the military campaign written by Sir Charles Webster and Noble Frankland<sup>31</sup>. The first volume of this work provides a detailed description of Britain's preparations for the strategic air offensive. The most important contribution made by Webster and Frankland is the detailed description they make of the offensive and the way in which it changed as more and more resources became available. The work of

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26 S. Zuckerman, *From Apes to Warlords*, Collins, London, 1988

27 W. Hornby, *Factories and Plant*, HMSO and Longmans Green, London, 1958

28 R. Sayers, *Financial Policy 1939-1945*, 1939-1945, HMSO and Longmans Green, London, 1956

29 P. Inman, *Labour in the Munitions Industries*, HMSO and Longmans Green, London, 1957

30 M. Postan, D. Hay and J.D. Scott, *Design and Development of Weapons: Studies in Governmental and Industrial Organisation*, HMSO, London, 1964, pp. 1-228

Webster and Frankland has been expanded on by a large number of authors who have written on the military aspects of strategic bombing.

One of the most useful modern works is *The Bomber Command War Diaries*, written by Martin Middlebrook and Chris Everitt<sup>32</sup>. The book is a compilation of all of Bomber Commands' operational records on flights during the war. It has been organised to provide the reader with a clear and concise record of each operational sortie, the reasons for it and the outcomes as well. The detailed information that Middlebrook and Everitt offer provides researchers of the offensive with a valuable resource allowing precise calculations of activity. Other useful sources include the works of Richard Overy<sup>33</sup>, Sebastian Ritchie<sup>34</sup>, David Edgerton<sup>35</sup> and Erik Lund<sup>36</sup>.

In researching this thesis, the most important archives, not surprisingly, were those held by the Public Record Office at Kew in London. However, use was

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- 31 Sir C. Webster and N. Frankland, *The Strategic Air Offensive Against Germany, 1939-1945*, HMSO, London, 1961
  - 32 M. Middlebrook and C. Everitt, *Bomber Command War Diaries: An Operational Reference Book, 1939-1945*, Midland Publishing, Hinckley, Leicester, 1995
  - 33 R.J. Overy, *The Air War 1939-45*, Europa Publications, London, 1980; *William Morris: Viscount Nuffield*, Europa Publications, London, 1976, *Goering: The Iron Man*, Routledge and Kegan Paul, London, 1984; *The Road to War*, London, 1989; *Why the Allies Won*, Jonathon Cape, London, 1995; *Bomber Command 1939-45*, Harper Collins, London, 1997; and 'The German pre-War Aircraft Production Plans: November 1936-April 1939', *English Historical Review*, Vol. 90, 1975
  - 34 S. Ritchie, *Industry and Air Power: The Expansion of British Aircraft Production, 1935-1941*, Frank Cass, London, 1997, also see S. Ritchie, 'A New Audit of War: The Productivity of Britain's Wartime Aircraft Industry Reconsidered', *War and Society*, Vol. 12, No. 1, May 1994, pp. 125-147.
  - 35 Edgerton, *England And The Aeroplane: An Essay On A Militant And Technological Nation*, Macmillan And Centre For The History Of Science, Technology And Medicine, University Of Manchester, Macmillan, London, 1991.

made of materials held by British Petroleum in their archives at BP House in London. These files provided most of the detailed information on petroleum prices and the shipping costs involved for British companies dealing with American suppliers of high-octane fuels. The Churchill Archives Centre at Churchill College, Cambridge holds many documents of interest including the papers of Sydney Bufton, the wartime Director of Bomber Operations at the Air Ministry. Finally, much use has been made of the electronic archive of the Franklin Delano Roosevelt Library and Museum at Marist University, New York<sup>37</sup>.

The purpose of this thesis is to analyse the financial cost of the strategic air offensive against Germany in order to provide a starting point for future work on the impact of World War II on Britain's subsequent economic performance. Understanding the impact of the strategic air offensive on Britain is important in analysing the contribution the offensive made to Allied victory. Today, there is no clear agreement on the value of Bomber Command's contribution to Allied victory over Germany in 1945, in spite of there having been almost no evaluation of the economic price paid by Britain to carry out the offensive. This thesis provides an appraisal of the financial cost involved in providing the factories, aircraft, airfields, manpower and other resources required by the strategic air offensive in an attempt to quantify the economic cost of the strategic air offensive against Germany. The

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36 E. Lund, 'The Industrial History of Strategy: Re-evaluating the Wartime Record of the British Aviation Industry in Comparative Perspective', 1919-1945, *The Journal of Military History*, Society for Military History, Lexington VA, 1998, pp. 75-99.

37 <http://www.fdrlibrary.marist.edu>, 12th June 2003.

investment demanded by the strategic air offensive ensured that its consequences would be serious for both Germany and Britain. A great deal of historical research has gone into measuring the impact of strategic bombing on Germany but almost no attention has been paid to the impact in Britain. This thesis begins the work of evaluating both sides of the strategic air offensive against Germany so that its true value can be more reliably ascertained.

## *Chapter 1*

### THE STRATEGIC AIR OFFENSIVE

In 1934, Sir Edward Ellington told his colleagues on the Chiefs-of-Staff Committee that victory in the next European war would go to the nation that could most quickly launch heavy and sustained air attacks on its opponents. Sir Edward described how hostilities would open with a series of heavy bombing attacks on the capital cities of the belligerents within the first 24 hours. These attacks would continue for four or five weeks until both sides became exhausted. The victory would go to the side that had the reserves to recover and regroup more quickly to bomb their defenceless opponent into submission<sup>1</sup>. When the next European war came in 1939, neither side would have the air power necessary to conduct such rapid and large-scale attacks and it would take the RAF two and a half years to build up the forces and infrastructure necessary to begin and sustain such a campaign. It would take another two and a half years and the defeat of the German armies on the ground by the combined armies of Britain, the Soviet Union and the United States before Germany would be defeated.

At first glance, there is a marked similarity between Sir Edward Ellington's description of strategic air warfare and the vision first proposed by General Giulio Douhet. Douhet was an early advocate of strategic air warfare and, unlike many of his contemporaries, he was an unapologetic advocate of using unrestricted

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1 N.H. Gibbs, *Grand Strategy*, History of the Second World War, Military Series, Vol 1, HMSO, London, 1956-1976, p.590.

bombing to induce terror in an enemy civilian population by killing and maiming undefended civilians. Despite the superficial similarities, the British advocates of strategic bombing were not as radical as Douhet.

The differences between Douhet's vision and the aspirations of the RAF are clearly shown in the minutes of a conference held in Sir Hugh Trenchard's office at the Air Ministry in July 1923<sup>2</sup>. At this conference, Trenchard, the Chief of the Air Staff (CAS) discussed the legitimacy of strategic bombing as a means of conducting war. The CAS is minuted as stating that 'factories in which war material (including aircraft) is made' constituted a legitimate target for air attack because the rules of armed conflict already allowed armies and naval forces to bombard defended cities and ports, even if such bombardment inflicted unintended civilian casualties<sup>3</sup>. However, Trenchard clearly enunciated that the 'indiscriminate bombing of a city for the sole purpose of terrorising the civilian population' was 'illegitimate and contrary to the dictates of humanity'<sup>4</sup>. For the RAF, attacking a factory was not equivalent to attacking a population. Terrorising munitions workers into not going to work 'was an entirely different matter' from simply bombing civilians in their homes<sup>5</sup>. Although the distinction was to be more theoretical than practical, the RAF initially attempted to confine its attacks to identified military targets, whether they were munitions factories,

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<sup>2</sup> Sir Charles Webster and Noble Frankland, *The Strategic Air Offensive Against Germany*, Vol. IV, pp. 66-73

<sup>3</sup> Sir Charles Webster and Noble Frankland, *The Strategic Air Offensive Against Germany*, Vol. IV, p. 73

<sup>4</sup> Sir Charles Webster and Noble Frankland, *The Strategic Air Offensive Against Germany*, Vol. IV, p. 73

<sup>5</sup> Sir Charles Webster and Noble Frankland, *The Strategic Air Offensive Against Germany*, Vol. IV, pp. 66-73

docks or military establishments. The strategic air offensive that the British Air Staff planned was not intended to carry out Douhet's vision.

This chapter describes the strategic air offensive conducted by Bomber Command during World War II in order to set the economic cost of the offensive into its military and political context. As such, this chapter will not provide a detailed analysis of the military or political effectiveness or otherwise of the strategic air offensive or its outcomes. As a result, the description of the offensive is chronological and divided into three stages with stage one being from 3<sup>rd</sup> September 1939 to 1<sup>st</sup> January 1942, stage two from 1<sup>st</sup> January 1942 to 6<sup>th</sup> June 1944, and stage three 6<sup>th</sup> June 1944 to 18<sup>th</sup> May 1945.

One of the most notable things about the history of the strategic air offensive is just how influential the earliest sources are. The sources in question are Sir Arthur Harris's *The Despatch of War Operations*<sup>6</sup>, 1945, The United States Strategic Bombing Survey (USSBS), reports of 1945 and 1947<sup>7</sup>, Sir Arthur Harris's 1947 book, *Bomber Offensive* and the British Bombing Survey Unit's, 1946 report, *The Strategic Air War Against Germany, 1939-1945*<sup>8</sup>. The significance of these sources lies in the fact that they were written by individuals

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6 Sir A. Harris, *Despatch on War Operations, 23rd February 1942 to 8th May 1945*, Frank Cass, London, 1995. Although only published in 1995 this document was available to the official historians, Sir Charles Webster and Noble Frankland.

7 United States Strategic Bombing Survey, 'Summary Report (European War)', 30th September 1945, and 'Overall Report 'The Effects of Strategic Bombing on the German War Economy'', *United States Strategic Bombing Survey* 31st October 1945 and 'Area Studies Division Report' January 1947, published by Garland, New York, 1976

8 British Bombing Survey Unit, *The Strategic Air War Against Germany 1939-1945: Report of the British Bombing Survey Unit*, Frank Cass, London, 1998

who had first hand experience of the strategic air offensive, either as senior officers like Air Marshal Harris, or as official researchers of the offensive. Adding to their importance is the fact that the official historians of the strategic air offensive, Sir Charles Webster and Noble Frankland, drew upon them when they wrote *The Strategic Air Offensive against Germany, 1939-1945*<sup>9</sup>. The central role played by the official history in much of the subsequent writing and research further increased the influence of these early sources.

Despite the heavy reliance of the official historians on the early sources, the official history they produced was controversial. Many ex-RAF officers and Air Ministry officials expressed reservations over the description of the air offensive. Senior officers, including Lord Portal, Sir Arthur Harris and Sir Robert Saundby, believed that the Air Ministry and the RAF should have had editorial control over the history. The story of the internal battles that raged around the publication of the official histories are well described in Noble Frankland's 1998 book, *History at War*<sup>10</sup>. Such was the angst that Air Chief Marshal Sir Richard Peirse, who commanded Bomber Command from 1940 to January 1942, threatened to sue the authors for defamation. Lord Portal, CAS from 1941 until 1945, was furious that, contrary to the accepted practice in British official histories of not naming officials, *The Strategic Air Offensive Against Germany*, openly used his demi-official correspondence with Air Chief Marshal Sir Arthur Harris.

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9 Sir C. Webster and N. Frankland, *The Strategic Air Offensive Against Germany, 1939-1945*, HMSO, London, 1961

10 N. Frankland, *History at War*, Giles de la Mare, London, 1998

Another senior officer, Air Chief Marshal Sir Robert Saundby, who had served as Harris's Senior Air Staff Officer (SASO) in Bomber Command, launched a sustained and determined attack on the official history in an attempt to have it changed. Amongst the changes, he wanted the official history to attribute some blame for Bomber Command's early ineffectiveness in 1940 to 'frugality by Treasury' and the 'loss of territory in Northern France'<sup>11</sup> and he wanted the 'Battle of Berlin', rewritten to show it as a draw rather than a British defeat. Both Saundby and Portal attempted to have the authors remove all reference to Portal's failure to force Harris to comply with his orders in 1944<sup>12</sup>. Harris himself claimed that he wanted nothing to do with the official history believing that the Air Ministry should have maintained tighter control over the history. All in all, the sustained criticism of Webster and Frankland's work have served to provide it with an aura of historical legitimacy that it may not have otherwise won.

Other early writers who dealt with the strategic air offensive included P.M.S. Blackett who wrote *Fear, War, and the Bomb*, in 1948<sup>13</sup>. Professor Blackett, the winner of the 1948 Nobel Prize for his work in physics and nuclear research, provided a critique of the strategic air offensive as part of his argument against the use of nuclear weapons in war. Blackett's book, unlike the official histories or Harris's memoir provides footnotes and a bibliography, which cite a number of

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11 Frankland, *History at War*, p.100

12 Frankland, *History at War*, pp. 99-101

other useful contemporary works including the United Strategic Bombing Survey's reports.

Another important source is Sir Winston Churchill's six-volume wartime memoir, *The Second World War*, published between 1948 -1954<sup>14</sup>. Although Churchill's work needs to be treated with care, it provides a useful insight into his view of the events in which he was intimately involved. Churchill, one of the most significant figures of World War II, provides a frank description of how he responded to these events and to the decisions made by his government<sup>15</sup>. Despite the fact that Churchill's work is self-serving, it remains an important source on the inner workings of the British Government and the mind-set of its leader during the war.

Other important offerings include the official history, *The Royal Air Force*, written in 1953 and 1954 by Denis Richards and Hilary St. George Saunders<sup>16</sup>, and John Herington's official Australian history of the war, *Air-War against Germany and Italy 1939-43*<sup>17</sup>, published in 1954 and *Air Power over Europe*<sup>18</sup>,

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13 P.M.S. Blackett, *Fear, War, and the Bomb: Military and Political Consequences of Atomic Energy*, Whittlesea House, McGraw Hill, New York, 1948

14 Sir W. Churchill, *The Grand Alliance*, The Second World War, Vol. III, Cassell and Company, London, 1950

15 cf. Churchill's inclusion of his Action this Day minute M.843/1 registered in PRO CAB 120/339 and reproduced in *The Grand Alliance*, p.635

16 D. Richards and H. St George Saunders, *The Royal Air Force*, Vol I and Vol II, HMSO, London, 1953-1954

17 J. Herington, *Australia in the War of 1939-1945, Air, Air-War Against Germany and Italy 1939-43*, Australian War Memorial, 1954

18 J. Herington, *Australia in the War of 1939-1945, Air, Air Power Over Europe*, 1943-1945, Australian War Memorial, 1963

which appeared in 1963. Herington's works are very useful in that they provide a more detached view of the strategic air offensive and the problems it encountered.

A large number of other general histories have followed. The most prolific writer on the air offensive has been Martin Middlebrook whose works include *The Nuremberg Raid*<sup>19</sup>, (1973), *The Battle of Hamburg*<sup>20</sup>, (1980), *The Peenemünde Raid*<sup>21</sup>, (1982), *The Berlin Raids*<sup>22</sup>, (1988) and the valuable reference book co-authored with Chris Everitt, *The Bomber Command War Diaries*, (1995)<sup>23</sup>. The latter has provided much of the raw data used in this thesis to calculate fuel usage and other operational activity. Dennis Richards, who wrote a sympathetic biography of Lord Portal, *Portal of Hungerford*, (1977) produced a 1994 history of Bomber Command in the Second World War called, *The Hardest Victory*, (1994)<sup>24</sup>.

A final authority on the strategic bomber offensive is the academic historian Richard Overy, who has written a number of significant works on the strategic air offensive. The first was a comparative analysis of the relative efficiency of the

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19 M. Middlebrook, *The Nuremberg Raid*, Allen Lane, London, 1973

20 M. Middlebrook, *The Battle of Hamburg*, Allen Lane, London, 1980

21 M. Middlebrook, *The Peenemünde Raid*, Allen Lane, London, 1982

22 M. Middlebrook, *The Berlin Raids: RAF Bomber Command, Winter 1943-44*, Viking Books, London, 1988

23 M. Middlebrook and C. Everitt, *Bomber Command War Diaries: An Operational Reference Book, 1939-1945*, Midland Publishing, Hinckley, Leicester, 1995

24 D. Richards, *Portal of Hungerford: Life of Marshal of the Royal Air Force Viscount Portal of Hungerford, KG, GCB, OM, DSO, MC*, Heinemann, London, 1977 and *The Hardest Victory: RAF Bomber Command in the Second World War*, Hodder & Stoughton, London, 1994

aircraft industries of Britain, Germany, Italy Japan and the United States during WW II. The book, *The Air War, 1939-1945*<sup>25</sup>, published in 1980, was one of the first to challenge the idea that the British aircraft industry was less efficient than its German or United States counterparts. Overy has followed it with *War and Economy in the Third Reich*<sup>26</sup>, (1991), *Why the Allies Won*<sup>27</sup>, (1995) and *Bomber Command, 1939-1945*<sup>28</sup>, (1997). The latter work provides a useful analysis of the achievements of the strategic air offensive.

### **The Beginnings - 3<sup>rd</sup> September 1939 to 23<sup>rd</sup> February 1942**

The initial phase of Bomber Command's war lasted from 3<sup>rd</sup> September 1939 until 23<sup>rd</sup> February 1942, when Sir Arthur Harris took command of the organisation. Bomber Command started the war as a small force of approximately 26,000 men, operating from 27 airfields<sup>29</sup>. On average, this small force launched seven sorties and dropped an average 52.7 tons of bombs per day against selected targets. Over the entire period, Bomber Command launched 58,381 sorties over 903.5 days and dropped 47,660 tons of bombs on a range of targets in France, the Low Countries and Germany<sup>30</sup>.

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25 R. Overy, *The Air War, 1939-1945*, Europa, London, 1980

26 R. Overy, *War and Economy in the Third Reich*, Oxford University Press, Oxford, 1991

27 R. Overy, *Why the Allies Won*, Pimlico Press, London, 1995

28 R. Overy, *Bomber Command, 1939-1945*, Harper Collins, London, 1997

29 Sir A. Harris, *Despatch on War Operations, 23rd February 1942 to 8th May 1945*, HMSO and Frank Cass, London, 1995, p153

30 Daily sortie rate calculated from data in Middlebrook and Everitt, *Bomber Command War Diaries*, Midland Publishing, Leicester, 1996

Bomber Command carried out its first operation on 3<sup>rd</sup> September 1939 when one Blenheim, nine Wellingtons and 18 Hampdens, were sent to look for German warships near the German coast. It was during this operation that Blenheim, N6215, crewed by Flying Officer A. McPherson, Commander Thompson RN and Corporal V. Arrowsmith, became the first British aircraft to fly over Germany during World War II<sup>31</sup>. On the following day, 4<sup>th</sup> September, 15 Blenheims and 14 Wellingtons attacked shipping at Wilhelmshaven and Brünsbuttel<sup>32</sup>. Of the 29 aircraft despatched, ten Blenheims and nine Wellingtons found their targets. Light damage was inflicted on the German Battle cruiser, *Admiral Sheer*, which was hit by three bombs, all of which failed to explode. The only damage inflicted was on *Emden*, when a Blenheim crashed onto it<sup>33</sup>. Two Danish civilians died when the Danish town of Esbjerg, 110 miles north of Brünsbuttel, was accidentally bombed<sup>34</sup>. British losses included five Blenheims and two Wellingtons shot down<sup>35</sup>.

This operation brought into sharp relief many of the problems that would afflict the strategic air offensive. Even though these early attacks occurred in daylight, navigational difficulties, poor bombing accuracy, failure of bombs and heavy losses amongst the attacking bomber aircraft were apparent. This first raid set a precedent that would continue for much of the subsequent offensive until the

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31 Middlebrook and Everitt, *Bomber Command War Diaries*, p.21

32 Middlebrook and Everitt, *Bomber Command War Diaries*, pp. 22-23

33 Middlebrook and Everitt, *Bomber Command War Diaries*, pp. 22-23

34 Middlebrook and Everitt, *Bomber Command War Diaries*, pp. 22-23

35 Middlebrook and Everitt, *Bomber Command War Diaries*, pp. 22-23

introduction of electronic navigational devices, such as GEE and H<sub>2</sub>S in 1942 and 1943, and the destruction of the German defences in late 1944.

A further problem shown up by these early raids was the unreliability of British bombs. This problem would remain unsolved at the end of the war and the high failure rates that were to persist may have greatly reduced the overall effectiveness of the strategic air offensive. The raid showed that a bomber attack designed to avoid civilian deaths could kill civilians in a neutral country over 100 miles away from the target. Finally, the operation indicated that, despite pre-war hopes, local air defences could inflict high casualty rates upon attacking bomber forces.

Take for example the attack on September 4<sup>th</sup> 1939. The seven aircraft lost during the attack constituted 23.3 percent of the total Bomber Command sorties for that day<sup>36</sup>. Calculating losses as a percentage of total daily operational flights was a useful management tool for working out attrition rates for the force. A side effect of this method of calculating losses was that it produced lower casualty ratios. For example, on the 4<sup>th</sup> September 1939, of the 30 aircraft sorties conducted 29 were against the targets at Wilhelmshaven and Brünsbuttel. The loss rate from the 29 attacking aircraft is marginally higher at 24.1 percent. If the casualty ratio is restricted to the 19 aircraft that arrived near Wilhelmshaven and Brünsbuttel, where they were subject to direct enemy attack, the seven lost aircraft constituted

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36 Middlebrook and Everitt, *Bomber Command War Diaries*, p.22

a casualty rate of 36.8 percent. Bomber Command was to calculate its daily loss rate as a proportion of total operational daily sorties flown throughout the period of the war. The effect of this method was that it minimised the true level of risk inherent in attacking defended targets.

The extent of these early casualties may have been a considerable shock to the Air Staff as they realised that attacking bombers were very vulnerable to both fighter and anti-aircraft artillery defences. A number of fundamental assumptions upon which the Air Staff had based their plans were wrong. When World War II started, Bomber Command was beginning the task of mobilising for the future war. It did not have the aircraft, the personnel, airfields or the technology available to enable it to carry out the heavy and sustained strategic attacks that Sir Edward Ellington had spoken about in 1934.

The aircraft operated by Bomber Command were the latest available aircraft, but they had been designed for a daylight war against France and not for a night offensive against a much more distant Germany<sup>37</sup>. The Wellingtons, Hampdens and Blenheims would have made up for their poor bomb-carrying capacity through the precision of their daytime attacks and the fast turn-around time that French targets would have allowed. Germany was a different matter, particularly after Germany defeated France and the Low Countries and established her forward air defences there.

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37 C. Sinnott, *The Royal Air Force and Aircraft Design, 1923-1939*, Frank Cass, London, 2001, p.3

Britain was not alone in having short-range tactical aircraft. In 1939, none of the major belligerents could conduct sustained, heavy, long-range air raids against enemy targets. Neither France nor Germany had any heavy bomber formations or organisations such as Bomber Command and their air forces were subordinate to the army. The Luftwaffe and the French air force were to provide operational and tactical fire support to the armies on the battlefield with some attacks being directed against the immediate rear areas of the opposing enemy forces. In 1939, no operational aircraft had the range, navigational capability, bomb load or defensive armaments to reach distant targets safely and to inflict the damage that pre-war commentators had feared. In the case of Germany, there was only the Fokker Wulf 200c Kondor, a maritime reconnaissance and strike aircraft, which was capable of covering the 600-mile distance from Germany to Britain<sup>38</sup>. On the British side, only the Wellington had the capacity to reach Berlin<sup>39</sup>.

The ability of Bomber Command to launch attacks against Germany was also limited politically by the fear of German retaliation. The French Government, greatly influenced by such fear, obtained a virtual ban on strategic air attacks by Bomber Command during the Anglo-French Staff Conversations in London in April 1939<sup>40</sup>. The joint memorandum issued by the parties stated that:

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38 A. Price, *Bomber in World War II*, MacDonald and Janes, New York, p.35

39 Price, *Bomber in World War II*, p.25

40 PRO CAB 54/11, Bombardment Policy, DCOS 164, 13 Aug 1939

The Allies would not initiate air action against any but purely 'military' objectives in the narrowest sense of the word, i.e., Naval, Army and Air Forces and establishments, and as far as possible would confine it to objectives of which attack will not involve loss of civil life<sup>41</sup>.

These fears prompted the western Allies to pressure Poland to ensure that 'no impetuous action on their part gives Germany an excuse for indiscriminate retaliation against them or us'<sup>42</sup>.

The restrictions on bombing were lifted once Winston Churchill became Prime Minister and on the night of 11 May 1940, Bomber Command launched its first attack on a German target, the town of Mönchengladbach<sup>43</sup>. The attack specifically targeted road and rail communications within the town and resulted in the deaths of four civilians, one an Englishwoman resident there. Two Hampdens and one Whitley were lost<sup>44</sup>.

From the very beginning of the strategic air offensive Churchill noted the poor striking power of Bomber Command. The small striking power of the bomber force frustrated Churchill and on November 1<sup>st</sup>, 1940, he sent a minute to the CAS:

It is deplorable that so few bombers are available even on good nights. I made various suggestions for increasing the bomber force. If instead of simply turning all these down, you and the Secretary of State recognised

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41 PRO CAB 54/11, Bombardment Policy, DCOS 164, 13 Aug 1939

42 PRO CAB 54/11, Bombardment Policy, DCOS 164, 13 Aug 1939

43 J. Lukacs, *Five Days in London May 1940*, Yale University Press, New Haven, 1998, p.5

44 Middlebrook and Everitt, *Bomber Command War Diaries*, p. 42

the need of increasing the bomb delivery, and set to work to contrive the means, of doing so, it would be a very great help<sup>45</sup>.

Churchill's frustration with Bomber Command's poor striking power continued over the next three years. Bomber Command would consistently fail to achieve the weight of attack that the Prime Minister desired, particularly as he saw 'the criterion of bomber strength' being the weight of bombs dropped<sup>46</sup>.

As the operational experience of Bomber Command gradually increased, suspicions over the effectiveness of the strategic air offensive began to grow. By early 1941, the intelligence system was finding very little evidence that bombing was having a decisive effect on the German war effort. The feedback from intelligence was disappointing to an Air Staff that had worked hard to develop a well co-ordinated intelligence as a fundamental part of air warfare<sup>47</sup>. The problems became more apparent in 1941, when flash photography of bomb explosions undermined the validity of post-operational crew debriefing reports. The discrepancy between the information contained in the photographs and the claims made by returning aircrew allowed Lord Cherwell to have one of his staff, Mr. D.M.B. Butt, conduct an analysis of bombing results. In the 1951 volume of his wartime memoirs, *The Hinge of Fate*, Churchill tells how he finally gave approval for Lord Cherwell to task his statistical staff with an investigation into the

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45 PRO CAB 120/292, Minute from Prime Minister to Chief of the Air Staff, 1st November 1940

46 PRO CAB 120/299, Minute Prime Minister to Lord Cherwell, 12th July 1941

47 Cited in Overy, *The Air War*, Europa Publications, London, 1980, p.110

strategic air offensive. He talks of this decision as coming after a period of growing questioning of the effectiveness of the air offensive<sup>48</sup>.

Mr. Butt's investigation analysed 650 photographs taken on 100 raids against 28 targets inside Germany, which Bomber Command attacked on 18 nights, from 2<sup>nd</sup> June to 25 July 1941. He found that only 33 percent of the aircraft recorded as attacking their specified target in Germany dropped their bombs within five miles of the planned aiming point. Nights with full moon increased to 40 percent the proportion of aircraft dropping their bombs within five miles of their assigned target. The investigation also disclosed that strong defences, such as those in the Ruhr, reduced to 10 percent the number of aircraft dropping their bombs within five miles of the target. Against lightly defended targets in France 33 percent of attacking bombers were able to drop their bombs within five miles<sup>49</sup>.

The evidence collated by Butt eroded the confidence of the Air Staff and Bomber Command in the effectiveness of the attacks. The investigation only considered those aircraft, which 'were recorded' as attacking their target and not the total number of aircraft that were despatched to the target<sup>50</sup>. Of the 6,103 aircraft despatched, 66 percent made an effective attack, leaving 33 percent unaccounted for in Butt's findings. This means Butt's calculations of one third of aircraft

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48 Sir W. Churchill, *The Hinge of Fate*, The Second World War, Vol. IV, Cassell and Company, London, 1951, pp. 235-243

49 Quoted in J. Terraine, *The Right of the Line: The Royal Air Force in the European War, 1939-1945*, Hodder and Stoughton, London, 1945, p.292

50 J. Terraine, *The Right of the Line: The Royal Air Force in the European War*, Hodder and Stoughton, London, 1945, p.292

finding the general area of a target is much higher than it really was<sup>51</sup>. A further problem was that, as Butt said, ‘by defining the target area ... as having a radius of five miles, an area of over 75 square miles is taken’<sup>52</sup>. Such an area would have, in Butt’s opinion, contained a significant proportion of open countryside with Berlin being the exception. Given this fact, Butt suggested that ‘the proportion of aircraft dropping their bombs on built up areas must be very much less’<sup>53</sup>.

The unflattering findings of the Butt investigation had a sobering influence upon British expectations of their air policy. Significantly, Churchill, who had been a strong advocate of striking back through bombing, began to demand a more economical use of aircraft and aircrew by Bomber Command. In July 1941, Churchill wanted more aircraft attacking Germany and he had asked CAS to check on Coastal Command’s employment of Boeing B-17 aircraft, suggesting they be diverted to bombing attacks on Germany. Churchill’s rationale for the request was ‘the C-in-C Bomber Command says he is very short and not expanding’<sup>54</sup>. By August, after Butt’s report was available, Churchill began to express concern over losses, particularly an attack on merchant shipping in Rotterdam Harbour, in which seven out of the 17 attacking Blenheim aircraft were lost. Churchill complained to the CAS that the ‘most severe’ losses were ‘disproportionate to an attack on

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51 Terraine, *The Right of the Line*, p.293

52 Terraine, *The Right of the Line*, pp. 293-294

53 Terraine, *The Right of the Line*, pp. 293-294

54 Sir W. Churchill, *The Grand Alliance*, The Second World War, Vol. IV, Cassell and Company, London, 1951 p.628

merchant shipping not engaged in vital supply work'<sup>55</sup>. Churchill expressed further concern over Bomber Command losses, which had been 'very heavy this month' and that while he greatly admired the bravery of the pilots he did not 'want them pressed too hard'. He considered it necessary to ask the CAS to find 'Easier targets giving a high damage return compared with casualties'<sup>56</sup>.

Churchill's concerns about bombing continued into September and in a letter to the CAS, dated 15<sup>th</sup> September, Churchill suggests ways of improving accuracy, including the use of master-bombers. The tone of the letter is subdued and Churchill is not demanding 'action this day' in his normal gruff manner. There is an air of disappointment that the air campaign was not living up to expectation. The letter closes with Churchill saying, 'It is an awful thought that perhaps three quarters of our bombs go astray'<sup>57</sup>. It would be interesting to have seen the impact upon his opinion if he had also been aware of the high failure rate of the fuses in the remaining quarter of the bombs dropped.

Things did not improve quickly for Bomber Command. On 5<sup>th</sup> November 1941, CAS minuted Churchill that analysis of further night photographs over the last three months showed no increase in bombing accuracy since Butt's findings in

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55 PRO CAB 120/339, Minute M.843/1 Prime Minister to Chief of the Air Staff, 29th August 1941. Churchill lists only seven aircraft being lost on this operation. The number of aircraft lost was eight, seven being destroyed by enemy action and one crashing on take-off. See Middlebrook and Everitt, *Bomber Command War Diaries*, p.197

56 PRO CAB 120/339, Minute M.843/1 Prime Minister to Chief of the Air Staff, 29th August 1941. See Middlebrook and Everitt, *Bomber Command War Diaries*, p.197

57 PRO CAB 120/293, Letter from Prime Minister to Chief of the Air Staff, 15th September 1941

June and July. Portal did his best to explain that the weather over the period had been consistently bad. He also took the opportunity to inform the Prime Minister that ‘complete plans have been made for a trial attack with a special fire raising force’, which was ready to be used when favourable weather was forecast<sup>58</sup>.

Portal’s attempts to raise Churchill’s confidence in the air offensive were not overly successful. On one day, 11<sup>th</sup> November, Churchill sent three minutes to Portal. The first told Portal to cut the number of fighter sweeps in France from four per month to two and to refrain from launching attacks into Germany during periods of bad weather. The reason given by Churchill for this action was that Britain ‘cannot afford losses on that scale’; particularly on what are routine missions without decisive military objectives<sup>59</sup>. The second minute demanded returns on aircraft lost or damaged each day. The third minute requested the reason for the drop in Bomber Command’s casualties<sup>60</sup>. Bomber Command was clearly in the Prime Minister’s unhappy sights.

The disappointment pervading the government may have prompted the Air Staff to put a more aggressive commander in charge of Bomber Command. On 23 February 1942, Sir Arthur Harris replaced Sir Richard Peirse. By January 1942, the Air Staff and the Air Ministry knew that if the RAF was to retain the strategic campaign it had to demonstrate greater striking power. Luckily, by early 1942 the

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58 PRO CAB 120/393, Minute CAS to Prime Minister, 5th November 1941

59 Churchill, *The Grand Alliance*, p.650

60 Churchill, *The Grand Alliance*, pp. 650-651

first of the heavy bombers were becoming operational, the airfields were being enlarged and improved and the flow of trained manpower was moving into operational service. Bomber Command was able to look forward to providing the government with the victories that it desperately needed.

By early 1942, the size of Bomber Command had grown to approximately 100,000 personnel in 37 operational and 18 non-operational squadrons<sup>61</sup> from 79 stations. They now had paved all-weather runways and improved facilities and accommodation<sup>62</sup>. The Halifax, the first of the four-engined heavy bombers to show real promise, had overcome its early technical problems and there were now two operational Halifax squadrons available to the Command and another three squadrons undergoing conversion. A further two squadrons were converting to the new Lancaster aircraft<sup>63</sup>. In addition, Bomber Command had over two years of experience in conducting bombing operations mostly at night and it was ready to start a new form of attack against German cities and their civilian populations.

### **Increasing Weight of Attack: 23<sup>rd</sup> February 1942 until 1<sup>st</sup> April 1944**

Sir Arthur Harris was the luckiest of Bomber Command's five wartime commanders in that his appointment coincided with the improvement of Bomber Command's capabilities in a whole range of areas. He had inherited an

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61 Harris, *Despatch*, p.146

62 C.M. Kohan, *Works and Buildings*, History of the Second World War, Civil Series, HMSO, London, 1952, p.284

organisation that had now completed its formative phase. The expansion of the manpower base, the completion of new airfields with better systems for air traffic control and the delivery of the improved Halifax and Lancaster aircraft, are good indicators of the growing effectiveness of Bomber Command in early 1942. The Lancaster made its operational debut on 3<sup>rd</sup> March 1942 when four of these aircraft conducted a mining mission off the German coast<sup>64</sup>. Another major milestone that Bomber Command accomplished was the bringing into service of the first in a series of more sophisticated and effective electronic navigational aids.

By February of 1942, Bomber Command was finally in a position to conduct a strategic air offensive. For Britain, early 1942 was the nadir of her wartime fortunes and the increasing capability of Bomber Command could not have come at a better time. As Bomber Command prepared for its new commander, British forces were being defeated in the Western Desert, Hong Kong, Malaya and Singapore. The German U-Boats were inflicting increased casualties against the unprotected coastal shipping on the eastern coast of the United States, a second 'happy time' in the protracted Battle of the Atlantic. At home, Churchill was facing a vote of no confidence and a cabinet reshuffle. Internationally, Australia was accusing Britain of considering the 'inexcusable betrayal' of evacuating

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63 Harris, *Despatch*, p.146

64 Middlebrook and Everitt, *Bomber Command War Diaries*, p.245

Singapore and Malaya<sup>65</sup>. Finally, on February 12<sup>th</sup>, the German battleships Scharnhorst, Gneisenau and the cruiser Prinz Eugen dashed unscathed up the English Channel from Brest to Germany. On the 15<sup>th</sup>, Singapore fell. The Japanese Army captured 85,000 Allied prisoners of war including 35,000 British and 17,000 Australians<sup>66</sup>.

Sir Arthur Harris had no doubt about his objectives. He saw his 'primary authorised task' as being to inflict the most severe material damage upon German industrial cities<sup>67</sup>. The Air Staff had developed these tactics as an answer to the findings of the Butt Report. Wing Commander Sydney Bufton, the director of Bombing Operations at the Air Ministry, signed off on the area attack policy on 25th August 1941. Bufton identified cities as being targets because the 'probability of effecting serious and lasting damage to specific key points as a result of area attack is, without doubt, extremely problematical'<sup>68</sup>. The focus for the area attack was 'the people in their homes and in the factories, the services such as electricity, gas and water upon which the industrial and domestic life of the area depends' and 'to focus attacks on the morale of the enemy civil population and, in particular, of the industrial workers'<sup>69</sup>.

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65 Letter from John Curtin to Winston Churchill 23 January 1942 and reproduced in W. Churchill, *The Hinge of Faith*, Vol.IV, Cassell and Company, London, 1951, pp. 61-62

66 Churchill, *The Hinge of Faith*, pp. 89, 93

67 Harris, *Despatch*, p.7

68 Churchill Archive, *BUFT 319*, Night Bombing Policy, 25th August 1941, Bufton Papers, Churchill Archive, Churchill College Cambridge.

69 Churchill Archive, *BUFT 319*, and Sir A. Harris, *Despatch*, p.7

The main weapon of this attack would be the 4lb incendiary bomb, which, entering buildings through the holes created blast from high explosive bombs, set them on fire. The original intention behind the greater use of incendiaries does not seem to have been fire raising but target identification. In his policy draft of 'Night Bombing Policy' the Director of Bombing Operations at the Air Ministry described the Germans as using incendiaries dropped by experienced crews as target markers for the following main force aircraft<sup>70</sup>. Bufton described the job of these experienced crews as 'the difficult task of finding the selected target area'<sup>71</sup>. By 5<sup>th</sup> November 1941, Portal was telling Churchill that 'complete plans have been made for a trial attack with a special fire raising force'<sup>72</sup>.

The first major attack launched by Harris was, ironically, a precision attack against the Renault factory at Billancourt on the night of 3<sup>rd</sup> March 1942<sup>73</sup>. It was the first centrally controlled attack launched by Bomber Command and only the second time that more than 200 aircraft had been despatched to a single target along a set route and with a set time of attack. The official Australian historian called the attack 'a land mark' for Bomber Command<sup>74</sup>. The damage inflicted on the works was substantial but the losses included 367 French civilians killed and 9,250 made homeless from bombs hitting the apartment blocks which surrounded

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70 Churchill Archive, *BUFT 319*, Night Bombing Policy, 25th August 1941

71 Churchill Archive, *BUFT 319*, Night Bombing Policy, 25th August 1941

72 PRO CAB 120/393, Minute CAS to Prime Minister, 5th November 1941

73 Middlebrook and Everitt, *Bomber Command War Diaries*, pp. 244-255

74 J. Herington, *Australia in the War of 1939-1945*, p.308

the factory<sup>75</sup>. The number of French dead was double the death toll that Bomber Command had so far inflicted on any German city<sup>76</sup>.

At Billancourt, Bomber Command used the tactic of forming the attacking aircraft into a bomber stream of three waves. This enabled the Command to get 121 aircraft over the target each hour and concentrated the destruction into a shorter timeframe<sup>77</sup>. The benefit was that it enabled the attacking force to be more closely co-ordinated and easily defended. It limited the time available to the defenders to inflict casualties and it delivered a more formidable psychological blow.

Over March 1942, Bomber Command launched eleven attacks against the German city of Essen. They failed to accomplish much other than the reinforcement of the local anti-aircraft defences. Only 50 high explosive bombs struck the city inflicting little damage and 35 aircraft were lost to the defences. However, a notable success was achieved in a successful fire-raising raid against Lübeck on the night of 28<sup>th</sup> March. This attack was carried out in good visibility and, because of light defences the attacking force was able to operate from low level, around 2,000 feet. Of the 234 aircraft despatched against the target 191 crews claimed to have successfully attacked the target. The bomb tonnage

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75 Middlebrook and Everitt, *Bomber Command War Diaries*, p.255

76 Middlebrook and Everitt, *Bomber Command War Diaries*, p.255

77 Middlebrook and Everitt, *Bomber Command War Diaries*, p.255

dropped was approximately 304 tons of which 144 tons were incendiaries<sup>78</sup>. The fires, which started in the centre of Lübeck, burned out an estimated 190 acres of the city destroying 1,425 buildings and damaging 10,387, 1,976 of them seriously<sup>79</sup>.

The next major attack against a German city took place the following month. The target was Rostock, a city with a high proportion of wooden buildings. The Official History describes this series of four raids, lasting from the 23rd to the 26th of April 1942, as being 'a masterpiece' and 'another great victory'<sup>80</sup>. At Rostock, Harris identified three questions he wanted answered: could the defences of a vital industrial area be swamped by a large scale attacks, could Bomber Command field the large numbers of aircraft needed, and could Bomber Command overcome the limitations imposed by weather<sup>81</sup>? The answer was yes and it allowed the first 'Thousand Plan' raid against Cologne<sup>82</sup>.

Cologne was the first German city attacked by a massive force of bombers<sup>83</sup>.

Harris achieved his concentration of force by drawing upon all available aircraft, including aircraft brought from operational and training units and Flying Training

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78 Harris, *Despatch*, p.13

79 Middlebrook and Everitt, *Bomber Command War Diaries*, p.251

80 Webster and Frankland, *The Strategic Air Offensive*, Vol I, pp. 393-395

81 Harris, *Despatch*, p.13

82 Harris, *Despatch*, p.13

83 Webster and Frankland, *The Strategic Air Offensive*, Vol. 1, Preparation, pp.402.-417

Command. By doing this Bomber Command was able to muster 1,047 aircraft<sup>84</sup> of which 868 were able to reach Cologne. They dropped an estimated 970 tons of incendiaries and 485 tons of high explosive bombs on the city in ninety minutes, constituting a concentration of 578 aircraft per hour over the target<sup>85</sup>.

The raid destroyed 3,300 buildings and damaged 9,510 more<sup>86</sup>. It also caused a drop in production in 328 firms with 36 large firms reporting a complete loss of production; 70 a drop of between 50 to 80 percent and 222 who reported less than a 50 percent loss<sup>87</sup>. The series of raids on Cologne, Essen and particularly Lübeck were seen as successes and, as Churchill pointed out to Roosevelt in a letter dated 1 April 1942, all of these raids were on a 'Coventry scale'<sup>88</sup>. In a statement to the House of Parliament on 2<sup>nd</sup> June, Churchill used the Cologne raid of 30<sup>th</sup> May and the Essen raid of the previous night to balance the bad news of Rommel's successes in the Western Desert. He flagged them as 'a new phase in the British air offensive against Germany'<sup>89</sup>.

A second 'thousand' raid followed against Essen on 1 June but this raid was not as successful. The GEE equipment did not work as well over the land-locked and heavily defended Ruhr and the bombing was widely scattered with bombs falling

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84 Middlebrook and Everitt, *Bomber Command War Diaries*, p.272

85 Sir A. Harris, *Despatch*, p.13

86 Harris, *Despatch*, p.13 and Middlebrook and Everitt, *Bomber Command War Diaries*, p.272

87 Middlebrook and Everitt, *Bomber Command War Diaries*, p.272

88 Churchill, *The Hinge of Fate*, p.174

89 Churchill, *The Hinge of Fate*, p.296

on Essen and 11 other towns in or near the Ruhr<sup>90</sup>. The poor results were noted by Churchill, probably because he had called it a 'great bombing' raid in his 2 June statement to the House. On 7 June 1942, he minuted the CAS stating that 'the relatively disappointing results of our second big raid' made it 'it doubly urgent' that the H<sub>2</sub>S ground reading radar device be made operational<sup>91</sup>.

The H<sub>2</sub>S ground reading radar was under development throughout most of 1941 and the first part of 1942<sup>92</sup>. The biggest problem with H<sub>2</sub>S was that it used the highly secret cavity magnetron to achieve its 9cm bandwidth. The sensitivity of the Admiralty and the Air Ministry over the cavity magnetron delayed the employment of H<sub>2</sub>S until July 1942, when two squadrons of aircraft were equipped with it. The Air Ministry maintained a ban on these aircraft flying over enemy occupied territory until January 1943<sup>93</sup>.

The first operational use of H<sub>2</sub>S occurred on the night of 30<sup>th</sup> January 1943 in an attack on Hamburg. H<sub>2</sub>S showed itself to be relatively reliable though a number of sets broke down during the flight to the target. Of the remainder, six navigators reported being able to identify the target as expected and the Stirlings carrying H<sub>2</sub>S used it to navigate the entire journey owing to incorrect GEE settings<sup>94</sup>.

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90 Middlebrook and Everitt, *Bomber Command War Diaries*, p.274

91 PRO CAB 120/393, Minute Churchill to Secretary of State for Air, 7th June 1942.

92 PRO CAB 120/393, Minute from CAS to Prime Minister, 28th February 1942

93 Harris, *Despatch*, p.70

94 Harris, *Despatch*, p.70

In addition to the undoubted benefits the use of H<sub>2</sub>S posed a number of problems for Bomber Command. The most significant was the inexperience of the crews in using them. As well the crews were concerned that as an active radar emitter attached to the aircraft the H<sub>2</sub>S betrayed the position of the aircraft to the German defenders. The concern of Bomber Command's crews was justified, as it was not long before German night fighters were equipped with NAXOS intercept equipment which allowed them to home onto British aircraft in the dark. It is unknown how many Bomber Command aircraft the German fighters destroyed through the detection of their H<sub>2</sub>S emissions, but the Luftwaffe made wide use of NAXOS intercept sets<sup>95</sup>.

The third 'thousand' bombing raid was directed against Bremen on 25<sup>th</sup> June 1942 and consisted of 1,067 aircraft and included 102 Coastal Command aircraft, listed separately from the Bomber Command effort<sup>96</sup>. The raid was not as effective as the Cologne raid but it was far more successful than the Essen raid<sup>97</sup>. Bomber Command continued its efforts in attacking a range of German cities including Essen, Hamburg, Frankfurt and Duisburg. The next major raid was against Düsseldorf on the night of 31<sup>st</sup> July. In this attack, 630 aircraft, including 113

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95 W. Murray, *The Luftwaffe, 1933-45: Strategy for Defeat*, Brassey's, Washington, 1996, p.216

96 Middlebrook and Everitt, *Bomber Command War Diaries*, p.280

97 Middlebrook and Everitt, *Bomber Command War Diaries*, p.280

Lancasters, were despatched and 484 aircraft claimed to have attacked the city, although some of them had photographed open countryside as the target<sup>98</sup>.

Throughout the period, the casualty rate of Bomber Command increased due to the high level of operations against Germany. Many of the losses, particularly those on the 'thousand' raids, were due as much due to accidents as to enemy action. The rise in the casualty rate was a sustained one and, at times, it surpassed four percent of the despatched force, the level at which the strength of Bomber Command declined in absolute terms, as losses at this level outstripped replacements<sup>99</sup>.

A further technical advance occurred on December 20<sup>th</sup> 1942, when Bomber Command first used OBOE, a tight radar beam that the attacking force flew along to the target. Sir Arthur Harris suggests that OBOE led to significant improvements in the weight of attacks delivered by Bomber Command<sup>100</sup>. The advantages of OBOE were that it improved navigation and accuracy and allowed even greater concentration of aircraft over the target. However, its major disadvantage was that the attacking aircraft flew in straight lines, which allowed the defenders to easily track them and predict their targets. The successful prediction of targets enabled the defenders to concentrate fighters over the radio beacons closest to the track in time to intercept the attacking bombers.

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98 Middlebrook and Everitt, *Bomber Command War Diaries*, p.292

99 Middlebrook and Everitt, *Bomber Command War Diaries*, p.300

## Increasing Intensity

The next stage of the strategic air offensive began on the night of 5<sup>th</sup> March 1943 with 442 aircraft despatched to attack Essen. Approximately 160 acres of the city suffered substantial destruction with 3,018 buildings destroyed, and 2,166 seriously damaged<sup>101</sup>. Bombs also hit 53 separate buildings within the Krupp works, making this a particularly effective raid<sup>102</sup>. The raid also set a new record for civilian deaths in Germany with around 482 people killed. As the first attack in the Battle of the Ruhr, which raged until 24<sup>th</sup> July 1943, it was an ominous sign of Bomber Command's increasing capability.

The major targets for Bomber Command during the Battle of the Ruhr were Bochum, Cologne, Dortmund, Duisburg, Düsseldorf, Essen, Frankfurt, Gelsenkerchen, Hamburg, Mannheim and Wuppertal<sup>103</sup>. During this time Bomber Command did attack other targets, including Berlin, Stetting, Turin, and La Spezia<sup>104</sup>, however the main effort was directed against the Ruhr. The average loss rate for this period of the war was 4.3 percent<sup>105</sup>, which was on the borderline of being prohibitive.

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100 Middlebrook and Everitt, *Bomber Command War Diaries*, p.15

101 Middlebrook and Everitt, *Bomber Command War Diaries*, p.366

102 Middlebrook and Everitt, *Bomber Command War Diaries*, p.366

103 Middlebrook and Everitt, *Bomber Command War Diaries*, pp. 362-409

104 Middlebrook and Everitt, *Bomber Command War Diaries*, pp. 362-409

105 Middlebrook and Everitt, *Bomber Command War Diaries*, p. 409

It was immediately after the Battle of the Ruhr that Bomber Command, supported by the United States 8<sup>th</sup> Air Force, launched the most successful air attacks of the strategic air offensive against Germany. These attacks on Hamburg took place between 24<sup>th</sup> July and 3<sup>rd</sup> August 1943<sup>106</sup>. The attacks on Hamburg were an around-the-clock operation with Bomber Command attacking at night and the USAAF attacking during the day. During these attacks, Bomber Command successfully jammed German radar defences by dropping WINDOW, bundles of aluminium strips cut to a length which overwhelming the German radar with false returns. Bomber Command launched 3,091 aircraft against Hamburg and they dropped 10,815 tons of bombs<sup>107</sup>. The loss rate for this series of attacks was 3 percent<sup>108</sup>. These raids resulted in over 43,000 deaths in Hamburg and the evacuation of approximately 1.2 million people from the city<sup>109</sup>. Around 16,000 multi-story residential buildings were destroyed and the productive capacity of the city was reduced by about 80 percent for almost a month as workers stayed at home to look after their families<sup>110</sup>.

A large number of other raids, mainly focussed on the Ruhr, followed up the successes at Hamburg. These operations were in preparation for the next big

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106 PRO AIR 24/257, Operational Order quoted in Middlebrook and Everitt, *Bomber Command War Diaries*, p.410

107 Middlebrook and Everitt, *Bomber Command War Diaries*, pp. 410-416

108 Middlebrook and Everitt, *Bomber Command War Diaries*, p.416

109 Middlebrook and Everitt, *Bomber Command War Diaries*, pp. 410-416

110 Albert Speer in his memoir, *Inside the Third Reich*, makes much of this raid describing it as 'catastrophic' and predicting that six more such attacks would defeat Germany. However, as Speer admits, his panic was misplaced and life soon returned to Hamburg. See Albert Speer, *Inside the Third Reich*, Weidenfeld and Nicolson, London, 1970, pp.283-285 Also see Middlebrook and Everitt, *Bomber Command War Diaries*, pp. 410-416

offensive, the 'Battle of Berlin'. Bomber Command's proposed attack on Berlin may have been seen as an opportunity to achieve a decisive outcome before the forthcoming invasion was launched. Planning for the invasion of Northern Europe was progressing and the Western Allies were making significant headway against the Germans in the Mediterranean. Harris had put the idea for the battle to both Portal and Churchill in November 1943, claiming that for the cost of between 400-500 aircraft, Bomber Command could defeat Germany<sup>111</sup>.

The 'Battle of Berlin' was a defeat for Bomber Command and it marked the end of the Command's ability to operate outside a wider strategic, joint-service environment increasingly influenced by the needs of Allied ground forces<sup>112</sup>. The period of the battle saw 33 large attacks against a variety of targets in Germany, with 17 attacks on Berlin itself. The loss rate of Bomber Command during this offensive was a very high 5.69 percent, 1.69 percent above the level whereby Bomber Command could not replace its losses. Sir Arthur Harris estimated the loss rate even higher at 6.2 percent of aircraft despatched on 16 raids. He claims that this loss rate 'could not be regarded as excessive in relation to the magnitude of the task'<sup>113</sup>.

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111 Sir Charles Webster and N. Frankland, *The Strategic Air offensive Against Germany, 1939-1945*, HMSO, London, 1961, pp. 190

112 Webster and Frankland, *The Strategic Air Offensive*, Vol II, p193., Middlebrook, *The Battle of Berlin*, pp. 323-325., Murray, *The Luftwaffe*, p.217

113 Harris, *Despatch*, p.21

In a number of the secondary sources, there is frank discussion of the impact of the casualty rates on the aircrew serving in Bomber Command<sup>114</sup>. There were concerns raised at the highest levels within Bomber Command itself, with Air Vice-Marshal Bennett writing to Bomber Command HQ of the ‘very large number of crews failed to carry out their attacks during the Battle of Berlin in their usual determined manner’<sup>115</sup>. The judgement of the Official History on the Battle of Berlin has coloured much of the subsequent history. Many British sources denied that the battle was lost or they attempted to justify the losses using an attritionist argument that ‘every pane of glass broken in Berlin was a tiny drain on Germany’s economy’<sup>116</sup>.

As the Battle of Berlin progressed, the necessities of the wider war began to divert aircraft to other objectives. The most significant of these was a defensive battle to destroy flying bomb sites in France and the Low countries. The first raid against a specific flying bomb site took place on 22 December 1943 with 51 aircraft, including 11 Lancasters and eight Mosquitoes, attacking sites at Abbeville and Amiens. These two targets alone absorbed 723 sorties during the period of the Battle of Berlin and represent an increasing demand for Bomber Command efforts to be committed to the defence of Britain and the preparatory attacks leading up to the invasion.

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114 Webster and Frankland, *The Strategic Air Offensive*, Vol II, p193., Middlebrook, *The Battle of Berlin*, pp. 323-325., Murray, *The Luftwaffe*, p.220

115 Memorandum 3rd November 1944, from AVM D. Bennett to Bomber Command HQ, quoted in Webster and Frankland, *The Strategic Air Offensive*, p.196

## **Crescendo**

On the night of the 30<sup>th</sup> March 1944, when the Battle of Berlin ended, the invasion of Europe from the West was less than ten weeks away. Bomber Command was committed to direct its full resources to preparatory attacks in France. These attacks cost 525 aircraft over 63 days<sup>117</sup>. The success of Bomber Command attacks during this phase of the war was much better than expected and good results obtained against quite small targets showing a significant increase in targeting capability. Aircraft losses also began to trend downwards as the shorter raids into France prevented the German defenders from decisively engaging British aircraft and as the USAAF daylight raids caused increasing casualties amongst the German night fighters<sup>118</sup>.

Bomber Command's major role in the pre-invasion attacks was the destruction or disruption of 37 railway centres. In 13,349 sorties, Bomber Command aircraft dropped 52,547 tons of bombs for a loss of 2.6 percent of the dispatched aircraft<sup>119</sup>. The accuracy of these attacks was so good that Harris stated that they were 'of an outstandingly high order'<sup>120</sup>. Bomber Command was very successful in achieving its mission to isolate the battlefield in Normandy from outside supply

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116 Middlebrook, *The Berlin Raids*, p.325. In his otherwise excellent book on the Battle of Berlin, Middlebrook attempts a half-hearted justification of the value of the battle, which his own analysis does not support.

117 Middlebrook and Everitt, *Bomber Command War Diaries*, p.520

118 Middlebrook and Everitt, *Bomber Command War Diaries*, p.491

119 Harris, *Despatch*, p.24

and reinforcement. The main rail junctions attacked were Nantes-Angers-Samur-Tours-Orleans, Orleans-Chateaudun-Chatres-Estampes-Drux, Paris and Rennes-Pontaubault<sup>121</sup>.

The programme of air attacks in support of the invasion continued until after the 6<sup>th</sup> of June. Bomber Command carried out many attacks against targets including troop positions, railways, coastal batteries and supply dumps. The launching of the first V weapons on June 12th interrupted the impetus of these attacks as the government ordered the diversion of a substantial part of Bomber Command's strength to destroy the launch sites for these weapons. The attacks on V weapons continued until August of 1944 and the German V1 offensive against London was successful in diverting 28.9 percent (13,540) of all Bomber Command sorties away from the main battlefield and the German logistical system onto the flying bomb sites<sup>122</sup>. By 10<sup>th</sup> September 1944, with Allied armies on the borders of Germany, the areas used to launch the V1 and V2 weapons were under Allied control and Bomber Command could return to the attack on Germany proper.

In the last part of the war, from 16<sup>th</sup> August 1944 until 8<sup>th</sup> May 1945, Bomber Command's effort grew enormously and the fact that 46.85 percent of the total wartime bomb tonnage despatched by Bomber Command was dropped during this period underlines this fact. Although the priority of attack remained oil

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120 Harris, *Despatch*, p.24

121 Harris, *Despatch*, pp. 24-25

targets and transportation, Bomber Command continued to launch attacks against German cities when it could. These attacks raised concerns at the Air Ministry that Bomber Command was concentrating too much effort on bombing cities. Some of this concern may have been due to a fear that Bomber Command was destroying infrastructure that Britain would need, once she took over her zone of occupation in Germany. Churchill was undoubtedly aware of the impact of British bombing. He certainly referred to the destruction of infrastructure when he sent a somewhat fatuous request to Stalin to, 'let me know in plenty of time when we are to stop knocking down Berlin so as to leave sufficient billeting accommodation for the Soviet Armies'<sup>123</sup>.

By January 1945, the Air Ministry and a number of other government agencies were becoming increasingly hostile to Bomber Command and the strategic air offensive. It was during this winding down of the war that Churchill moved to distance himself from the strategic air offensive by issuing a minute decrying the continued attack on German cities. The vigour with which Harris had pursued the strategic air offensive has led to an unfair belief that he alone was responsible. Harris was a strong advocate of strategic air attack and was undeniably an advocate of attacking the civilian population of the enemy, but he was only one of many commanders carrying it out. The notoriety that Harris achieved has allowed other individuals to avoid responsibility. Amongst these are Sir Winston

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122 Calculations based on figures contained in Middlebrook and Everitt, *Bomber Command War Diaries*, pp. 521-564

123 PRO CAB 120/858, Heads of State Telegrams to Marshal Stalin, FROZEN 1204, 9th Jan 1944.

Churchill who, as Prime Minister, must take a significant degree of responsibility for the campaign, and Sir Charles Portal, the CAS through most of the war. Much of the history of the offensive overlooks the substantial role that both these men played in the planning and conduct of the strategic air offensive.

## **Conclusion**

Prior to the outbreak of war in September 1939, the concept of a strategic air offensive as a new and cheaper way to fight a war had gained considerable currency within the RAF, Air Ministry, the British Government and wider British society. The Air Staff stated that such an offensive would begin within 24 hours of the declaration of war and would consist of a series of major bombing attacks on the enemy's capital, which would continue for four, or five weeks until both sides became exhausted. Victory would go to the side better prepared with the reserves necessary to allow them to recover first and launch the second series of bombing attacks against their now defenceless enemy.

The period between 3<sup>rd</sup> September 1939 and 23<sup>rd</sup> February 1942, the beginning of the strategic air offensive, was the period when operational experience influenced the aspirations of the Air Ministry and the Air Staff. It was during this time that the RAF identified aircrew reports as being unreliable and that the accurate navigation and bombing accuracy of their aircraft were as bad as was feared. They also realised that civilian morale would not break easily and that very heavy weights of explosives and incendiaries would be required to destroy urban areas.

The Air Staff and Bomber Command spent this time building operational experience whilst waiting for the airfields and infrastructure, the heavy bombers and the aircrews and the ground staff which would allow a strategic air offensive of sufficient size to be undertaken. They also had to wait whilst the technology was developed that would enable those bombers to identify their target areas and to defend themselves against the increasing technical proficiency of the German defences. This period ended at the beginning of 1942, when Sir Arthur Harris became the Air Officer Commanding in Chief of Bomber Command.

When he took command in February 1942, Harris's predecessors had done most of the preliminary work. Bomber Command now had the personnel, aircraft, airfields, aircraft, technology and operational experience that made it possible to launch strategic air attacks on the scale envisaged by Sir Edward Ellington in 1934. Under Harris's command, Bomber Command entered a period of maturity, which lasted from February 1942 until March 1944. During the early part of this period, Bomber Command stood alone as the one British military organisation able to inflict apparently substantial damage on what appeared to be the victorious Germans. In 1942, Britain faced an unprecedented series of military failures and defeats. As the Germans and Japanese advanced and British military prestige crumbled in the Middle and Far East, Bomber Command was able to carry out its first 'thousand' bomber raids. Whilst the military value of the thousand bomber raids may have been questionable, their role in maintaining British domestic morale and international prestige was not. In a time of darkness, the strategic air

offensive was the only effective means that Britain had of striking back at the enemy.

Towards the end of 1942, as Britain and the Soviet Union gained the victories of El Alamein and Stalingrad and as American military and industrial power began to show itself in Europe, the importance of the strategic air offensive began to decline as other options for action became available. With the invasion of Sicily and the advance of the Red Army to the west, the importance of a second front in northern Europe grew and again the importance of the strategic air offensive declined. Once the commitment to invasion was made, strategic bombing was subordinated to the needs of the ground forces and the opportunity had passed for it to prove itself a war-winner in its own right.

In June 1944, the western Allies finally launched the ground operations that the Soviet Union had been demanding and from this time until the end of the war in May 1945, the decisive military actions were those conducted on the ground. Where it could, Bomber Command diverted resources from bombing military objectives in France and the Low Countries to strike at the industries and civilian populations of Germany. Nevertheless, these efforts were not sufficient to achieve the dramatic victory that the Air Staff and Air Ministry hoped for, and besides, it was far too late to disentangle the effects of strategic bombing from those inflicted by the ground forces invading Germany from the East and West. It was during this final stage of the war that the operational activity of Bomber Command reached its crescendo. With the capture and destruction of the German

early warning radar system and its advanced air defences, Bomber Command was able to carryout 46.6 percent of its 387,416 wartime sorties and dropped 59 percent of the 955,044 tons of bombs it despatched during World War II<sup>124</sup>.

Bomber Command efforts during this last stage of the war was spread over a wide variety of targets including major industrial centres, oil refineries, transportation net works, V Weapon sites and storage facilities and specific military, civilian and political targets. The destruction was significant, but Bomber Command achieved it after it was obvious that Germany had lost the war. The continued destruction, coupled with the hyperbole of the arguments over to which plan, transportation, oil or city attack, Bomber Command should commit has led to a wide spread perception that Bomber Command was solely interested in killing as many German civilians as it possible could. This perception is very simplistic and is wrong.

While it is true that Bomber Command did target German civilians, military necessity prevented the majority of such attacks. Bomber Command dutifully attacked higher priority targets in the form of German military forces, V Weapon sites, oil refineries and transportation networks when directed to do so. Sir Arthur Harris may have ensured that his bombers attacked as many cities as possible, but he did not carry out such attacks at the expense of higher priority targets. The result was that, in the last year of the war, Bomber Command directed much of its

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124 Harris, *Despatch*, p.24

effort at more conventional military targets than had been the case up until that time. The reality is that the attack on Dresden, terrible though it was, was rather the exception than the rule. By mid-1944, the strategic air offensive was a subordinate activity in a larger war effort by Britain and her American and Soviet Allies. In the end, it was the overall effort that defeated Germany.

The strategic air offensive against Germany did not deliver the decisive victory that Sir Edward Ellington outlined to his colleagues on the Chief of Staffs Subcommittee in 1934. After the Air Staff initiated the strategic air offensive in September of 1939 it took Britain two and a half years to achieve a scale of attack that even approached the bottom end of Sir Edward's predictions. It took another two and a half years to develop the offensive into a major military undertaking, and it took the defeat of the German armies in Russia, the Mediterranean and France, before Bomber Command and the USAAF achieved the sort of aerial dominance for which the Air Staff of the 1930s had hoped. The financial cost of Britain's strategic air power was much higher than anyone expected and it did not defeat Germany, it did not even contribute the most significant military effort in that defeat. That honour belongs to the Red Army.

The size and ferocity of the fighting in the East diminishes any claim that the strategic air offensive was the major contributing factor to the Allied victory.

From the evidence examined so far, the intention behind the strategic air offensive was that it would lead to the quick and economical defeat of the enemy through damage to the enemy's industrial and social systems. Measured against this intention the strategic air offensive conducted between 1939 and 1945 was a

failure. Measured however as a means of keeping British soldiers off European battlefields, there is no doubt that the strategic air offensive was a substantial success, though it did not make the strategic air offensive a major factor in the military defeat of Germany. The question that now needs answering is what was the intention behind the strategic air offensive. Did Britain have a theoretical framework for a doctrine of strategic air warfare or was the strategic air offensive simply a handy means of striking back at a powerful continental enemy? This is the subject under examination in the next chapter as the need for an analysis of British military thinking on air power is vital to an understanding of the historical and intellectual context in which Bomber Command functioned.

## *Chapter 2*

### AIRMINDEDNESS AND THE DEVELOPMENT OF A BRITISH THEORY OF STRATEGIC BOMBING

At the outbreak of World War II, the British Air Staff had some vague plans on how they were going to conduct a strategic air offensive. Initially, the intention was to ensure that these plans did not generate overwhelming German retaliation. However, Britain was not alone in looking at strategic air war as more threat than support. Despite enthusiastic public interest in aircraft throughout Europe, no national military establishments had developed a practical capability for the strategic framework they had developed for using bomber aircraft as stand-alone war winning weapons. On the continent, the predominant concept was that aircraft would fulfil the auxiliary roles of reconnaissance, ground attack and local attacks on military objectives in support of their own surface forces. The French, German and Polish military saw the air forces as an extension of their artillery arms, able to bring heavy firepower to bear at critical points and times on the battlefield. The British were slightly different.

In Britain, public interest in air power had developed into a distinctive body of thought, an 'air-mindedness', which allowed the new Royal Air Force (RAF) to establish for itself a strategic role independent of the Army and Royal Navy. The development of the concept of an independent strategic air offensive grew out of this British air-mindedness and the initial attempts to conduct a strategic air

offensive in the closing months of World War I. These aspirations of the RAF did not amount, however, to a practical methodology for conducting military operations.

This chapter will argue that, between 1919 and 1939, Britain had developed no unified theoretical framework for strategic bombing. The doctrine that did exist developed from ideas expressed in a wide range of sources. These included ideas expressed by imaginative writers and the theoretical ideas of military thinkers such as Duhet, Mitchell and Liddell-Hart, and concepts gleaned from the limited experience the RAF had gained in using air power to police the Empire. In 1939, British thinking on strategic air power was disorderly, with little holding it together other than a blind faith in the effectiveness of technology and a lack of faith in the ability of civil populations to withstand danger and deprivation. As Tami Davis Biddle has said, World War II would force the British Air Staff to reduce the gap between ‘imagined possibilities and technical realities’<sup>1</sup>.

One of the major characteristics of British thinking on air power was the impact of the ideas of the imaginative writers of the Edwardian Era, of whom H.G. Wells was the exemplar, upon the development of air power policy. The first step taken in this chapter is to survey the ideas expressed in popular writing on air power and discuss the way in which these may have influenced government policy. The next step is to describe how British military doctrine changed as the military gained

experience in air operations during World War I, the inter-war period and during World War II.

British air mindedness has been the subject of a number of substantial works of which the earliest was Robin Higham's, *The Military Intellectuals in Great Britain 1918-1939*, (1966)<sup>2</sup>. Higham's book was the first critical analysis of British military planning in the interwar period and it preceded by ten years, Barry Powers's excellent description of the personalities who dominated British strategic thinking during the same period<sup>3</sup>. Another writer, H. M. Hyde, provided a thorough analysis of the development of official attitudes to air power and the efforts of Sir Hugh Trenchard and Lord Swinton, to develop an offensive bomber arm for the RAF. Neither Powers nor Hyde are as critical of possible intellectual failings in inter-war British military thinking as is Higham<sup>4</sup>, but their analysis provides substantial support for Higham's thesis.

On a broader canvas, Uri Bialer has written about how the British Chiefs of Staff approached the question of attacking civilian populations<sup>5</sup>. Bialer takes his argument further when he explored the way in which the 'imagined possibilities'

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- 1 Tami Davis Biddle, *Rhetoric and Reality in Air Warfare: The Evolution of British and American Ideas About Strategic Bombing, 1914-1945*, Princeton University Press, Princeton, New Jersey, 2002, p.11
  - 2 R. Higham, *The Military Intellectuals in Great Britain, 1918-1939*, Rutgers University Press, New Brunswick, New Jersey, 1966
  - 3 B. Powers, *Strategy without Slide Rule: British Air Strategy, 1914-1939*, Croom Helm, London, 1976
  - 4 H. M. Hyde, *British Air Policy between the Wars, 1918-1939*, Heinemann, London, 1976
  - 5 Uri Bialer, 'The British Chiefs of Staff and the "Limited Liability" Formula of 1938, A Note', *Military Affairs*, Vol. 42, Issue 2, April 1978, pp. 98-99

of air warfare reduced the British Government's capacity to stand up to Hitler<sup>6</sup>. Possibly taking his lead from Churchill, Bialer argues that the fear induced by the threat of bombing led Britain to develop an inherently defensive doctrine, which attempted to use air defences and bomber attack, to keep the nation out of a larger European war.

Other writers who have dealt with the subject include Brian Bond<sup>7</sup>, Malcolm Smith<sup>8</sup>, Alfred Gollin<sup>9</sup> and David Edgerton<sup>10</sup>. The last two are more critical of the way in which the British Government allowed public expectations to guide the development of air power policy. Gollin argues that there was a significant level of 'hysteria' in the response of both the British public and the government to the threat posed by bombing attacks. Edgerton, who proposes the thesis that the British were attracted to air power because of an inherent reliance on technology, similarly describes British public responses to air power as 'over enthusiasm'. In his view, the commitment of England to the aeroplane exemplifies a commitment to armed force, science, technology and industry.

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6 Uri Bialer, *The Shadow of the Bomber: The Fear of Air Attack and British Politics, 1932-1939*, Royal Historical Society, London, 1980

7 B. Bond, *British Military Policy Between The Two World Wars*, Oxford University Press, Oxford, 1980.

8 M. Smith, *British Air Strategy between the Wars*, Oxford University Press, Oxford, 1984.

9 A. Gollin, *The Impact Of Air Power On The British People And Their Government, 1909-14*, Stanford University Press, California, 1989

10 D. Edgerton, *England and the Aeroplane: An Essay on a Militant and Technological Nation*, MacMillan London, 1991

Michael Paris<sup>11</sup> and Tami Davis Biddle<sup>12</sup> are among the most perceptive of the recent writers on this subject. Paris emphasises the influence of Social Darwinist and imperialist ideas in the development of British military thinking on how civilian populations would react to aerial bombardment. Davis Biddle describes how British and American advocates of strategic bombing drew upon the work of the imaginative writers to bolster their arguments for organisational and institutional independence from the older military services in both countries. Davis Biddle provides a substantial analysis of how the advocates of strategic bombing attempted to convince their governments to use this form of warfare as the sole means of defeating the enemy. She argues most convincingly that the focus of the RAF and the USAAF on the 'knockout blow' led to a 'near catastrophic failure' of air strategy during World War II<sup>13</sup>.

The lack of a clear success for strategic air power during World War II, what Davis Biddle calls 'near catastrophic failure', may be a reflection of the gap that existed between pre-war expectations and wartime accomplishment<sup>14</sup>. Strategic bombing did not cause social, economic or military collapse in any of the

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11 M. Paris, *Winged Warfare: The Literature and Theory of Aerial Warfare in Britain, 1859-1917*, Manchester University Press, 1992

12 Davis Biddle, 'British and American Approaches to Strategic Bombing: Their Origins and Implementation in the World War II Combined Bomber Offensive', *The Journal of Strategic Studies*, vol. 18, no. 1, March 1995; 'Bombing by the Square Yard: Sir Arthur Harris at War, 1942-1945', *International History Review*, Vol XXI, No. 3, Sept 99; and *Rhetoric and Reality in Air Warfare: The Evolution of British and American Ideas About Strategic Bombing, 1914-1945*, Princeton University Press, Princeton, New Jersey, 2002

13 Davis Biddle, *Rhetoric and Reality in Air Warfare*, p.301

14 Davis Biddle, *Rhetoric and Reality in Air Warfare*, p.301

belligerent countries and the contribution that it made to the Allied victory remains unclear. The major difficulty in assessing the efficacy of the strategic air offensive is that it adopted many guises during World War II. The period from September 1939 to February 1942 was, as the official history written by Sir Charles Webster and Noble Frankland describes it, a period of preparation. It was also a period of failure. The major problem confronting Bomber Command was that the majority of its attacking aircraft could not even find their target cities let alone hit them and even where bombs struck populated areas the civilian population did not panic as predicted.

The period from February 1942 to May 1944 saw the efficacy of the strategic air offensive most nearly approached the ideas of the pre-war theorists. During this time, Bomber Command could launch attacks against German cities without having to deal with competing claims on its resources. By April 1944 all of this had changed and Bomber Command found itself subordinated to the overall planning of the Supreme Commander in Europe and its bombers were diverted to attacks on tactical targets including German troop concentrations, lines of communication and even to flying bomb sites. This diversion of bombers from the strategic attacks on German cities to tactical support of ground forces led to the famous confrontation between the CAS, Sir Charles Portal, and the Air Officer Commanding-in-Chief Bomber Command, Sir Arthur Harris.

The operational support that Bomber Command provided to Allied ground forces in France and the attacks against German flying bomb bases diverted substantial

resources away from the strategic bombing of German cities. There is no doubt that Bomber Command proved itself a valuable tool in reducing German military effectiveness in France and Northern Europe during 1944 and 1945. There is also little doubt that the 1944-45 attacks on oil production and communications severely damaged Germany's war making capability. Despite these successes, the fact is that Bomber Command's attacks on German cities, the concept that formed the kernel of the Air Staff's strategic air offensive, did not produce the results that they had predicted. This failure was absolute. Germany fell after the largest ground invasions in history. Millions of soldiers and civilians on all sides died and the fighting devastated vast areas of Europe. Whatever else can be said about the theory of strategic air warfare, it cannot be claimed that it was anywhere decisive in defeating Germany. This honour still belongs to the infantry and ground forces of the Red Army and its allies.

### **The Intellectual Framework**

Although it is hard to accept at times, one of the most influential British writers on air power was, and is, H.G. Wells. Wells was the most popular and prominent writer of science fiction in the world of his day. His description of air warfare reached large audiences and helped generate the belief in social collapse that fuelled British efforts to place themselves amongst the leading air powers. In 1908, Wells published *First and Last Things*, one of the first serious works on the possibility of strategic air warfare. In the book, Wells described air raids on cities

that left them 'red with destruction while airships darken the sky'<sup>15</sup>. It would be, Wells believed, the first time in the history of warfare that 'the rear of the fighting line becomes insecure, assailable by flying machines and subject to unprecedented and unimaginable panics' and in which 'No man can tell what savagery of desperation these new conditions may not release in the soul of man'<sup>16</sup>. Wells's vision was apocalyptic and lacked faith in the resilience of humanity to overcome adversity. He reiterated this vision in his next book, one of pure imagination, *The History of Mr. Polly and the War in the Air*<sup>17</sup>. These two books laid the foundation for what became a wider acceptance of the Social Darwinist vision that the lower orders of society would revert to primeval behaviour under the stress of air attack<sup>18</sup>. The view coincided with the growing concern of conservatives that the working class were weak and unreliable and that the social and political equality they demanded would inevitably weaken the nation.

Others, many others, followed Wells and they were given plenty of space for their views in the columns of the newspapers, especially Lord Northcliffe's *Daily Mail* and in *London Times*. In 1909, a serious thinker, Sir Hiram Maxim, the inventor and armaments manufacturer, wrote that 'if a thousand tons of pure nitro-glycerine were dropped on to London in one night, it would make London look like a last year's buzzard's nest'<sup>19</sup>. Major B.F.S. Baden-Powell, founder of the

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15 H.G. Wells, *First and Last Things: A Confession of Faith and a Rule of Life*, G.P. Putnam's Sons, New York, 1908, p.224

16 Wells, *First and Last Things*, p.224

17 H.G. Wells, *The History of Mr. Polly and the War in the Air*, Odhams Press, London, 1908

18 Edward Warner, 'Douhet, Mitchell, Seversky: Theories of Air Warfare', *Makers of Modern Strategy: Military Thought from Machiavelli to Hitler*, edited by Edward M. Earle, Princeton University Press, Princeton, 1973, p.486

19 Gollin, *The Impact of Air power*, p.18

Boy Scouts, and a prominent member of the Aeronautical Society of Great Britain, advocated for increased government funding of air defence<sup>20</sup>. By 1911, a broad interest in aeronautical matters had produced over 300 books and 25 periodicals<sup>21</sup>. A rapid growth in the popular literature demonstrated that the British public had developed an apparently unquenchable interest in aeronautical information, which may have reflected an underlying mood of insecurity within Britain at that time<sup>22</sup>. Indeed, David Edgerton has argued that this late Edwardian interest in aviation was an anti-liberal push by conservative forces to undermine the growing acceptance of increased involvement by working people in the government of the nation<sup>23</sup>.

At the same time as Wells's was writing his book official interest in air power was growing. This interest grew out of unease in official circles that the development of aircraft by Germany and, to a lesser extent, France posed a threat to the British Isles that neither the Army nor the Royal Navy could counter. In October 1908, the Committee of Imperial Defence formed a Sub-Committee under Lord Esher to investigate the 'dangers to which we would be exposed on sea or on land by any developments in aerial navigation reasonably probable in the near future'<sup>24</sup>. The Esher Committee found that Britain did not face 'any

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20 Gollin, *The Impact of Air power*, p.5

21 B.D. Powers, *Strategy without Slide-Rule: British Air Strategy 1914-1939*, Croom Helm, London, 1976, p.111

22 N. Jones, *The Origins of Strategic Bombing: A Study of the Development of British Air Strategic Thought and Practice up to 1918*, William Kimber, London, 1973, pp. 27-29 and A. Gollin, *The Impact of Air Power*, p.1

23 Edgerton, *England and the Aeroplane*, pp. 12-13

24 Quoted in N. Jones, *The Origins of Strategic Bombing*, p.26

serious danger' in the immediate future from the developments in aeronautics but there was a danger, which when it came, would come from bomber aircraft<sup>25</sup>.

It is likely that the official concern about strategic bombing was a reaction to the growing popular interest in the destructive possibilities of aircraft, which, in turn, were growing out of the writings of H.G. Wells and other imaginative writers. Although there is no evidence to suggest that the imaginative writers directly influenced British official policy, there was a confluence of popular and official concern at exactly the same time and the two became mixed together. The later conviction of Air Staffs that aerial bombardment would bring about social collapse seems to reflect more of H.G. Wells than it does a systematic and rigorous evaluation of the potentialities of bomber aircraft between 1914 and 1939.

Official thinking on air power continued with a second official investigation by the Aerial Navigation Sub-Committee of the Committee of Imperial Defence. This investigation recommended in November 1911 that the government establish a Central Flying School and a Flying Corps, consisting of naval and military wings. The 'Technical Sub-Committee', which evaluated the recommendations, supported the recommendations and emphasised Britain's backwardness in comparison to her continental adversaries. According to Neville Jones, the report of the Technical Sub-Committee is one of the more important, if curious

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25 Quoted in N. Jones, *The Origins of Strategic Bombing*, p.26

documents, on the early development of British ideas on the use of aircraft<sup>26</sup>. It suggested that the functions of aircraft included reconnaissance, counter-reconnaissance, inter-communication, the observation of artillery fire and the ‘infliction of damage’ upon the enemy army<sup>27</sup>. The government adopted the recommendations, and in April 1912 established the Royal Flying Corps.

### **Strategic Bombing, World War I and Britain**

Within three weeks of the outbreak of World War I Britain undertook her first strategic air attack when, on 27 September 1914, Royal Naval Air Service (RNAS) aircraft bombed the German Zeppelin sheds at Düsseldorf<sup>28</sup>. Three further attacks followed with Cologne being bombed on 8 October, Friedrichshaven on 21 November, and Cuxhaven, deep within enemy territory, attacked on 25 December 1914<sup>29</sup>. These raids attempted to destroy Germany’s Zeppelins on the ground where they were more easily located. In effect, they were a defensive act and, as such, they were successful, in that they damaged the Zeppelin programme enough to halt production. However, they also galvanised the Germans into using their Zeppelin fleet before they were destroyed by further

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26 Jones, *The Origins of Strategic Bombing*, p.36

27 PRO AIR 1/21, The Recommendations of the Standing Sub-Committee on Aerial Navigation and the Report of the Technical Sub-Committee, 29th February 1912

28 Quester, *Deterrence Before Hiroshima*, p.21

29 Quester, *Deterrence Before Hiroshima*, p.21

enemy action and this led to a series of Zeppelin raids on London and Britain throughout 1915<sup>30</sup>.

The Zeppelin raids of 1915 further strengthened the arguments for strategic bombing. Winston Churchill, who had ordered the RNAS raids of 1914, Admiral Fisher and Field Marshal Kitchener advocated bomber attacks on German industrial and military targets. The debate about the efficacy of bombing continued until well after the first Zeppelin raids of 1915. The lack of retaliatory action may have reflected the limited damage that the raids accomplished. All of this changed on 13<sup>th</sup> June 1917, when Gotha Bombers conducted the first daylight bombing raids on London.

The Gotha raids enraged British public opinion and Lord Northcliffe's newspapers, led by the *Daily Mail*, took up a loud cry for revenge by advocating that British forces carry out retaliatory attacks against Germany<sup>31</sup>. The British press used graphic descriptions and photographs of the child victims killed in the raids and the *Daily Mail* even printed a reprisal map of Germany<sup>32</sup>. A number of prominent individuals, including the Members of Parliament, Pemberton Billings and Joynson-Hicks, led the charge in the Commons, while Lord Northcliffe used his position as a member of the House of Lords to promote the retaliatory bombing of German cities in that Chamber. To these voices were added those of

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30 Quester, *Deterrence Before Hiroshima*, p.21

31 Powers, *Strategy Without Slide-Rule*, pp. 82

32 Powers, *Strategy Without Slide-Rule*, pp. 82

the public whose views were expressed by the attendees at a public meeting organised by the Lord Mayor at the London Opera House on 13<sup>th</sup> June 1917:

That this meeting of London's inhabitants hereby expresses its utter abhorrence of the German method of warfare by the murder of innocent women and children in air raids on open towns and cities, and is of the opinion that the only means of bringing the inhumanity and cruelty of these dastardly and criminal attacks home to the German people is by systematic and ruthless reprisals. It, therefore, calls on the Government to initiate immediately a policy of ceaseless air attacks on German towns and cities in order that their population may experience the effects of such methods of warfare and thus be induced to force the German authorities to cease this wanton and useless destruction of life and property<sup>33</sup>.

David Lloyd George, the politically astute Prime Minister, reacted quickly and on 11<sup>th</sup> July 1917, he formed the Prime Minister's Committee on Air Organisation.

The Committee comprised Lloyd George, General Smuts, who would write the report, and representatives from the Admiralty, the General Staff and the Staff of the Commander-in-Chief, Home Forces<sup>34</sup>. The make-up of the Committee shows the impact of the public mood on the government and, in his 1937 memoir, Lloyd-George frankly admits he formed the Committee in order 'that we should not be held up, in the adoption of measures to put our growing air strength to its fullest use'<sup>35</sup>. The outcome of the Committee's deliberations was the handing down of two reports, the first on the 19<sup>th</sup> July 1917 and the second on the 17<sup>th</sup> August 1917. The second report dealt with the organization of the independent air force that would attack the heart of Germany<sup>36</sup>.

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33 Powers, *Strategy Without Slide-Rule*, note, p.85

34 Lloyd George, *War Memoirs*, Ivor Nicholson and Watson, London, p.1869

35 Lloyd George, *War Memoirs*, p.1869

36 Smith, *British Air Strategy Between The Wars*, Clarendon Press, Oxford, 1984, p.18

The RFC formed the new Independent Air Force (IAF) in October 1917 by transferring control of 41 Wing, based at Nancy in France, from General Headquarters, Western Front (GHQ) to Colonel Cyril Newall<sup>37</sup>. The force comprised three squadrons: a day bombing squadron; a night bombing squadron; and a Handley Page squadron from England<sup>38</sup>. The IAF conducted its first raid on 17 October 1917 against an iron foundry near Saarbrücken<sup>39</sup>. The first night raid occurred three weeks later. However, General Haig, the Commander-in-Chief, did not welcome the creation of the new force and neither did his supporters, amongst whom was Major General Sir Hugh Trenchard, the new Chief of the Air Staff. The infighting caused by the formation of the IAF was so great that even the carefully written Official History could not gloss over the difficulties. The official historian, W. Raleigh commented:

It will be enough to say that Major-General Trenchard took a much wider view of the responsibilities of the Chief of the Air Staff than it appeared to him the Secretary of State was willing to accord, but it is clear, also, that there were differences of temperament<sup>40</sup>.

Sir Hugh Trenchard, who Lloyd-George had appointed as the first Chief of the Air Staff, resigned his commission and, with Major Sir John Salmond, locked himself in the Hotel Cecil, where they orchestrated a campaign of destabilisation

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37 Powers, *Strategy Without Slide-Rule*, note, p.103

38 Powers, *Strategy Without Slide-Rule*, note, p.103

39 Powers, *Strategy Without Slide-Rule*, note, p.103

40 Sir W. Raleigh and H.A. Jones, *The War in the Air, being the story of the part played in the Great War by the Royal Air Force*, Clarendon Press, Oxford, 1922-1937, Vol VI, p.26

against their Secretary of State. In the end, their campaign was successful and the new Supreme Commander on the Western Front, General Foch, regained control of the force. General Foch, the new Supreme Commander in France, made it clear that he would not tolerate an Independent Air Force and he demanding that it be placed under his supervision or be removed from French soil. It is possible that Haig put Foch up to this, but whatever the case, Foch got his way and on 26 October 1918, the British Government placed the IAF under his command as the Inter-Allied IAF. The force was to 'carry the war into Germany by attacking her industry, commerce and population', but, the Western Front had first call on its services<sup>41</sup>.

Despite the arguments over who controlled the air forces at the end of the war, Britain was a leading air power. The new RAF had 22,171 aircraft on charge, with 20,100 pilots and observers serving as aircrew<sup>42</sup> and a further 270,900 officers and men working as ground support staff<sup>43</sup>. The wartime demand for aircraft had created an industry of 122 firms with a workforce of 112,000<sup>44</sup> and an annual production 26,685 airframes and 29,561 aircraft engines<sup>45</sup>. The First World War however ended before the new Independent Air Force had an

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41 Powers, *Strategy Without Slide-Rule*, note, p.105

42 J.M. Spaight, *The Sky's The Limit: A Study Of British Air Power*, Hodder and Stoughton, London, 1940, p.13

43 J.A. Cross, *Sir Samuel Hoare: A Political Biography*, Jonathan Cape, London, 1977, p.84

44 P. Fearon, 'The Growth of Aviation in Britain', *Journal of Contemporary History*, Vol. 20, 1985, pp. 21-40

45 Fearon, 'The Growth of Aviation in Britain' , pp. 21-40

opportunity to provide ‘convincing proof of the offensive power of aircraft’<sup>46</sup>.

The effectiveness of strategic air warfare remained a theoretical construct.

### **The Official Position 1919 - 1939**

When the war ended, the RAF all ideas about strategic warfare took second place to the development of ideas on how to develop a meaningful peacetime role for the RAF. The answer lay in policing the empire. The RAF’s first success in the new role of imperial police force occurred in 1919, when the simple expedient of lying aircraft over Kabul forced the Amir of Afghanistan to the negotiating table<sup>47</sup>. Later the same year, Sheikh Hassan, the ‘Mad Mullah’, was defeated in Somaliland by the RAF at a cost of only £77,000<sup>48</sup>. The Air Ministry and the Air Staff promoted the RAF as a cheap imperial police force and were able to convince a financially pressed government to maintain the Air Ministry and the RAF. The RAF therefore found itself being widely used in the 1920s and 1930s in Iraq, Aden, India and Palestine<sup>49</sup>.

The problem for the Air Staff was that imperial policing did not going provide the experience necessary for the development of a theory of strategic air warfare applicable to European warfare. In 1923, the search for a doctrinal enemy led the

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46 Saundby, *Air Bombardment*, p.23

47 M. Paris, ‘Air Power and Imperial Defence 1880-1919’, *Journal of Contemporary History*, Vol. 24, 1989, p.222

48 M. Smith, *British Air Strategy Between the Wars*, Clarendon Press, Oxford, 1984, p.25

49 Saundby, *Air Bombardment*, p.41

Air Staff and the new Secretary of State for Air, Sir Samuel Hoare, to choose France as the likely enemy air power<sup>50</sup>. According to Colin Sinnott, this choice had serious ramifications for British air policy and planning<sup>51</sup>. Sinnott argues convincingly that the selection of France as the doctrinal enemy led to the design and development of bomber aircraft suitable for conducting short-range daylight attacks on Northern France rather than on the longer-range targets in Germany and Italy that were to be the targets for Bomber Command in 1939. The problem arose from the fact that the function of doctrinal enemies extends beyond military exercises into the design and development of weapons systems and the choice of France led to the development of short range, light bombers with quick turn-around times that could operate under RAF fighter protection. Such aircraft were not suitable against an enemy like Germany. The long lead times needed to raise a specification, produce a prototype and put an aircraft into production inevitably meant that the aircraft designed to attack France in 1923 would be coming into service in the early 1930s. For Sinnott, the fact that the aircraft available for operations in 1939 were unsuitable for bombing Germany was due to strategic assessment and not to poor design or bad specifications<sup>52</sup>.

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50 PRO CAB 21/261, Air Policy and A One-Power Air Standard, Memorandum by the Secretary of State for Air, 74, N.D.4, February 1923

51 PRO CAB 21/261, Air Policy and A One-Power Air Standard, Memorandum by the Secretary of State for Air, 74, N.D.4, February 1923

52 C. Sinnott, *The Royal Air Force and Aircraft Design, 1923-1939: Air Staff Operational Requirements*, Frank Cass, London, 2001, p. 146

By 1928, the Air Staff was beginning to extend its claims to include that the RAF could defeat an enemy's field forces by bombing the enemy's industrial centres<sup>53</sup>. Trenchard formulated the idea of the RAF being able to defeat an enemy by attacking their industrial centres in a memorandum to the Chiefs of Staff Sub-Committee of the Committee of Imperial Defence in May 1928<sup>54</sup>. The First Sea Lord, Admiral of the Fleet Sir Charles Madden, and the Chief of the Imperial General Staff, Field Marshal Baron Milne of Salonika and Rubislaw, challenged elements of Trenchard's memorandum. Madden strongly attacked strategic bombing as being 'a departure from the principles of war which cannot be justified by experience'<sup>55</sup>. He argued that there was no evidence to support the Air Staff's claims that aerial attack on centres of production, transportation and communications would paralyse 'the life and effort of the community'<sup>56</sup>. The hostility forced Trenchard to tone down his claims and in a speech to the Imperial Defence College in October 1928, he accepted that co-operation between services was essential in war. However, he maintained that offensive bombing attack against industrial cities would be the crucial strategy in any future war.

As has been already been alluded to, British view of strategic bombing had a lot in common with the ideas of the Italian General, Giulio Douhet<sup>57</sup>. Like Douhet,

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53 A. Boyle, *Trenchard: Man of Vision*, Collins, London, pp. 576-578

54 Admiral Milne, Quoted in Davis Biddle, *Rhetoric and Reality in Air Warfare*, p.95

55 Sir Charles Webster and Noble Frankland, *The Strategic Air Offensive Against Germany*, Vol. IV, p. 83

56 Admiral Milne, Quoted in Davis Biddle, *Rhetoric and Reality in Air Warfare*, p.95

57 Although there is no indication that the British Air Staff had made a study of Douhet or other foreign theorists like the American, Billy Mitchell, it is highly likely that the writings of

the British Air Staff believed that aerial bombardment was a legitimate means of marking war and that terror could subdue a population. However, unlike Douhet, who advocated the unrestricted use of terror upon an enemy population, even the British Air Staff held that such an attack was ‘illegitimate and contrary to the dictates of humanity’<sup>58</sup>. This reluctance in unrestricted attack on civil populations did not extend to workers in munitions factories, stevedores in ports or rail workers at rail yards. These were legitimate targets for air attack because they were supporting the military forces of their nation through their work<sup>59</sup>. Even with these reservations, as seen above other British military leaders were highly uncomfortable with the watered down proposals being put forward by the Air Staff.

### **Review But No Reform, Air Staff Thinking 1931 to 1939**

Britain had used the threat of the French air force as a notional enemy in order to provide a framework for the development of the RAF in the 1920s, but by the

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these theorists were known to RAF officers and members of the Air Staff. Edward Warner, reports that an abstract of Douhet’s book was published in April 1936 in the RAF Quarterly, see Edward Warner, ‘Douhet, Mitchell, Seversky: Theories of Air Warfare’, *Makers of Modern Strategy*, p.489. There also may have been some knowledge of Billy Mitchell’s activities, which were publicised in the US prior to 1923 and 1928 arguments within the Chiefs of Staff Sub-Committee of the Committee of Imperial Defence on the effectiveness of aircraft against capital ships. The British Air Staff concepts of strategic air war focussed on offensive strike without the uncompromising acceptance of terror that Douhet recommended. See John McCarthy, ‘Douhet and the Decisiveness of Airpower’, *The Strategists*, edited By Hugh Smith, Australian Defence Studies Centre, University of New South Wales, Canberra, 2001, pp.65-73

58 Sir Charles Webster and Noble Frankland, *The Strategic Air Offensive Against Germany*, Vol. IV, p. 73

59 Sir Charles Webster and Noble Frankland, *The Strategic Air Offensive Against Germany*, Vol. IV, pp. 63-83

early 1930s, even before the Nazis' took power, Germany was beginning to cause concern for some British officials. British concern with Germany began to grow as German officials and leaders betrayed increasingly belligerent attitudes towards their neighbours<sup>60</sup>. Amongst the incidents that caused concern was the public celebration by German government leaders and officials of the French withdrawal from the Rhineland<sup>61</sup>. Actions like these prompted British officials to investigate German intentions and capability. In 1930, General G.F. Milne, the British Chief of the Imperial General Staff (CIGS), presented a memorandum to Cabinet detailing how the German government 'in contravention both of the spirit and the letter of the Treaty of Versailles' was increasing the efficiency of the armed forces<sup>62</sup>. It is notable that such concerns were prompting a military commander as senior as the CIGS into signing a memorandum literally accusing Germany of bad faith and breaching its agreements under the Versailles Treaty. By 1932, the British Committee of Imperial Defence (CID) did not need a notional French enemy.

The British military establishment's concerns very quickly spread to other areas of government, as did their assessment of German capabilities. In 1932, the Home Defence Committee was using the Air Staff's estimates of German

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60 C3872/140/18, Note by His Majesty's Military Attaché, Colonel J.H. Marshall-Cornwall, May 8th, 1930 Quoted in *Documents on British Foreign Policy 1919-1939*, edited by E.L. Woodward and R. Butler, HMSO, London, 1947, p.478

61 C5354/16/18, Telegram No. 761 from Lord Tyrrell, H.M. Ambassador to France to Mr. A. Henderson in Foreign Office, July 3, 1930 Quoted in *Documents on British Foreign Policy 1919-1939*, p.479

62 C326/136/18: C.I.D. 979 B, The Military Situation in Germany, January 1930, Memorandum by the Chief of the Imperial General Staff, General G.F. Milne Quoted in *Documents on British Foreign Policy 1919-1939*, p.492

capability to plan for attacks that would see between 600 and 1,000 tons of bombs per day dropped on London, with occasional attacks delivering up to 3,500 tons a day<sup>63</sup>. The most striking thing about the Home Defence Committee's calculations lies in the fact that, at the time they made them, Germany had no aircraft capable of flying to London with the bomb tonnages required. Despite this glaring fault, the estimates provided to the Home Defence Committee led them to conclude:

It is obvious that the weight of attack...is so great that even if unlimited money and resources were available it would be impossible to prevent heavy casualties and great destruction of property<sup>64</sup>.

The impact of these estimates on British official thinking was profound. The professional advisors working at the Air Ministry and in the Air Staff had successfully convinced other departments and ministers that bombing attack would kill up to 600,000 dead and injure 1.2 million injured in the first six months of war<sup>65</sup>. Richard Titmuss, the post war official historian of the social services volume of the civil histories, lays the responsibility for this massive miscalculation directly at the feet of the Air Staff. Titmuss argues that the Air Staff persisted in using the calculation of '50 casualties per ton of bombs dropped' because it was 'easily remembered'<sup>66</sup>. The result was that a simplistic calculation 'acquired a validity' to which it was 'hardly entitled'<sup>67</sup>. Titmuss was

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63 Smith, *British Air Strategy Between the Wars*, p.78

64 Quoted in Smith, *British Air Strategy*, p.78

65 R.M. Titmuss, *Problems of Social Policy*, History of the Second World War, Civil Series, HMSO, London, 1950, p.13.

66 Titmuss, *Problems of Social Policy*, p.12

67 Titmuss, *Problems of Social Policy*, p.12

the first critic to highlight the appalling lack of intellectual rigor that permeated Air Ministry thinking on strategic air war. Based upon the flawed advice of the Air Ministry and Air Staff the British government prepared to supply and man up to 2.8 million hospital beds and find 20 million square feet of coffin wood per month at a cost of £300,000 to bury the dead<sup>68</sup>. Plans were made to burn the bodies in lime instead<sup>69</sup>.

Looking back, it appears odd that the British government accepted these figures without challenge. Churchill later defended the government's unquestioning acceptance of the Air Staff's figures pointing out that Government ministers were dependent upon their professional advisors and that by the mid-1930s bombing had 'become obsessive in men's minds, and also a prime military factor'<sup>70</sup>. This process forced government ministers 'to imagine the most frightful scenes of ruin and slaughter in London if we quarrelled with the German dictator'<sup>71</sup>. Churchill later went on to place in writing his view that the Air Staff's pre-war advice 'was so exaggerated it had depressed the statesmen responsible for pre-war policy'<sup>72</sup> and so undermined the government in its efforts to confront Hitler. The British Government accepted the professional advice that any bombing would be effective<sup>73</sup>. The British Government was also subject to public and parliamentary

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68 Titmuss, *Problems of Social Policy*, p.12

69 Titmuss, *Problems of Social Policy*, p.12

70 Churchill, quoted in R.M. Titmuss, *Problems of Social Policy*, p.21

71 Churchill, quoted in R.M. Titmuss, *Problems of Social Policy*, p.21

72 PRO CAB 120/300, Minute Churchill to CAS, 7th October 1941. In the original minute draft, Churchill used the word terrified but later replaced it with depressed.

73 Davis Biddle, *Rhetoric and Reality in Air Warfare*, p.91

pressure from Trenchard, Moore-Brabazon and Wing Commander Archibald James<sup>74</sup>, which reinforced the effectiveness of strategic bomber<sup>75</sup>.

The above evidence clearly shows that the British Air Staff did not rigorously evaluate bomber capabilities. Further evidence for a lack of intellectual rigor is also apparent in the interpretation of the results of air exercises in the early to mid-1930s<sup>76</sup>. In these exercises, the Air Staff and exercise umpires consistently favoured the attacking bombers simply on the basis that they were attacking. For example, in one exercise, the umpires awarded Red forces the victory over Blue on the basis that they had conducted offensive operations whilst Blue had only defended<sup>77</sup>. In a 1931 exercise, the umpire, Major C.C. Turner, judged the attacking bombers had won as they had attacked and damaged 'London's nerves'<sup>78</sup>. Major Turner apparently was unmoved by the fact that other umpires judged that 84 out of 112 attacking bombers had been destroyed. The expectation was that any degree of bombing would have an enormous impact upon the urban working class.

The air exercises conducted by the RAF did not test the doctrine of an Air Staff dominated by a belief in the effectiveness of bombing. The failure to test the doctrinal orthodoxy handed down by Trenchard was a major failure of policy.

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74 N. MacMillan, *The Chosen Instrument*, Bodley Head Press, London, 1938, pp. 42-44

75 Smith, *British Air Strategy*, p.81

76 Smith, *British Air Strategy between the Wars*, pp. 72-74

77 Smith, *British Air Strategy Between The Wars*, p.72 and Davis Biddle, *Rhetoric and Reality in Air Warfare*, p.90

Tami Davis Biddle argues that the RAF leadership was ‘often resistant to grappling with details in advance of events’ and that their preference for ‘general principals’ and ‘improvisation’ would prove ‘increasingly risky’ in an age of growing mechanisation<sup>79</sup>. This evaluation of the Air Staff and the Air Ministry is supported by no less a figure than Air Marshal, Sir John Slessor, who had served as the Deputy Director and Director of Plans from May 1937 until January 1939. In his book, *The Central Blue*, Slessor states that the Air Staff approach was ‘intuitive-a matter of faith’<sup>80</sup>. It took the operational experience of World War II to show that the Air Staff had been ‘too optimistic’ on the ability of a strategic air offensive’<sup>81</sup>.

It is worth noting how close the Air Staff’s expectations were to H.G. Wells’s vision of civilised life collapsing under the impact of aerial attack. In March 1938, the Air Staff identified morale, what they called the ‘will to win’, as the leading factor in a nation’s ability to prosecute war. The nation would collapse when sufficient ‘houses, water, gas, electric and food supplies, communications, power stations and certain social services, e.g. the medical, sanitary and distributing organisations’ had been destroyed, making ordinary life impossible<sup>82</sup>. This unequivocal statement suggests that, despite their stated reservations, the British Air Staff still saw the civilian population as a primary target in any

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78 Davis Biddle, *Rhetoric and Reality in Air Warfare*, p.90

79 Davis Biddle, *Rhetoric and Reality in Air Warfare*, p. 93

80 Sir John Slessor, *The Central Blue: Recollections and Reflections*, Cassell and Co., London, 1956, p.92

81 Sir John Slessor, *The Central Blue*, p.205

strategic air offensive. Ironically, the Air Staff's own predictions generated enough fear in both the French and British governments that bomber attacks were restricted to isolated targets where there was little chance of inflicting civilian casualties and, as a result, when the war broke out Bomber Command found itself attacking remote naval bases on the North Sea<sup>83</sup>.

### **War and Strategic Bombing 1939 to 1945**

Bombing attacks on German cities were not to begin until 11<sup>th</sup> May 1940, over eight months after the outbreak of the war. The sudden knockout blow had not eventuated and the raids, when they did start, were small affairs, which inflicted little damage. The Air Staff patiently waited for the new heavy bombers to be ready and for Bomber Command to build up sufficient infrastructure and resources for a sustained bomber offensive. Planning for the strategic air offensive continued throughout this initial period of the war and operational information from both British and German raids was analysed to provide useful lessons for Bomber Command. An example of this process was the work of the Bombing Committee, which, at a meeting in February of 1941, considered the optimum size of bomb and method of fuzing required to do as much damage as possible to the 'ordinary town target'<sup>84</sup>. The Committee concluded that industrial

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82 PRO AIR 2/8812, Air Staff Note on Bombing Policy, 8th March 1938

83 PRO CAB 54/11, Bombardment Policy, 13 August 1939

84 PRO AIR 2/8655, Minutes of the 25th Meeting of the Bombing Committee, 5<sup>th</sup> February 1941

targets were highly resistant to damage from blast and fragmentation bombs and that using incendiary bombs would provide a better return.

The problem with incendiary bombs was that they were highly inaccurate and were therefore not particularly useful against small targets such as factories.

However, their lack of accuracy was not a problem if the target was something as large as a small city. The concept that was developed was to use blast bombs to remove roofs, windows and doors to provide openings into which the small incendiaries could fall and start fires. In this way, an attacking bomber force could create large-scale fires within a metropolitan area<sup>85</sup>. Two of the strongest proponents of this method of attack were the Deputy Chief of the Air Staff, Sir Arthur Harris and the Senior Air Staff Officer from Bomber Command, Sir Robert Saundby<sup>86</sup>. Although the British were never to use the mustard gas attacks that Douhet had envisaged, they held both the stocks of gas and the munition containers for conducting such attacks.

The strategic objective of the Air Staff, as detailed at the Bombing Committee by Harris and Saundby, was that of area attack against civilian housing. This strategy, which was solely directed at civilians, was seen by the Air Staff as ‘the decisive factor in [causing] the German collapse’<sup>87</sup>. The evaluation was based

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85 PRO AIR 2/8655, Minutes of the 25<sup>th</sup> Meeting of the Bombing Committee, 5<sup>th</sup> February 1941

86 PRO AIR 2/8655, Minutes of the 25<sup>th</sup> Meeting of the Bombing Committee, 5<sup>th</sup> February 1941

87 PRO AIR 9/41 Joint Planning Staff, 12th June 1941

upon a belief that there was ‘considerable fear of intensified RAF bombing’ in Germany. Information coming out of Germany from ‘neutral observers’ suggested ‘that intensified and concentrated bombing might have tangible effects’ and it was suggested that bombing for morale effect ‘must be severe’<sup>88</sup>.

The United States was not as comfortable with the idea of deliberately attacking civilian populations. In a staff paper dated 30<sup>th</sup> July 1941, the Air Staff bluntly stated that as the strength of Bomber Command grew it would ‘pass to a planned attack on civilian morale with the intensity and continuity which are essential if a general breakdown is to be produced’<sup>89</sup>. The Americans replied to this statement by pointing out that ‘it is not enough to set forth the “destruction of morale” as a military objective’<sup>90</sup>. The American reaction caused sufficient concern for the War Cabinet American Liaison Section to intervene to calm American concerns. In a note explaining that the term ‘morale’ was being used for want of a better word, the Liaison Section strongly emphasised that killing civilians was not the objective, although ‘the fear of death’ was ‘unquestionably an important factor’<sup>91</sup>.

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88 PRO *AIR 9/41* Joint Planning Staff, 12th June 1941. Despite this evidence of German fear, the German civil population persevered. The logical flaw in the theory of destroying civilian ‘morale’ by bombing was that whilst civilian morale might be momentarily destroyed by an attack there was no capacity on the part of the attacker to exploit the situation and the lull in the attack allowed for it to recover. Despite the evidence gleaned from the USSBS survey into civilian morale in 1945, the fact is that civilian morale is not a crucial military factor. Even if civilian morale is broken, the enemy cannot immediately exploit the advantage. This logical flaw in air power theory remains today.

89 PRO *AIR 9/41* J.B. No. 325 (serial 729), Joint Planning Staff, 30th July 1941

90 PRO *AIR 9/41* J.B. No. 325 (serial 729), Joint Planning Staff, 30th July 1941

91 PRO *AIR 9/141*, American Liaison (41) Minutes of 8th Meeting, 21 November 1941

The Americans were not alone in their unease over the deliberate bombing of civilians. Within the British government and the military there were many who only supported such attacks, because there was no other way for them to carry the war directly into the heart of Germany. Even within the Air Ministry and the RAF there was concern over the prevailing doctrinal view. Amongst those who expressed such concerns were the scientist Sir Henry Tizard and the Minister for Aircraft Production, Mr. Moore-Brabazon. These men were closely associated with promoting air power and the impact of their open criticism caused consternation within the Air Ministry.

In addition, the report by Mr. Butt of the Cabinet Office on the lack of bomber accuracy had seriously undermined the credibility of Bomber Command. The findings of the Butt Report and the open questioning of strategic bombing provoked a quick response by the Air Staff and Air Ministry. Throughout the period from September to December 1941, Sir Charles Portal, the Chief of the Air Staff, sent a number of minutes on accuracy to Churchill in an attempt to diffuse the impact of the growing criticism of bomber accuracy<sup>92</sup>. Portal attempted to defuse the critical analysis of bombing by talking up Bomber Command's growing superiority in navigation over Germany<sup>93</sup>. Unfortunately, in his eagerness to answer this criticism, Portal overplayed his hand and he pushed Churchill for support in obtaining 4,000 heavy bombers for Bomber Command in

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92 PRO CAB 120/393, Minute CAS to Prime Minister 11th Sept 1941, Minute CAS to Prime Minister 4th Nov 1941 and Minute CAS to Prime Minister 21 Jan 1942

93 PRO CAB 120/300, Development and Employment of the Heavy Bomber Forces, 22nd September 1941

order that it might ‘obtain decisive results against German morale’ in ‘about six months’<sup>94</sup>. Portal’s rationale for this request was that the strategic bomber offensive was an ‘adaptation, though on a greatly magnified scale, of the policy of air control’ which had proved ‘so outstandingly successful in recent years in the small wars in which the Air Force has been continuously engaged’<sup>95</sup>. Apparently, Portal and the Air Staff believed that Germany would be as easily intimidated by bombing, as were the lightly armed semi-nomadic tribesmen in Somalia, Iraq and Afghanistan.

The minute from Portal provoked a blistering reply from Churchill. The fact that Churchill took three weeks to compose and send his reply strongly suggests that he consulted widely on the issue. Churchill bluntly told Portal that the physical and moral effects of bombing are ‘greatly exaggerated’ and that if Bomber Command increased its accuracy by 100 percent it would increase the weight of the British bomber force attack ‘to four times its strength’<sup>96</sup>. The best that Churchill could say was that Bomber Command’s attacks on Germany ‘will be a heavy and I trust a seriously increasing nuisance’<sup>97</sup>.

In a second minute, dated the 7<sup>th</sup> October 1941, Churchill returned to the attack, telling Portal that he deprecated ‘placing unbounded confidence in this means of

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94 PRO CAB 120/300, Minute CAS to Prime Minister, 25th September 1941

95 PRO CAB 120/300, Development and Employment of the Heavy Bomber Forces, 22nd September 1941

96 PRO CAB 120/300, Minute Churchill to CAS, 27th September 1941

97 PRO CAB 120/300, Minute Churchill to CAS, 7th October 1941

attack and still more in expressing that confidence in terms of arithmetic'. He went on to point out his view that bombing was simply the 'most potent method of impairing the enemy's morale we can use at the present time'<sup>98</sup>. The invasion of Europe by armoured forces combined with bombing and other forms of warfare were the only sure way that Churchill saw for success. The Prime Minister again accused the Air Staff of misleading the government 'by the pictures they painted of the destruction that would be wrought by air raids'. This action, says Churchill, 'was so exaggerated it depressed the statesmen responsible for pre-war policy'<sup>99</sup>. As far as Churchill was concerned, the Air Staff compounded their incompetence by convincing the government that 'our position would be impossible owing to air attacks', if Germany gained control of the Low Countries and France<sup>100</sup>. Churchill told Portal that Britain had managed to survive 'by not paying too much attention to such ideas'<sup>101</sup>.

To make matters worse, in February and March 1942, Sir Henry Tizard returned to the attack with a full-scale criticism of strategic bombing. Tizard, in a minute to Moore-Brabazon, the Minister for Aircraft Production, painted an unflattering comparison between the achievements of Bomber Command and those of the air forces operating obsolescent aircraft against the enemy in the Mediterranean<sup>102</sup>.

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98 PRO CAB 120/300, Minute Churchill to CAS, 7th October 1941

99 PRO CAB 120/300, Minute Churchill to CAS, 7th October 1941. In the original minute draft Churchill had originally used the word terrified but replaced it with depressed.

100 PRO CAB 120/300, Minute Churchill to CAS, 7th October 1941

101 PRO CAB 120/300, Minute Churchill to CAS, 7th October 1941

102 PRO AIR 9/46, Sir Henry Tizard, Offensive Uses of the Heavy Bomber, 15th February 1942 and Minute 2nd March 1942

At a cost of one Swordfish and two Blenheims destroyed and five other Blenheims damaged, the RAF in the Middle East had sunk three submarines, a 20,000-ton liner and two barges, and had seriously damaged four merchant ships, two tankers, one submarine, a destroyer and another naval vessel, as well as lightly damaging six other vessels<sup>103</sup>. Bomber Command, in the same period, had conducted 2,080 sorties and lost 52 aircraft with another 19 damaged for no appreciable gain<sup>104</sup>.

On 25<sup>th</sup> March 1942, Moore-Brabazon used Tizard's analysis in a report to Major General Ismay at the War Cabinet Offices. Moore-Brabazon accused the Air Staff of failing to support the other services and other theatres of the war and of risking losing the war. This potential outcome would become reality, Moore-Brabazon claimed, unless 'the RAF is compelled to get off its perch and help the general effort'<sup>105</sup>. By this time though the debate had petered out and Ismay, in his 30<sup>th</sup> March response gently let Moore-Brabazon know that his foray into bombing policy was not welcome. The ramifications of the internal debate may have concerned Churchill. The implication for the government was that they faced accusations of having ploughed enormous resources into an ill-conceived campaign. In April 1942, following the long string of disasters earlier in the year, Churchill re-entered the arena with a minute to the Secretary of State for Air telling him that 'we must spare no pains to justify the large proportion of the

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103 PRO AIR 9/46, Sir Henry Tizard, Offensive Uses of the Heavy Bomber, 15th February 1942

104 PRO AIR 9/46, Sir Henry Tizard, Offensive Uses of the Heavy Bomber, 15th February 1942

105 PRO CAB 120/291, Private Report from Moore-Brabazon to Cabinet of February 1942

national effort' that had been devoted to the bomber offensive<sup>106</sup>. Churchill wanted bombing accuracy and navigation improved and he wanted blast bombs and incendiaries used as well. The government desperately needed the successes that Bomber Command under Harris would now begin to deliver.

Given the level of criticism directed at the strategic air offensive, it is unsurprising that the first thing Sir Arthur Harris did on taking over at Bomber Command was to order a series of thousand bomber raids in May and June of 1942. The need to justify the strategic air offensive against accusations of failure was important to the Air Staff, the government and the Prime Minister. Seen from this perspective, the series of heavy bomber attacks launched by Sir Arthur Harris in early to mid-1942 may have been nothing less than an attempt by the Air Staff and the government to divert attention away from the string of military disasters being inflicted upon Britain. As a public relations exercise, the thousand bomber raids were very successful and they gained public support both in Britain and abroad, particularly in then United States. As a result, the bomber programme remained in place and the strategic bomber offensive against Germany continued.

Throughout the rest of World War II debate continued over the way in which the Air Staff were conducting the strategic air offensive. This argument was not concerned with the usefulness of strategic bombing but with the particular targets that should be bombed. The debate circled around whether Bomber Command

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106 PRO CAB 120/300, Minute Churchill to Secretary of State for Air, 11th April 1942

should concentrate its main effort on German oil production, aircraft factories, transportation links, military formations or cities. At some time or other during the last 22 months of the war, Bomber Command attacked all of these targets. The fundamental outcome was that Bomber Command was unable to win the war in its own right. From April 1944, the major military effort of the western Allies was the invasion of France and Bomber Command found itself subordinated to General Eisenhower, the Supreme Commander of the Allied forces in Northern Europe.

The changing priorities imposed upon Bomber Command after early 1944 made it impossible for a unified doctrine of strategic bombing to be developed so that when the war ended in May 1945, the Air Staff were in no better position than they had been in 1939. What they did know though was that strategic bombing had required massive resources, that civil populations were more robust than had been thought and that final victory had required the combined efforts of all available military forces.

## **Conclusion**

In 1945, the British public still drew its expectations of strategic bombing from the 'imagined possibilities' of the Edwardians. The advocates of air power were able to sweep aside any suggestion that the strategic air offensive had failed when the atom bomb demonstrated its destructive power in Japan. Now a single bomber could destroy a whole city. The vision of H.G. Wells was again possible

and the airforces could deliver it. All of these events make assessing the validity of the British Air Staff's strategic doctrine difficult but not impossible. The evidence suggests that there was no doctrine but rather only expectations. The failure of the city attacks during World War II represents a failure of the strategic air offensive envisaged by Britain's Air Staff.

As World War II began, the British Air Staff had only a vague idea of how they would achieve victory through a strategic air offensive. The Air Staff derived its strategic concepts from the Social Darwinist writings of many authors including H.G. Wells. The expectation was that aircraft could intimidate urban populations by destroying their homes, places of work and disrupting their lives. The success enjoyed by the RAF in its imperial policing role gave impetus to these ideas. In this role, the RAF was able to subdue large areas of the Empire by using 'air control', a form of bombing demonstration, which worked on the tribes of Somalia, Iraq and Afghanistan. The Air Staff believed that the industrial workers in advanced countries did not have the fortitude, character or stamina to withstand air attack. World War II proved this assumption wrong<sup>107</sup>.

The British Air Staff's assumptions about the weakness of industrial workers coloured its advice to government. The bleak picture that the Air Ministry painted of the effects of air attacks coloured the ideas and plans of the other

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107 As stated earlier, the logical flaw in the theory of destroying civilian 'morale' by bombing was that an attacker could not exploit the temporary destruction of civilian morale. Despite the evidence gleaned from the USSBS survey into civilian morale in 1945, the fact is that civilian morale is not a crucial military factor.

organs of government and it undermined the confidence of the government itself at a critical juncture in European affairs. This led to gross over-estimates of casualties with the government and local authorities expecting 600,000 dead and 1.2 million injured in the first six months of war<sup>108</sup>. The way in which the Air Ministry arrived at these figures displayed the lack of intellectual rigor that they applied to their assessment of operational capability shown during their annual air exercises.

The air exercises that the RAF conducted during the 1930s showed that bomber aircraft were more vulnerable than the Air Staff believed. The appointed umpires interpreted the results of the exercises in such a way that the results would always be in favour of the attacking bomber formations. The outcome was that the Air Staff deprived itself of any chance it had of obtaining an empirical basis for its theory of strategic air warfare. If the results of these exercises had been interpreted correctly, the heavy losses suffered by Bomber Command in its early daylight raids may have been avoided and the need to prepare for a night only bomber offensive would have been predictable. When the bombers did come in 1940, they were German bombers and though they did get through they suffered grievous losses. The workers and citizens of the bombed cities and towns remained calm and continued their way of life as the First Sea Lord, Admiral of the Fleet, Sir Charles Madden, had argued they would.

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108 R.M. Titmuss, *Problems of Social Policy*, History of the Second World War, Civil Series, HMSO, London, 1950, p.13

The crisis came in 1941 when objective analysis showed that in spite of all of the predictions and promises made by the Air Staff and all of the money, men and resources provided to it, Bomber Command had failed as a decisive weapon. The best that Britain could hope for, said Churchill, was that the strategic air offensive would become a heavy and ‘seriously increasing annoyance’<sup>109</sup>. The failings of Bomber Command led to open criticism of the Air Staff’s strategic conception. By mid-1943, there was a closing window of opportunity for the Air Staff to achieve their goal of defeating Germany before large-scale ground forces were committed on the continent.

In the years after 1945, the RAF and its supporters fought to maintain that the government was to blame for the lack of success enjoyed by the strategic air offensive during World War II. In their view, the British government had not financed the development and construction of the advanced aircraft that were essential to this type of warfare and abetted by the other military services, the British cabinet had rejected the obvious utility of strategic bombing. The result was that Bomber Command was unable to bring the weight of attack to bear on Germany, which would have resulted in her quick defeat. As this chapter has shown, this argument is spurious.

In 1939, Britain faced a war with the leading industrial power in Europe believing that this war threatened to result in massive civilian casualties and widespread

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109 PRO CAB 120/300, Minute Churchill to CAS, 27th September 1941

destruction. Unsure of how to counter this threat, Britain placed faith in the promises made by the Air Staff and the Air Ministry. What the British did not know was that in turn the Air Staff had placed their faith in what was a policy based on a concoction of ideas drawn from a profound belief in the power of technology to overcome adversity. It also incorporated a fervent attachment to a Social Darwinist analysis of human behaviour. The class consciousness, even racist bigotry, of many British military thinkers of the inter-war period blinded them not only to the resilience of the human spirit when faced with adversity, but also to the more practical fact of the size of the resources which would be required to damage seriously the infrastructure of Germany.

The subsequent chapters will evaluate the financial cost to Britain of the strategic air offensive, which the Air Staff, Air Ministry and the RAF anticipated would win the war for Britain. The importance of this evaluation lies in the size of the resources that finally had to be committed to the strategic air offensive.

Historians have not yet fully evaluated the size of the economic commitment that Britain made to the strategic air offensive. The importance of identifying the costs associated with conducting the strategic bombing of Germany lies in the damage that meeting this commitment did to the capacity of the British people to recover from the economic and financial demands of World War II. The suspicion is that the strategic air offensive may have damaged the economic viability of the Britain more than it damaged the economic activity of Germany.

## Chapter 3

### THE BRITISH AIRCRAFT INDUSTRY

On Empire Air Day 20<sup>th</sup> May 1939, C.G. Grey, the editor of *The Aeroplane* and long-time critic of British aviation policies, estimated that ‘about a million’ British people visited 78 aerodromes, of which the RAF operated 60<sup>1</sup>. Public interest in aeronautical activity was high in Britain, as it was in many other western nations<sup>2</sup>. The histories of the period frequently refer to the general interest in air power and note the almost equal play between the attraction of the adventure in air travel and the fear of the consequences of attack from the air. The literature of the strategic air offensive includes coffee table books, works by enthusiasts of obscure detail, such as the paint schemes of individual squadrons and the fate of individual aircraft as well as serious historical analysis. In all of this writing, a major omission has been the economic cost for Britain in conducting the strategic air offensive.

The economic impact of the strategic air offensive on Britain is important because there has been almost no serious quantitative analysis of the total economic cost to Britain of building, operating and maintaining Bomber Command and its entire infrastructure. The size of the investment made by Britain in the strategic air offensive was large enough in the end to have seriously weakened the British

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1 C.G. Grey, *A History of the Air Ministry*, George Allen and Unwin Ltd., London, 1940, p.300

2 Grey, *A History of the Air Ministry*, p.300

economy and delayed the post-war recovery of the nation well into the 1980s. As a first step in the quantitative analysis of the financial and economic cost of the strategic air offensive to Britain, my study lays out how this took place and how the intellectual ideas behind strategic bombing led the British government to dedicate a large proportion of the wealth of the country to a single military campaign.

As part of a quantitative analysis, it is important to survey the British aircraft industry prior to World War II in order to compare its technical proficiency with its foreign rivals. This permits a realistic evaluation of the British aircraft industry's strengths and weakness in comparison with its foreign competitors. It also allows a quantification of the government's involvement in the development of the British aircraft industry. Such an evaluation is essential in order to address the larger debate on the decline of British education, industry and society since the end of the Victorian era. Because of the innovative and technical nature of the aircraft industry, the proponents of British technical and educational decline have used it as a yardstick and an example of this decline.

My analysis does not support the conclusion that Britain was technically or economically in a decline before and during World War II. The evidence, I will argue, shows that the British aircraft industry was highly efficient, ably managed and a commercial success between the wars. Instead, after 1945, the relative decline of Britain as an aircraft manufacturer was due to the nation's bankruptcy

caused by the cost of the war. The strategic air offensive contributed greatly to this bankruptcy.

This chapter applies the accrual method to the British aircraft industry in order to examine the capital costs of building factory space at government expense as well as the indirect and opportunity costs of importing the necessary raw materials needed for the manufacture of bomber aircraft, including the cost of losses of these materials to enemy action at sea. As part of the analysis, I will also identify the approximate costs for subsidiary activity such as research and development conducted at government expense on behalf of the aircraft industry, in addition to the costs of transporting and storing materials and finished aircraft.

The history of British aircraft production began in 1949 with the publication of the first volume of the official civil histories of the Second World War commissioned by the British Government<sup>3</sup>. The editor of the series W.K. Hancock wrote the first volume in co-operation with M.M. Gowing, and established a high standard of scholarship for subsequent writers in the series. The second volume of the history, written by M.M. Postan, became available in 1952<sup>4</sup>. These were the first works to address the economic cost of the war for Britain and they are somewhat pessimistic, and indeed Postan is distinctly more pessimistic about and critical of Britain's wartime economic and industrial

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3 W. Hancock and M. Gowing, *British War Economy*, History of the Second World War, Civil Series. HMSO, London, 1949

4 Postan, *British War Production*, History of the Second World War, Civil Series, HMSO, London, 1952.

performance than Hancock and Gowing<sup>5</sup>. Later writers including Ely Devons<sup>6</sup>, Sir Alec Cairncross<sup>7</sup>, Sir Roy Fedden<sup>8</sup> and Correlli Barnett<sup>9</sup> added to the pessimism.

The importance of Devons, Cairncross and Fedden is that they were significant actors in the management of British aircraft production during and after World War II. Devons and Cairncross both worked in the Directorate General of Planning and Statistics of the Ministry of Aircraft Production. The significance of this unit on the state of post-war Britain is unknown, but a number of subsequently prominent men, including the future Labour Prime Minister, Harold Wilson, worked within it. The Directorate constituted a major part of the central planning machinery established by the British wartime government and its members would have experienced the problems presented in managing an aircraft industry that gladly took government money while resisting any element of government interference.

Devons, who along with many of his colleagues were in tune with the prevailing mood supporting a centrally planned economy, expresses a significant degree of exasperation at the inefficiencies of the aircraft industry and its unwillingness to undertake rational planning. The post-war Labour Government implemented a

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5 Ritchie, 'A New Audit of War', *War and Society*, p.125

6 E. Devons, *Planning in Practice: Essays in Aircraft Planning in War-Time*, Cambridge University Press, 1950, p.21.

7 Sir A. Cairncross, *Planning in Wartime: Aircraft Production in Britain, Germany and the USA*, MacMillan & St. Anthony's College, Oxford, London, 1991

8 Fedden, *Britain's Air Survival*, p.18

more centrally planned economic model and its maintenance by later Conservative governments is an acknowledgement of the popular desire for government intervention to achieve greater equality in British society. The experiment in social democratic government survived until Margaret Thatcher's Conservative Government in the 1980s.

M.M. Postan is a useful reference for identifying the extent of government expenditure on the RAF and the aircraft industry in the late 1930s and provides a good summary of the government's expenditure on fixed capital infrastructure for war purposes. Postan was co-author, with D. Hay and J.D. Scott, of another volume of the official history dealing with the design and development of weapons<sup>10</sup>. In it too, the mood of pessimism persists. It is a useful work in terms of providing detail on the number of aircraft produced, structure-weight produced, man-hours used, resources and technical developments in the weapons systems. Unfortunately, it provides very little information on the costs of designing and developing aircraft.

The series of official histories continued with Richard Sayers's volume on financial policy<sup>11</sup>, Peter Inman's volume on labour in the munitions industry<sup>12</sup>

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9 C. Barnett, *The Audit of War: The Illusion and Reality of Britain as a Great Nation*, Macmillan, London, 1986

10 Postan, Hay and Scott, *Design and Development of Weapons*, pp. 1-228.

11 R. Sayers, *Financial Policy 1939-1945*, HMSO and Longmans Green, London, 1956.

12 P. Inman, *Labour in the Munitions Industries*, HMSO and Longmans Green, London, 1957.

and William Hornby's excellent description on factories and plant<sup>13</sup>. There is enough detail in these three volumes to provide most writers with the information they needed to support their descriptions of aircraft production, air operations, specific aircraft or the general conduct of the war. The lack of footnotes and sources in all of these books reduces their usefulness on decision making in the British Government. They are however essential reading for anyone working on the British wartime economy.

Sir Roy Fedden, between 1918 and 1960, was one of the most significant figures within the British aircraft industry. The Chief Engine Designer, and a significant stockholder, in the Bristol Aircraft Company, he was also the most successful of Britain's engine designers. Between 1921 and 1942, his radial engines dominated the world aviation market. Fedden was a strong critic of the British government over its failure to prevent the decline of the British aircraft industry. In 1957, he wrote a book strongly critical of Britain's failure to duplicate the American aircraft industry's approach to research and development<sup>14</sup>. The idea that Britain's aircraft industry, abetted by government, failed to respond effectively to the growing strength of the American industry appears to have its roots in Fedden's ideas.

In the post-war assessment of the relative efficiency of the British aircraft industry, the influence of Fedden has been profound. From the early 1920s to the

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13 Hornby, *Factories and Plant*, 1958

14 Fedden, *Britain's Air Survival*, p.18

1950s, Fedden was a highly successful engine designer, businessman and advisor to government. He was also very well connected and respected within the American aircraft industry. His air-cooled radial engines were almost a 'standard power-plant' for commercial flying in the United States<sup>15</sup>. In one anecdote about him it is claimed that in 1931, when the United States Army's carburettor specialist Luke Hobbs was asked why he had not yet made a two-row engine he replied "Because Fedden hasn't"<sup>16</sup>.

Because of this, the British government commissioned Fedden on two occasions during World War II to conduct a comparative analysis of the British and American aircraft industries. The theme running through Fedden's findings was that the British educational system, unlike its American counterpart, was failing to produce the technically-educated personnel the British aircraft industry needed. He also emphasised the large size and importance of design departments within the American aircraft firms compared with British firms. The critical comparisons contained in Fedden's reports are identical to those reproduced in the official histories and later published by Fedden.

Recently, Eric Lund has questioned the premise on which Fedden based his arguments<sup>17</sup>. By contrast, Lund argues that Britain was producing relatively more technicians and engineers for the aircraft industry than were Germany and the

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15 G.L. Meade, Inline Liquid Cooled versus Air Cooled Engines, *SAE Journal*, Vol. XXVII, No. 2, August 1930,p.427.

16 B. Gunston, *Fedden; the Life of Sir Roy Fedden*, Rolls Royce Heritage Trust, Derby, 1998, p.95.

United States. He points out that Fedden and the subsequent critics do not take into account the flow-on effect for the British aircraft industry of the Air Ministry training young men as apprentices in the RAF. After their service was over, they sought employment within the commercial aircraft industry<sup>18</sup>. Also according to Lund, British government funding of research establishments shouldered much of the design burden that in America was borne by individual firms. Finally, Lund suggests that Fedden simply misunderstood the organisation of design departments within American aircraft firms<sup>19</sup>.

The pessimistic view of the British aircraft in the early histories has greatly influenced later writers. Correlli Barnett<sup>20</sup> more strongly took up Peter Fearon's<sup>21</sup> original argument on the disruptive role of government funding of the aircraft industry<sup>22</sup>. Barnett is much more critical than Fearon and uses the aircraft industry as an example of unsatisfactory British education leading to poor economic performance<sup>23</sup>. Barnett's book injected a substantial amount of passion into the

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17 Lund, 'The Industrial History of Strategy', *Journal of Military History*, pp. 75-99.

18 Lund, 'The Industrial History of Strategy', p.78.

19 Lund, 'The Industrial History of Strategy', p.78.

20 C. Barnett, *The Audit of War: The Illusion and Reality of Britain as a Great Nation*, Macmillan, London, 1986

21 Articles written by P. Fearon, 'The formative Years of the British Aircraft Industry, 1913-1924', *Business History Review*, Vol. 43, 1969; 'The British Aircraft Industry and the State, 1918-35', *Economic History Review*, Vol. 27, 1974; 'The Vicissitudes of a British Aircraft Company: Handley Page Ltd. Between the Wars', *Business History*, Vol. 20, 1978; 'Aircraft Manufacturing', *British Industry Between the Wars: Instability and Industrial Development 1919-1939*, compiled and edited by N.K. Buxton & D.H. Aldcroft, Scholar Press, London, 1979; and 'The Growth of Aviation in Britain', *Journal of Contemporary History*, SAGE, London, Vol. 20, 1985

22 S.N Broadberry, *The Productivity Race: British Manufacturing in International Perspective, 1850-1990*, Cambridge University Press, Cambridge, 1997, pp. 235-238

23 Barnett, *The Audit of War*, pp. 125-158

discussion of British industrial decline. The debate has resulted in a crop of revisionist writers who have refuted both Fearon's and Barnett's conclusions<sup>24</sup>.

Richard Overy's comparative analysis of British, German, United States, Russian, Italian and Japanese aircraft production<sup>25</sup> informed David Edgerton's critical assessment of Barnett's thesis on British industrial decline<sup>26</sup>. Overy's work was a seminal step in the analysis of the British aircraft industry's wartime performance. Overy's student, Sebastian Ritchie, provides what is currently the most detailed survey of Britain's aircraft manufacture during the early years of the war<sup>27</sup>. Latterly the American Erik Lund has entered the fray with a paper claiming that rather than being backward Britain's aircraft industry was more 'flexible, technologically sophisticated, and effective' than those of America or Germany<sup>28</sup>.

Alongside Overy in importance is Peter Fearon, a prolific writer on all aspects of the British aircraft industry in its first forty years. He is probably the most influential writer arguing that the British aircraft industry was adversely affected

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24 A. Robertson, 'The British Airframe Industry and the State in the Interwar Period: A comment', *Economic History Review*, Vol 28, 1975 and David Edgerton, *England And The Aeroplane: An Essay On A Militant And Technological Nation*, Macmillan And Centre For The History Of Science, Technology And Medicine, University Of Manchester, Macmillan, London, 1991 and *Science, Technology and Industrial 'Decline*, Cambridge University Press, Cambridge, 1996

25 R.J. Overy, *The Air War 1939-45*, Europa Publications, London, 1980

26 D. Edgerton, *England And The Aeroplane: An Essay On A Militant And Technological Nation*, Macmillan And Centre For The History Of Science, Technology And Medicine, University Of Manchester, Macmillan, London, 1991

27 S. Ritchie, *Industry and Air Power: The Expansion of British Aircraft Production, 1935-1941*, Frank Cass, London, 1997, also see S. Ritchie, 'A New Audit of War: The Productivity of Britain's Wartime Aircraft Industry Reconsidered', *War and Society*, Vol. 12, No. 1, May 1994, pp. 125-147

28 Lund, 'The Industrial History of Strategy', *The Journal of Military History*, pp. 75-99

by poor government policy making<sup>29</sup>. Fearon's and Edgerton's reach is broader than that of Overy and Ritchie in that they address the wider social and political roles of aircraft and the aircraft industry. Fearon provides a detailed analysis of the interaction between the state and industry in the formation and operation of the aircraft industry and that Britain saw an effective aircraft industry as essential to its standing as a leading world power.

Significantly, as this chapter will show, Britain's aircraft manufacturers became world leaders in aircraft manufacture by selling licences to foreign companies and governments. For a neo-conservative historian, Barnett is surprisingly ignorant of how an open market operates and the ways in which, if there is any chance of making a reasonable profit, commercial companies will find ways around government regulation. Rather than being poorly managed, the evidence indicates that the British aircraft industry was innovative, well informed and versatile in its efforts to make profits from the manufacture of aircraft and aircraft parts. The thesis that Britain at this time was in industrial decline may be more of an expression of the British national character that betrays 'a liking for criticising ourselves'<sup>30</sup>, than it is of careful historical analysis. The evidence in this chapter indicates that the pessimistic view of the British aircraft industry's performance in

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29 P. Fearon, 'The formative Years of the British Aircraft Industry, 1913-1924', *Business History Review*, Vol. 43, 1969; 'The British Aircraft Industry and the State, 1918-35', *Economic History Review*, Vol. 27, 1974; 'The Vicissitudes of a British Aircraft Company: Handley Page Ltd. Between the Wars', *Business History*, Vol. 20, 1978; 'Aircraft Manufacturing', *British Industry Between the Wars: Instability and Industrial Development 1919-1939*, compiled and edited by N.K. Buxton & D.H. Aldcroft, Scolar Press, London, 1979; and 'The Growth of Aviation in Britain', *Journal of Contemporary History*, SAGE, London, Vol. 20, 1985

30 C.G. Grey, *A History of the Air Ministry*, George Allen and Unwin, London, 1940, p.165

the 1920s and 1930s lies in the insular view of industrial activity of many of the earlier writers. In reaching their conclusions they have simply drawn upon figures relating to domestic production and exports rather than looking at the full range of the industry's commercial activities including joint venture investments with overseas competitors.

In addressing the issues in this debate, I have opted to take the broader view of the British aircraft industry's activities and have looked at the way in which British aircraft firms operated their commercial activities, particularly their financial investments in the aircraft industries with other nations. What this approach shows is that whilst the exports of British aircraft and aircraft parts may have been low, British firms dominated the world industry. They did this by investing in joint ventures or by licensing foreign manufacturers to produce their products locally. The reason for this lay in the desire of governments to develop domestic aircraft industries. By investing in joint ventures with foreign governments and firms, or issuing manufacturing licences, British aircraft firms facilitated the rapid growth of domestic aircraft industries in a number of countries and reaped the financial rewards of these investments throughout the 1920s and 1930s.

The insular viewpoint also fails to acknowledge the inevitability of British economic decline relative to other nations. The fact that British companies were exporting aircraft technology provided her international partners with the competitive advantage of quickly obtaining already developed technology. Foreign firms in joint ventures with British companies or manufacturing under

licence also enjoyed the potential benefit of having a larger pool of untapped investment. Britain's industrial advantage, established during the industrial revolution and the later nineteenth century, declined, not because of a failure of British education or industry but because of the improvement in foreign industrial output. This relative decline came into sharper relief when the financial and economic cost of World War II began to affect in an adverse way Britain's post-1945 recovery.

Having placed the argument on decline into a clearer perspective it is now possible to set aside the question of British decline and move onto the analysis of the cost of the strategic air offensive. The state of the British aircraft industry and the financial outlays required to prepare it for war is central because the prices paid to manufacturers for aircraft excluded all costs that the government had already funded through loans or capital grants. The true cost of the aircraft includes the value of these investments and it is necessary to consider how much it cost to set the aircraft industry on its war footing.

### **The Aircraft Industry 1910 to 1939**

Britain was not slow in creating an aircraft industry. In Edwardian England, the dominant cultural trend was for industrial, scientific and technological progress and the new aircraft and motorcar industries epitomised the promise of science and

technology<sup>31</sup>. Prior to 1914, five aircraft companies, Fredrick Handley-Page (1908), Robert Blackburn (1910), A.V. Roe (1910), T.O.M. Sopwith (1911) and Noel Pemberton-Billing (1913)<sup>32</sup>, were beginning to produce aircraft. Of course, these new firms had to source components such as magnetos and engines from overseas as such products were not available in Britain<sup>33</sup>. The speed with which the British Government developed a national approach to the development of the aviation industry reflected the British people's widespread interest in aircraft and air power.

The government was quick to respond. By 1909, the Royal Aircraft Factory at Farnborough was operational<sup>34</sup>, although the private firms like Blackburn, Handley-Page and A.V. Roe were not inclined to be too supportive of a government-funded manufacturer. They thought they were dealing with an aeronautical version of the Admiralty's shipyards and therefore worked to keep Farnborough out of large-scale production. This resulted in it becoming a specialised factory producing and testing prototype machines. In 1914, only 24 out of the 122 orders for aircraft by the War Office went to Farnborough<sup>35</sup>.

The potential for profit in the aircraft industry attracted a significant number of the existing and well-established armaments firms. These included Vickers,

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31 Edgerton, *England and the Aeroplane*, p.13

32 Edgerton, *England and the Aeroplane*, p.8

33 G.W. Williamson, Aircraft Production for War, *Journal of the RUSI*, Vol xcii, No. 567, Aug 1947, p.440 and C. Barnett, *Audit of War*, p.127

34 Edgerton, *England and the Aeroplane*, p.7

Armstrong-Whitworth, Breadmore, The Coventry Ordnance Works, Bristol Tramway Ltd, later the British and Colonial Aeroplane Company and Short Brothers. Other companies followed, amongst them The Aircraft Manufacturing Company, formed by G. Holt, publisher of the *Graphic* and *Daily Graphic*, and the boat-builders, S.E. Saunders and J.S. White<sup>36</sup>.

Motorcar companies, including Austin Motors, Brazil Straker, Daimler, Napier, Siddeley Deasy, Sunbeam, Bentley and ABC also became involved in aircraft manufacturing<sup>37</sup>. Even furniture makers, Boulton Paul of Norwich, and architectural decorators, H.H. Martyn of Cheltenham became aircraft builders forming the Gloster Aircraft Company as a joint venture with The Gloucestershire Air Company<sup>38</sup>. In addition, start-up firms such as Westland (1915) and Fairey Aviation Company (1918) were formed during World War I<sup>39</sup>.

The end of World War I resulted in a substantial contraction of the world economy and the almost complete cessation of British government orders for aircraft. Effectively, the market for new aircraft disappeared overnight and governments dumped large amounts of surplus aircraft onto the second hand market. The impact on the aircraft industry was profound. Highly profitable companies quickly fell into financial difficulties. The effect was little short of catastrophic and the

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35 Edgerton, *England and the Aeroplane*, p.7

36 Edgerton, *England and the Aeroplane*, p.9

37 Edgerton, *England and the Aeroplane*, p.9

38 Edgerton, *England and the Aeroplane*, p.9

39 Edgerton, *England and the Aeroplane*, p.9

industry suffered from disillusion as the economy fell into recession and depression<sup>40</sup>. Whatever the aircraft industry may have felt it is worth recalling that the British Government via the Air Ministry worked hard to ensure that the industry survived the re-adjustments in economic fortunes.

The frequently claimed idea that the British government abandoned the aircraft industry grew out of the disillusionment that pervaded the industry and the country at this time. Perhaps it is unfortunate that the later official historians, particularly M.M. Postan, accepted this idea and it has passed into the broader historical literature of the period. Postan uses the idea that the British Government failed to finance adequately the aircraft industry and RAF to argue that the government overlooked the importance of air power to Britain and that this led to Britain being unable to meet its plans for expansion in time for 1939<sup>41</sup>.

Sebastian Ritchie provides a salutatory reminder against generalising the bad financial outcomes of some aircraft firms into an industry wide experience<sup>42</sup>. The financial support provided to British aircraft firms via Air Ministry orders and funding was part of the commercial opportunities available to astute companies. However, it was only one source of income and a number of the more successful aircraft manufacturers and engine makers between the wars looked to overseas

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40 G. Bulman, *An Account of Partnership, Industry, Government and the Aero-engine*, Rolls Royce Trust, Derby, 2001, p.89; Ritchie, *Industry and Air Power*, p.7

41 Postan, *British War Production*, pp. 4-5

42 Ritchie, *Industry and Air Power*, p.13

opportunities that were to make them the dominant players in the international aviation market.

The aircraft industry experienced a period of normal post-war contraction during the interwar years. It imposed stresses on the industry and some firms failed to survive. The subsequent histories of the period have been heavily influenced by these failures which in turn downplay the success of the British aircraft industry in maintaining four aero-engine and sixteen airframe manufacturers in what has been called the 'Air Ministry Ring Companies'.

A great number of the sources attributed the success of these companies to the financial and other support provided by the Air Ministry and not to the technological and managerial prowess of their owners, managers and workers. This viewpoint reflects the reliance of much of the history on official Air Ministry sources, which always tend to emphasise the importance of government assistance to industry. It also reflects the aircraft industry's own tendency to cry poor in an attempt to obtain public funding of their development of the domestic aircraft and air transportation industries. By contrast historians have paid little attention to how British aircraft companies organised their commercial activities.

The survival of eighteen aircraft manufacturers in Britain, which had almost no internal air transportation, suggests that there were profits being made somewhere other than in Britain. British aircraft companies were amongst the first in the world to invest in and draw profits from foreign interests to whom they had

licensed their technologies. They were also doing what any commercial enterprise would do, they were exploiting government funding as much as they could and using this to reduce the risk incurred in their overseas activity.

<b>The Air Ministry Ring Companies</b>			
<b>Ser.</b>	<b>Company</b>	<b>Location</b>	<b>Activity</b>
1.	Armstrong-Siddeley	Coventry	Engines
2.	Armstrong-Whitworth	Coventry	Airframes
3.	Blackburn	Yorkshire	Airframes
4.	Boulton-Paul	Norwich	Airframes
5.	Bristol	Bristol	Airframes & Engines
6.	De Havilland	London	Airframes & Engines
7.	Fairey	London	Airframes
8.	Gloster	Gloucester	Airframes
9.	Hawker	London	Airframes
10.	Napier	London	Engines
11.	Handley-Page	London	Airframes
12.	Avro	Manchester	Airframes
13.	Rolls Royce	Derby	Engines
14.	Saunders Roe	Isle Of Wright	Airframes
15.	Short Brothers	Kent	Airframes
16.	Supermarine	Southampton	Airframes
17.	Vickers	London	Airframes
18.	Westland	Yeovil	Airframes

**Fig. 3.1:** Source: D. Edgerton, *England and the Aeroplane*, p.24

The companies in the Air Ministry ring underwent substantial internal changes between the wars. A lot of this change was consolidation within the industry as the more profitable companies acquired smaller companies that became vulnerable to take-over. In a new industry where the market is limited to a few powerful consumers like governments, the best way for a company to increase its share of the market quickly is to acquire its competitors. If take-over decisions are made logically, the most attractive targets are those companies with good technological advantages that are under capitalised; or those that have existing contracts that cannot be serviced. Between the wars the British aircraft industry

underwent what can only be described as a normal period of rationalisation. Such rationalisations upset those displaced from the industry, but, economically, they are actually a sign of health.

In 1928, the attraction of the aircraft industry led the large armaments manufacturer Vickers to acquire the Supermarine Company<sup>43</sup>. Supermarine had been investing in developing modern aerodynamic airframes to carry large powerful engines. The technological development undertaken by Supermarine was expensive and it quickly used up the capital resources available to such a small company making it a likely target for a larger company like Vickers, particularly once the technology proved itself. For Supermarine the Schneider Trophy proved the value of their design work and it made them a target for takeover by Vickers.

In May of the same year the Armstrong Siddeley Development Company, owned by Armstrong Whitworth and Armstrong Siddeley, acquired A.V. Roe, and the manufacturer of piston components, Peter Hookers Ltd, which was renamed High Duty Alloys<sup>44</sup>. This may have been a defensive measure designed to ensure that Vickers did not become dominant within the industry. This type of commercial activity is both normal and logical, as companies attempt to gain control of as much of the available market as they can.

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43 Ritchie, *Industry and Air Power*, p.13

44 R. Cook, *Armstrong Siddeley-The Parkside Story, 1896-1939*, Rolls Royce Heritage Trust, Derby, 1988, p.71

A final pre-war consolidation occurred in 1935 when John Siddeley took advantage of Bristol's withdrawal from a possible merger with Hawker to sell his holdings to T.O.M. Sopwith of Hawker who had been in the process of acquiring both Gloster and Bristol<sup>45</sup>. All of this activity demonstrates an industry that was both vigorous and well managed. The reliance on technology alone as an indicator of an industry's vigour and success is too simplistic to be useful. Successful companies are those that balance all of their activities, internal management, technological innovation, domestic capitalisation and foreign investment, and achieve innovation across the majority of these activities. During the inter-war years, the British aircraft industry had a number of companies operating within it who demonstrated these qualities. In 1934, there were eighteen firms listed as part of the Air Ministry Ring giving the impression that many small operators were surviving on the money provided by the Air Ministry. The reality was that six major company groups existed. These were Hawker Siddeley, Vickers Supermarine, Handley Page, Bristol and de Havilland and, in aero-engines, Rolls Royce. These groups were maximising their access to government funds and reducing the impact of commercial failure on the parent company by maintaining the original companies after they had taken them over.

### **Technological Prowess**

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45 R. Cook, *Armstrong Siddeley*, p.108

In the debate over quality versus quantity, the emphasis has been on technology and the way in which British companies implemented technological change in their aircraft designs. This emphasis occurs because there is an assumption that innovation is a technological process rather than a way of reacting to the overall environment. The analysis of the British aircraft industry has tended to exclude consideration of the industry's overall commercial performance both domestically and more importantly overseas.

Aircraft manufacturing, and particularly aero-engine manufacture, requires the investment of substantial financial and other resources in order to develop leading edge products that will claim significant market share. The problem with designing and developing aircraft is that it is only when the prototypes fly that technological problems with the aircraft are recognised. It is only when prototypes move to production that technological problems with mass-producing the design are identified. All of these problems combine to make the design, development and production of aircraft a highly risky business.

From the very beginning historians and commentators have criticised Britain for having produced 'too many duplicates'. The argument is that the resources spent in developing unsuccessful aircraft types were wasted and this waste prevented Britain from maximising the production of the successful aircraft designs<sup>46</sup>. This simplistic argument rests heavily upon hindsight. It is only with the benefit of

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46 See Postan, Hay and Scott, *Design and Development of Weapons*, p.19

such hindsight that successful aircraft designs can be identified. In October 1940, no one within the Air Ministry envisaged Avro's Manchester as anything other than an unmitigated disaster. The Air Ministry intended to cancel all orders for the aircraft<sup>47</sup>. It was only when Avro's proposal for a four-engined version of the Manchester was accepted and tested that the Lancaster success story began.

The idea that it is important to ensure redundancy in aircraft design was well established prior to the outbreak of World War II. Prime Minister Chamberlain, on 25<sup>th</sup> May 1938, told the House of Commons that 'in order to get the best results' from the rapid nature of technological change within the aircraft industry of the time 'the inventive genius of our people in manufacturing and design' should be left unrestricted<sup>48</sup>. Chamberlain defended the development of large numbers of aircraft against individual specifications on the basis that at worst one of these designs would be a success. Events justified Chamberlain's argument.

The decision to allow the aircraft industry to continue with its competitive approach to the design and development of its products paid dividends well beyond those expected. Bureaucratic organisations are concerned with ensuring certainty and reducing conflict. This leads to two characteristics in the specifications laid down by bureaucratic organisations. First, they rarely write specifications that go beyond proven technology and they always attempt to ensure that these specifications appease the demands of as many stakeholders as

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47 M. Garbett and B. Goulding, Lancaster, Promotional Reprint Company, Leicester, 1992, p.155

48 Sir N. Chamberlain, *H. of C. Deb.*, Vol. 136, Col. 1257, 25 May 1938.

possible. Like many bureaucratic requirements, the specifications issued by the Air Ministry suffered from their moderation.

The Air Ministry and RAF were no different from any other government bureaucracy. They issued specifications that were technologically feasible, met the multiple requirements of stakeholders and were within the constraints dictated by budgetary imperative. The aircraft derived by this process were mediocre. In terms of technological innovation, the main impetus came from competition between the manufacturers who worked hard to outdo one another in the way in which their design met the issued specifications.

The examples of the Mosquito and the Lancaster, the two most successful aircraft used by Bomber Command during the Second World War, provide evidence of the problems posed in attempting to pick winners. Neither of these aircraft would have seen operational service if the Postan view of efficient aircraft development had been in place. He admits as much in the official history<sup>49</sup>. If there had been a government ban on modifications or new design work, the RAF would never have had the Lancaster, which developed out of the poorly performing Manchester<sup>50</sup>.

The design of the original Manchester was carried out to meet Air Ministry Specification P13/36, which had called for an airframe structure capable of sustaining the loads incurred in catapult launching. To meet the specification,

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49 Postan, Hay & Scott, *Design and Development of Weapons*, p.19

50 M. Garbett and B. Goulding, *Lancaster*, p.155

Avro engineered the aircraft with heavier wings and used thick aluminium alloy sheets to absorb catapult-launching stresses. This heavy structure made the Manchester too heavy for the two engines that the specification required. The Air Ministry and RAF knew the Manchester was a failure, but used it on operations until its small bomb load and high losses finally sealed its fate. If A.V. Roe did not improve the Manchester there was a strong likelihood that the company would be faced with the prospect of having to build Handley Page's Halifax. In order to avoid this outcome A.V. Roe redesigned the Manchester by lengthening its fuselage and replacing the two Vulture engines with four Merlin engines<sup>51</sup>. The result was the Lancaster, the most effective British strategic bomber to serve in World War II.

Another example of the creative interplay between official specifications and commercial reality was the de Havilland Mosquito. This aircraft was a private venture which was taken up by the Air Ministry after the Vice-Chief of the Air Staff, Sir Wilfred Freeman, ordered 50 on the 1<sup>st</sup> March, 1940<sup>52</sup>. The aircraft had not received official sanction in its early design and development stages because it was made of wood and only had two engines. Despite this, the Mosquito was built in substantial numbers throughout World War II and was to become one of

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51 M. Garbett and B. Goulding, *Lancaster*, pp. 155-156

52 Lord Tedder, *With Prejudice*, Cassell and Company, London, 1966, p.10; [www.aviation-history.com/dehavilland/mosquito.html](http://www.aviation-history.com/dehavilland/mosquito.html)

the most successful and versatile of the aircraft used by Bomber Command and the RAF<sup>53</sup>.

### **Technical Developments in Aeronautics: a Comparison – The Boeing Monomail and the Bristol Type 142**

The first truly modern-looking aircraft designed and developed in the west was the Monomail Model 200, designed by Boeing in the late 1920s and finally built in 1929<sup>54</sup>. Designed as a high-speed mail plane, the Monomail design became the standard adopted by aircraft industries throughout the world. It was the first all aluminium, monocoque fuselage aircraft with low set, fully cantilevered wings with no struts. The aircraft also had retractable landing gear, and, in keeping with its smooth, streamlined fuselage, an engine covered by an anti-drag cowling<sup>55</sup>. It also used tubular trussed-type spars, which became the standard construction system for all later Boeing aircraft<sup>56</sup>.

The Monomail was 41 feet long with a wingspan of 59 feet. It had a range of 600 miles carrying a payload of 2,300 pounds<sup>57</sup>. The top speed of the Monomail,

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53 Eric Lund points out that the Mosquito could not have been built in the United States either as there the Congress had banned the use of wood in military and commercial aircraft. See Lund, 'Industrial History of Strategy', *Journal of Military History*, p.89

54 F.P. Liedan, R.J. Minshall and J.K. Ball, Design and Construction of Large Aircraft, *SAE Journal*, Vol XL, No. 2, Feb 1937, p.67

55 Boeing Corporation, 'Monomail', [WWW.Boeing.com/companyoffices/history/Boeing/Monomail.html](http://WWW.Boeing.com/companyoffices/history/Boeing/Monomail.html), 28th September, 2002

56 Liedan, Minshall and Ball, Design and Construction of Large Aircraft, *SAE Journal*, p.67

57 Boeing Corporation, 'Monomail', [WWW.Boeing.com/companyoffices/history/Boeing/Monomail.html](http://WWW.Boeing.com/companyoffices/history/Boeing/Monomail.html), 28th September, 2002

though, was a modest 158 mph. This low speed was the result of the low power produced by the single 525-hp Pratt and Whitney Hornet radial engine<sup>58</sup>. The Monomail made its first flight on 6<sup>th</sup> May 1930<sup>59</sup>.



**Fig. 3.2: Monomail 200** (Courtesy of Boeing Corporation)

One of the more prosaic but important advances in the Monomail was the all-metal engine cowling. It reduced drag and shielded the engine, preventing ignition interference with radios carried by the aircraft. The cowling was included to meet the requirement of the United States Army Air Corps (USAAC), who wanted improved radio reception transmission from aircraft<sup>60</sup>. The

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58 Boeing Corporation, 'Monomail', *WWW.Boeing.com/companyoffices/history/Boeing/Monomail.html*, 28th September, 2002

59 Boeing Corporation, 'Monomail', *WWW.Boeing.com/companyoffices/history/Boeing/Monomail.html*, 28th September, 2002

60 E.A. Roberts and L.M. Hull, Suppressing Ignition Interference, *SAE Journal*, Vol XXVII, July 1930, No. 1, Society of Automotive Engineers, pp. 78-91

Monomail also included electrical wires wrapped in metal and earthed to the metal fuselage. It was the first electronically friendly aircraft<sup>61</sup>.

The Monomail led to the development of the Boeing 247, which appeared before the Douglas DC-2. The designers wanted these aircraft to appeal to long distance American travellers by providing faster transcontinental travel than the railways. The 247 cut the travel time between New York and Los Angeles to 20 hours and seven stops<sup>62</sup>. The DC-2 established 19 American speed and distance records<sup>63</sup>. In 1934, KLM purchased the DC-2 and this helped make it the first American aircraft to be a commercial success outside of the United States. It was also the first American aircraft to challenge the comfort and space provided by British aircraft such as the Handley Page HP-3<sup>64</sup>. In addition, the DC-2 reduced the vibration and noise produced by engines strongly fixed to the fuselage by mounting both the engines and the passengers' seats on rubber plugs, carpeting the cabin floors and placing insulation material to reduce noise in the walls of the fuselage<sup>65</sup>. Boeing exported five 247s to Deutsche Lufthansa in Germany and a single aircraft went to a private owner in China<sup>66</sup>.

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61 Roberts and Hull, 'Suppressing Ignition Interference', *SAE Journal*, p. 81

62 Boeing Aircraft Corporation, *WWW.Boeing.com/company offices/mdc/dc-2.html*, 28th September, 2002

63 Boeing Aircraft Corporation, *WWW.Boeing.com/company offices/mdc/dc-2.html*, 28th September, 2002

64 Lund, 'The Industrial History of Strategy', p.88

65 Boeing Aircraft Corporation, *WWW.Boeing.com/company offices/mdc/dc-1.html*, 28th September, 2002

66 Boeing Aircraft Corporation, *WWW.Boeing.com*, 28th September, 2002

At first glance, the British industry's response to the development of Boeing and Douglas aircraft was slow. It was a full five years before a British company built an all metal-stressed skin, cantilevered monoplane. There were good reasons why British companies took so long to adopt the new American design features. First, the British Parliament imposed no laws forbidding the construction of wooden aircraft and there was no imposed urgency on the adoption of the new American designs. A second reason was the natural tendency of existing manufacturers to see how the new designs performed commercially, before they committed to changing their production methods. Commercially, these were significant disincentives. The adoption of stressed metal aircraft involved moving from woodworking to metalworking and this entailed new plant, equipment and a new workforce. These are not easy changes to accomplish in an established industry.

The first modern British aircraft was The Bristol Aeroplane Company's Type 142 and was called 'Britain First'<sup>67</sup>. The Type 142 had a metal framework with stressed-metal skin, retractable landing gear, flaps, variable pitch propellers and other modern features<sup>68</sup>. Roy Fedden envisaged the aircraft in 1934 in response to a request from Blos Lewis, the editor of the *Bristol Evening News*. Lewis had asked Fedden to design the aircraft in an effort to tempt Lord Rothermere, the publisher of The *Daily Mail* and *Bristol Evening News*, to buy a British aircraft instead of the American Douglas DC-2 acquired by Rothermere's rival Max

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67 Postan, Hay and Scott, *Design and Development of Weapons*, p.91

68 Gunston, *Fedden*, p.185

Beaverbrook<sup>69</sup>. Rothermere wanted an aircraft that was faster than Beaverbrook's DC-2 and he demanded one with a speed of over 200 mph<sup>70</sup>. Lewis had initially approached Fedden about building the aircraft for Rothermere and Fedden had agreed before clearing it with his Board, who were less than enthusiastic about the project<sup>71</sup>. Fedden developed the 142 design from an existing project, the 135, a six-seater aircraft powered by Aquila engines. The fact that Bristol already had a design, the 135, shows they had already copied American technological developments. The Bristol Type 142 cost Rothermere £18,500<sup>72</sup>.

The Rothermere press made much of the aircraft, named 'Britain First', and, in a grand public display, Rothermere presented the aircraft to the nation for the Air Ministry to use as a test aircraft<sup>73</sup>. In June 1935, 'Britain First' arrived at Martlesham Heath for its test acceptance. The test pilots found it a delight to fly and safer than any contemporary RAF aircraft. At 280 mph at 16,000 ft<sup>74</sup> and 307 mph in level flight, it was faster than the American aircraft<sup>75</sup>. To the relief of Bristol's directors, the Air Ministry immediately issued specification B28/35 for a medium bomber, based on the performance of the 142<sup>76</sup>.

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69 Postan, Hay and Scott, *Design and Development of Weapons*, p.91

70 Postan, Hay and Scott, *Design and Development of Weapons*, p.91

71 Gunston, *Fedden*, p.182

72 RAF And Bomber Command Association, 'Aircraft', [www.raf.mod.uk/bombercommand/aircraft/blenheim.html](http://www.raf.mod.uk/bombercommand/aircraft/blenheim.html), 28th September, 2002

73 Gunston, *Fedden*, p.186

74 RAF And Bomber Command Association, 'Aircraft', [www.raf.mod.uk/bombercommand/aircraft/blenheim.html](http://www.raf.mod.uk/bombercommand/aircraft/blenheim.html), 14th October, 2002

75 Gunston, *Fedden*, p.186

76 RAF And Bomber Command Association, 'Aircraft', [www.raf.mod.uk/bombercommand/aircraft/blenheim.html](http://www.raf.mod.uk/bombercommand/aircraft/blenheim.html), 14th October, 2002

Bristol altered the 142 to Type 142M, placed the wings in the mid-fuselage position, in order to accommodate the bomb bay, and used of two Bristol Mercury VIII engines as power plant<sup>77</sup>. The aircraft was capable of carrying 1,000 lb of bombs at a top speed of 280 mph, which made it far more effective than any light bomber<sup>78</sup>. The Air Ministry ordered 150 off the drawing board for immediate service, with provision made for a further 450 aircraft<sup>79</sup>. The first production Type 142M, renamed 'Blenheim', flew on 25 June 1936, and underwent its airworthiness trials at Boscombe Down on 27 October 1936<sup>80</sup>. Squadron deliveries began on 10 March 1937<sup>81</sup>. By 1938 a further four squadrons, 44, 90, 139 and 144 had been equipped with Blenheims<sup>82</sup>.

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77 RAF And Bomber Command Association, 'Aircraft', [www.raf.mod.uk/bombercommand/aircraft/blenheim.html](http://www.raf.mod.uk/bombercommand/aircraft/blenheim.html), 14th October, 2002

78 RAF and Bomber Command Association, 'Aircraft', [www.raf.mod.uk/bombercommand/aircraft/blenheim.html](http://www.raf.mod.uk/bombercommand/aircraft/blenheim.html), 14th October 2002 It is worth noting that M. Postan erroneously refers to the Type 142M as a 'light bomber', see Postan, Hay and Scott, *Design and Development of Weapons*, p.91

79 RAF And Bomber Command Association, 'Aircraft', [www.raf.mod.uk/bombercommand/aircraft/blenheim.html](http://www.raf.mod.uk/bombercommand/aircraft/blenheim.html), 4th October, 2002

80 RAF And Bomber Command Association, 'Aircraft', [www.raf.mod.uk/bombercommand/aircraft/blenheim.html](http://www.raf.mod.uk/bombercommand/aircraft/blenheim.html), 14th October, 2002

81 RAF And Bomber Command Association, 'Aircraft', [www.raf.mod.uk/bombercommand/aircraft/blenheim.html](http://www.raf.mod.uk/bombercommand/aircraft/blenheim.html), 14th October, 2002

82 RAF And Bomber Command Association, 'Aircraft', [www.raf.mod.uk/bombercommand/aircraft/blenheim.html](http://www.raf.mod.uk/bombercommand/aircraft/blenheim.html), 14th October, 2002



**Fig. 3.3: Bristol Blenheim Mk 1**      **Courtesy: RAF Historical branch**

The subsequent poor operational record of the Blenheim led Postan to criticise Bristol's technical capability by insinuating that Bristol was only able to produce the Blenheim because the Air Ministry was prescient enough to issue a specification for a similar aircraft in 1931<sup>83</sup>. This specification, which possibly led to the Bristol 135 design, gave Bristol the experience needed to build the Blenheim<sup>84</sup>. The official history claims that this un-named specification created the 'first of the new race of aircraft'<sup>85</sup>, but only after Bristol had 'greater official

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83 Postan, Hay & Scott, *Design and Development of Weapons*, p.92

84 Postan, Hay & Scott, *Design and Development of Weapons*, p.92

85 Postan, Hay & Scott, *Design and Development of Weapons*, p.92

guidance than usual'<sup>86</sup>. The official historians criticise British aircraft design of the 1930s as being 'merely a brilliant practical development' grown from 'American seeds'<sup>87</sup>. They also state that all of the 'theoretical' advances in aerodynamics and engines were the work of 'people outside the British aircraft firms', where the 'practical' men ruled<sup>88</sup>. This view is erroneous, as the evaluation of British aero-engine developments will show. America did not dominate aero-engine manufacture in the continental United States, let alone in the world market. As contemporary American sources openly admitted, British designed air-cooled radial engines had practically become 'the standard power-plant for our commercial flying'<sup>89</sup>.

By the early 1930s, technological innovation and commercial reality was driving aircraft manufacturers into new processes including metallurgy, metalwork, electronics and petrochemicals. Developments in engine design were increasing the need for more fundamental metallurgical knowledge and were demanding an increasing understanding of chemistry as fuels improved and components changed. Electrical engineering became important as both civil and military aircraft operators added more electronic gadgets to their aircraft. Electronics also became important as aircraft and engines grew in size and number of engines.

The time and energy needed to hand crank large multiple engines were

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86 Postan, Hay & Scott, *Design and Development of Weapons*, p.92

87 Postan, Hay and Scott, *Design and Development*, fn, p.34

88 Postan, Hay and Scott, *Design and Development*, fn, p.34

89 G.L. Meade, Inline Liquid Cooled versus Air Cooled Engines, *SAE Journal*, Vol. XXVII, No. 2, August 1930, p.427

unacceptable and electronic ignition became a standard. By the mid-1930s, aircraft manufacturers in Britain and throughout the world had to increase their levels of technical expertise in areas where they had never previously ventured. These technical changes placed considerable strain on the industry and individual firms. Yet, by 1935, Britain was operating three metal bi-plane aircraft, the Fairey Swordfish, Gloster Gladiator and the Gloster Gauntlet, as frontline combat aircraft.

### **The British Aircraft Industry Measured by Commercial Success**

In the 1920s and 30s, the British industry played a leading role in the world aviation marketplace by developing strong ties with foreign aircraft companies in order to penetrate national aircraft industries. The major strategy they used was to transfer British technology to the foreign partner in return for equity or financial rewards through royalty payments. In the international industry, the most aggressive British firm was the Bristol Aeroplane Company. Roy Fedden, in association with Wallace Devereux of High Duty Alloys, drove this activity and aggressively pursued markets through whatever means were available<sup>90</sup>. Where Fedden sold his Bristol licences, Devereux signed contracts for the supply of light alloy forgings and, in some cases, the building and development of a local factory to manufacture light alloys<sup>91</sup>. In February 1927, Fedden made the first of 50 visits to the USA, where he established a firm reputation as one of the world's

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90 Gunston, *Fedden*, p.108

91 Gunston, *Fedden*, p.108

leading aero-engine designers<sup>92</sup>. A great believer in licence agreements, Fedden had designed his entire system of design to make the selling of these licences more attractive. Bristol's design system used standardised drawings and standardised formatting of drawing for each part to enable licensees to comply more easily with Bristol's quality assurance systems<sup>93</sup>. Bristol was selling a franchise system for the construction of aircraft.

Bristol was not alone in pursuing international commercial opportunities. The Blackburn Aircraft Company designed aircraft for a number of foreign firms including Piaggio, Boeing Canada and Nakijima and, from 1925 until 1930, ran the Greek National Aircraft Factory for the Greek Government. In 1929, Blackburn unsuccessfully attempted to expand its operations into the United States by opening a subsidiary<sup>94</sup>. The Wall Street crash badly affected the initiative and it failed when its initial venture capital was used up.

Other British aircraft companies were busy as well. Fairey Aviation, which obtained the manufacturing rights for the Curtiss D12 engine, found itself stymied by the Air Ministry. Following the development of the Fox, the Air Ministry ordered 12 aircraft and promptly issued a specification based on the Fox<sup>95</sup>. This allowed Rolls Royce to develop the F engine, which resulted in the Hawker Fury

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92 Gunston, *Fedden*, p.95

93 Bulman, *An Account of Partnership*, p.107

94 Lund, 'The Industrial History of Strategy', p.79

95 Bulman, *An Account of Partnership*, pp. 119-120

displacing the Fox<sup>96</sup>. Richard Fairey then took his Fairey Fox and its Curtiss engines to Belgium where he set up production and won a 'fair return' in foreign orders<sup>97</sup>. In this way, a British aircraft company, Fairey, established itself as the dominant aircraft manufacturer in Belgium when it put an American engine into a British airframe.

Internationally, the most successful British aircraft firm remained Bristol. Until 1927, Bristol built the majority of its Jupiter engines overseas under licence and this accounts for the poor export figures which some commentators have used to justify their arguments of poor performance. Amongst those holding licences overseas for the Jupiter were Gnome et Rhône in France; E.W. Bliss in the USA and Nakijima in Japan. Amongst the governments were the Italian Government and Alfa Romeo and Societa Piaggio in Italy, the Swedish Government and Nydqvist & Holm and Trolhätten in Sweden. In Germany Siemens und Halske held a licence as did SA Saurer, Arbon in Switzerland. Soc. J. Walter a Spol in Czechoslovakia; SABCA in Belgium; IAMR in Yugoslavia; SA des Acières Manfred Weiss in Hungary; Sociedad Union Naval Levante in Spain; parquet de Material Aeronautico d'Alverca in Portugal; Trust d'Estat de l'Aviation in the USSR; the Polish Government and Skoda Co. in Poland; Bristol Engines of Canada and Linne-och Jern-Manufaktur AB of Finland<sup>98</sup>.

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96 Bulman, *An Account of Partnership*, p.120

97 Bulman, *An Account of Partnership*, p.120

98 Gunston, *Fedden*, pp. 108-109

Bristol obtained over £10 million in royalties in the ten years from 1925 to 1935<sup>99</sup>, and Fedden, as well as receiving a ‘handsome’ salary, received 0.5 percent commission on every engine of his design that Bristol sold<sup>100</sup>. The £1 million in annual royalties paid to Bristol does not include the financial returns from the extra business generated by the supply of support equipment, training, accessories and other items and services<sup>101</sup>. In dealing with the international marketplace, Bristol adopted a very versatile approach that ensured its radial engines penetrated smaller markets or were built under licence or through subsidiary companies in the larger markets<sup>102</sup>.

Licensing allowed foreign companies to obtain government approval to use Bristol engines as the holding of a manufacturing licence meant that even if a country went to war against Britain it could fight using British aeronautical technology. It was a cost-effective approach to national security and one which Germany, the exemplar of the advances in the theoretical sciences of aeronautics, seemed to prefer. Bristol engines powered even the Junkers K37 bomber and K47 dive-bomber, both clandestinely built in Sweden for the Germans<sup>103</sup>.

In contrast, the United States was drawing heavily upon British innovation in engine design and between the wars there was a net transfer of technology from

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99 Gunston, *Fedden*, p.108

100 Gunston, *Fedden*, p.149

101 Gunston, *Fedden*, p.108

102 E. Lanchbery, Introduction p.xii in Fedden, *Britain's Air Survival*

103 Gunston, *Fedden*, pp. 123-124

Britain to the United States<sup>104</sup>. Well-informed American engineers agreed that British designed radial air-cooled engines had practically become 'the standard power-plant for our commercial flying'<sup>105</sup>. The high value of British engine technology led to Pratt and Whitney, in collusion with the United States Government, reverse engineering a Bristol Jupiter V engine in order to improve their own designs. Fedden discovered the illicit copying of Bristol's technology during a visit to Pratt and Whitney's experimental design workshop, where he found the Jupiter V engine that the British government had given the United States Government for official evaluation completely stripped down<sup>106</sup>.

In France, Bristol achieved an immediate success with the Jupiter engine at the Paris Aviation Salon of 1921. Because of this, the French engine maker Gnome-Rhône bought a licence to manufacture the Jupiter, making France the first of 16 countries to manufacture the Jupiter under licence<sup>107</sup>. The dominant position which the Jupiter achieved in the 1920s was such that the French aeronautical newspaper, *L' Aero*, complained of a 'Scandale Jupiter', when their correspondent discovered that seventy percent of the aircraft on display at the 1929 Paris Aviation Salon were powered by Jupiter engines<sup>108</sup>. At the Paris Aviation Salon of 1930 out of 66 aircraft on display only three were British, an Armstrong

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104 Bulman, *An Account of Partnership*, P.215

105 G.L. Meade, 'Inline Liquid Cooled versus Air Cooled Engines', *SAE Journal*, Vol. XXVII, No. 2, August 1930, p.427

106 Gunston, *Fedden*, p.95

107 Bulman, *An Account of Partnership*, p.107

Whitworth Atlas bi-plane, a Bristol Bulldog and a de Havilland Pussmoth.

However, the majority of the other aircraft, 3 German, 4 Italian, 2 Dutch, 2 Polish and 52 French, used British engines or were British designs manufactured under licence<sup>109</sup>.

Foreign companies also drew upon the expertise of British technicians and executives. One of the most notable was the British aero-engine designer S. D. Heron, who invented the American sodium-cooled exhaust valve, a system that immensely improved the transference of heat from valve heads to stems. The sodium-cooled exhaust valve was one of those technological advances, according to the declinist view, which indicate the second rate nature of the technical competence of the British aircraft industry<sup>110</sup>.

Bristol was not the only British aero-engine manufacturer to find success abroad. Armstrong Siddeley and Rolls Royce were also working very successfully. Armstrong Siddeley was Bristol's major competitor in the highly profitable air-cooled radial engine market<sup>111</sup>. Between 1918 and 1932, Armstrong-Siddeley produced 16 engines, ranging from the 246 hp Puma of 1918 to the 840 hp Tiger of 1932<sup>112</sup>. One technical advance that Armstrong-Siddeley made was the

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108 E. Lanchbery, Introduction p.xii in Sir A. Fedden, *Britain's Air Survival*; Gunston, *Fedden: The Life of Sir Roy Fedden*, Rolls Royce Heritage Trust, Derby, 1998, p.79 quotes 80 percent of the military and civil aircraft on display as having Jupiter engines.

109 F.M. Smith, *SAE Journal*, Vol xxviii, No. 3, Mar 31, p.397

110 Cook, *Armstrong Siddeley*, pp. 113

111 Lanchbery, Introduction p.xii in Sir A. Fedden, *Britain's Air Survival*

112 Cook, *Armstrong Siddeley*, pp. 128-129

development, in 1921, of a remotely guided Bristol F2B fighter using Sperry's gyroscopic principles and pneumatically controlled servos to operate the controls. Armstrong-Siddeley went on in 1927 to build the Larynx, a larger and more powerful remotely guided aircraft for use as a flying bomb and target aircraft for air defence gunners. In co-operation with Airspeed, Armstrong –Siddeley continued to work in the area of remotely piloted aircraft until the 1990s<sup>113</sup>.

In 1922, Armstrong-Siddeley obtained a £40,000 contract from the Greek Government for the supply of Jaguar engines for 25 Gloster Mars Mark VI aircraft<sup>114</sup>. The contract was a 'considerable coup' as the rival bidder had been Bristol with its Jupiter engine<sup>115</sup>. The elation lay not just in winning a good contract but also in beating Fedden of whom the Chief Designer at Siddeley, Major F.M. Green, was an implacable professional competitor<sup>116</sup>.

### **Relations between Government and Industry**

The British Government may not have created Britain's aircraft industry, but, during the First World War, it financed its expansion and showed businessmen that there was a market for aircraft. By 1916, the aircraft industry comprised both new companies and the older established armaments manufacturers. All of these companies were accustomed to working with government. The close relationship

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113 Cook, *Armstrong-Siddeley*, pp. 44-45

114 Cook, *Armstrong Siddeley*, p.47

115 Cook, *Armstrong Siddeley*, p.47

between government and the aircraft industry was a function of a broad belief that aircraft were as important to national defence as were ships<sup>117</sup>.

In Britain, the state and the industry were equal partners in designing, developing and producing aircraft<sup>118</sup>. The aircraft industry depended upon government as a customer but it also depended on government to supply the primary research, which it appears they were selling abroad for profit. The research was conducted at the Royal Aircraft Establishment (RAE) at Farnborough, at the Aeroplane and Armament Experimental Establishment at Boscombe Down, at the National Physical Laboratory and, during the war, at the Directorate of Scientific Research at the M.A.P<sup>119</sup>. This primary research was important as it provided the British aircraft industry with what appears to be a competitive advantage and it was readily adopted by United States firms, who had few similar resources at their disposal<sup>120</sup>.

The British government enjoyed a dual relationship with the aircraft industry. In one form, it was a client and in the second, it was co-venturer. Different branches of government managed this duality. The client relationship existed between the officers of the RAF, who set Air Ministry specifications for aircraft and judged the

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116 Gunston, *Fedden*, p.51

117 A. Smith, *The Wealth of Nations*, Everyman's Library, London, 1991, pp. 405-407 Adam Smith uses shipbuilding and shipping as the example of an industry that government needed to protect from market forces, i.e. foreign trade.

118 Postan, Hay & Scott, *The Design and Development of Weapons*, p.68

119 Postan, Hay & Scott, *The Design and Development of Weapons*, p.71

120 Bulman, *An Account of Partnership*, pp. 214-216

performance of the respective designs. The co-venturer relationship was exercised between the various government research organisations and the aircraft industry. This relationship provides an example of how government involvement with an industry can benefit that industry. The benefit derived by the British aircraft industry was that they were able to pass the expensive work of proving the theoretical science through experimental work. This enabled all British firms to benefit from a competitive advantage which their American competitors lacked.

United States aircraft companies had to make up for the shortfall in government support in basic aeronautical research by having larger project teams involved in their design processes and by being net importers of aircraft technology and aerodynamic research. During a visit to the United States, in 1934 a British official, George Bulman, the Chief Inspector of Engines of the Aeronautical Inspection Division of the Air Ministry, found that the Americans had only a passing understanding of the science underpinning current British aero-engine developments<sup>121</sup>. As well, he found that the American aircraft industry was subject to far greater government control than their British counterparts<sup>122</sup>.

Bulman also was amazed at the arcane budgetary practices used by the US Army which placed a one-year limit on the time taken to deliver a finished product. This meant that American aircraft companies could only supply existing and therefore obsolescent aircraft, because the manufacturer had to deliver within one year from the date the Army had placed the order. He also found that the US imposed a

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121 Bulman, *An Account of Partnership*, p.216

122 Bulman, *An Account of Partnership*, p.214

stifling level of secrecy on all activity that adversely affected the development of new ideas by preventing open discussion<sup>123</sup>.

Adding to the difficulties of the American system was the fear that the US Congressional oversight system seemed to generate amongst government officials and the broader American aircraft industry. Bulman concluded that it took more strength of character and dedication to drive any change through the 'fog, and bog, of officialdom' than it did in Britain<sup>124</sup>. However, Bulman found that the Americans had one significant advantage; plenty of money to finance their operations and develop their aircraft industry<sup>125</sup>.

### **The Cost of Preparing the Aircraft Industry for War**

The technology that Britain's aircraft manufacturers and government research institutions developed enabled the country to consider using air power as a significant part of military preparedness. The aircraft that British aircraft firms were developing showed a full understanding of the advances in aerodynamics, engine development, fuel technology and all of the associated areas of hydraulics, electrical engineering, metallurgy and chemistry. The combined effort of all of these allowed Britain to become a major manufacturer of aircraft during World War II.

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123 Bulman, *An Account of Partnership*, p.215

124 Bulman, *An Account of Partnership*, p.215

125 Bulman, *An Account of Partnership*, p.216

Between 1935 and 1945, Britain produced 139,318 aircraft weighing 724,140,000 pounds in structure weight<sup>126</sup>. In 1935 the annual production of aircraft was 893 and, at the peak of production in 1944, 26,461, a production increase of 2,963 percent over 10 years<sup>127</sup>. In order to accomplish this type of growth the British Government had to fund the aircraft industry. The decision to undertake the expansion of the aircraft industry was not straightforward. There were a number of significant impediments to expansion and not all of them were financial. However, the first impediment was financial.

The worldwide economic depression and the significant drop in Britain's economic activity led to a significant reduction in tax collected. The shortfall in taxation combined with increased welfare payments for the growing number of unemployed reduced the funding that the government could make available for re-armament. The ability of the government to raise loans was also limited because Britain had already defaulted on US loans which originally were obtained for the supply of goods during World War I. A further impediment was that the government adhered to classical economic theory.

In classical theory, governments kept the books balanced, never ran deficit budgets and kept taxation to a minimum. Classical economics did not provide a

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126 Central Statistical Office, *Statistical Digest of the War*, HMSO, London, 1951, Tables 130 and 131, pp. 152-153

127 Central Statistical Office, *Statistical Digest of the War*, Tables 130, p.152

mechanism for stimulating economic activity by running deficit budgets. Consequently, the effects of depression were exacerbated, as the government did not stimulate activity by pumping money into the economy. P.R. Shay lays a large part of the blame for the slow growth in Britain's pre-war armaments production at the door of the Treasury<sup>128</sup>. There is little doubt that the financing of defence expenditure was the subject of a furious debate within the government. Treasury opposition received substantial support from Sir Neville Chamberlain, first as Chancellor of the Exchequer and then as Prime Minister. The major concern of Treasury, including Chamberlain and an influential section of British society, was that increased expenditures on defence would be 'particularly dangerous to the capitalist states of Western Europe with their depressed incomes, their high taxation and their excessive national debts'<sup>129</sup>. The danger was that increased taxation would remove disposable income from people leading to increasing poverty and social unrest. They did not consider that the money taken by government in tax would return to the economy as payments, salaries and wages, which, in turn, would have stimulated a recovery.

The result was that government capital investment in defence remained low, reaching a cumulative total of only £12,700,000, in 1939. The low rate of government investment suggests that aircraft firms may have re-invested profit into their businesses to accomplish the initial jumps in aircraft production<sup>130</sup>.

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128 P.R. Shay, *British Rearmament in the Thirties: Politics and Profits*, Princeton University Press, Princeton, New Jersey, 1977, p.74

129 Treasury Minute Quoted In P.R. Shay, *British Rearmament*, p.75

130 Hornby, *Factories and Plant*, p.202

William Hornby supports this conclusion when he suggested that some managements were concerned that they would be creating an over-capacity in production that would only be met by a war<sup>131</sup>. In order to address these concerns the government, through the Air Ministry, introduced capital clauses in their contracts. From 1936 onwards, expansion of the industry's manufacturing capacity was overwhelmingly at government expense<sup>132</sup>.

A second impediment to the rapid expansion of British aircraft production was an Air Ministry fear that if they placed large orders for existing aircraft the RAF would be left with a large inventory of obsolete types<sup>133</sup>. The United States Army Air Corps was also concerned that it could end up with a similar problem<sup>134</sup>. In the mid-1930s, the technical development of airframes and aero-engines was progressing rapidly. For political reasons, the Air Ministry ordered some aircraft types such as the Fairey Battle, Blenheim, Whitley and the Hampden. None of these aircraft served in Bomber Command beyond 1941.

The correctness of the reservations about rushing to order aircraft in the mid-1930s is borne out by the problems encountered in later aircraft types. The earlier Stirling, Manchester and Halifax aircraft did not perform as well in Bomber Command as did the Lancaster and the Mosquito. The Hurricane was another

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131 Hornby, *Factories and Plant*, p.202

132 Hornby, *Factories and Plant*, p.202

133 Hornby, *Factories and Plant*, p.202

134 SAE Journal, 'Engineering for National Defence', *SAE Journal*, Vol 44, No. 2, February 1939, p.1

example and it did not perform as well as the Spitfire. The lag arises from the fact that by the time an aircraft is designed and a prototype built for testing it is, from a technical perspective, approaching obsolescence unless valuable time and effort are expended in continuously modifying it. The most valuable aircraft were those, like the Lancaster, Mosquito and Spitfire, that could absorb technical upgrades without having to be massively re-engineered.

The restraints placed upon British re-armament during the 1930s were significant and it is arguable whether any British government could have overcome them.

Under Chamberlain, the government continued to adhere to classical economic concepts. The pump-priming fiscal policy being implemented in the United States under the 'New Deal' and the theoretical modelling being done by Keynes held little appeal for Chamberlain or Treasury. The fear was that increased government expenditure would lead to increased taxation and the subsequent reduction in the money circulating within society would lead to an outbreak of unrest. Britain also faced the problem that she had defaulted on her loans when few other governments had money to spare. At the time that the decision to re-arm was made, there were no examples of capitalist governments successfully using spending as a means of stimulating the wider economy. There was little likelihood that the British government could have increased its spending much beyond the £12.7 million that it managed up until 1939.

### **Building the Infrastructure**

As war approached, the British government abandoned the commitment to classical economics and decided that the funding of the nation's defences had to take priority. The defaulting on the American loans would lead to significant difficulties for Britain in raising capital from that quarter. The US Lend Lease Act partially overcame this difficulty, but that was not available in 1939. In Britain, by 23<sup>rd</sup> September 1939, the government had made commitments to 75 firms totalling £61,893,366 through the Air Ministry<sup>135</sup>. The amount was divided into £30,048,866 for the extension of manufacturing capacity in 53 firms<sup>136</sup>; £7,435,000 to 24 aircraft industry companies under the provisions of the 'Capital Clause' scheme for capital extensions to buildings, plant and machinery; and £24,409,500 was given to 13 companies to build Shadow Factories to produce airframes, aero-engines, airscrews, bombs, carburettors and petrol containers<sup>137</sup>. By 19<sup>th</sup> December 1939 the list had grown to 146 companies receiving £109,604,984, broken down into £50,968,134 for the extension of manufacturing capacity in 125 companies; £7,459,000 for the 24 companies under the provisions of the 'Capital Clause' scheme; and £51,177,300 for 20 companies to operate 27 Shadow factories<sup>138</sup>.

**FIRMS FINANCED BY GOVERNMENTAL CAPITAL SCHEMES  
JUNE 1943**

<b>ACTIVITY</b>	<b>NUMBER OF FIRMS</b>	<b>EXPENDITURE (Millions £)</b>
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135 PRO CAB 68/1, Supply and Production First report by the Air Ministry, W.P.(R)(39) 16, 23<sup>rd</sup> Sept 39, pp. 146-152

136 PRO CAB 68/1, p.146

137 PRO CAB 68/1, p.146

138 PRO CAB 68/1, pp. 337-349

Airframes <sup>a</sup>	665	93
Engines And Accessories	120	117
Propellers	57	16
Bombs	123	-
Guns	43	8.5
Turrets	9	-
Instruments	88	3.3
Aircraft Equipment	244	6.2
Radio and Radar	55	10
Light Alloy Fabrication	81	70
Aluminium	16	-
Magnesium	27	-
Engine Repairs	23 <sup>b</sup>	-
Airframe Repairs	146 <sup>b</sup>	-

a. Including undercarriages

b. Includes many firms involved in airframe and engine manufacture.

**Fig. 3.4:**                      **Source: Hornby, *Factories and Plant*, p.252**

If there were concerns in the Chamberlain Government about the escalating cost of the war, they were justified. The cost of financing private production escalated throughout the war. In June 1943, 1,697 firms had received £324,000,000 in government financing<sup>139</sup>. Figure 3.4 above details the number of firms receiving government finance in the various areas of production activity at this time.

Hornby estimates that by September 1944, Britain had committed £370.8 million to building the factories and plant necessary to produce aircraft for the war effort<sup>140</sup>. By September 1945, he conservatively concludes, Britain had spent £425 million<sup>141</sup>. This estimate did not include money spent on government owned establishments and ‘certain other schemes’<sup>142</sup>. Given that bomber aircraft

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139 Hornby, *Factories and Plant*, p.252

140 Hornby, *Factories and Plant*, p.214

141 Hornby, *Factories and Plant*, p.211

142 Hornby, *Factories and Plant*, p.214

accounted for 52.5 percent of all aircraft production by structure weight, it is a conservative estimate that they consumed a similar proportion of the total government expenditure on factories and plant<sup>143</sup>. The strategic air offensive would therefore have consumed £212.75 million, or 52.5 percent of the £425 million reported by Hornby.

The government incurred further costs in four schemes to put aircraft production underground in September of 1940<sup>144</sup>. Despite a Cabinet ban on such activity in other than special cases, the Secretary of State for Air, Max Beaverbrook, ordered the four schemes<sup>145</sup>. The cost of the four schemes justified the objections made to placing factories underground and all of them were overtime and over-cost and much more expensive than comparable factories built in the normal manner. The underground projects were unsuccessful, the first Browning gun barrel did not appear until August 1942; and the first Bristol engine took until September 1943. The overall cost of this activity was around £4,250,000<sup>146</sup>. Bomber Command's portion of this amount, 52 percent, would have been £2,210,000.

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143 Central Statistical Office, *Statistical Digest of the War*, Table 131, p.153

144 Hornby, *Factories and Plant*, p.206

145 Hornby, *Factories and Plant*, p.206

146 Hornby, *Factories and Plant*, p.207

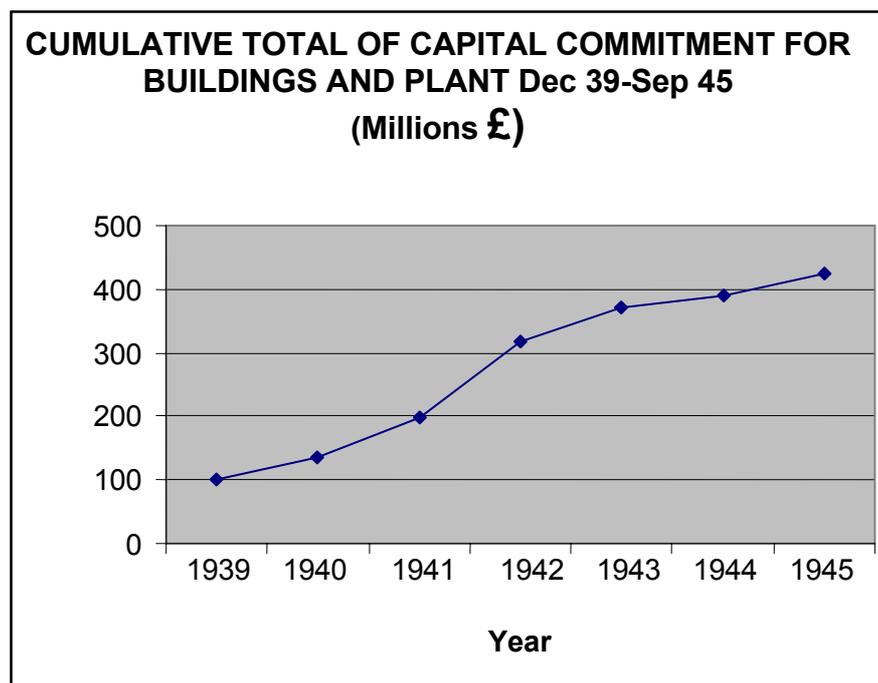


Figure 3.5:

Source: Hornby, *Factories and Plant*, p.211

The plans for increasing floor space for aircraft production relied heavily on the dispersal of component manufacture. Parent companies could contract out the manufacture of everything from nuts and washers to engines and entire wing and tail assemblies. This allowed productive capacity to be utilised well away from the parent firms' factories. The value of this capacity must have been very substantial; but the spread and small size of the firms involved makes it very difficult to estimate the value of this activity. As a result, the figures for the overall costs established for plant in this chapter do not include the value of the contribution made by these small operations. There was an enormous, and un-measured, amount of existing factory floor space incorporated into the aircraft industry at no additional capital cost to the government or industry. Figure 3.6 below provides a listing of the floor space required per assembled aircraft and gives a good indication of the very large volume of the buildings needed.

<b>FLOOR SPACE REQUIRED PER AIRCRAFT TYPE</b>		
<b>AIRCRAFT TYPE</b>	<b>LENGTH AND SPAN (feet)</b>	<b>NET AREA REQUIRED (square feet)</b>
<b>Mosquito</b>	48 x 34	1,600
<b>Spitfire</b>	37x 30	1,110
<b>Hurricane</b>	40 x 32	1,280
<b>Lancaster</b>	102 x 70	7,140
<b>Whitley</b>	84 x 72	6,046
<b>Anson</b>	56 x 42	2,352
<b>Sunderland</b>	112 x 85	9,520
<b>Halifax</b>	104 x 71	7,384
<b>Beaufort</b>	58 x 44	2,552
<b>Blenheim</b>	56 x 44	2,646

Fig.3.6: Source: W. Hornby, *Factories and Plant*, p. 237

An increase in the cost of transportation was one cost that sub-contracting did increase. It is impossible to evaluate the impact of the increased cost of transporting the raw materials, components and parts around the country because they were absorbed without attribution by the government funded transport system. Neither were the costs of improving or extending the roads and rail lines that dispersed factories required<sup>147</sup>.

As to the cost of floor space in factories, Hornby estimates that the per-foot cost of a wartime aircraft factory was between 15/- and £2 pounds, without taking into account the cost of plant which was usually larger than the cost of the buildings<sup>148</sup>. Using these estimates the average cost of a heavy bomber factory would have been

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147 Hornby, *Factories and Plant*, p.208

148 Hornby, *Factories and Plant*, p.232

between £1,241,250 and £3,310,000, and for a fighter factory, between £1,020,000 and £2,720,000.

The use of smaller factories in Britain had provided one means of quickly and cheaply increasing manufacturing floor space. It was also recognition of the fact, not often mentioned by the critics, that Britain was running out of room. Britain could not simply erect American style plants in the closely populated British Isles. The government had already made significant demands upon the rural population by seizing land for airfields, military establishments, ordnance stores and other wartime uses. There was little room for more and even larger factories to be established. Of course, another factor with which Britain had to contend, and the US did not, was the direct threat posed by German air attack.

**ALLOCATION OF FLOOR SPACE FOR AIRCRAFT PLANT  
(Square Feet)**

<b>PROCESS</b>	<b>BOMBER FACTORY</b>	<b>FIGHTER FACTORY</b>
<b>Flight Sheds For Flight Assembly</b>	180,000	130,000
<b>Final Assembly Of Airframe</b>	130,000	80,000
<b>Component Assembly</b>	400,000	300,000
<b>Fitting And Sub-Assembly</b>	130,000	-
<b>Stores</b>	400,000	450,000
<b>Machine Shop And Tool Room</b>	125,000	100,000
<b>Other Process Work</b>	100,000	120,000
<b>Administrative And Drawing Office</b>	130,000	180,000
<b>Factory Service And Engineering</b>	60,000	-
<b>Total</b>	<b>1,655,000</b>	<b>1,360,000</b>

Fig. 3.7: Source: W. Hornby, *Factories and Plant*, p. 237

The use of small factories enabled a quicker initial expansion of capacity at a reasonable cost and the lack of available land close to large conurbations of skilled industrial workers and the threat posed by enemy air attack, reinforced the appeal of smaller, less critical targets which were widely separated. The major consequence of dispersal was a decrease in efficiency and an increase in the expense of manufacturing aircraft. The logistics alone would have been a significant and constant headache. Any disruption in the flow of raw materials to parts manufacturers, or finished parts to component manufacturers, or assemble components to the aircraft assembly area, would have forced halts in production. It is little wonder that the productivity of British aircraft workers contrasted badly with their American counterparts.

Hornby finds that the dispersion and smaller factory size limited the efficiency of the British industry by imposing smaller economies of scale per production unit. Factories with longer runs of production per month, say 50 to 60 fighters or 20 to 30 bombers, were able to achieve levels of unit of production close to the best of the American plants<sup>149</sup>. Part of the problem, Hornby suggests, was that the problem of low productivity in British airframe plants compared to their United States counterparts was due to an oversupply of assembly facilities in relation to the manufacturing capacity of the parts and component makers.

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149 Hornby, *Factories and Plant*, p.247

## Raw Materials - Aluminium

In the first of its 'Monthly Supply and Production Reports', the Air Ministry mentioned the supply of aluminium, 'in the form of sheet, strip and extrusion' as essential for the manufacture of aircraft<sup>150</sup>. Increased capacity was planned through the extension of Northern aluminium's factory at Banbury in South Wales and their taking over of a disused steel works at Rogerston for Aluminium production under Northern's management<sup>151</sup>. These two plants were to produce an expected 20,000 tons of aluminium annually<sup>152</sup>. One company, High Duty Alloys, would use the old Beardmore Works at Motherwell to produce an expected 7,500 tons per annum. The Air Ministry also funded a Canadian plant capable of producing 5,000 tons<sup>153</sup> per year at a projected cost of between £2,250,000 and £2,750,000<sup>154</sup>. North America was an important source of aluminium for Britain<sup>155</sup> and between 1938 and 1945, Britain imported 1,375,600 tons of bauxite and 812,900 tons of aluminium from these countries<sup>156</sup>. The figures for imports of aluminium do not include the aluminium lost at sea. Hornby estimated the cost of purchasing bauxite and aluminium and of building aluminium capacity in Canada at £17,000,000<sup>157</sup>.

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150 PRO CAB 68/1, p.107

151 PRO CAB 68/1, p.120

152 PRO CAB 68/1,120

153 PRO CAB 68/1,120

154 PRO CAB 68/1, p.121

155 PRO CAB 68/1, p.108

156 Central Statistical Office, *Statistical Digest of the War*, Table 96, p.110

157 Hornby, *Factories and Plant*, p.213

These supplies were supplemented by secondary (used) aluminium, scavenged from old pots and pans or the remains of crashed and written off aircraft. This latter source provided 448,860 tons of aluminium<sup>158</sup>. The total amount of aluminium imported or produced from imported Bauxite in Britain from 1938-1945 was 1,521,190 tons<sup>159</sup>. The aircraft industry consumed a substantial proportion of this aluminium and bauxite. Of the aluminium used by the aircraft industry, it is reasonable to say that Bomber Command consumed 794,000 tons, 52.5 percent of it, at a cost of £8.9 million.

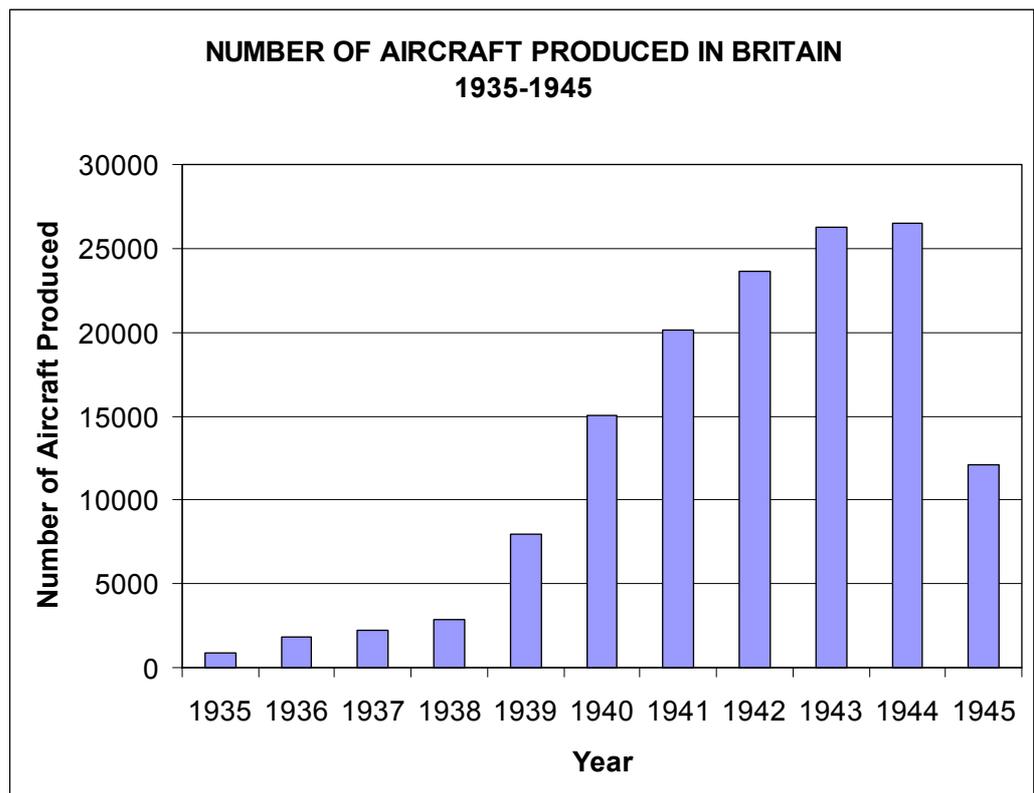


Fig. 3.8: Source: central Statistical Office, *Statistical Digest of the War*, p. 152

158 Central Statistical Office, *Statistical Digest of the War*, Tables 148 and 149, pp. 169-169

159 Central Statistical Office, *Statistical Digest of the War*, Table 97, p.111

## Airframe Construction

Aluminium was the major raw material for airframes and the production of these has been the subject of much research into the relative efficiency of the industry overall. As already noted, from 1935 until 1945 Britain produced 139,318 aircraft with a total structural weight of 724,140,000 lbs<sup>160</sup>. A significant amount of this aluminium went into heavy bombers. Of the aircraft built in British factories, 14,706 were heavy bombers destined for Bomber Command. They accounted for 10.5 percent of all aircraft manufactured in Britain between 1935 and 1945, and 13.5 percent of all aircraft manufactured between 1940 and 1945<sup>161</sup>.

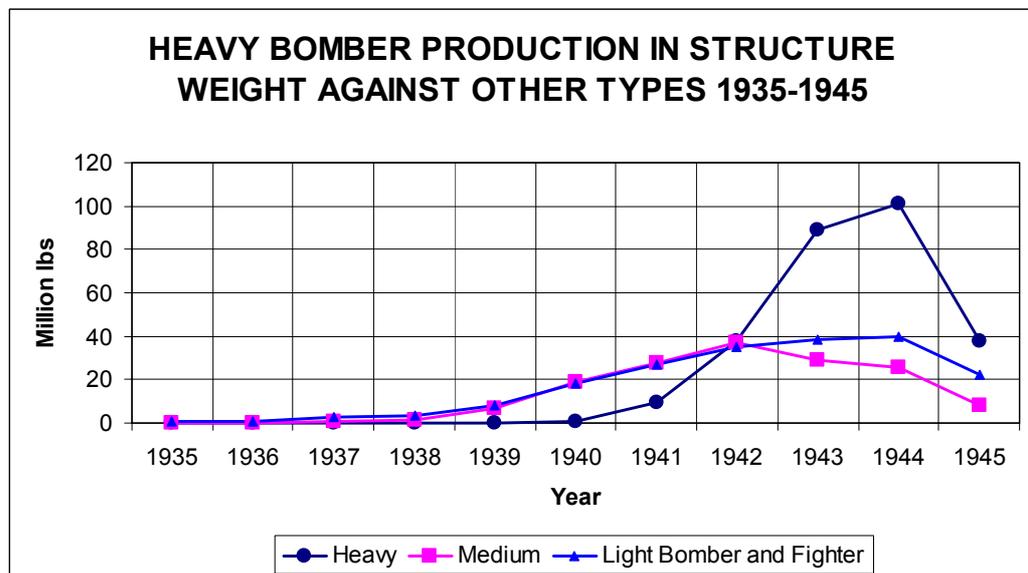


Fig. 3.9:

Source: *Statistical Digest of the War*, p.153

160 Central Statistical Office, *Statistical Digest of the War*, p.153

161 Central Statistical Office, *Statistical Digest of the War*, Tables 130 and 131, pp. 152-153

Numerically, the number of heavy bombers does not appear to be large.

Measured in terms of structure weight the heavy bomber becomes far more significant. Between 1940 and 1945, the three British heavy bombers - the Halifax, Stirling and Lancaster - accounted for 45.81 percent of all British aircraft production. When medium bombers are included, many of which served in Bomber Command, the percentage rises to 52.2 percent<sup>162</sup>.

The hope that Britain would be able to supplement her domestic production with US imports from the US was never realised. During the period of the war, Bomber Command received 1,253 aircraft from this source, a small contribution given the size of British production of similar aircraft. However, the subject of these aircraft and their costs will be dealt with in Chapter 4.

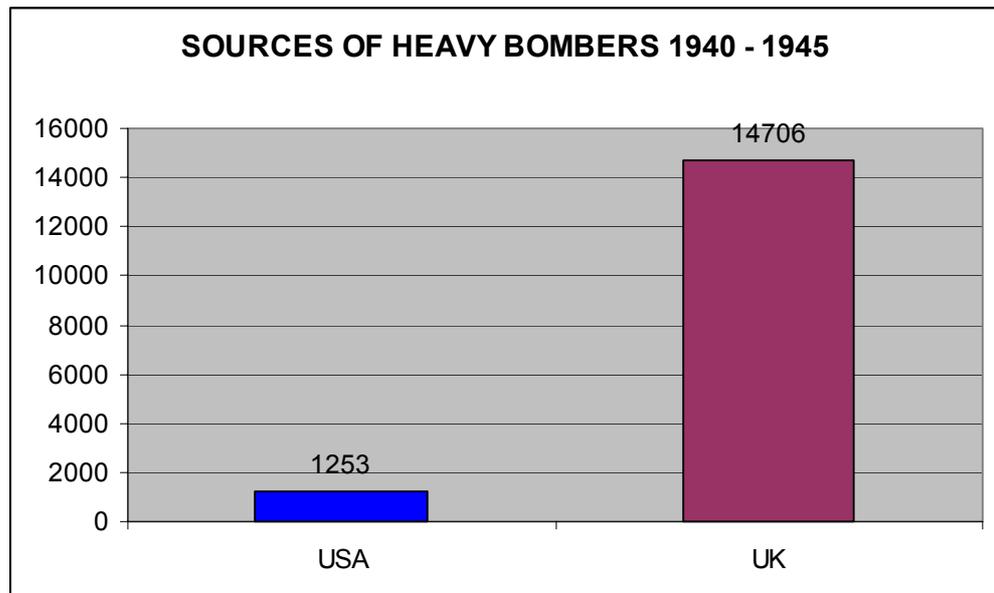


Fig. 3.10:

Source: *Statistical Digest of the War*, p.156

162 Central Statistical Office, *Statistical Digest of the War*, Tables 131, p.153

## **Aero-engines**

Sebastian Ritchie claims that the aero-engine lay ‘at the heart of aircraft design, production and programming’<sup>163</sup>. According to Sir Alex Cairncross, the aero-engine dictated aircraft production because of the length of time it took to develop a working engine and to get it into mass production<sup>164</sup>. In terms of its aero-engine capability, Britain was in the lucky position of having what was probably the most advanced aero-engine manufacturing sector in the world. British aero-engine firms dominated the world aircraft industry from the early 1920s until the mid-1930s and the technological and competitive advantages that they enjoyed put them in a good position to develop further highly successful engines. The most famous of these were the large liquid cooled inline engines of Rolls Royce. The technological advantage that Rolls Royce built up using the wartime support of government strengthened the company so that it was positioned to dominate the aero-engine market after the end of World War II.

Today Rolls Royce engines are widely used by United States manufacturers and by other countries including France and Germany. In September 1940, the Packard Company of New Jersey began the process of setting up production of the Merlin variant, the V-1650 liquid-cooled engine. The capabilities of the first two Packard ‘Merlins’ were demonstrated in Detroit on August 2, 1941, when a group of senior government officials and industry representatives observed a test run of

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163 Quoted in Ritchie, *Industry and Air Power*, p.113 from Cairncross, *Planning in Wartime*, p.15

164 Quoted in Ritchie, *Industry and Air Power*, p.113

the engines. Full production began in 1942<sup>165</sup>. The time lag of over 18 months for a United States engine firm to accomplish mass production of an already developed engine gives some indication of the complexity of setting up engine plants. It also shows that there was little difference between British or American firms when it came to incorporating new technology, and it is evidence that perhaps Britain's aero-engine manufacturers were as efficient as were their United States counterparts.

By 1945, Rolls Royce had produced 100,000 Merlin engines in 24 marks in the United Kingdom alone, along with 10,000 Griffons in 17 marks by Rolls Royce and its shadow factories<sup>166</sup>. The Merlin accounted for 32.56 percent of all aero-engines manufacture in Britain during World War II<sup>167</sup>. A further 16,000 Merlins were produced in the U.S.A and numbers of them were exported to Britain for use in Spitfire, Mosquito and Lancaster production<sup>168</sup>. In order to ensure a timely supply of engines, the Air Ministry decided to build shadow factories, one to manufacture 400 Bristol engines a month, and another to manufacture 2,000 Napier engines a year.

## **AIRCRAFT ENGINES**

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165 US Air Force Museum, [www.wpafb.af.mil/museum/engines/eng33.htm](http://www.wpafb.af.mil/museum/engines/eng33.htm), 23rd October, 2002

166 Hornby, *Factories and Plant*, p.256

167 Hornby, *Factories and Plant*, p.256

168 US Air Force Museum, [www.wpafb.af.mil/museum/engines/eng33.htm](http://www.wpafb.af.mil/museum/engines/eng33.htm), 23rd October 2002

Year	Engines Produced	Engines Imported	Engines Repaired
1939	12,499	-	-
1940	24,074	-	-
1941	36,551	2,704	20,082
1942	53,916	3,145	27,563
1943	57,985	9,441	35,832
1944	56,931	11,327	44,594
1945	22,821	4,528	26,689
<b>Total</b>	<b>275,896</b>	<b>31,145</b>	<b>154,760</b>

Fig. 3.11: Source: *Statistical Digest of the War*, p.155

Motorcar makers, Rover, Standard Motorcars, Austin and Rootes respectively made and repaired Armstrong Siddeley, de Havilland and Rolls Royce engines. These companies contributed 34 percent of all engines manufactured during World War II<sup>169</sup>.

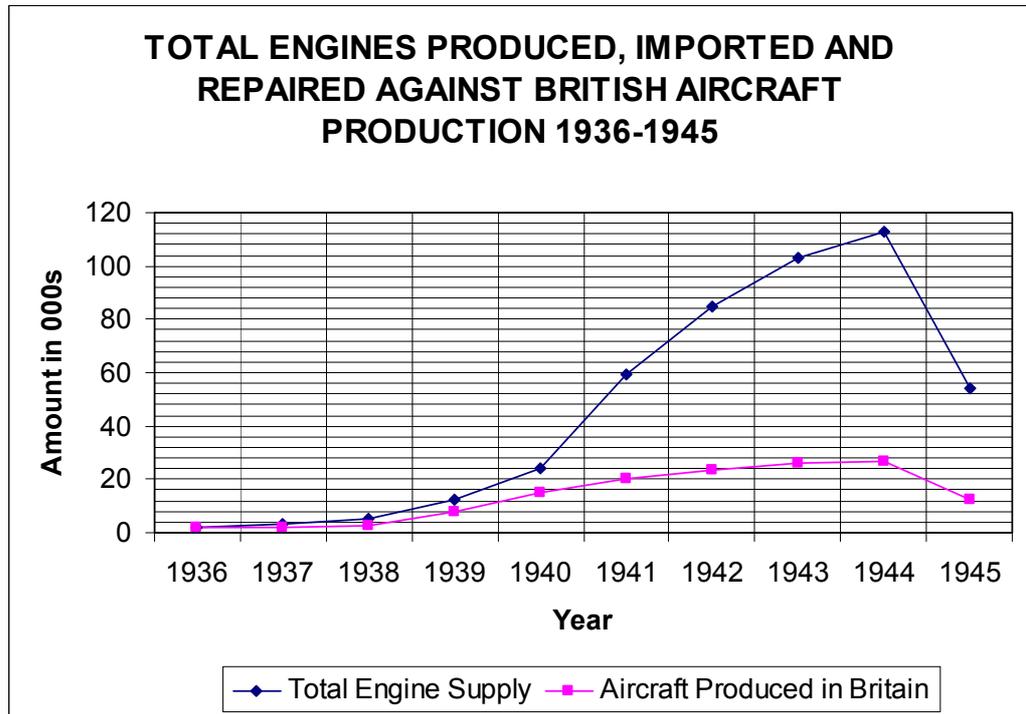


Fig.3.12: Source: *Statistical Digest of the War*, pp.152, 155

169 Central Statistical Office, *Statistical Digest of the War*, Table 134, p.155

As can be seen from Figure 3.12 above, engine production and supply from repair and import remained ahead of requirements and grew rapidly from 1940 onwards. By 1943, the British Government had spent £117 million financing the expansion of the aero-engine industry. This represented 27.5 percent of the total amount of £425,000,000 expended on all aspects of the aircraft industry at that time (see Figure 3.4 above)<sup>170</sup>.

**TOTAL ENGINE DELIVERIES JUNE 1939 TO DECEMBER 1945\***

<b>Engine</b>	<b>Deliveries</b>	<b>Number Of Types</b>
Bristol	100,932	6
Rolls Royce	112,183	5
Napier	5,267	2
Armstrong Siddeley	32,868	1
De Havilland	10,905	1
<b>Total</b>	<b>262,155</b>	<b>15</b>

\* Excluding Jet engines of which Rolls Royce delivered 661, in 2 types, and de Havilland 85 of one type

**Fig.3.13:**

**Source: Hornby, *Factories and Plant*, p.252**

**Aero-engine Accessories**

The Ministry of Aircraft Production also substantially extended the use of sub-contractors to make components of engines under the supervision of existing motorcar or aero-engine manufacturers who had the engineering expertise required for the tooling up the production of engines. Other components, such as carburettors and magnetos, were manufactured by specialist firms such as Hobsons of Wolverhampton, Standard in Coventry (both carburettors) and B.T.H. of

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170 Hornby, **Factories and Plant**, p.252

Leicester for magnetos<sup>171</sup>. The provision of these products, as well as of spark plugs, was centrally controlled by the Air Ministry and, later, the MAP and they were issued free of charge to the manufacturing firms on receipt of their orders<sup>172</sup>.

The Supply and Production Reports in September and December 1939 show Hobsons allocated £30,000 for extensions of plant and £215,000 for the construction of a shadow factory for carburettors<sup>173</sup>. Standard also had £267,000 allocated for the building of another shadow carburettors factory and B.T.H. received £421,000 for its shadow magneto plant. Another company, Simms Motor Units, received £25,000 for magneto production<sup>174</sup> and Rotax received £230,000 under the 'Capital Clause Scheme'<sup>175</sup>. The two largest employers in these areas, B.T.H and Rotax, employed approximately 7,000 and 6,000 workers respectively at about 10 plants, showing that considerable resources and manpower were invested in the production of these essential products<sup>176</sup>.

As with engine accessories, the Air Ministry and the MAP carefully controlled propellers. The government purchased all propellers and then issued them upon demand, at no charge, to aircraft construction firms. The reason for this was that the manufacture of variable pitch airscrews was much more complex. This

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171 PRO CAB 68/3, Supply and Production Report by the Air Ministry, 19<sup>th</sup> Dec 1939, p.349

172 Hornby, *Factories and Plant*, p.265

173 PRO CAB 68/1, Supply and production First report by the Air Ministry, 23<sup>rd</sup> Sept 39 and PRO CAB 68/3, Supply and Production Report by the Air Ministry, 19<sup>th</sup> Dec 1939

174 PRO CAB 68/1, Supply and production First report by the Air Ministry, 23<sup>rd</sup> Sept 39 and PRO CAB 68/3, Supply and Production Report by the Air Ministry, 19<sup>th</sup> Dec 1939

175 PRO CAB 68/1, Supply and production First report by the Air Ministry, 23<sup>rd</sup> Sept 39

activity demanded a very skilled workforce and highly specialised milling machinery<sup>177</sup>. The British variable pitch propeller arose out of a joint venture between Bristol and Rolls Royce, which in 1937 came, to be the Rotol Company<sup>178</sup>. Rotol finally developed its hydraulic variable pitch propeller from the Hele Shaw and by 1939 both Rotol and de Havilland, which persisted with its own design, had their respective propellers in large-scale production<sup>179</sup>. In order to achieve this outcome the British Government invested £1.257 million in the period between September and December 1939<sup>180</sup>. As a result of this investment and the both companies were able to develop modern plants and de Havilland's plant at Boulton went on to become the most self-contained and automated in the country<sup>181</sup>.

## **Workforce**

At its peak in June/July of 1943, the Air Ministry and MAP had approximately 3,619,500 civilian workers under their direct or indirect control<sup>182</sup>. This figure represents 20.7 percent of the total civil work force available at the time; or over one in every five people. The demands of the Air Ministry, Air Staff and the MAP

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176 Hornby, *Factories and Plant*, p.266

177 Hornby, *Factories and Plant*, p.267

178 Bulman, *An Account of Partnership*, p.210 and Hornby, *Factories and Plant*, p.268

179 Bulman, *An Account of Partnership*, pp. 209-211

180 PRO CAB 68/1, Supply and production First report by the Air Ministry, 23<sup>rd</sup> Sept 39 and PRO CAB 68/3, Supply and Production Report by the Air Ministry, 19<sup>th</sup> Dec 1939

181 Hornby, *Factories and Plant*, p.268

182 Compiled from manpower tables in the *Statistical Digest of the War*, pp. 8-29

was to be a major problem as demands for more and more workers for the various aircraft production programmes strained the available workforce. The crux of the problem lay in the inability of the aircraft industry to meet the optimistic production targets that had been set. A lack of manpower was one of the major reasons given for the continued shortfall in production and the obvious answer was to increase the workforce available to the MAP. On the other hand, the size of the Air Ministry and MAP demands on available labour was having adverse effects on the other services and the overall economy.

The figure of 3,619, 500 is twice as much as the 1.8 million suggested by Cairncross<sup>183</sup> and more than double the 1.5 to 1.6 million identified by Hornby<sup>184</sup>. The major reason for this is that both Cairncross and Hornby confined their analysis to the number of people directly working within the airframe, aero-engine and closely associated industries. The problem with this approach is that it serves to minimise the size of the manpower resources that the Air Ministry and MAP used as they worked to build and administer the entire infrastructure needed to support manufacturing and operations.

The figures supplied by Hornby do not take into account male workers aged over 65 years or females over 60 years; and neither do they take into account work done by workers under 16<sup>185</sup>. A further group not counted are the employees of

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183 Cairncross, *Planning in Wartime*, MacMillan, London, 1991, p.72

184 Hornby, *Factories and Plant*, p.251

185 Central Statistical Office, *Statistical Digest of the War*, p.17

sub-sub-contractors, that is, those people employed in carrying out small work in small factories employing less than 100 persons, of which there were a considerable number. These omissions make Hornby's calculations conservative, as the total numbers employed in the aircraft industry were probably much larger than previously accepted.

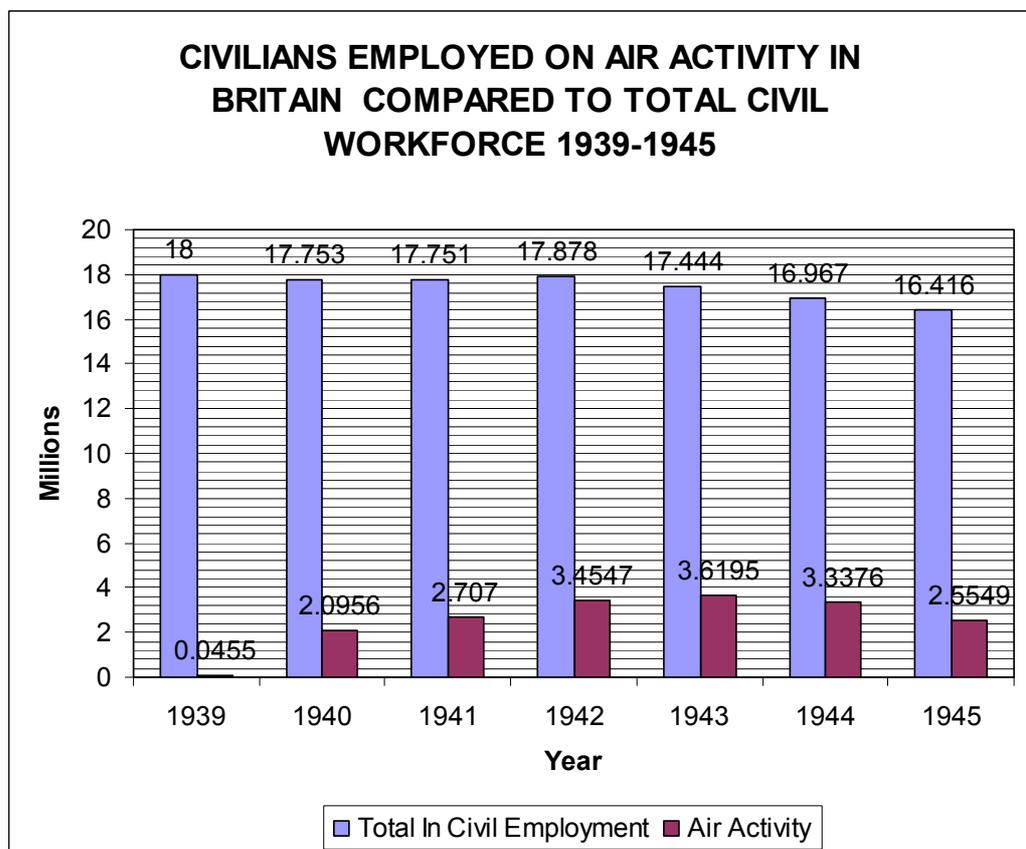


Fig.3.14: Source: *Statistical Digest of the War*, pp.8, 9, 20

The distribution of workers within aircraft manufacturing shown above is at the peak of activity in 1943. Hornby estimates that the 18 pre-war airframe-

manufacturing firms employed approximately 243,769 workers<sup>186</sup>. Amongst the largest employers was the Hawker Group, which employed 100,000 people. Of these, Hawker had 65,000 workers in its own plants and another 35,000 people at A.V. Roe<sup>187</sup>. Despite employing such large numbers, Hawker, like many of its competitors, deployed its workforce in a large number of small factories spread around the country. This dispersal of workers and productive capacity in small factories is often criticised as an example of British inefficiency. These criticisms are based on the higher per capita costs associated with providing facilities for smaller numbers of workers. Hornby suggests that the labour costs in a factory employing 3,000 workers were half those of a factory with a work force of 1,000<sup>188</sup>.

## **Conclusion**

In the last forty years, a debate has developed between historians of the British aircraft industry about the relative efficiency and technical prowess of Britain's aircraft manufacturers and the wisdom, or otherwise, of the Air Ministry and government officials who supported the industry. While this debate has produced a great deal of useful information, it has led historians of the aircraft industry into a wider controversy over the decline of Britain as an industrial power. The debate itself is rather pointless. The claims and counter claims over such esoteric matters

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186 Hornby, *Factories and Plant*, p.241

187 Hornby, *Factories and Plant*, pp. 239-240

188 Hornby, *Factories and Plant*, pp. 247

as how long it took an individual British, German or American worker to add another pound of structure weight to an aircraft is technically irrelevant and detracts from the commercial reality in which the industry was operating.

The conventional view that the British aircraft industry emerged from World War I as a second rate performer is based on an idea that the industry was completely dependent upon orders from the Air Ministry. A reassessment of the evidence suggests that this was not the case. The support offered by successive British governments was undoubtedly important to the aircraft industry, but it only relied on orders from the Air Ministry to maintain profitability in their UK based operations, or in those divisions of their companies that manufactured aircraft. From my analysis, it appears that the British aircraft industry was shrewdly managed to make full use of its opportunities and advantages.

One of the most important facets of the relationship between the British government and its aircraft industry was the unfettered access that the latter had to the output of basic research from the government-owned research organisations. The basic and applied research undertaken by these establishments removed a significant overhead from the account books of British aircraft firms and enabled some of them to dominate the world aircraft industry by exporting British government technology for profit. One of the outstanding characteristics of the interwar British aircraft industry was the extent of its involvement in the aircraft industries of other countries. Outside of the Commonwealth nations, British aircraft firms were heavily involved in the domestic aircraft industries of

Belgium, Czechoslovakia, Finland, France, Germany, Hungary, Italy, Japan, Poland, Portugal, Spain, the USA, the USSR and Yugoslavia. This did not include their involvement in South America or other parts of the world including Africa. Far from being overly dependent on the government, the evidence suggests that the British aircraft firms used the government's support to position themselves as suppliers of modern aircraft technology to a large number of foreign governments, including some that Britain may have regarded as less than friendly.

The technology that British firms like Bristol were transferring to other nations was also of an excellent standard. Many American authorities of the day publicly admitted the importance of the British technology to their own industry. The significant contribution of Sir Roy Fedden to the American aero-engine industry of the time was probably the best example of this dependence but there were a number of other British firms involved in the American marketplace.

The interaction between these groups enabled the British to produce aircraft that met the operational requirements of the RAF. The problems that were encountered in British aircraft in the early part of World War II were not due to a failure of British technical capability or to a lack of government funding or an over supply of government short-sightedness. Instead, as Colin Sinnott has identified, the Air Staff had not foreseen a war against Germany in the early 1920s and subsequently the aircraft that they specified did not have the

characteristics necessary for such a war<sup>189</sup>. The identification of Germany as the most likely enemy led to the rapid expansion of the aircraft industry and the production of a remarkable range of aircraft of which three were to be amongst the most advanced in the world until 1944/45.

The British aircraft industry was not a second rate industry operating in a nation in decline, rather it was a commercially astute industry that managed to have the British government finance a large part of its basic research and supply it with a source of trained technical labour. The British aircraft industry was an imaginative, ruthless and commercially successful group of firms who knew how to exploit their governments' sensitivities and the sensitivities of foreign governments to obtain the funds they needed to dominate the world aviation market. In Britain, the industry was to produce the aircraft that Bomber Command was to use to carry out the strategic air offensive against Germany.

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189 Sinnott, *The Royal Air Force and Aircraft Design, 1923-1939*, p.3

## *Chapter 4*

### THE AIRCRAFT OF THE STRATEGIC AIR OFFENSIVE

Britain created her aircraft industry in order to have access to the modern aircraft that she needed to conduct a strategic air offensive as part of her military campaigns in a European war. Early fears that the RAF may not have had the power to resist the Luftwaffe proved to be ill founded. These concerns arose out of the fear generated by poor intelligence assessments of German strength and the faith of the Air Staff in the psychological effects of bombing. When the war came in 1939, the British aircraft industry and the government had advanced the preparations necessary to deliver the heavy aircraft needed to conduct a strategic air offensive against Germany.

Britain's self-sufficiency in the manufacturing of aircraft is the strongest evidence of the capabilities of the aircraft industry during World War II. Over the period of the war, Britain manufactured 43,322 bombers of which 16,266 were heavy bombers<sup>1</sup>. The majority of these aircraft served in Bomber Command where 10,949 of them would be destroyed in action or in operational crashes<sup>2</sup>. The remaining aircraft were also an economic write-off. Heavy bombers have no usefulness outside their roles as heavy bombers and the rapid disappearance of

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1 Central Statistical Office, *Statistical Digest of the War*, HMSO, London, 1951, Tables 130-136, pp. 152-155

2 Middlebrook and Everitt, *Bomber Command War Diaries*, p.707

aircraft like the Lancaster and the B-17 at the end of the war would seem to bear this out<sup>3</sup>. Effectively, the bomber programme was a wartime necessity from which Britain would derive no fundamental long-term economic benefit. In 1945, the British aircraft industry experienced a second post-war downturn but this time there was a booming American industry with the experience, money and domestic market that would enable it to become the dominant aircraft industry in the world.

In researching the material for this analysis, the most important sources of information were the Ministry of Aircraft Production's *Price Books*, held at the RAF Museum Hendon, and the on-line details of aircraft types and prices on the website of the United States Air Force (USAF) Museum. In only two cases, Armstrong Whitworth's Whitley Bomber and Lockheed's B-34 Ventura, were these sources deficient in detail on prices. In both these cases, I have used an estimate of prices<sup>4</sup>. The estimated prices for the Whitley and Ventura are the average cost per pound of structure weight of similar aircraft built at the time. In any event, these two aircraft account for only 2.78 percent of all Bomber Command sorties and were not major contributors to the cost of the strategic air offensive<sup>5</sup>.

One useful clue provided by the above sources was that the prices paid by the British government for British manufactured aircraft was substantially less than

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<sup>3</sup> Compare the rapid disappearance of the bomber aircraft with the continued use of the DC-3

<sup>4</sup> US Air Force Museum, [www.wpafb.af.mil](http://www.wpafb.af.mil), 23rd October, 2002

<sup>5</sup> Middlebrook and Everitt, *Bomber Command War Diaries*, p.707

that paid by the US Government for similar aircraft made in the USA. This fact, underlined by the frequent changes in British aircraft prices, indicates that the Air Ministry constantly adjusted the price paid for aircraft in order to offset the value of government investment.

The analysis provided here is the first quantitative measurement of the overall size of Britain's spending on the strategic air offensive aircraft during World War II and the prices paid for the 15 types of aircraft constituted a significant part of the overall cost. The direct cost of bomber aircraft supplied to Bomber Command during World War II is conservatively assessed here as being £1.3 billion in 1942 prices. The evidence supporting £1.3 billion as being conservative lies in the marked disparity between the recorded prices of American and British aircraft types of the period. The documentary evidence suggests that American aircraft and aircraft parts were, on average, over twice as expensive as a similar aircraft of British manufacture. For example, the USAF Museum reports the price of a Boeing B-17 as being equivalent to £64,637<sup>6</sup>. Technologically, the Boeing B-17 was an equivalent aircraft to a Lancaster<sup>7</sup>, yet the average price paid by the MAP for a Lancaster during World War II was £31,985, £32,652 less than the cost of the B-17<sup>8</sup>.

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<sup>6</sup> US Air Force Museum, [www.wpafb.af.mil/museum/engines/eng33.htm](http://www.wpafb.af.mil/museum/engines/eng33.htm), 23rd October, 2002

<sup>7</sup> Ministry Of Aircraft Production, *Price Books*, Contract No. Aircraft/239 (W.22550) plus 7,000 lbs payload

<sup>8</sup> Ministry Of Aircraft Production, *Price Books*, Average of all prices paid for all Lancasters listed

The discrepancy is also seen in the difference in price between a Martin B-26G Marauder, a two engined aircraft costed at £53,411<sup>9</sup>, and a Wellington at £20,606<sup>10</sup>. It is unlikely that the price discrepancy is due to technological differences. These aircraft were technologically very similar with neither nation's aircraft industry enjoying a significant lead in technology. The difference cannot be put down to inefficiency in the American aircraft industry as its size, organisation and capitalisation are acknowledged as being well above that of its British counterpart. It is also unlikely that the American aircraft firms were able to profiteer to the degree where they could double the price of a finished aircraft. The evidence indicates that the American price reflects the true values of a B-17 and Liberator whereas the MAP *Price Books* reflect the values of the Lancasters and Wellingtons after the British government had taken into account the subsidies and capital grants provided to the manufacturers.

A comparison of the price of a finished Merlin engine provides more evidence that British prices took into account the government's investment in industry. The price quoted for the Packard Merlin during World War II by the USAF Museum is \$US25,000.00. Using a conversion factor of \$US4.25 to £1.00, this equates to £5,952.38<sup>11</sup> or £3,452.38 more than the £2,500.00<sup>12</sup> British price for a

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9 US Air Force Museum, [http://www.wpafb.af.mil/museum/air\\_power/ap19.htm](http://www.wpafb.af.mil/museum/air_power/ap19.htm)

10 Ministry of Aircraft Production, *Price Books*, Average of all prices paid for all Wellingtons listed

11 US Air Force Museum, [www.wpafb.af.mil/museum/engines/eng33.htm](http://www.wpafb.af.mil/museum/engines/eng33.htm), 23rd October, 2002

12 Target Costs in *War Savings*, Vol 3, No.11, Feb, 1943, p.25

Rolls Royce engine quoted by the Royal Air Force Museum at Hendon<sup>13</sup>. The Merlin engine built by Packard and Rolls Royce was the same design and Packard benefited from the fact that Rolls Royce had completed the design and development of the Merlin. The more expensive price for the Packard-built Merlin is most likely a simple reflection of the true cost, plus profit than the Rolls Royce price.

The documentary evidence available in the PRO and through the RAF Museum at Hendon gives prices that take into account the investment of public money in the expansion of the aircraft industry. This means that the true cost of a Lancaster consists of the price paid to Avro for the aircraft and a proportion of total government expenditure in factories, plant and government supplied goods and services.

In the case of the price of a Lancaster, the MAP *Price Book* may be as much as 50 to 60 percent below the true cost. Harry Holmes estimates that the average price for a Lancaster Bomber was £58,974<sup>14</sup>. If Holmes's figure is correct, the total cost of 7,377 Lancaster aircraft would have been £435 million, a figure almost twice the £235.9 million estimated here. Despite this, the estimate derived in this chapter is conservative as I have opted to separately identify the cost of factories and plant in the last chapter and will separately analyse the cost of government

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<sup>13</sup> Attachments to letter from P.J.V. Elliott, Keeper of Research and Information, RAF Museum, Hendon, 5th Sep 96. It appears that RAF Museum Hendon drew their information from a wartime publication, 'Target Costs', *War Savings*, Vol 13, No.11, Feb 1943, p.25

supplied goods and services later in this chapter. As the subject of this thesis is the overall cost of the strategic air offensive, and not the cost of individual aircraft, this approach is better than simply assigning an inflated price to individual aircraft based on my estimate of the proportion of expenditures the British government may have made on that aircraft type.

The analysis will cover the aircraft used by Bomber Command during World War II before detailing government expenditure on equipment such as machine guns, radars and radios and, finally, spare parts supply. The description of the 15 aircraft used by Bomber Command during the strategic air offensive has been broken into three groups, in order of the overall contribution of each to the strategic air offensive. The groupings reflect the contribution made by the aircraft in terms of the overall offensive. The first group consists of five aircraft: the Wellington, Lancaster, Halifax, Mosquito and Stirling. Britain built 34,436 of these aircraft and between them they carried out 88.9 percent of Bomber Command's wartime sorties<sup>15</sup>. The Lancaster was responsible for 40.1 percent (156,192 sorties) of all sorties during World War II<sup>16</sup>. These aircraft dominated the strategic air offensive.

The second group comprises the five early wartime models, 8,886 individual aircraft, which Bomber Command had used before the heavy bombers became

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<sup>14</sup> H. Holmes gives a figure of £58.974 for a Lancaster. See H. Holmes, *AVRO Lancaster: The Definitive Record*, AirLife Publishing, Shrewsbury, 1997, p.35

<sup>15</sup> Middlebrook and Everitt, *Bomber Command War Diaries*, p.707

available. The Battle, Hampden, Blenheim, Whitley and Manchester carried out 10 percent of all sorties and made a small contribution to the overall campaign.

The final group of aircraft that served in Bomber Command were the five American imports, the Boston, Boeing B-17, Ventura, Liberator and Mitchell, which totalled 2,217 aircraft<sup>17</sup>. These American aircraft conducted 4,656 sorties in Bomber Command. This represents 1.1 percent of all sorties within the Command for the war and it clearly shows that Britain's aircraft industry was able to supply the nation's requirements for bomber aircraft.

The analysis lays out the prices paid for the bomber aircraft, their equipment and their spare parts during World War II. The costs identified here are conservative but the analysis of government investment in factories and plant provided in Chapter Three serves to identify the components of cost that are not reflected in the prices that the British government paid to British aircraft manufacturers for the aircraft that would carry out the strategic air offensive.

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16 Middlebrook and Everitt, *Bomber Command War Diaries*, p.707

17 PRO AVIA 15/2023, Letter from C. Fairey with British Air Mission in Washington to Minister of Aircraft Production, 14<sup>th</sup> July 1944

## The Aircraft

Both the Vickers Wellington and Handley Page's Hampden arose from Air Ministry Specification B.9/32<sup>18</sup>, which sought the development of a twin engined heavy bomber weighting approximately 6,500 lbs empty<sup>19</sup>. The specification attempted to keep the resulting aircraft within the limits the Air Ministry feared the Geneva Conference on disarmament might impose<sup>20</sup>. Of the two aircraft, the Wellington was the more successful. By 1946, Vickers had produced 11,460 Wellingtons<sup>21</sup>, at an average cost of £14,367.77 per aircraft<sup>22</sup>. The total cost of this aircraft type was £164,654,753 which makes this aircraft the second most costly after the Lancaster.

The Wellington had an all-metal geodetic framework and fabric skin, which gave it exceptional durability on operations. The aircraft could carry a substantial bomb load of 4,500 lbs over a range of 1,540 miles at an average cruising speed of 180 mph<sup>23</sup>. The length of the Wellington's service is a reflection of its utility and its roles including carrying freight, reconnaissance,

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18 Postan, Scott and Hay, *Design and Development of Weapons*, p.11

19 C. Bowyer, Wellington at War, in *Halifax and Wellington*, Promotional Reprint Company, Leicester, 1994, p.135

20 RAF And Bomber Command Association, [www.raf.mod.uk/bombercommand/aircraft/Wellington.html](http://www.raf.mod.uk/bombercommand/aircraft/Wellington.html), 23rd October, 2002

21 Bowyer, Wellington at War, in *Halifax and Wellington*, p.135

22 Ministry of Aircraft Production, *Price Books*

23 RAF and Bomber Command Association, [www.raf.mod.uk/bombercommand/aircraft/Wellington.html](http://www.raf.mod.uk/bombercommand/aircraft/Wellington.html), 23rd October, 2002

maritime patrol, and signals intelligence (SIGINT) and strategic bombing<sup>24</sup>. The Wellington was the longest serving operational British bomber aircraft of World War II. The first operational sorties of a Wellington took place on 3<sup>rd</sup> September 1939<sup>25</sup> and it went on to fly 47,409 sorties, or 12.16 percent of Bomber Command's 389,809 sorties identified to date<sup>26</sup>. The wide spread use of the Wellington in other theatres, including the Middle East, Mediterranean, East Africa, India, and in Coastal and Transport Commands, means that only a proportion of its cost is attributable to the strategic air offensive<sup>27</sup>. If the value of the Wellington used by Bomber Command is restricted to the 1,727 Wellingtons (15.06 percent of all Wellingtons manufactured) that were lost on Bomber Command operations<sup>28</sup>, the cost is £24,813,139.00. This is a conservative cost, as it does not include the Wellingtons written off within the Command or transferred to other Commands after serving in Bomber Command.

### **Avro Manchester and Lancaster**

Although the Manchester did not play a significant role in the strategic air offensive, it did provide the basis for the Lancaster, which was to become the mainstay of the campaign. A.V. Roe designed the Manchester in response to

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24 Postan, Scott and Hay, *Design and Development of Weapons*, p.15

25 Middlebrook and Everitt, *Bomber Command War Diaries*, p.21

26 Middlebrook and Everitt, *Bomber Command War Diaries*, p.707

27 Postan, Scott and Hay, *Design and Development of Weapons*, p.15 and C. Bowyers, *Wellington at War*, p.135

Air Ministry specification P.13/36. The aircraft had two Vulture engines and an all-up weight of 45,000 lbs, as against the four engines and 55,000 lbs of the Lancaster<sup>29</sup>. The original intention was for 1,500 Manchesters before April 1942<sup>30</sup>. The size of the order was beyond the productive capability of Avro and the Air Ministry formed a group of companies into a production group led by Avro Ltd. The Manchester Group included Metropolitan Vickers, Sir W.G. Armstrong Vickers and Vickers Armstrong Ltd. at Castle Bromwich<sup>31</sup>.

The major problem with the Manchester was the Rolls Royce Vulture engine, which was an indifferent attempt by Rolls Royce to avoid diverting design and development resources from the Merlin to other projects<sup>32</sup>. The Vulture was highly complex as it combined two Rolls Royce Kestrel engines mounted on one crankshaft<sup>33</sup>. The resulting Vulture was extremely unreliable and difficult to maintain due to constant over-heating<sup>34</sup>.

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28 Middlebrook and Everitt, *Bomber Command War Diaries*, p.707

29 Postan, Scott and Hay, *Design and Development of Weapons*, p.92

30 Postan, Hay and Scott, *Design and Development of Weapons*, p.125, n6

31 PRO AVIA 15/1466, Programme and Policy of the Lancaster Group, 1943

32 Bulman, *An Account of Partnership*, p.273

33 Bulman, *An Account of Partnership*, p.273

34 RAF and Bomber Command Association,  
[www.raf.mod.uk/bombercommand/aircraft/manchester.html](http://www.raf.mod.uk/bombercommand/aircraft/manchester.html), 23rd October, 2002

The problems with the Manchester were obvious from the beginning and the RAF officers who inspected the prototypes were quick to express their concerns. Amongst these officers were Air Marshals Lord Tedder and Sir Wilfred Freeman. On their visit to Avro, they flew in the second prototype of the plane and afterwards discussed the failings of the aircraft with Avro Chief Designer, Sir Roy Dobson. Dobson asked Freeman about Avro having future access to Merlin engines for the Manchester. Freeman assured Dobson that there were plenty of Merlins and Dobson then produced two wings with four engines, attached them to a model of a Manchester, and asked the two RAF officers, ‘How’s that?’<sup>35</sup>.

The average cost of a Manchester was £36,812.25, or £7,362,450.00<sup>36</sup> for the total 200 aircraft manufactured. The higher than usual average price paid was due to the small production run of the aircraft. Of the 200 aircraft that were manufactured, 76 (38 percent)<sup>37</sup>, were destroyed whilst on charge to Bomber Command. The financial value of these losses was £2,797,731.00. In the face of the Manchester’s failure, the quick thinking by the designers and access to the Merlin engine allowed A.V.Roe to retrieve the situation, as they

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35 Lord Tedder, *With Prejudice: The War Memoirs of Marshal of the Royal Air Force, Lord Tedder*, Cassell and Company, London, 1966, pp. 9-10

36 Ministry of Aircraft Production, *Price Books*

37 Middlebrook and Everitt, *Bomber Command War Diaries*, p.707

incorporated the vast majority of the materials, components and parts produced for the Manchester into the Lancaster<sup>38</sup>.

A.V. Roe's Managing Director, Sir Roy Dobson, and Chief Designer, Roy Chadwick, salvaged the Lancaster from the wreckage of the failed Manchester<sup>39</sup>. The task was not easy and Avro faced some hostility from within the Air Ministry and MAP, whereby not everybody was convinced that A.V. Roe could salvage the Manchester project. The Air Ministry initially denied A.V. Roe access to the additional materials; particularly the four Merlin engines that they needed to develop the prototype aircraft<sup>40</sup>. Although it is difficult to establish how strong the resistance was, it did not stop E.W. Hives at Rolls Royce arranging for A.V. Roe to have the Merlins<sup>41</sup>.

The Lancaster bomber was the most effective British strategic bomber of World War II. This aircraft conducted 40 percent (156,192) of the 389,809<sup>42</sup> sorties and dropped an estimated 650,000 tons of bombs between 3<sup>rd</sup> of March 1942 and 3<sup>rd</sup> of May 1945. This equates to 68 percent of all bomb tonnage dropped

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38 PRO AVIA 15/1466, Programme and Policy of the Lancaster Group, 1943

39 See above, and Harris, Foreword in M. Garbett and B. Goulding, *Lancaster at War*, Promotional Reprint Company, Leicester, 1992, p. 7. Also, see Postan, Scott and Hay, *Design and Development of Weapons*, p. 94 and Bulman, *Account of Partnership*, p.273. Bulman suggests that Hives and Dobson had probably worked on the problem of the Manchester before Sir Wilfred Freeman and Tedder saw the aircraft.

40 H. Holmes, *AVRO Lancaster: The Definitive Record*, Airlife, Shrewsbury, 1997, p.10

41 Holmes, *AVRO Lancaster*, Shrewsbury, 1997, p.10

during the entire war by Bomber Command. The cost of these operations was the loss of 4,265<sup>43</sup> of the total production of 7,366 Lancasters built in Britain and Canada<sup>44</sup>. These figures, 58 percent, are the largest losses incurred by any aircraft type that served in Bomber Command during World War II.

The reason for this high casualty rate amongst Lancasters was the high operational tempo of these aircraft against the most difficult targets attacked during the strategic air offensive<sup>45</sup>. The Lancaster undertook 40 percent of Bomber Command's offensive sorties with a loss of 57.9 percent of the total number of Lancasters produced. This loss rate, which appears high, was actually quite good when compared with an aircraft like the Hampden. In the case of the Hampden, which undertook only 4.25 percent of Bomber Command's operational sorties<sup>46</sup>, the loss rate was 43.56 percent (633) of the 1,453 aircraft manufactured.

Sir Arthur Harris lauded the Lancaster as the most successful British strategic bomber of the Second World War. It also won the respect of the men who served in Bomber Command. Harris referred to the Lancaster as 'that shining

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42 M. Middlebrook & C. Everitt, *Bomber Command War Diaries*, p.707

43 Holmes, *AVRO Lancaster*, pp. 117-156

44 N. Franks, *Claims to Fame: Lancaster*, Arms and Armour, London, 1995, p.8

45 Harris, *Bomber Offensive*, p.102

46 M. Middlebrook & C. Everitt, *Bomber Command War Diaries*, p.707

sword' that was 'beyond doubt, a major factor in beating the Nazi enemy'<sup>47</sup>. As Commander-in-Chief of Bomber Command Harris stated in his Despatch, 'the Lancaster, measured in no matter what terms, was, and still is, incomparably the most efficient. In range, bomb carrying capacity, ease of handling, freedom from accident and particularly in casualty rate it far surpassed the other heavy types'<sup>48</sup>. Harris admired the Lancaster so much he later stated that he was willing to forego 'a year's industrial production from the Halifax factories if the government forced the conversion of these factories to the production of Lancasters'<sup>49</sup>. In order to build the required number of Lancasters the MAP simply renamed the Manchester Group the Lancaster Group and these firms incorporated the necessary modifications into the existing production to produce the new aircraft. This strategy enabled A.V. Roe to make use of existing productive capacity that had been organised in the smaller firms making the component parts of the Manchester.

This organisation produced the 6,944 aircraft manufactured by the Lancaster Group between December 1941 and December 1945<sup>50</sup>. The Lancaster Group were contracted to produce 6,944 aircraft of which 6,918 were delivered, the

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47 Harris, Foreword in M. Garbett and B. Goulding, *The Lancaster at War*, The Promotional Reprint Company, Leicester, 1992, p. 7

48 Harris, *Despatch on War Operations*, p.155

49 Harris, *Bomber Offensive*, p.103

50 PRO AVIA 15/1466, Programme and Policy of the Lancaster Group, 1943

deficit of 26 aircraft being outstanding from Austin until December 1945<sup>51</sup>. The group accomplished this production using bi-monthly meetings of a Group Committee, chaired by Sir Roy Dobson. It operated a variety of sub-committees, including materials, bought out parts, spares and sub-contractors. In this way, Britain was able to expand rapidly the manufacture of the Lancaster without disrupting the flow of other aircraft already in service.

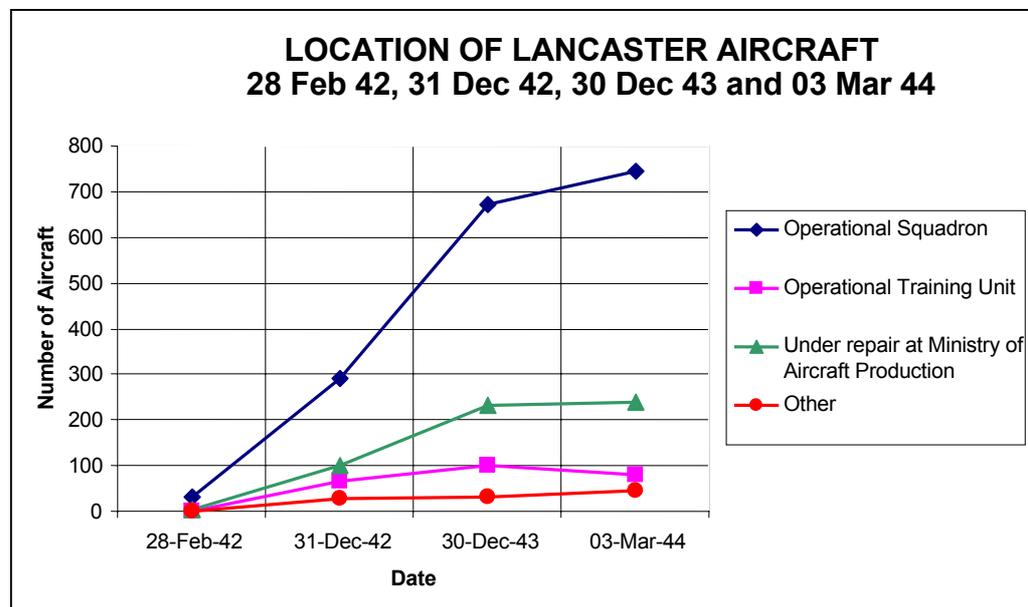


Fig. 4.1: Source: PRO AVIA 9/51, D.D.G.P.S. 20.3.44 and AVIA 10/391 D.D.G. Stats P. 2.4.42

Another indicator of efficiency was the number of man hours required to build an aircraft. In March 1945, the MAP estimated that it took A.V. Roe approximately 20,000 man-hours<sup>52</sup> to build a complete Lancaster. This was almost a quarter of the time it took to build a Lancaster Mk I in 1942<sup>53</sup>. From the perspective of the MAP, this meant that there had been a substantial

51 PRO AVIA 15/1466, Programme and Policy of the Lancaster Group, 1943

reduction in labour, the major cost to the private industry, and they subsequently reduced the price paid per aircraft.

A review of the prices paid to the manufacturers for their aircraft has resulted in a large number of differing contract prices for Lancasters. The average of these prices is £31,985, which is the figure used here to estimate the total cost of providing Lancaster aircraft to the RAF. The reason for rejecting the higher, and probably more accurate estimates of cost, is due to the risk of double-counting aircraft costs. Given this, the estimated cost of providing the RAF with 7,377 Lancasters during World War II was £235,952,091. The value of the 4,265<sup>54</sup> aircraft destroyed within Bomber Command was £136,416,025<sup>55</sup>. This figure does not include the price of government-supplied equipment ranging from engines to radios, to machine guns, to escape equipment, toilets, radars and so forth.

### **Handley Page Halifax**

Handley Page designed the Halifax in response to Air Ministry Specification P.13/36, which also brought about the Manchester. As was the case with the

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52 PRO CAB 120/351, Note by Secretary of State for Air and Minister of Aircraft Production to Prime Minister, 5th March, 1945

53 PRO AVIA 10/269, Manhours Calculations, 1944

54 Holmes, *AVRO Lancaster*, pp. 117-156

55 Prices derived from Ministry of Aircraft Production, *Price Books*

Lancaster, the Halifax was produced by a group of companies under the direction of the designing company, Handley Page. Amongst these were Rootes Securities, English Electric, London Passenger Transport Board and Fairey Aviation<sup>56</sup>. All operated under the direction of Handley Page<sup>57</sup>. There were also a large number of sub-contractors supplying raw materials, components and parts to the group members. The Halifax Group manufactured 6,176 Halifaxes for the RAF<sup>58</sup>.

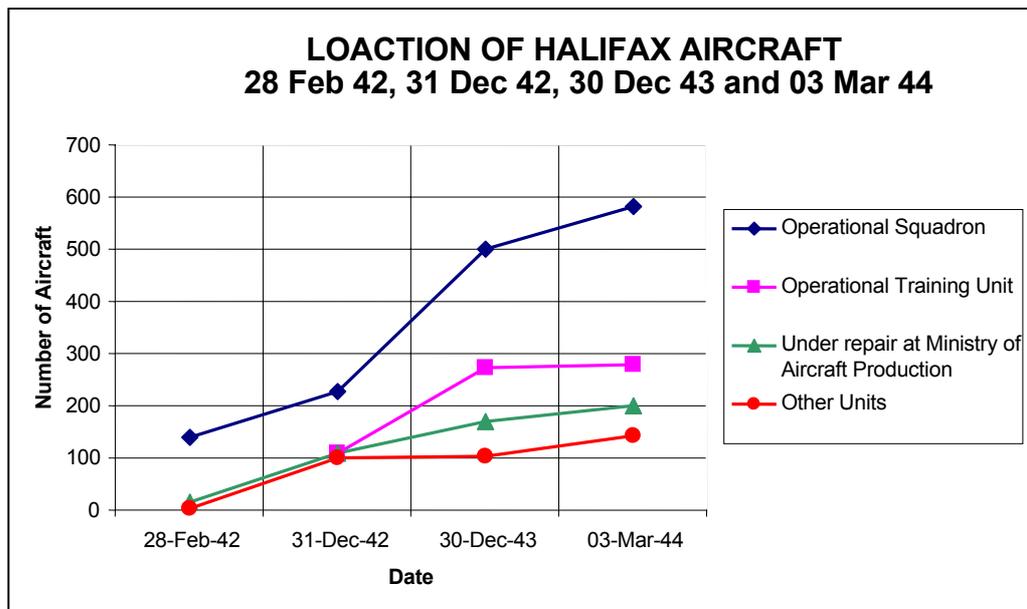


Fig. 4.2: Source: PRO AVIA 9/51, D.D.G.P.S. 20.3.44 and AVIA 10/391 D.D.G. Stats P. 2.4.42

The MAP Price Books show London Passenger Transport building 710, English Electric 2,470 and Handley Page and Rootes assembling the remaining 3,696

<sup>56</sup> PRO AVIA 15/1852, Absenteeism Sept to Nov 1942

<sup>57</sup> PRO AVIA 15/1852, Absenteeism Sept to Nov 1942

aircraft<sup>59</sup>. Based upon a calculation of the prices listed in the MAP Price Books, the average cost of a Halifax during the war was £23,354<sup>60</sup>. Given this price, the full cost paid to the Halifax Group for 6,176 aircraft was in the region of £140,819,964.

The early Halifaxes suffered from a number of design flaws, the worst of which involved the rudders failing under violent or sudden manoeuvring. Early models of the Halifax had a tendency to veer unexpectedly leading to crashes during take-off, which were often serious due to the full fuel tanks and bomb loads. The Halifax also suffered overbalancing and tipping at low speeds and, if power became asymmetrical because of a damaged engine, the aircraft was prone to tipping out of control in the sky or on the ground. Many aircrews died before Handley Page identified and fixed these flaws.

The Halifax was less attractive to Bomber Command than was the Lancaster, which outperformed it in load characteristics, range and operating height. In an effort to make the Halifax as effective as the Lancaster, Bomber Command stripped down the defensive armament and removed all non-essential external projections. Further improvements included the replacement of the Bristol Hercules engine with a Rolls Royce Merlin. These efforts produced a marginal

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58 RAF and Bomber Command Association, [www.raf.mod.uk/bombercommand/aircraft/halifax.html](http://www.raf.mod.uk/bombercommand/aircraft/halifax.html), 23rd October, 2002

59 Ministry of Aircraft Production, *Price Books*

60 Ministry of Aircraft Production, *Price Books*

increase in the operational altitude of 2,000 ft, but the aircraft was unable to achieve parity with the Lancaster, which continued to perform better on the high profile missions into Germany<sup>61</sup>. One advantage that the Halifax had over the Lancaster was that it was easier to escape from and a higher proportion of its crews survived being shot down. For this reason, it was a popular aircraft amongst flyers.

Over 1,421 Halifax aircraft were lost through 'wastage', because of either crashes or being written off for a range of reasons<sup>62</sup>. The average cost of a Halifax during the war was £23,354<sup>63</sup> and the value of the loss of these 1,421 aircraft is £33,186,034. Wastage from accidents and other causes equalled 23 percent of all Halifax production and this is for only a 14-month period of the war. In addition, 1,884 Halifaxes were lost in Bomber Command operations<sup>64</sup>. The total number of Halifaxes lost was 3,504 or 56.7 percent of total production. The total value of the 3,504 lost Halifaxes was £81,832,416.

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61 RAF and Bomber Command Association,  
*<http://www.raf.mod.uk/bombercommand/aircraft/halifax.html>*, 23rd October, 2002

62 B.J Rapier, *Halifax at War*, Promotional Book Company, Enderby, Leicester, pp. 98-99

63 Ministry of Aircraft Production, *Price Books*

64 Middlebrook and Everitt, *Bomber Command War Diaries*, p.707

## **De Havilland Mosquito**

The de Havilland Mosquito was probably the best-known example of the private venture aircraft developed in the late 1930s. Designed by the de Havilland Company against the opposition of the Air Ministry, but with the support of the Chief of the Air Staff and a number of other RAF officers, the Mosquito became the most versatile and successful military aircraft of World War II<sup>65</sup>. The credit for the official recognition of the value of this aircraft lies with de Havilland and Air Marshal Sir Wilfred Freeman, the then Air Member for Research and Development, and on whose initiative 50 of these radical aircraft were ordered off the drawing board<sup>66</sup>.

The concept behind the de Havilland Mosquito was for a very fast intruder capable of conducting bombing raids deep within enemy territory. In order to ensure high speed the aircraft was to be lightly constructed and unarmed. In November 1940, when Geoffrey de Havilland took the prototype Mosquito into the air for the first time, few within the Air Ministry or the RAF would have predicted its success. The Mosquito performance was impressive: its two Merlin engines produced a bomber that had the speed and agility of the best

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65 RAF and Bomber Command Association, [www.raf.mod.uk/bombercommand/aircraft/mosquito.html](http://www.raf.mod.uk/bombercommand/aircraft/mosquito.html), 23rd October, 2002

66 Lord Tedder, *With Prejudice*, p.10 and Bulman, *An Account of Partnership*, p.275

fighters. Initially, the Air Ministry envisaged it as a reconnaissance aircraft only. Subsequently, it was adapted into a fighter, a night fighter, an armed intruder and lastly, a fast bomber, the role that de Havilland had originally designed for it<sup>67</sup>. The growth in orders for Mosquito aircraft reflected the versatility of the aircraft<sup>68</sup>.

The proof of de Havilland's conception lies in the operational performance of the aircraft. The first Mosquitos were sent into action with Bomber Command on the 31<sup>st</sup> of May 1942, when they conducted a daylight reconnaissance of Cologne. During this operation, one Mosquito was hit by flak and subsequently crashed into the North Sea, killing its crew<sup>69</sup>. Despite this, it was an auspicious beginning. A daylight raid on Cologne by any other aircraft in Bomber Command would have resulted in significant losses for the entire attacking force. The first five sorties over Cologne in May 1942 were the first of the total of 39,795 sorties, 10.20 percent of the Bomber Command total, making the Mosquito the fourth most used aircraft in the Command<sup>70</sup>.

Bomber Command increased its use of the Mosquito because it was fast and accurate. In 1944, the United States Air Force estimated that it took an average

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67 Postan, Scott and Hay, *Design and Development of Weapons*, p.86

68 Postan, Scott and Hay, *Design and Development of Weapons*, p.86

69 Middlebrook and Everitt, *Bomber Command War Diaries*, p.273

of 188 tons of bombs to destroy a V Weapon site. The average tonnage of bombs used varied from 165 tons for a Boeing B-17 to 182 tons for a B26 Marauder and 219 tons for a B25 Mitchell<sup>71</sup>. The Mosquito took 40 tons to destroy these targets. The Mosquito was also a very safe aircraft with only 310 (4.61 percent) of the total production of 6,710 being lost to enemy action or other causes<sup>72</sup>.

The cost of building a Mosquito was £9,829 making the total cost of 6,710 Mosquitos £65,949,571. Of this, £3,046,850 worth of Mosquitos was lost in Bomber Command<sup>73</sup>. Whether from versatility, performance, operational effectiveness or economy the Mosquito was one of the most notable wartime successes of the British aircraft industry. It was also one of the few British aircraft that the United States acquired for its own use, obtaining 40 Canadian variants and 100 British aircraft under reverse Lend-Lease<sup>74</sup>.

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70 Middlebrook and Everitt, *Bomber Command War Diaries*, p.707

71 RAF and Bomber Common, [www.raf.mod.uk/bombercommand/aircraft/mosquito.html](http://www.raf.mod.uk/bombercommand/aircraft/mosquito.html), 23rd October, 2002

72 A.J. Jackson, *de Havilland Aircraft Since 1909*, Putnam, London, 1962,p. 11

73 Ministry of Aircraft Production, *Price Books*

74 RAF and Bomber Command Association, [www.wpaafb.af.mil/museum/air\\_power/ap18.htm](http://www.wpaafb.af.mil/museum/air_power/ap18.htm), 23rd October 2002

## **Bristol Blenheim**

On the 3<sup>rd</sup> of September, 1939, a Blenheim Mark IV, serial Number N6215, of 139 Squadron was the first RAF aircraft to fly over Germany. It conducted the armed reconnaissance of German naval units in the vicinity of Wilhelmshaven<sup>75</sup>.

The story of the development of the Bristol 142 and its subsequent transformation into the Blenheim Mark I have been dealt with in Chapter 3<sup>76</sup>.

Bristol built 2,450 of these aircraft at an average cost per aircraft of £9,880<sup>77</sup>.

The total cost of this aircraft to the British Government was £24,206,245<sup>78</sup>.

Although at the start of the war the RAF considered the Blenheim out-of-date, it was available for service and carried out 12,214 sorties for Bomber Command<sup>79</sup>.

These constituted 3.13 percent of the Command's total wartime sorties<sup>80</sup>. The

use of the Blenheim in the operations led to a relatively high loss rate with 541

Blenheims destroyed, due to crashes or enemy action<sup>81</sup>. The figures indicate

that 22.08 percent of all Blenheims manufactured were lost within Bomber

Command activity at a cash value of £5,345,134.00.

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75 RAF and Bomber Command Association, [www.raf.mod.uk/bombercommand/aircraft/blenheim.html](http://www.raf.mod.uk/bombercommand/aircraft/blenheim.html), 23rd October 2002

76 See pp.35-38 in Chapter 3 above.

77 Ministry of Aircraft Production, *Price Books*

78 Ministry of Aircraft Production, *Price Books*

79 Middlebrook and Everitt, *Bomber Command War Diaries*, p.707

80 Middlebrook and Everitt, *Bomber Command War Diaries*, p.707

81 Middlebrook and Everitt, *Bomber Command War Diaries*, p.707

## **Handley Page Hampden**

Handley Page designed the Hampden as a medium bomber intended to operate during daylight. It was one of the few British aircraft influenced by German design principles. The source of the German influence was probably a German designer at Handley, Dr. Lachmann, who introduced these principles from Messerschmitt where he had previously worked<sup>82</sup>. The Hampden was not a particularly good aircraft and reportedly suffered from poor manoeuvrability and inadequate defensive firepower due to its use of hand held machine guns, a distinctly German feature. The first flight by a Hampden occurred on 21 June 1936, six days after the Wellington. Subsequently, the Air Ministry placed an order for 180 Hampdens and the first aircraft entered service with 49 Squadron in August of 1938. The Hampden was the first British aircraft to bomb Berlin when 67 British bombers, 30 Hampdens and 37 Wellingtons, attacked the German capital on the night of 25<sup>th</sup> August 1940<sup>83</sup>.

By the time of the thousand -bomber raids of May/June 1942, the Hampden was nearing the end of its service. The final operation by Hampdens took place in mid-September 1942 when No 408 Squadron RCAF was in action over Wilhelmshaven. Of the 389,809 sorties conducted by Bomber Command, the

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82 Postan, Scott and Hay, *Design and Development of Weapons*, fn. p.34

83 Middlebrook and Everitt, *Bomber Command War Diaries*, pp. 76-77

Hampden carried out approximately 16,541, or 4.24 percent of the total<sup>84</sup>. The total number of aircraft lost on these operations was 633, representing 43.64 percent of the 1,453 aircraft that had been manufactured<sup>85</sup>. The price paid by the MAP for a Hampden was £10,571.85<sup>86</sup>, giving a total value for the aircraft manufactured of £15,360,908.00. At these figures, an estimate of the value of the lost aircraft is £6,691,981.00.

### **Armstrong Whitworth Whitley**

The Whitley was an adaptation of an earlier Armstrong Whitworth design intended for the export market. In July 1934, when the Air Ministry issued its heavy bomber specification, B.3/34, Armstrong modified their design and put it forward<sup>87</sup>. The Air Ministry ordered the Whitley off the drawing board and issued a contract for 80 aircraft in 1935. The Whitley first flew in 1936 and was capable of carrying an impressive 7,000 lbs of bombs 1,650 miles at an average cruising speed of 185 mph<sup>88</sup>. Although the RAF soon considered the Whitley

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84 Middlebrook and Everitt, *Bomber Command War Diaries*, p.707

85 RAF and Bomber Command Association , [www.raf.mod.uk/bombercommand/aircraft/hampden.html](http://www.raf.mod.uk/bombercommand/aircraft/hampden.html), 23rd October, 2002

86 Ministry of Aircraft Production, *Price Books*

87 Postan, Scott and Hay, *Design and Development of Weapons*, p.12

88 RAF and Bomber Command Association , [www.raf.mod.uk/bombercommand/aircraft/whitley.html](http://www.raf.mod.uk/bombercommand/aircraft/whitley.html), 23rd October, 2002

obsolete, Armstrong Whitworth delivered 1,812 aircraft out of the 1,932 ordered<sup>89</sup>.

Whitley bombers cost an average of £11,160.00 per aircraft and the total output of 1,812 aircraft cost the British Government around £20,221,920<sup>90</sup>. Of the total number of Whitleys 458 (26.27 percent) were lost whilst serving in Bomber Command, a capital loss somewhere around £2,111,280.00. These losses are high, given that the majority of Whitleys never left aircraft storage<sup>91</sup> and that Whitleys carried out only 9,858 sorties, 2.52 percent of the Bomber Command total<sup>92</sup>.

### **Short Stirling**

Short Brothers built the Stirling against Air Ministry specification B.12/36 which set a requirement for four engines and an empty weight of around 55,000 lbs<sup>93</sup>. Unlike the Lancaster or the Halifax, the Stirling was the only heavy British bomber whose initial design included four engines. The Stirling was

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89 Postan, Scott and Hay, *Design and Development of Weapons*, p.494

90 An approximate figure of £11,160.00 has been calculated for the Whitley based upon an estimate the average cost per lb of structure weight for other aircraft manufactured at the time. No figure for the Whitley could be identified in the Ministry of Aircraft Production, *Price Books*

91 Postan, Scott and Hay, *Design and Development of Weapons*, p.12

92 Middlebrook and Everitt, *Bomber Command War Diaries*, p.707

93 Postan, Scott and Hay, *Design and Development of Weapons*, p.20

also the tallest, longest and slowest bomber built by Britain during World War II. It also had the shortest wingspan of any bomber<sup>94</sup>.

The Stirling entered squadron service on or around the 2<sup>nd</sup> of August 1940<sup>95</sup>. As suspected from Falconer's description, the Stirling was not a good aircraft. Due to its short wingspan, it needed very long take-off and landing distances<sup>96</sup>. The answer that Shorts came up with was to double the wing angle of incidence which then required the lengthening of the undercarriage making an already high aircraft even higher. Whilst this enabled the Stirling's wings to bite into the air at a more acute angle, it led to unwieldiness on the ground, which resulted in a significant number of these aircraft suffering severe damaged through the failure of their undercarriage. The undercarriage design also imposed a heavy maintenance burden and the aircraft suffered a much higher degree of down time than the other aircraft used within Bomber Command<sup>97</sup>. The Stirling carried out 18,440 sorties, 4.73 percent of all Bomber Command's wartime sorties<sup>98</sup>.

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94 J. Falconer, *Stirling Wings: The Stirling Goes to War*, Budding Books, Stroud, 1997, p.xiii

95 P. Moyes, *Bomber Squadrons of the RAF and their Aircraft*, MacDonald, London, 1996, p.369

96 RAF and Bomber Command Association, [\\_www.raf.mod.uk/bombercommand/aircraft/Stirling.html](http://www.raf.mod.uk/bombercommand/aircraft/Stirling.html), 23rd October, 2002

97 Tedder, *With Prejudice*, p.10

98 RAF and Bomber Command Association, [www.raf.mod.uk/bombercommand/aircraft/Stirling.html](http://www.raf.mod.uk/bombercommand/aircraft/Stirling.html), 23rd October, 2002

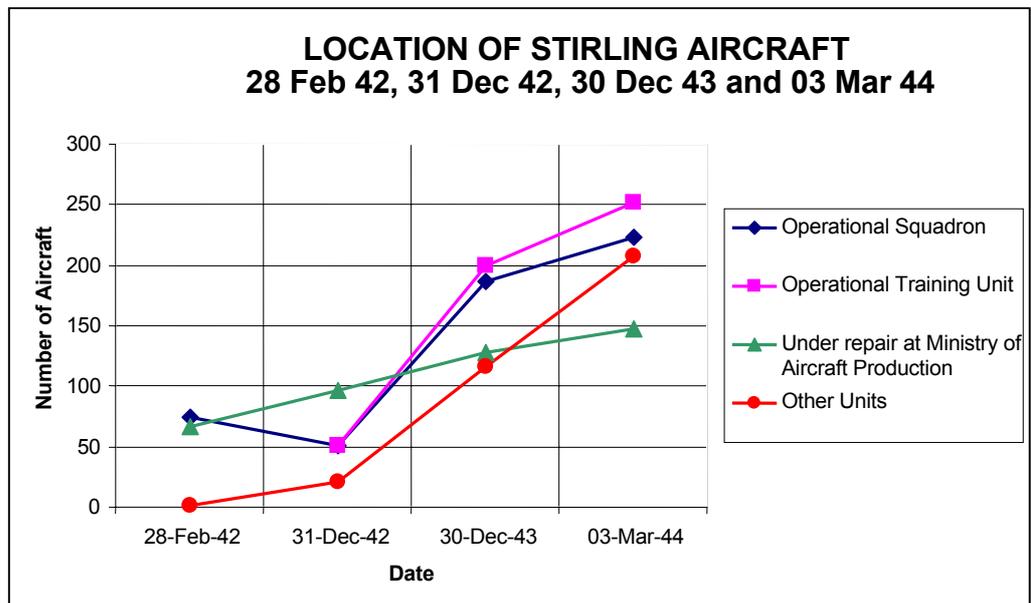


Figure 4.3: Source: PRO AVIA 9/51, D.D.G.P.S. 20.3.44 and AVIA 10/391 D.D.G. Stats P. 2.4.42

During the war, Bomber Command lost 684 Stirlings due to crashes or enemy action<sup>99</sup>. These 684 aircraft comprised 25.04 percent of the 2,731 Stirlings built<sup>100</sup>. The total cost to the British government of buying 2,731 Stirlings was £64,153,124.00, based on an average figure of £23,490.70 per aircraft. The total cash write-off for the 684 aircraft £16,067,639.00. This does not include the loss of 11 of these aircraft destroyed in successful Luftwaffe raids on the Short's factories at Rochester and Belfast in September 1940<sup>101</sup>.

99 Middlebrook and Everitt, *Bomber Command War Diaries*, p.707

100 Falconer, *Stirling Wings*, p.xiii

101 RAF and Bomber Command Association, [www.raf.mod.uk/bombercommand/aircraft/Stirling.html](http://www.raf.mod.uk/bombercommand/aircraft/Stirling.html), 23rd October, 2002

## Fairey Battle

The Battle was developed and built by Fairey Aviation in response to Air Ministry Specification, P.27/32, which the official history claims was issued as ‘little more than a tentative project’, to provide a single engined aircraft for comparative purposes with the twin-engined aircraft expected to eventuate under Specification B.9/32<sup>102</sup>. The Battle was to be a reasonably robust aircraft in that it had a standard life flying life of 900 hours, substantially above the more successful Wellington at 540 hours<sup>103</sup>. Approximately 2,200 of these aircraft were built but most of them did not see service in Bomber Command.

In 1932, when the specification was written, the Fairey Battle represented a significant step forward in aircraft technology. It was an all-metal monoplane, with retractable undercarriage and it had all of the modern features that the RAF would have been seeking in 1932. The problem was a lack of engine power and the Battle was not the only early 1930s aircraft affected by this. The Boeing Monomail suffered the same problem of being underpowered: the single Rolls Royce Merlin powering the Battle was not sufficient for the weight of the aircraft<sup>104</sup>. Changes of specification, including the addition of a third

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102 Postan, Scott and Hay, *Design and Development of Weapons*, p.11

103 PRO AIR 72/24, A1-A10/1940

104 Boeing Corporation, [www.Boeing.com/companyoffices/history/Boeing/Monomail.html](http://www.Boeing.com/companyoffices/history/Boeing/Monomail.html), 23rd October 2002

crewmember, increased the weight of the aircraft and exacerbated the problem of its marginal performance<sup>105</sup>.

Of the 2,200 Fairey Battles built, 44 were lost due to enemy action and of these, only four were lost on Bomber Command operations in 1940 against the Channel Ports<sup>106</sup>. At an average cost of £9,722.04 per aircraft for the various production runs, the cost of building 2,200 Battles was £21,388,491.00<sup>107</sup>. The cost of the four aircraft lost due to Bomber Command operations is £38,888.16. Although the vast majority of these aircraft did not see active service, they contributed to the strategic air offensive serving as target tugs and Battles made up a significant proportion of the 800 aircraft supplied to the Empire Air Training Scheme in Canada<sup>108</sup>.

### **The American Bombers**

Five American bomber aircraft saw service in Bomber Command. These were the Douglas Boston, the Boeing B-17, the Consolidated Liberator, the Lockheed Ventura and the North American Mitchell. The Douglas Boston was originally designated the Douglas A-20 Havoc and orders were placed by the French

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105 RAF and Bomber Command Association, [www.raf.mod.uk/bombercommand/aircraft/battle.html](http://www.raf.mod.uk/bombercommand/aircraft/battle.html)

106 Middlebrook and Everitt, *Bomber Command War Diaries*, pp. 53-114 and Moyes, *Bomber Squadrons of the RAF*, p.369

107 Ministry of Aircraft Production, *Price Books*

government at the start of World War II. With the fall of France, the French order of 270 aircraft was diverted to Britain and the aircraft was re-designated as the Boston. The first Bostons entered service with Bomber Command in July 1941, and performed reliably as a light day bomber. In June 1943, the Air Staff transferred the last of the Bostons to the Second Tactical Air Force when No. 2 Group transferred from Bomber Command to the Tactical Air Force. These aircraft continued to serve as ground support aircraft until April 1945, when the RAF replaced them with Mosquitos<sup>109</sup>.

In an effort to make up for the shortfall in long-range bomber aircraft Britain purchased 20 Boeing B-17C, which came into service with Bomber Command in May 1941<sup>110</sup>. The Boeing was a high flying, long range aircraft that seemed to meet Bomber Command's requirements. The RAF found that the B-17C lacked the bomb-carrying capacity that Bomber Command needed. It also found that the B-17 suffered from a number of technical problems that kept its altitude lower than expected<sup>111</sup>. For these reasons, and probably Treasury concerns about buying outside the sterling block, Britain purchased very few Boeing B-17s.

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108 PRO CAB 120/299, Answers to Mr. Justice Singleton's questions to the Air Staff, 14th January 1941.

109 RAF and Bomber Command Association, [www.raf.mod.uk/bombercommand/aircraft/boston.html](http://www.raf.mod.uk/bombercommand/aircraft/boston.html), 23rd October 2002

110 US Air Force Museum, [www.wpafb.af.mil/museum/research/bombers/b2-17.htm](http://www.wpafb.af.mil/museum/research/bombers/b2-17.htm), 23rd October 2002

111 Bulman, *An Account of Partnership*, p.295

Another concern that Bomber Command had about the aircraft was the manual defensive armament. Bomber Command had insisted on power operated turrets for all of its aircraft and saw the manual defensive system in the B-17 as being a serious flaw. The first operational deployment of the B-17C was a raid by three Fortresses on Wilhelmshaven on 8 July 1941<sup>112</sup>. The aircraft did not impress Bomber Command and the B-17 subsequently saw most of its service in the Middle East and Coastal Command. Flying Fortresses later returned to Bomber Command where they served as electronic countermeasures aircraft in 100 Group. Their main task during this phase of their career was the jamming of German radar defences.

Britain imported 109 Boeing B-17s of which 18 (16.51 percent) were destroyed in Bomber Command<sup>113</sup>. The average cost of a Boeing Flying Fortress is reported as £64,637.00 (\$US126,000.00)<sup>114</sup>. The cost of buying the 109 aircraft was approximately £7,045,466.00. The value of the 18 B-17s destroyed whilst in Bomber Command was therefore around £1,163,466.00.

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112 Middlebrook and Everitt, *Bomber Command War Diaries*, p.177

113 PRO AVIA 15/2023, Listing of All Aircraft Obtained Under Lend lease, June, 1944

114 US Air Force Museum, [www.wpafb.af.mil/museum/air\\_power/ap16.htm](http://www.wpafb.af.mil/museum/air_power/ap16.htm), 23rd October, 2002

The Air Ministry ordered the Ventura Mk.I aircraft from Lockheed in February 1940 as a replacement for the Blenheim day bombers serving in No. 2 Group<sup>115</sup>. By May of 1940, Britain increased its order to 300 aircraft, ordering 375 more towards the end of that year. Significantly, Lockheed consistently failed to meet the orders and the Ventura I did not fly until 31 July 1941. By the time Lockheed put the Ventura into production the United States had entered the war and began to divert completed aircraft for its own use. The records show that by June 1944 Britain had imported 406 Venturas<sup>116</sup>.

The Ventura entered British service in May 1942, a lot later than planned. By this time, the aircraft was out-of-date and its poor handling characteristics made it unpopular with those flying it. Of the 406 Venturas imported into Britain 41 (10.09 percent) were destroyed in Bomber Command, 11 of these losses occurring on a single raid when German fighters shot down 10 of the 12 attacking and seriously damaged another. The Ventura flew only 997 sorties, 0.25 percent of the total, for Bomber Command and ceased to operate within the Command after September 1943<sup>117</sup>. The cost of importing the 406 aircraft was £7,064,400.00 with the average cost of each aircraft being approximately

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115 RAF and Bomber Command Association, [www.raf.mod.uk/bombercommand/aircraft/ventura.html](http://www.raf.mod.uk/bombercommand/aircraft/ventura.html), 23rd October, 2002

116 PRO AVIA 15/2023, Listing of All Aircraft Obtained Under Lend lease, June, 1944

117 RAF and Bomber Command Association, [www.raf.mod.uk/bombercommand/aircraft/ventura.html](http://www.raf.mod.uk/bombercommand/aircraft/ventura.html), 23rd October, 2002

£17,400.00. The cost of the losses within Bomber Command was approximately £713,400.00.

Of the 18,000 Liberators built by Consolidated, Britain obtained 785. The aircraft had a reported range of 2,850 miles<sup>118</sup>, but RAF sources only rated it as being 2,100 miles with a bomb load of 5,000 lb<sup>119</sup>. The Liberator did not see much service within Bomber Command, carrying out only 662 sorties, 0.16 percent of the total. Only 0.38 percent of the 785 Liberators were lost while in Bomber Command at a cost of £237,174. The cost of a Liberator is reported as being £79,058.00 (\$US336, 000.00) making the cost of the total number of aircraft £62,060,530.00<sup>120</sup>.

The Mitchell Bomber was one of the more successful American aircraft with 9,800 manufactured by North American during World War II. It became famous following the Tokyo raid of April 1942, led by Colonel Doolittle. Despite this success, the relatively small payload of a Mitchell made it unattractive to Bomber Command. A Mitchell cost £22,588.00 (\$US96,000), and Britain imported 537<sup>121</sup> of these aircraft by June 1944 at a cost of £12,129,756.00. Mitchells carried out 84 (0.02 percent of the total) sorties on behalf of Bomber Command, making it a

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118 US Air Force Museum, [www.wpafb.af.mil/museum/air\\_power/ap8.htm](http://www.wpafb.af.mil/museum/air_power/ap8.htm), 24th October 2002

119 US Air Force Museum, [www.wpafb.af.mil/museum/air\\_power/ap8.htm](http://www.wpafb.af.mil/museum/air_power/ap8.htm), 24th October 2002

120 US Air Force Museum, [www.wpafb.af.mil/museum/air\\_power/ap8.htm](http://www.wpafb.af.mil/museum/air_power/ap8.htm), 24th October 2002

121 PRO AVIA 15/2023, Listing of All Aircraft Obtained Under Lend lease, June, 1944

minor contributor to the strategic air offensive. The entire career of the Mitchell in Bomber Command lasted from 22 January 1943 until the 31<sup>st</sup> of May 1943<sup>122</sup>.

### **Additional Costs to New Aircraft**

Outside of naval vessels, bomber aircraft were the most sophisticated weapons systems used by the Allies during World War II. Their task was to carry multiple man crews long distances, find a small target area and accurately drop their bombs on target whilst defending themselves against attacks by the defending German aircraft and avoiding anti-aircraft fire from the ground. In order to meet these tasks the aircraft had to be provided with engines, internal and external communications systems, navigational systems, bomb aiming equipment, heating systems for crew and weapons, and other capabilities such as a hot drink dispensers and Elsan toilets. They also had to be provided with machine guns, ammunition channels, life rafts and a variety of other equipments.

The government supplied this equipment, which did not form part of the aircraft price, although the aircraft manufacturer might install it during construction. The Air Ministry and the MAP met the cost of this government equipment. The items supplied by the government were dinghies, parachutes, machine guns, wireless sets and cameras. The costs of these items added around 2.5 percent to the cost of a finished aircraft and the total costs of providing this equipment for the 47,457

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122 Middlebrook and Everitt, *Bomber Command War Diaries*, pp. 384-395

aircraft considered here was £33,136,035<sup>123</sup>. The cost for those aircraft destroyed or written-off whilst in Bomber Command would have been around £9,079,197, if no salvage were involved. Figure 4.4 below outlines the average cost for government equipment in each aircraft type.

### Government Equipment Costs

Aircraft	Estimated Cost per Aircraft	Total Number Built	Total Cost of Government Equipment	Number of Aircraft Lost in BC	Cost of Government Equipment in Lost Aircraft
Whitley	£640.00	1,812	£1,159,680	458	£293,120.00
Blenheim	£605.00	3,421	£2,069,705	541	£327,305.00
Battle	£465.00	2,200	£583,000	44	£25,652.00
Hampden	£570.00	1,453	£486,755	633	£360,810.00
Wellington	£815.00	11,460	£9,339,900	1,727	£1,407,505.00
Stirling	£900.00	2,731	£2,457,900	684	£615,600.00
Manchester	£710.00	200	£142,000	76	£53,960.00
Halifax	£935.00	6,176	£5,959,840	2,083	£1,947,605.00
Mosquito	£395.00	6,710	£2,650,450	310	£122,450.00
Lancaster	£900.00	7,377	£6,639,300	4,265	£3,838,500.00
Ventura	£815.00	406	£330,890	41	£33,415.00
Mitchells	£675.00	537	£362,475	20	£13,500.00
Boston	£745.00	380	£283,100	46	£34,270.00
Boeing B-17	£935.00	109	£101,915	18	£16,830.00
Liberator	£725.00	785	£569,125	3	£2,175.00
<b>Total</b>		<b>45,757</b>	<b>£33,136,065</b>	<b>10,949</b>	<b>£9,092,697</b>

Fig. 4.4

Source: *War Savings, Wings for Victory Issue*, February, 1942, pp.25-27

The prices paid for the aircraft above covered a range of items and services carried out by the manufacturers. For example, under Contract Number Aircraft/239, the Air Ministry paid Sir W.G. Armstrong Whitworth to supply

123 Calculated from information supplied in *War Savings, Wings for Victory Issue*, February, 1943, HMSO, London, p.25

1,650 Lancasters at prices between £23,548 and £37,778<sup>124</sup>. This price did not include the cost of fuel for test and delivery flights, although the cost of non-bought out materials made redundant by modifications was included<sup>125</sup>. On contract number Aircraft/2221/C.4(a) with Metropolitan Vickers Electrical Co., the price of £17,200 paid for each of 108 Lancaster Mark I type aircraft had been adjusted to take account ‘for savings in the labour efficiency, offset to some extent by the wages award (555) to women’<sup>126</sup>. The detailed adjustment of the prices relating to individual batches of long production runs would suggest a very close monitoring of the activity within the aircraft firms.

This minute tweaking of prices within production runs by the MAP shows a level of day-to-day monitoring that is rare in today’s world. Nevertheless, this level of detailed costing suggests that the MAP financial officers were alert to any saving on cost that might influence the price of a finished aircraft. This willingness of the MAP, and presumably Treasury, is shown in contract Aircraft/2221/CB.6 (a) where the cost of jigs and tools used in the manufacture of the Lancasters at metropolitan Vickers Electrical Company is specifically excluded from the final payments as these had already been paid for in the preceding batches of aircraft<sup>127</sup>.

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124 Ministry of Aircraft Production, *Price Books*

125 Ministry of Aircraft Production, *Price Books*, contract number Aircraft/2221/C.4(a)

126 Ministry of Aircraft Production, *Price Books*, contract number Aircraft/2221/C.4(a)

127 Ministry of Aircraft Production, *Price Books*, contract number Aircraft/2221/CB.6 (a)

A similar exclusion exists in earlier contracts such as Contract Number 763825/38 with Short Brothers for the supply of 350 Short Stirling Bombers. In this 1941 contract, the costs of jigs, tools and flight tests were met by the manufacturer, presumably on the basis that these costs had been paid for in earlier batches of the aircraft. The prices paid include an amount to pay for the replacement of parts damaged by the Luftwaffe raid on 14<sup>th</sup> May 1941<sup>128</sup>. This level of detailed analysis of the costs incurred in manufacturing the aircraft lends further weight to the belief that the prices quoted in the MAP Price Books specifically excluded any element of payment as recompense for the capital investments in buildings and plant, probably on the justifiable basis that the government had already paid these costs. The significance is that the MAP Price Book figures seriously underestimate the true cost of building the aircraft used by the RAF.

### **Modifications**

Modifications to aircraft in production were expensive in terms of both money and lost production. The need for modifications occurred as a result from the operational problems encountered by Bomber Command; from problems that existing design caused in production or from the needs of the aircraft manufacturers to improve their processes. Thus, modifications were routinely sought by the firms in the production group, from the MAP or from the RAF. The modifications that were approved, whether from within the designing firm or

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128 Ministry of Aircraft Production, *Price Books*, contract number Aircraft 763825/38

the production group, were mostly concerned with changing the aircraft to allow for faster production. This was not always the case and the firms were responsible for identifying a number of modifications needed to improve the performance of the aircraft<sup>129</sup>. The MAP appears to have been strategic in the changes in design it brought forward. Many of these were suggested in an effort to manage problems such as shortages of strategic materials, including aluminium and rubber, or the need to meet changes in the types of equipments being provided or even shortages of labour<sup>130</sup>.

There were four classifications of modifications. Class One was used to designate those modifications needed to correct extreme safety precautions and such modifications took priority over operational requirements. These were directed at the safety of the aircraft and not at the safety of the crew, as the failure to modify the Lancaster escape hatches attest to. Class Two modifications were for reasons of operational or safety urgency and had to be to be incorporated into production lines as soon as practicable. Class Three modifications were discretionary and Commands could decide to have them or not. Class four modifications were the lowest priority and would only be implemented if they did not interfere with production schedules or lead to a scrapping of materials.

The modifications recommended by the RAF were mostly concerned with improving the operational effectiveness of the aircraft or in reducing the

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129 Postan, Hay and Scott, *Design and Development of Weapons*, p.520

130 Postan, Hay and Scott, *Design and Development of Weapons*, p.520

maintenance and repair overheads inflicted upon operational units<sup>131</sup>. The RAF also recommended modifications where safety or the comfort of the crew was concerned, although the RAF made no effort to modify the escape hatches of the Lancaster, which many have held responsible for the poor survival of crew from Lancasters that were shot down<sup>132</sup>.

In order to see the impact of these modifications upon aircraft production the best example is the Lancaster. From its inception as the Manchester to its final characterisation as the Lincoln, the aircraft had 1,402 modifications<sup>133</sup>. Of these 391 were adjustments to drawings and blue prints or to drawing adjustment sheets. Other than occupying the time of the drawing office they had little impact upon the aircraft's production. A further 400 of the modifications related to the Manchester were discarded when the decision was made to produce the Lancaster. This leaves 611 modifications of substance.

By 5<sup>th</sup> March 1945, of the 611 modifications 336 had already been incorporated in the production line, 101 had been superseded or cancelled, 23 related to special requirements for small numbers of aircraft to be modified to carry special ordnance, like 'TALLBOY, UPKEEP or special radar'<sup>134</sup>. A further 87 modifications were in hand, either in the design or production phase and the final

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131 Postan, Hay and Scott, *Design and Development of Weapons*, p.520

132 R. Neillands, *Bomber War; The Allied Air Offensive Against Nazi Germany*, The Overlook Press, Woodstock and New York, 2001, p.222

133 PRO CAB 120/351, memo from E.I.G. Jacob to Prime Minister, 6th March, 1945

134 PRO CAB 120/351, memo from E.I.G. Jacob to Prime Minister, 6th March, 1945

64 had not yet been started. A further 37 were outstanding and were awaiting official acceptance<sup>135</sup>.

The MAP estimated the cost of modifications to Lancasters in early 1945 was equivalent to the production of 231 new Lancasters, or a financial cost of £7,388,535<sup>136</sup>. The impact on man-hours was an increase on the production line of 1,020 hours per Lancaster/Lincoln and an additional 4,621,240 man-hours of labour spread across the manufacturing group, RAF maintenance and civilian repair organisations. The estimates of the man-hours and costs above do not take into account the cost in man-hours or cash of the work needed for the production of embodiment loans or bought out parts, such as turrets, heaters etc<sup>137</sup>.

The government was well aware of the adverse impact of modifications on the output of finished aircraft. Mr. E.I.G. Jacob of the Cabinet Office advised that the size of the modification problem was very large and long-term. Jacob found that despite the large number of modifications the Air Ministry and MAP were exercising 'strict control' on the amount of effort diverted to this activity and everything possible was being done to limit the impact of modifications on production and that modifications were going to continue<sup>138</sup>.

## **Parts**

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135 PRO CAB 120/351, memo from E.I.G. Jacob to Prime Minister, 6th March, 1945

136 PRO CAB 120/351, memo from E.I.G. Jacob to Prime Minister, 6th March, 1945

137 PRO CAB 120/351, memo from E.I.G. Jacob to Prime Minister, 6th March, 1945

As important as new aircraft and fuel was a ready supply of spare parts which were essential for the repair and maintenance of existing aircraft. In early 1940, the Air Ministry identified the importance of having an adequate number of spares. At that time, the Air Ministry had directed an increase in the production of spare parts in an effort to keep as many existing aircraft as airworthy as possible. The Air Ministry imposed this policy even at the cost of aircraft production<sup>139</sup>. This policy persisted until the formation of the MAP and the appointment of Max Beaverbrook, as the Minister for Aircraft Production. Beaverbrook instituted a production drive that sacrificed production at the expense of all other activity, including spare parts production<sup>140</sup>.

The untrammelled requisitioning of spare parts by the Beaverbrook MAP is described by the Director of Engine Development, G. Bulman, as 'looting' which produced a 'miserable squabble' between Beaverbrook and the Air Marshals<sup>141</sup>. Bulman's own judgement is that the Air Ministry team Beaverbrook had inherited worked very hard to protect the fundamental machinery of production from the depredations of Beaverbrook and 'his boys'. Bulman dismisses Beaverbrook's claims to have increased aircraft production. He notes sourly that 'Rome (increased production) was not built in one day or by the genius of one man'<sup>142</sup>.

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138 PRO CAB 120/351, memo from E.I.G. Jacob to Prime Minister, 6th March 1945.

139 Ritchie, *Industry and Air Power*, p.222

140 Ritchie, *Industry and Air Power*, p.231

141 Bulman, *An Account of Partnership*, p.269

142 Bulman, *An Account of Partnership*, p.268

Spare Part	Cost of Parts	
	Price Twin Engined Bomber	Price Four Engined Bomber
Engine	£2,000	£2,500
Undercarriage	£1,000	£1,500
Wheels	£60	£120
Control Column	£30	£30
Tail Plane	£200	£300
Tail Wheel	£10	£10
Tyres	£30	£50
Tyres with Wheels	£95 x no. required	£95 x no required
Instruments	£300	£400
Turret	£500	£500
Machine Gun Browning	£45	£45
Propeller	£350	£350
Wireless	£200	£250
Oxygen Apparatus	£15	£15
Fuel Tank	£80	£100
Parachute	£35	£35
Camera	£35	£35
Bomb sight	£60	£60
Dinghy	£30	£30
Pilot's Seat	£15	£15
Ailerons	£100	£100
Oil Tank	£40	£40
Through Type Spinner for Propeller	£35	£35
Nose Cap Spinner for Propeller	£8	£8
Fuel Gauge	£4	£4
Clock	£3	£3
Thermometer	£1	£1
Sparking Plug	£0.8.0	£0.8.0
Rivets	£0.0.6	£0.0.6
Automatic Pilot	£200	£200

**Figure 4.5:**

Source: *War Savings, Wings for Victory Issue*, February, 1942, pp.25-27

Beaverbrook's regime at the MAP increased the production of new aircraft whilst reducing the capability of workforces, the RAF or anyone whom he could rob in order to achieve success. After his departure from the MAP, the production of spare parts was increased and by February 1944, 18 percent of the labour

employed in airframe manufacturing was working on making spare parts<sup>143</sup>.

Figure 4.6 below shows an example of spare parts production at one plant.

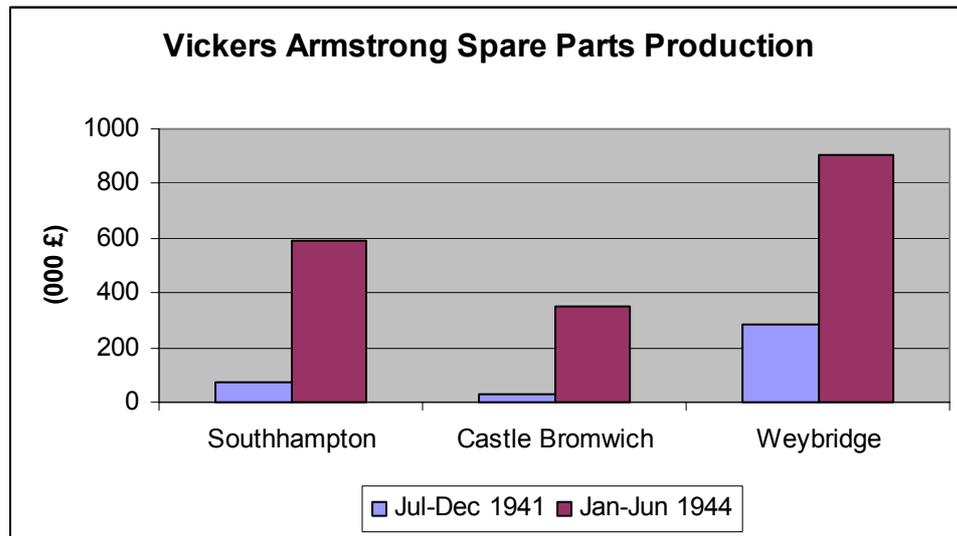


Fig. 4.6:

Source: S. Ritchie, 'Industry and Air Power', p.240

Similar increases occurred at the London Passenger Transport Board (LPTB), where the parties agreed to a fee of £21,319,693 for the supply of 710 Halifax aircraft, 450 Mk II and 260 Mk III. 15.68 percent (£3,966,147) of the total contract paid for spare parts<sup>144</sup>. Although some of the manufacturing firms, such as LPTB above, did manufacture spare parts, it was usually the role of the parent firm in the group to supply spares. For example, in the Lancaster Group A.V.Roe managed the supply of spares very closely<sup>145</sup>.

143 Ritchie, *Industry and Air Power*, p.239

144 Ministry of Aircraft Production, *Price Book*, Contract No. B.124357/40-450 and Aircraft/2595

145 PRO AVIA 15/1466

The total cost of spares to the government is almost impossible to estimate. This difficulty comes from the way in which spares were arbitrarily moved within production groups and between firms, the RAF and the MAP itself. The best estimate possible is that spare parts production was equivalent to 25 percent of the cost of manufacturing an aircraft type. The Director of Engine Development, George Bulman, reports that Beaverbrook issued a 'Ukase' demanding an increase in the production of engine spares from 10 to 20 percent of engine output<sup>146</sup>. Whilst this placed strain on the manufacturers, Bulman concedes that it was a wise move<sup>147</sup>.

The cost of the spare parts provided under the above contract with LPTB above appears to have been 23.9 percent of the cost of a delivered Halifax bomber. This would mean that the potential costs of spares provided to both repair and maintain aircraft for the strategic bomber offensive may have been in the region of £251,399,329. Given the wide use made of the aircraft under discussion here, not all of the above cost is attributable to the strategic air offensive. However, given the large number of highly complex aircraft used by Bomber Command it is reasonable to attribute 75 percent of the cost to the offensive, giving a value of £188,549,497 as the cost of spares to the strategic air offensive.

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146 Bulman, *An Account of Partnership*, p.263

147 Bulman, *An Account of Partnership*, p.263

## Repair of Aircraft

Between the second quarter of 1940 and the third quarter of 1945, the RAF, MAP and commercial industry returned 71,109 damaged aircraft to the RAF for operations in the United Kingdom. Of them, approximately 6,333 were medium and heavy bombers<sup>148</sup>. Around 2,030 repaired aircraft re-entered service prior to 14<sup>th</sup> January 1941<sup>149</sup>. The repair organisation returned 4,303 heavy and medium bombers between December 1941 and September 1945<sup>150</sup>. At an average cost per bomber aircraft of £19,386, the total value of the repairs undertaken is approximately £122,771,538<sup>151</sup>, a figure that represents 12.2 percent of the estimated total cost of £1.5 billion paid to all manufacturers for bomber aircraft and accessories.

Responsibility for repairs rested with the Director of Repair and Maintenance of the MAP. The impact of the heavy bomber on Bomber Command added to the problem of repair and maintenance. These aircraft were larger and more complex than previously and represented, as seen above, a significant and growing investment. The repair system instituted supplied Bomber Command with 6,333

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148 Central Statistical Office, *Statistical Digest of the War*, p.154

149 PRO CAB 120/299, Answers to Mr. Justice Singleton Questions 14 Jan 41

150 Central Statistical Office, *Statistical Digest of the War*, p.154 The figure for medium bombers, which were progressively moved out of Bomber Command, was obtained by taking the percent of repaired heavies, 14 percent, and applying it to the number of mediums repaired up till mid 1944.

151 Based on average price, derived from Ministry of Aircraft Production, *Price Books*, for all types used in Bomber Command over the war except the Fairey Battle, Manchester and United States supplied aircraft.

aircraft at a substantially reduced cost, making the repair of aircraft a major value adding activity throughout the strategic bomber offensive.

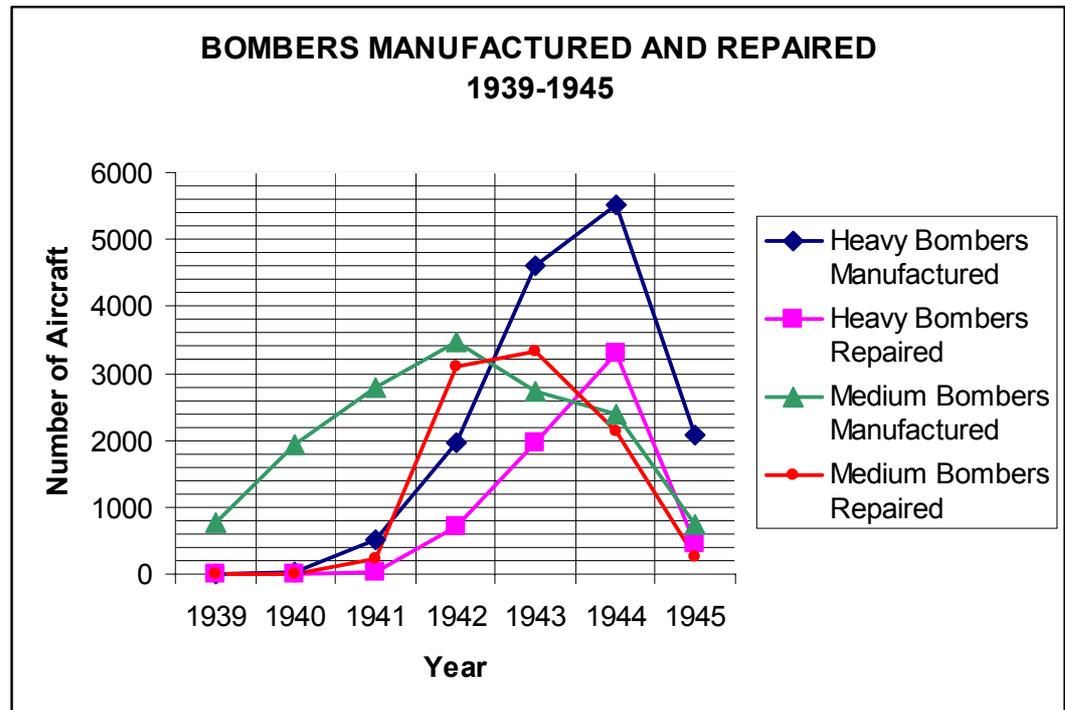


Fig. 4.7:

Source: *Statistical Digest of the War*, pp.152, 154

### Servicing and Maintenance

It is almost impossible to provide an accurate breakdown of the cost of servicing and maintaining the aircraft of the strategic bomber offensive. Servicing and maintaining aircraft was the core activity for a large percent of the personnel serving in Bomber Command. The demands placed upon Bomber Command personnel and Ground Support Equipment (GSE) by the changeover to heavy

bombers was substantial. Sir Arthur Harris notes that practically all of the ground handling equipment would not work with the new larger aircraft and that the increase in size was accompanied by an increase in complexity that made the scale of workshop, power plant and technical accommodation totally unsuitable<sup>152</sup>.

The change in aircraft increased already pressing problems on Bomber Command's airfields. In order to deal with them, the Command organised a completely new servicing structure as part of the re-organisation of bomber stations. In November 1943, servicing and maintenance functions on Bomber Command's stations were removed from the control of the operational squadrons and centralised in a Servicing Wing commanded by the Base Chief Technical Officer, who reported directly to the Base Commander<sup>153</sup>. The Servicing Wings were organised into a Headquarters, Daily Servicing Squadron and a Repair and Inspection Squadron. The function of the Daily Servicing Squadron was to command the groundcrew and servicing equipment used to carry out the routine and daily servicing of the operational aircraft. In reality this meant that, with the exception of the HQ, all of the personnel posted to the Daily Servicing Squadron worked in an operational squadron. The major benefit of this system was that the Servicing Wing could move the servicing personnel and their equipment from their assigned squadron to another of the operational squadrons on the base without the normal wrangling over command and control that previously had

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152 Harris, *Despatch on War Operations*, p.149

153 Harris, *Despatch on War Operations*, p.154

arisen. This enabled a much higher degree of versatility and provided a much greater surge capability in servicing<sup>154</sup>.

Deprived of the need to assist in the daily routine maintenance of aircraft, the Repair and Inspection Squadron could concentrate on carrying out the 'deep' servicing of aircraft on charge to the squadrons<sup>155</sup>. Deep servicing of equipment is a routine cycle of inspection and servicing applied to all aircraft and equipment. The RAF had a strict policy of deep servicing on its bases. This required a wide range of engine and airframe inspections to be undertaken and for considerable technical services to be immediately available. The benefit was that Bomber Command kept control of aircraft requiring substantial inspections which prevented the repair organisation retaining heavy bombers once the inspection, modification or repair was completed.

Teams of tradesmen and technicians supplied by the firms who had designed particular aircraft supplemented the Repair and Inspection Squadrons, although this was probably to a small extent. The main work of the manufacturers' teams was on modifications during repairs on bomber stations or in the Civilian Repair Depots (CRD)<sup>156</sup>. The role undertaken by these teams relieved RAF groundcrew of some workload associated with modifications. Vickers Armstrong and Bristol were the two most active firms in providing mobile teams for modification work.

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154 Harris, *Despatch on War Operations*, p.154

155 F.J. Adkin, *RAF Ground Support Equipment Since 1918*, Airlife, Shrewsbury, 1996, pp. 153-188

156 Postan, Scott and Hay, *Design and Development of Weapons*, pp. 526-527

Both companies established teams and they staffed them with specialist workers who could be sent away to work on their own. Other companies, such as Handley Page, A.V.Roe and Supermarine tended to take personnel off their production lines in order to work in ad hoc mobile teams.

<b>Equipment</b>	<b>Cost</b>
Crash Tender	£950.00
Ambulance	£750.00
Tractors	£1,000.00
Trolley Accumulator	£250.00
Servicing Platforms	?
Cranes	£1,500.00
500 Gal Fuel Tankers	£850.00
450 Gal Fuel Trailers	£250.00
Air Compressor	£75.00
Tracjac Salvage Trolleys	?
Bedford Truck	?
Queen Mary Trailer	?
Engine Erection Stand	?
Oil Primer Mk 2	?
Oil Filling Rig	?
Hydraulic Test Set	?
Engine Test Stands	?

**Fig. 4.8:** Source: *War Savings, Wings for Victory Issue, February, 1942, pp.25-27*

The equipment supplied to bomber stations was substantial, as was the cost of obtaining and maintaining it. An idea of this equipment and its costs can be seen at Figure 4.8 above. The amount of equipment held on each station reflected the type of aircraft flying from that station. Nevertheless, most of the aircraft operating from bomber command stations had multiple crews, usually between five and seven men. In order to deal with the potential casualties from the crashing of one of these aircraft at least two ambulance vehicles would have been required as well as two crash tenders or fire engines. The bill per station for this

equipment alone would have been £3,400.00 per station. Given that Bomber Command had 125 stations under its control, this would have produced an overall bill of £425,000, for ambulances and fire engines.

Bomber stations used many tractors, particularly the Fordson and David Brown Taskmasters. Tractors were the main means of moving aircraft, bombs, trailers and heavy equipment. The average cost of a tractor during the period was somewhere around £500 and there were significant numbers of these vehicles operating within Bomber Command at any one time. At this stage, there is not enough hard information to estimate the cost of tractors on bomber stations but there was definitely more than one.

Although an estimate of the full cost of the above equipment is difficult to establish, the listing of it provides some idea of the costs involved.

## **Conclusion**

In looking at the prices paid for bomber aircraft by Britain it has been necessary to survey the type of aircraft involved in the strategic air offensive and the role each played. This survey has shown that five aircraft, the Lancaster, Halifax, Wellington, Mosquito and Stirling, carried out 88.9 percent of all Bomber Command sorties. The cost of these aircraft alone was £613 million. The total cost of supplying Bomber Command with approximately 43,322 operational bomber aircraft during World War II was £1.3 billion, including a cost of £224

million for the value of factories and plant. The cost of £1.3 billion is conservative. It does not reflect a number of hidden costs incurred during production such as transportation and storage. Nor does it include the full cost of repair and maintenance, or the cost of transportation of the aircraft and their component parts or of storage during their operational life.

During World War II, Britain manufactured or imported 43,322 bomber aircraft, a large proportion of which served in Bomber Command. Of these aircraft 10,949 were lost due to enemy action or crashes at a financial cost of £288,049,591. The figure represents 26.6 percent of the total of £1.5 billion paid to the makers of the aircraft and suppliers of some aircraft equipment, such as machine guns, wireless sets, parachutes and dinghies. The £1.5 billion paid for bomber aircraft represents 3.75 percent of all British Government expenditure during the years 1939-1945; and 4.7 percent of all spending on defence for the same period. This is a substantial outlay in any terms.

The analysis of aircraft losses within Bomber Command also shows that these have been understated. In the official records of operational activity, reproduced by Middlebrook and Everitt in *Bomber Command War Diaries*<sup>157</sup>, the emphasis has been on operational losses and that these figures have excluded aircraft lost due to misadventure whilst on Bomber Command's own stations. Harry Holmes in *Avro Lancaster* indicates that a further 588 Lancasters were destroyed or

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157 Middlebrook and Everitt, *Bomber Command War Diaries*, p.707

damaged beyond repair whilst on the ground<sup>158</sup>. The extra Lancasters lost in this way constitute 7.9 percent of all Lancasters produced and the equivalent of 15.99 percent of the 3,677 Lancasters lost or crashed because of operational activity<sup>159</sup>. If a similar number of accidents occurred amongst other aircraft types, it is likely that another £40 million worth of aircraft was lost to Bomber Command during the period of the strategic air offensive.

The importance to this analysis of the value of aircraft losses in Bomber Command during the strategic air offensive is low. This is because the bomber aircraft produced for the offensive had very little intrinsic worth at the end of the war. After 1945, only a very small number of the aircraft in Bomber Command remained on the peacetime establishment. The government sold the vast majority of these aircraft for scrap. Even those aircraft that remained provided Britain with little in the way of economic value due to the limited role that heavy bombers could play in peacetime military operations within what remained of the Empire. On the basis that these aircraft soon ceased to have any value, this thesis argues that the total cost of the heavy bombers is attributable to the strategic air offensive.

In order to get a clearer idea of how much the strategic air offensive cost Britain it is necessary to evaluate the costs incurred in providing the infrastructure and manpower necessary to operate these aircraft during World War II. The

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158 H. Holmes, *AVRO Lancaster*, pp. 117-156

159 Middlebrook and Everitt, *Bomber Command War Diaries*, p.707

implications are that the cost of manpower is a significant component part of the costs associated in maintaining the aircraft involved in the air offensive. These costs will be surveyed in Chapter 8. Of more immediate importance is the cost of infrastructure in the form of the airfields without which the bombers would not have been able to operate.

## *Chapter 5*

### AIRFIELDS

When Sir Archibald Sinclair, the Secretary of State for Air, addressed Parliament during the Estimates Debate on 29<sup>th</sup> February 1944, he took the opportunity to acknowledge the sacrifice and effort of the British people in supplying the Royal Air Force (RAF) with the resources needed to conduct the war. The biggest challenge that Britain had met was building the airfields. Sinclair said, ‘Four and a half years ago, we started the most gigantic civil engineering and building programme ever undertaken in this country’<sup>1</sup>. This engineering marvel had required the government to ‘dispossess people of their land, their houses, and their crops, often with little notice and with no reprieve’<sup>2</sup>. He went on to say, ‘It has not been a pleasant thing for the people of this country to have had their land turned into an air base’ and he was ‘glad to say that we have almost reached the end of our territorial demands’<sup>3</sup>.

Sinclair’s speech is one of the few public acknowledgements of the enormous size of the Air Ministry’s airfield building programme. The construction effort needed to provide enough airfields for the RAF and American 8<sup>th</sup> Air Force was immense with more than one million buildings constructed and enough pavement laid for a

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1 Sir A. Sinclair, 396, *H.C. Deb. 5s*, 29 Feb 44, Column 1275

2 Sinclair, 396, *H.C. Deb. 5s*, 29 Feb 44, Column 1275

3 Sinclair, 396, *H.C. Deb. 5s*, 29 Feb 44, Column 1275

25m wide road from London to Peking<sup>4</sup>. Of the resources that went into this programme, Sinclair estimated that ‘the largest share is given to Bomber Command’<sup>5</sup>. His estimates provide a useful starting point for an evaluation of the economic costs to Great Britain of building the operational infrastructure needed for the strategic air offensive against Germany. Given that the government of the day readily acknowledged the enormous size of this undertaking and the sacrifices made, it is important that we produce an effective estimate of the cost of building, maintaining and operating Bomber Command’s airfields. This chapter traces the building of the airfields in order to estimate the direct and indirect financial cost of this effort, including those incurred in providing the infrastructure, consumables and labour necessary to operate the bomber fleets during the strategic air offensive.

In conducting a bomber offensive, airfields were to prove as important as bomber aircraft. Without all-weather airfields that could enable the rapid take-off and landing of large numbers of heavy aircraft in all weathers, the strategic air offensive would never have reached the size it did during World War II.

Evaluating the costs arising from the construction of airfields and the other facilities needed by Bomber Command are complex. The list of activities examined in this chapter is by no means complete. Amongst the costs not attributed to Bomber Command in this analysis are those associated with the maintenance and repair of aircraft, the transportation and accommodation of

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4 Sinclair, 396, *H.C. Deb. 5s*, 29 Feb 44, Column 1275

5 Sinclair, 396, *H.C. Deb.*, 29 Feb 44, Column 1273

service personnel and the transportation and storage of munitions, petroleum and general stores. The problem encountered in these areas is the impossibility of accurately quantifying the percentage of shared facilities dedicated to Bomber Command from the available documentary records. As a result, the overall costs of these facilities and services that could be credited against Bomber Command cannot be evaluated at this time. Suffice it to say, the inability to identify the full costs makes it probable that they were substantially higher than this chapter suggests.

The first part of this analysis is concerned with the description of airfield design and development during the war. The airfields that Britain built between 1939 and 1945 were revolutionary. Prior to World War II, no nation had built runways of the size that Bomber Command would subsequently require. The needs of Bomber Command were to grow so much that they forced the Air Ministry Department of Works to design and build the first modern airfields, their pavements, traffic control systems and ancillary services from scratch. The control systems, airfield layout that we today see in the larger airports arose out of the wartime activity of the RAF and Bomber Command.

The second part of this chapter deals with the resource implications of developing and operating the air traffic management systems that were needed to control the large number of aircraft movements that arose out of wartime operations. Because of the dominant role of Bomber Command in generating aircraft movements, the national air traffic control system was a part of Bomber

Command during World War II. The final area considered in this analysis is the cost of providing the accommodation and utilities for the personnel and aircraft that served within Bomber Command.

The historical literature dealing with the construction of airfields in wartime falls into three categories. The first comprises first person and participant accounts by individuals intimately involved in the conduct of the strategic air offensive and the contemporary official records such as the House of Commons Debates. The second category consists of works dealing with the technicalities of planning and building airports and pavements. The third category is the later analyses of the building programme and comprises only three books.

Among the primary materials, the most important source is the *House of Commons Debates*. It was in parliamentary debate that Sir Archibald Sinclair, the then Secretary of State for Air, described the size of the airfield construction programme and answered the questions of members in the House of Commons<sup>6</sup>. For example, on 24<sup>th</sup> September 1943, the Member for Abingdon, Sir Ralph Glyn, queried the work ethos of Irish labourers employed on government airfield construction<sup>7</sup>. As well, Sir Arthur Harris's official report on the strategic air offensive of 1948, *Despatch on War Operations*, surveyed the development of Bomber Command's airfields. This report has been used heavily by the later histories on the subject.

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6 Sinclair, 396, *H.C. Deb 5s*, 29 Feb 44, Column 1275

7 Sir R. Glyn, *H.C. Deb 5s*, 392, 24 Sep 43, Column 629-630

Sir Arthur Harris rated the shortage of airfields as one of the most significant restrictions on the expansion of the striking power of Bomber Command, and placed it even before the shortages of aircraft and manpower<sup>8</sup>. While acknowledging that the introduction of heavy bombers led to requirements for longer airstrips, paved taxiways, hard standing and a multitude of traffic control systems, Harris sheeted home blame for delays in making airfields operational to poor planning<sup>9</sup>. In his view, the Air Ministry mismanaged airfield construction and in one case, he even claimed an airfield was ready for operations a year before it was completed<sup>10</sup>. In these matters, Harris displays what was a typical disregard for the effort already expended to provide his command with resources.

Harris's analysis also overlooks the unexpected arrival of the USAAF and their need to have Air Ministry airfields allocated to them. In the case of airfield construction, he completely ignores the engineering innovation in constructing large paved airfields<sup>11</sup>. There is also no acknowledgement of the fact that Bomber Command was the source of most of the requests for modifications to runways and areas of hard standing for parking aircraft on. The need for extensive modifications to existing airfields was caused by the arrival of the larger and heavier bombers and the increased operational tempo as the strategic air

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8 Harris, *Despatch*, p.149

9 Harris, *Despatch*, p.149

10 Harris, *Despatch*, p.149

offensive grew in size. All of these developments led to demand for larger airfields and better layouts as increasing numbers of aircraft made use of the available airfields.

The second category of literature on this subject is the technical writings dealing with the design and construction of airports. The major sources comprise a small number of pre-war works, including the German Carl Pirath, whose earlier German language papers were translated in 1938 into an English edition titled, *Aerodromes, Their Location, Operation and Design*<sup>12</sup>. Pirath's work covered airport locations, the design of terminal buildings, runways and ancillary taxiways and hard standing parking areas. In Germany, airport design had become important at an early stage because Hitler was interested in legitimising air travel as a means of domestic transportation and in the design of the airport buildings themselves<sup>13</sup>.

The other writings in this category are all post war and they describe in detail the engineering of airports and pavements. The bulk of the technical writing of the period is American, and Charles Froesch and William Prokosch were amongst the first to write on the subject with their 1946 book, *Airport Planning*<sup>14</sup>. This work

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11 The Air Staff question Harris's comments on airfield construction in the Air Staff memorandum on the Despatch by Air Chief Marshal Sir Arthur Harris, GCB, OBE, AFC on Bomber Command's Operations 1942/1945' in Harris, *Despatch on Air Operations*, pp. 210-211

12 C. Pirath, *Aerodromes, Their Location, Operation and Design*, Pitman, London, 1938

13 I. Kershaw, *Hitler; 1939-1945, Nemesis*, Allan Lane, The Penguin Press, London 2000, pp. 82-83

14 Charles Froesch and William Prokosch, *Airport Planning*, John Wiley and Sons, New York, 1946

is a technical description on how to plan and build airports. The usefulness of this text is the information it provides on the difficulties of airfield construction and the importance of the knowledge and experience gained in building all weather airfields during World War II. A second American text, *Airport Engineering*, published in 1948 and written by three engineers, H. Oakley Sharp, G. Reed Shaw and J. A. Dunlap, supplies a similar description of airfield development to that given by Froesch and Prokosch<sup>15</sup>.

The Institution of Civil Engineers, Airport Engineering Division, published the first British text on the subject of airfield design in 1948<sup>16</sup>. This work, written by W.J. Cozens, describes the specific details of airfield construction and the experience gained by British engineers during World War II. In 1951, an official publication, written by E.H. Davis, dealt with the construction of pavements for roads and airfields and also acknowledged the importance of the developmental work carried out during the building of military airfields in Britain during World War II<sup>17</sup>. Davis's work is a technical description of engineering calculations and directions on the selection of suitable ground for pavements and the preparation of the ground for the laying of the pavement system. It describes how British engineers used the limited experience of American highway engineers in the construction of the Air Ministry's airfields during World War II. Davis also

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15 H. Oakley Sharp, G. Reed Shaw and J. A. Dunlap and, *Airport Engineering*, John Wiley and Sons Inc., New York, 1948

16 W.J. Cozens, *Problems in the Selection of Sites for Civil and Military Air Stations*, The Institution of Civil Engineers, Airport Engineering Division, London, 1948, p.6

17 E.H. Davis, *Pavement Design for Roads and Airfields*, HMSO, London, 1951, pp. 1-14

describes how British engineers developed their understanding of pavement design by trial and error during the war<sup>18</sup>.

This body of material describes how British engineers drew on the limited information available from American highway projects in the late 1930s to develop concrete and macadamming as load bearing layers for airfields. The airfields used by the RAF and the United States Army Air Forces during the Second World War were to be the testing ground for these new engineering techniques as they were the first large scale paved structures to be erected for heavy wheeled traffic. The contemporary and technical nature of these sources makes them essential reading for anyone attempting to establish how technically innovative the building of pavements was in 1939. The general history of the period completely ignores the innovative nature of pavement design and the enormous size of the Air Ministry's airfield programme.

In contrast to the large volume of work that deals with the military aspects of the air war there is little historical work available on airfield construction during World War II. Of the official histories, the most useful is Charles Mendel Kohan's volume of the Civil Series, *Works and Buildings*<sup>19</sup>. Kohan's volume provides a mine of information on wartime labour and resource costs in general and it is one of the most readable of the volumes of the official history. Aside

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18 Davis, *Pavement Design*, pp. 1-14

from Kohan, none of the other official historians pays attention to the construction of airfields. Webster and Frankland, in their 1961 military history of the strategic air offensive<sup>20</sup>, state only that the Air Ministry built the necessary airfields<sup>21</sup>.

Other more recent works on airfield construction during World War II include Bruce Robertson's 1977 work on airfield archaeology<sup>22</sup> and Roger Freeman's 1978 work on the airfields used by the American Eighth Air Force in Britain<sup>23</sup>. Freeman provides interesting detail on the cost of building the airfields and maintaining these airfields and is a useful source on British airfield construction during World War II. Later works include David Smith's *Britain's Military Airfields*<sup>24</sup> written in 1989, and Robin Higham's 1998 *Bases of Air Strategy: Building Airfields for the RAF 1914-1945*<sup>25</sup>. Of the four works Higham's is the most useful and is less of a 'buffs' book. Higham details the technical and economic cost of airfield construction in all theatres of operations during World War II, including the strategic air offensive against Germany. The book is a comprehensive and detailed evaluation of this area to date and provides a wealth

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19 C.M. Kohan, *Works and Buildings*, History of the Second World War, Civil Series, HMSO, London, 1952

20 Webster and Frankland, *The Strategic Air Offensive*, Vol I, p.19

21 Webster and Frankland, *The Strategic Air Offensive*, Vol I, p.19

22 B. Robertson, *Aviation Archaeology: A Collectors Guide to Aeronautical Relics*, Stephens, Cambridge, 1977

23 R.A. Freeman, *Airfields of the Eighth: Then and Now*, After the Battle Publications, London, 1978, p.8

24 D. Smith, *Britain's Military Airfields, 1939-45*, P. Stephens, Wellingborough, 1989

25 R. Higham, *Bases of Air Strategy: Building Airfields for the RAF, 1914-1945*, AirLife Publishing, Shrewsbury, 1998

of information on construction techniques, problems and costs. To date, it is the best available general source on this subject.

Before 1938, few engineers really understood the technical challenges of building concrete or paved airstrips<sup>26</sup>. Based on the experience of road building the civil engineering profession knew that building a large paved airstrip would be a major project. What they did not know was that building airstrips on the scale needed to conduct the strategic air offensive would present problems of space. Britain was not going to be large enough for all of the activity required to conduct an air war on the scale that eventuated. The most significant problems were a scarcity of large areas of stable soil and a shortage of clear airspace. In siting airfields, the first requirement was to find a large enough area of stable soil that would support a large flat concrete surface. Once found, such an area was had to take as many airfields as possible and this required clear flight paths, approaches and sufficient airspace for the operation of large numbers of aircraft. Putting these two requirements together ruled out substantial parts of the United Kingdom. This lack of airspace was significant and it is unlikely that the British air war could have been as large as it was if the main part of the air training scheme had not been located in Canada<sup>27</sup>.

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26 Davis, *Pavement Design*, p.1

27 British Bombing Unit, *The Strategic Air War Against Germany, 1939-1945*, Frank Cass, London, 1998, p.1

It is most probable that British engineers picked up their information from the United States, where road building led to the first technical innovations in pavement design<sup>28</sup>. One piece of evidence for this is the widespread use by British engineers of O.J. Porter's California Bearing Ratio Method (CBRM), which Porter had developed while working for the California State Highway Department prior the World War II<sup>29</sup>. British engineers throughout World War II used the CBRM and in Britain it remained the most widely used method for designing flexible pavements until well after World War II<sup>30</sup>. British engineers publicly admitted the debt they owed to their American colleagues for the initial developments in the pavement designs that enabled the building of 'economical but stable runways for the heavier aircraft which first came into general use during the last war'<sup>31</sup>. In turn, the engineers later used the new airfield developments in road building as heavy motor vehicle traffic increased and led to a need for more robust road surfaces<sup>32</sup>.

The programme of construction confronting the Air Ministry Directorate of Works presented a host of challenges not just in size and expense, but also in the development of new engineering and industrial techniques. In addition, the imperative to build airstrips as quickly as possible did not allow time for experimentation or testing and, as a result, there were some serious faults with the

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28 C. Froesch and W. Prokosch, *Airport Planning*, John Wiley and Sons, New York, 1946, p. vii

29 Davis, *Pavement Design*, p.14

30 Sharp, Shaw and Dunlap, *Airport Engineering*, p.51 and Davis, *Pavement Design*, p.14

31 Davis, *Pavement Design*, p.1

work done<sup>33</sup>. However, given the demand for rapid construction, it is most surprising that so little went wrong and it is a mark of the Air Ministry's success with this programme that it was able to construct enough airfields to meet American needs as well as its own. At the end of the war, airfield construction was one activity where, under the lend lease arrangements, Britain supplied the United States with resources that were regarded as reciprocal aid and credited against Britain's liabilities<sup>34</sup>. It was a startling success and an example of British engineering excellence and industrial expertise.

### **A Bomber Airfield**

In 1939, the typical Bomber Command airfield varied very little from those used during World War I. Such airfields occupied an area of approximately 250 hectares and provided the facilities and accommodation for the 1,134 personnel who maintained and operated one squadron of 12 aircraft<sup>35</sup>. Each of these stations had a single satellite station manned by a further 586 personnel which duplicated some of the essential services found on the main station. Of the 27 airfields in Bomber Command in 1939, only nine had limited paved landing strips<sup>36</sup>. The low number of paved airfields did not cause major problems during

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32 W.H. Glanville, Director of Road Research, Road Research laboratory, Department of Scientific and Industrial Research, Foreword in Davis, *Pavement Design*, 1951

33 Kohan, *Works and Buildings*, p.280

34 Hancock and Gowing, *British War Economy*, p.547

35 Kohan, *Works and Buildings*, p.282

36 PRO AIR 14/298 Minute on Number of Stations Opened, 29<sup>th</sup> Jan 1939 and Kohan, *Works and Buildings*, p.278

the earlier part of the war because the aircraft available at the time could easily operate from grass airstrips. Until late 1940, the largest aircraft operated by Bomber Command was the Wellington. The Wellington weighed 14,500 kg at its heaviest<sup>37</sup>. By comparison, the Stirling, Halifax and Lancaster had loaded weights of 30,000 lbs<sup>38</sup> and could not operate off a grass strip.

Amongst the services provided by a main station were facilities for maintenance, flying operations, personnel and utility supply. Maintenance facilities included hangars, workshops, administration offices, stores and the mechanical and electrical engineering installations needed to maintain the aircraft. For flying operations there were control towers, metrological offices, briefing rooms, gun butts, bomb dumps, armouries, petrol, oil and lubricant (POL) storage facilities and rudimentary lighting systems at some airfields<sup>39</sup>. For personnel there were water reservoirs and pumping systems, sewage systems, sleeping quarters, messes, kitchens, medical centres, churches, cinemas, offices and rest facilities for both air and ground crews. In order to operate all of the above facilities and to co-ordinate them as part of a military campaign each airfield required electricity, gas and telecommunications. All of these had to be planned, designed, manufactured and constructed before a single aircraft could begin military operations against the enemy.

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37 Higham, *Bases of Air Strategy*, p.67

38 Higham, *Bases of Air Strategy*, p.67

39 Higham, *Bases of Air Strategy*, p.50

## Selecting the Site

The first step in preparing an RAF airfield was the engineering assessment of the prospective site carried out by the Air Ministry Directorate of Works. For the engineer there were four basic problems: First, maximum safety in take off and landing; second, minimizing taxiing distances so as to expedite take off and landing; third, efficient handling and loading of aircraft on the ground; and fourth, arranging the runways to provide suitable air separation in the air traffic patterns of landing and taking off aircraft<sup>40</sup>.

In addressing these four problems the engineer also had to consider general topography, slope and soil analysis. In selecting an airfield, the surveyors and engineers paid careful attention to surrounding topography. Given the intention to place large numbers of quickly trained volunteers into large, heavily loaded aircraft and have them fly great distances into enemy territory, it was essential that the terrain around a bomber airfield provided large expanses of flat land<sup>41</sup>. Heavily laden or damaged bombers of the size and construction of a Halifax, Stirling and Lancaster required a very large airspace to allow for the long, clear flying approaches so that aircraft could make safe approaches from a large variety of directions<sup>42</sup>. It comes as no surprise that suitable sites were very quickly

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40 Froesch and Prokosch, *Airport Planning*, p.93

41 Froesch and Prokosch, *Airport Planning*, p.92

42 Kohan, *Works and Buildings*, p.278

developed leading to more and more unsuitable sites having to be utilised<sup>43</sup>.

Despite all attempts to overcome these problems, Bomber Command faced significant congestion of its airspaces due to the placement of its airfields in South Yorkshire, Lincolnshire, Huntingdonshire, Cambridgeshire and Norfolk<sup>44</sup>.

The type of airfield that the RAF required dictated the geographical location in which the Directorate of Works would build it. A fighter airfield had to be close to areas of expected threat, so that quick intercept and turn-around times (landing for refuelling and re-arming) could be obtained. A 1940s bomber airfield had to have a large area due to the wider wingspans creating a need for much bigger spaces to taxi and park such aircraft; a training station required open flat areas free of housing and interference from other air traffic<sup>45</sup>. Given the above requirements, it is not hard to see why the RAF deployed Fighter Command to the Southern and Eastern coasts and placed the Empire Air Training Scheme in Canada.

Once the Directorate of Works staff had identified a site as suitable they carried out the quantity survey, conducted detailed investigations and undertook other preliminary operations until the Air Ministry issued the contracts for construction.

In order to do this job the Directorate of Works had to keep abreast of developments in the techniques of airfield building, changes in RAF policies and

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43 Kohan, *Works and Buildings*, p.283

44 Harris, *Despatch*, p.156

the resources available. This was, as Kohan puts it, ‘an arduous and exacting duty’<sup>46</sup>. Adroitness in technical and administrative manoeuvre and good liaison between the technical branches of the Ministry, surveyors, contract branches and contractors did much to smooth the way<sup>47</sup>.

### The Runway



Fig. 5.1 Source: B. Baxter, <http://www.bomber-command.info/afl.htm>

The engineering profession was well aware that the construction of an airfield runway had now become a major engineering work and that even a simple grass strip required careful siting. The selection of an airstrip site involved the survey, testing and analysis of the ground upon it was to sit and the topography of the region. The major concerns were drainage, gradient of the ground and the type of

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45 W.J. Cozens, *Problems in the Selection of Sites for Civil and Military Air Stations*, The Institution of Civil Engineers, Airport Engineering Division, London, 1948, p.6

46 Kohan, *Works and Buildings*, p.280

47 Kohan, *Works and Buildings*, p.280

soil and grass that covered it<sup>48</sup>. Careful selection of the site was vital to limit the cost of development. Drainage was important because of the need to remove large quantities of water that sealed runways would collect. Soil type was also important because of the need for a solid weight-bearing sub-stratum for load bearing. Slope was also important because of the need to have exact gradients for aircraft to land upon and any variation from these gradients would require excavation to achieve the correct gradient. The building of a landing strip was no minor technical problem and the Air Ministry soon found that obtaining good sites became more and more difficult as the number of stations increased and there was an increasing use of less appropriate sites leading to greatly increased excavations and rising costs<sup>49</sup>.

After the surveying and detailed investigations were completed the Air Ministry obtained the potential site for an airfield either through direct compulsory purchase or forced renting through administrative orders for the duration of hostilities. Once the Air Ministry had control of the site, the contractor excavated the airfield and installed the drainage system. At the same time, the trenches, conduits, access points and manholes of the electrical and communications systems were constructed. Once these sub-surface services were installed, the sub-base soil was compacted and a stone sub-surface put down and compacted.

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48 Froesch and Prokosch, *Airport Planning*, pp. 83, 124; W.J. Cozens, *Problems in the Selection of Sites*, p.21; Davis, *Pavement Design*, p.3 and Sharp, Shaw, and Dunlop, *Airport Engineering*, p.47

49 Kohan, *Works and Buildings*, p.283

After all of this was completed, the wearing surface of concrete paving was laid and the airstrip was complete.

In 1940, the standard dimensions of a bomber airfield were three runways 915 m long by 45 m wide (1,000 by 50 yards) with dispersed buildings and accommodation blocks and services such as water and sewage all being incorporated into the site. By 1944, Bomber Command's airfields had grown with one 1,830 m long by 45m wide, (2,000 by 50 yards) main runway and two subsidiaries of 1,281m long by 45m wide (1,400 by 50 yards)<sup>50</sup>. The sizes of these airfields increased when hangars of even greater size and more accommodation for the larger numbers of personnel based on the airfields were added.

One negative impact of airfield construction was the opportunity costs associated with the displacement of the normal activity previously conducted on the site.

One of the leading opportunity costs associated with the building of the airfields was the displacement of agriculture<sup>51</sup> and this problem was significant enough for the Secretary of State for Air, as noted above, to tell Parliament in 1944 that he was glad that 'we have almost reached the end of our territorial demands'<sup>52</sup>.

Sinclair's sensitivity over the displacement of agriculture may have been due to

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50 Kohan, *Works and Buildings*, p.283

51 Cozens, *Problems in the Selection of Sites for Civil and Military Air Stations*, p.5

52 Sinclair, *H of C Deb 5s*, 29 Feb 44, Column 1275

the number of questions directed to government ministers about the timing of the release of land from the Air Ministry back to agricultural and other uses<sup>53</sup>.

Sinclair had good reason to be concerned over the amount of land being taken up by the Air Ministry. In 1942, the average size of a Bomber Command airfield was 1.6 Km x 2.4 Km, an area of 320 hectares or 988 acres. In that year Bomber Command had 79 such airfields, by 1944 the number of these airfields had grown to 131<sup>54</sup>. These figures give a total area for Bomber Command airfields alone of 78,052 acres in 1942 increasing to more than 129,428 acres by late 1944. In terms of opportunity cost measured as a loss of potential crop production, this represented either 3,792,023 tons of potatoes, 542,308 tons of wheat or 4,807,223 tons of sugar beet, depending on the crop sown on the land<sup>55</sup>.

In relation to overall British production of these crops during the war, the loss due to the diversion of agricultural land for use by Bomber Command represents enough land to have grown either 7.5 percent of the total potato crop, 3.2 percent of the wheat crop or 19.4 percent of the sugar beet crop<sup>56</sup>. Although the significance of these losses to the war effort is unclear there is no doubt that Britain's economic health was damaged as imports, particularly of flour, refined

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53 H.C. Deb., Vol. 397-406

54 Harris, *Despatch*, p.153

55 Central Statistical Office, *Statistical Digest of the War*, HMSO, Tables 57, 59 and 65

56 Central Statistical Office, *Statistical Digest of the War*, Tables 57 and 59

sugar and animal products, were increased and the exports of such products almost ceased<sup>57</sup>.

Based on an average export price of £52.00<sup>58</sup> per ton for British wheat, and if wheat had been the crop sown on the land, then the opportunity cost of Bomber Command's airfields in wheat production was around £28.2 million over the period of the war. Even if the much lower 'Farm Gate' price of £14.5 per ton<sup>59</sup> paid to the farmer under the governments pricing system is used, the financial loss for the same period was £7,863,466.

<b>Estimated Potential Crops Losses Due to Bomber Command Airfields</b>			
<b>Year</b>	<b>Potato (Tons)</b>	<b>Wheat (Tons)</b>	<b>Sugar Beet (Tons)</b>
1939	19,740	24,809	27,476
1940	304,304	35,766	383,334
1941	414,960	52,759	551,304
1942	569,780	79,613	725,883
1943	746,928	106,170	971,006
1944	854,225	126,192	996,597
1945	882,086	116,998	1,151,613
<b>Total</b>	<b>3,792,023</b>	<b>542,308</b>	<b>4,807,223</b>

Fig. 5.2: Source: Based on figures in Tables 59 and 60 Statistical Digest of the War, p.60

If potatoes had been planted instead of wheat the loss at the farm gate would have been £6.65 per ton, giving us a loss in the order of £25,216,952, without taking

57 Central Statistical Office, *Statistical Digest*, Tables 72, 144, 147

58 Central Statistical Office, *Statistical Digest*, Table 144. This average excluded 1944 where an estimate of £283 per ton is obtained.

59 Mr. R.S. Hudson, Minister of Agriculture, *H.C. Deb.*, 396, 26 Jan, 44, Column 714

into account any value adding or export premiums<sup>60</sup>. For sugar beet, the farm gate loss was £15, 046,608<sup>61</sup>. Aside from the financial value of this potential loss is the cost of importing wheat and other produce to make up the national deficit. From 1940 until 1944 Britain was forced to import 21.13 million tons of wheat (£1.09 billion in equivalent value), 31.1 million tons of flour and meal and 1.7 million tons of potatoes<sup>62</sup>. This need to import basic foodstuffs added to the shortage of shipping and, as almost 5 percent of all wheat imported into Britain during the period 1940-1945 was lost at sea<sup>63</sup>, the cost is measured in lives as well as cash.

### **Excavation**

As already mentioned above, the design of an airfield requires the landing strips to be oriented to minimise the dangers of cross winds and to enable omnidirectional take off and landing<sup>64</sup>. Landing of aircraft also requires a slope with a grading of no more than 7.5 cm<sup>65</sup> and a surface and supporting structure that can rapidly transmit the stresses imposed by the landing of heavy aircraft through the airstrip structures into the surrounding earth<sup>66</sup>. In order to achieve

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60 Hudson, *H.C. Deb.*, 396, Column 714

61 Hudson, *H.C. Deb.*, 396, Column 714

62 Central Statistical Office, *Statistical Digest*, Table 72

63 Central Statistical Office, *Statistical Digest*, Table 72

64 Sharp, Shaw and Dunlop, *Airport Engineering*, p.73

65 Higham, *Bases of Air Strategy*, p.67

66 Kohan, *Works and Buildings*, p.283

this effect the runway is built in several layers, each with its own function<sup>67</sup>. In a concrete runway, the concrete slab is the wearing surface and its function is to distribute loads over as wide an area as possible. An underlying layer of compacted stone chippings or stabilised soil acts to distribute the loads and to provide a satisfactory surface upon which to lay the concrete. Under these layers is the soil sub-grade. The sub-grade is levelled and compacted to increase the speed of transmission of landing forces on the wearing surface.

In order to prepare the ground for these layers it has to be excavated. The amount of excavation required for an average Bomber Command airstrip varied from 38,250m<sup>2</sup> in 1939 to 229,500m<sup>2</sup> later in the war<sup>2</sup>, although as the war progressed and the available sites became more difficult the amount of excavation required increased with some stations requiring the removal of up to 764,555 m<sup>3</sup> of spoil<sup>68</sup>. This activity placed an immense burden on the already stretched transport resources available within Britain. If it is accepted that the average four ton truck of the time was able to carry approximately 3-4m<sup>3</sup>, depending on moisture content, then the above figures would roughly suggest that the average Bomber Command airfield required 9,562 truck loads of spoil moved in 1939 rising to 57,375 later in the war<sup>69</sup>. This estimate is conservative, as it does not include the return trip of empty vehicles. For the period of the war, and using the figures above as a basis, it is reasonable to estimate an approximate total of 3.5 million 4

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67 Davis, *Pavement Design*, p.1

68 Kohan, *Works and Buildings*, p. 284

69 Calculated from figures of spoil removed in Higham, *Bases of Air Strategy*, p.60

ton truck loads of spoil removed and dumped on behalf of Bomber Command.

This would give a daily average of 1,687.5 loads or round trips.

Excavation of the area also had to take into account the need for underground structures, particularly the placement of up to 81 Km of drains needed to remove approximately 950,000 litres of water that paved runways could collect on the surface of the concrete<sup>70</sup>. The rapid removal of such large volumes of water was essential to keep a paved landing strip operational in the wet weather so common in Britain. It was also important to remove water as rapidly as possible from the area of an airstrip so that it did not penetrate the small cracks in the structure and cause structural damage through the cycles of freezing and melting of water trapped within the layers of the airstrip<sup>71</sup>. The engineers had to plan carefully the diversion of such large amounts of water, as, even in 1939, the impact on the local county side had to be minimised. Local authorities were proactive in ensuring that the diversion of airfield runoff into existing watercourses did not cause flooding or damage to the surrounding waterways or catchments<sup>72</sup>. As well as drains, the builders had to install conduit for telephone and extensive electrical cable required to operate an all-weather, night time airfield<sup>73</sup>. After the

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70 Higham, *Bases of Air Strategy*, p.57

71 In the United Kingdom the problems consisted of direct water damage to the concrete and its base soils and damage cause by low temperatures leading to ice formation within the sub-soils. This ice expanded the space in which it formed before thawing leaving a cavity, which then collapsed causing cratering of the surface above.

72 Kohan, *Works and Buildings*, p.280

73 Kohan, *Works and Buildings*, p.285

contractors had installed all of these services, the ground could be prepared and the landing strip pavement put down.

### **Laying the Pavement**

Although engineers had been working on the rational design of pavements from as early as the first two decades of the twentieth century, it was the necessity of ‘providing economical but stable runways for the heavier aircraft’ that brought about the adoption of widely accepted methods of design and construction in Britain<sup>74</sup>. As noted above runways usually consisted of several layers with each having a special function. The concrete slab provides the wearing surface and distributes the load. Where the sub-grade soil is poor then a base of compacted stone or stabilized soil is required to distribute the load and to provide a satisfactory surface upon which to construct the slab<sup>75</sup>. Most structural failures in this type of paving arose out of excessive traffic stress, moisture or temperature damage to the layers (including the concrete) and failure of the adhesive bonds in the concrete or bitumen due to poor workmanship<sup>76</sup>.

For Bomber Command the impact of the speed of the programme prevented engineers from experimenting to find the most effective way of constructing

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74 Davis, *Pavement Design*, p.1

75 Davis, *Pavement Design*, p.1

76 Davis, *Pavement Design*, p.1

paved surfaces<sup>77</sup>. This caused ‘an enormous amount of repair work to runways and perimeter tracks’ to be undertaken<sup>78</sup>. One of the causes of this large rate of failure is identified by Higham as being due to the speed of construction lowering quality assurance<sup>79</sup>, poor drainage, the lack of the ‘ironing effect’ by constant traffic<sup>80</sup> and the use of unwashed ballast<sup>81</sup>. The areas most affected by this wear and tear appear from the available evidence to have been the taxiways and hard standing around the periphery of the airfields<sup>82</sup>.

<b>Airfield Construction 1939-1945</b>			
<b>Year</b>	<b>Airfields Provided with Paved Runways</b>	<b>Bomber Command Airfields</b>	<b>Airfields on Which Extensions to Runways were Carried Out</b>
1939	9	27*	-
1940	40		14
1941	143		49
1942	136	79	63
1943	78	105	31
1944	38	128	16
1945	-	121	-

**Fig. 5.3: C.M.Kohan, *Buildings and Works*, p.284, \* Harris, *Despatch*, 153,**

The taxiways were the areas of an airfield that were subjected to the most use and, as the engineers explained, taxiways and hard standing were also badly affected by the vibrations created by the running of aircraft engines as part of warm up

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77 Kohan, *Works and Buildings*, p.279

78 Harris, *Despatch*, p.157

79 Higham, *Bases of Air Strategy*, p. 58

80 Higham, *Bases of Air Strategy*, p.68

81 Higham, *Bases of Air Strategy*, p.69

82 Harris, *Despatch*, p.153

procedures and routine maintenance<sup>83</sup>. In 1948 the recommended thickness for such areas was ‘at least 12 inches’ of material which is ‘non-capillary in nature’<sup>84</sup>, otherwise the pavement would crumble. This factor, combined with the lack of time British engineers had in which to experiment, is the most likely explanation for the serious problems affecting taxiways that caused Sir Arthur Harris complaints.

Another factor affecting the design and construction of Bomber Command’s airfields was enemy activity. The need to secure the collected bomber aircraft from damage due to enemy raids led to a large number of dispersal schemes. The major source of these changes was Bomber Command itself and approximately 2,600 such schemes were prepared for implementation on its airfields<sup>85</sup>. The threat was real and the Luftwaffe made 877 actual attacks against what they thought were Bomber Command airfields, 434 made against operational airfields and the 443 attacks against decoy airfields<sup>86</sup>.

The need to disperse aircraft increased the amount of paved taxiway required to 4.8Km per bomber station. Added to this was an increased need for added hard standing to park growing numbers of aircraft<sup>87</sup>. With the introduction of the heavy bombers, all of these taxiways, hard standing and runways needed

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83 Sharp, Shaw and Dunlop, *Airport Engineering*, p.73

84 Sharp, Shaw and Dunlop, *Airport Engineering*, p.73

85 Harris, *Despatch*, p.157

86 Higham, *Bases of Air Strategy*, p.61

87 Kohan, *Works and Buildings*, p.283

strengthening through thickening<sup>88</sup>. From 1943 until the end of the war in 1945, the Air Ministry works Department resurfaced 30,810,000m<sup>2</sup> of pavement in order to strengthen them. This work appears to have been in addition to an ‘enormous amount of repair work’ which Harris comments upon in *The Despatch*<sup>89</sup>.

### **Cost of Extensions to Existing Airfields 1943**

CCRC	£27,000,000
OTU	£3,500,000
Fighter Command	£4,000,000
Coastal Command	£2,000,000
Army Co-Operation Command	£50,000
Minor Extensions	£50,000

**Fig. 5.4:**

**Source: C.M.Kohan, *Buildings and Works*, p.298**

The design of taxi tracks and hard standing had to balance dispersal with the fast and efficient movement of aircraft on the ground and to take account of larger aircraft. For example, the 1939 Wellington had weighed no more than 14,500Kg, it was 18.54m long and it had a wingspan of 26.26m<sup>90</sup>. In 1942, the Lancaster weighted 30,909 Kg, it was 21.08m long and it had a wingspan of 31m<sup>91</sup>. These later aircraft not only required thicker paving, they also required greater surface area for turning and parking and taxiways wide enough to allow for the fast taxiing essential if a Bomber Command station was going to get its 32 aircraft

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88 Harris, *Despatch*, p.153

89 Harris, *Despatch*, p.157

90 Higham, *Bases of Air Strategy*, p.67

91 Kohan, *Works and Buildings*, p.283

airborne in a reasonable time, which was set at 45 seconds<sup>92</sup>. Bomber Command was more generous with landing, allocating three minutes to each returning aircraft<sup>93</sup>.

When Harris changed Bomber Command's tactics from independent flight to bomber stream in 1942, the importance of rapid movement and take-off increased substantially. Using the above figures the fastest that the 32 aircraft at an individual station could become airborne was 24 minutes. It would be interesting to see how often this happened. If all 32 aircraft returned, it took, at best, 1 hour 36 minutes for them all to land. This dwell factor affected bomb loads, fuel consumption and aircrew exhaustion, although Harris makes no comment on the latter effect<sup>94</sup>. It would be equally interesting to note if there was a higher incidence of crashes amongst later landing aircraft than amongst those landing first.

The construction of runways, perimeter tracks and hard standings at a standard Bomber Command station required an enormous amount of materials, such as crushed stone (metal), cement and ballast. Although it is unknown how the engineers managed the logistics of this activity, perhaps the empty trucks that had taken away the useless spoil were loaded for the return journey. C.M. Kohan estimates that the average Bomber Command station used approximately

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92 Higham, *Bases of Air Strategy*, p.60

93 Harris, *Despatch*, p.189

94 Harris, *Despatch*, p.189

688,099m<sup>3</sup> of ballast, usually in the form of stone chippings, and 18,288 tonnes of cement. The total mass of these two materials was 132,086 tonnes. With the average lorry of the period being only 4.06 tonnes, it would have required approximately 32,512 one-way trips to remove waste soil and replace it with stone chips and other building materials. The total amount of materials moved as part of constructing Bomber Command's 131 stations was 17,303,266 tonnes in 4,259,113 trips<sup>95</sup>.

<b>Airfields Under Construction 1943</b>			
<b>Category</b>	<b>More than 25 percent Complete</b>	<b>Less than 25 percent Complete</b>	<b>Total</b>
Bomber	28	29	57
Emergency Runway	1	0	1
Fighter	3	2	5
Advanced Landing Grounds	0	8	8
Coastal	5	0	5
Army Co-Operation	1	0	1
Transport	2	0	2
Flying Training	1	1	2
Ferry Command	0	1	1

**Fig. 5.5:**

**Source: C.M. Kohan, *Buildings and Works*, p.298**

To make these figures more understandable the construction of landing strips, taxiways and hard standing (excluding all building construction) for Bomber Command alone required the movement of 8,477 tonnes in 2,087 4.06 tonne lorry trips of up to 100 miles every day of the Second World War<sup>96</sup>. Added to the trips to remove waste soil there was an average of 3,754.5 daily round trips by four ton

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95 Calculated from figures given in Kohan, *Works and Buildings*, p.285

96 Calculated from figures given in Kohan, *Works and Buildings*, p.285

lorries. This represented a considerable problem for Britain, as lorries were in short demand from the very beginning of the war when the impressment of contractors' vehicles by other departments slowed work on RAF bases<sup>97</sup>.

Kohan has estimated the financial cost of constructing a 1942 triangular airstrip with its attendant taxiways and hard standing as being 'more than £500,000.00'<sup>98</sup>. Harris in *Despatch* reports that the average airfield in 1944 had doubled in price from £500,000 in 1942 to £1,000,000 in 1944<sup>99</sup>. Robin Higham, in *Bases of Air Strategy*, gives a much higher figure of £1,800,000 for a bomber airfield, 'not including buildings, water supply and sewage'<sup>100</sup>. The problem with the figures is that there is no agreement in any of the sources regarding the costs of building an airfield. It is likely that the figure given by Kohan is too low and that Higham's figure is too high. The average of the three figures is £1,100,000 and this figure is probably reasonably close to the actual cost of constructing the airstrip runways, taxiways and hard standings built for Bomber Command during World War II.

In 1942, figures in Kohan give a cost for the 79 operational stations used by Bomber Command at around £39,500,000<sup>101</sup>. This includes the cost of upgrading the 27 operational airfields Bomber Command held at the beginning of the war.

The upgrading of these stations during war operations can only have increased the

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97 PRO CAB 68/1, Supply and production First report by the Air Ministry, 23<sup>rd</sup> Sept 39, p9

98 Kohan, *Works and Buildings*, p.281

99 Harris, *Despatch*, p.153

100 See Higham, *Bases of Air Strategy*, p.40

101 Kohan, *Works and Buildings*, p.281

complexity and cost of such work. In 1943, the Air Ministry spent £36.6 million on extending existing airfields and of this figure £33,300,000 went to extending Bomber Command airfields<sup>102</sup>.

In 1943, which was not the peak year for airfield construction, Kohan gives a figure of £126,000,000 for actual expenditure on Air Ministry construction<sup>103</sup>, including 82 airfields of which 69.5 percent were for Bomber Command<sup>104</sup>. The cost of £126,000,000 given by Kohan is £4 million higher than the £122,000,000 that the Central Statistical Office gives for military construction work carried out in the United Kingdom that year<sup>105</sup>. Given the central role of airfields in the war operations of the RAF it is reasonable to assume that if 69.5 percent of the airfields were for Bomber Command approximately that percentage flowed into all other aspects of RAF construction. If so, 69.5 percent or £87,600,000 of the Air Ministry's 1943 expenditure on construction was for Bomber Command. This percent would be in line with the Secretary of State for Air, Sir Archibald Sinclair's, statement to the House of Commons that; 'Of the resources allocated to the air war the largest share is given to Bomber Command'<sup>106</sup>.

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102 Kohan, *Works and Buildings*, p.298

103 Kohan, *Works and Buildings*, p.281

104 Kohan, *Works and Buildings*, p.29

105 Central Statistical Office, *Statistical Digest*, Table 54. p.56

106 Sinclair, *Hof C Deb 5s*, 29 Feb 1944, Column 1273

### Expenditure on Buildings

Year	Expenditure
1935	£750,000 - £1,250,000
1938	£25,000,000
1939	£50,000,000
1940	£75,000,000
1941	£125,000,000
1942	£145,000,000
1943	£126,000,000
1944	£40,000,000
1945	-

Fig. 5.6:

Source: C.M.Kohan, *Buildings and Works*, p.281

Kohan provides a total figure of £587,250,000.00 for Air Ministry construction between 1939 and 1945. Based on a percentage of 69.5 percent, the total cost allotted to Bomber Command is £408,138,750. This is the equivalent of £3,108,584.00 per station. This figure makes the £1,100,000 average cost for the construction of an airstrip and paving derived from the figures given by Sir A. Harris and C.M. Kohan in the official histories<sup>107</sup> and quoted by other sources such as R.A. Freeman in *Airfields of the Eight*<sup>108</sup> and Robin Higham, to be a reasonable figure. The total cost of paving the 128 Bomber Command stations is therefore around £140,800,000.

The Air Ministry spent a further £5.25 million on three large emergency runways at Carnaby, Woodbridge and Manston. These emergency landing strips came under the control of Bomber Command, which was responsible for all air traffic control in the UK, although all Allied aircraft in distress used them. These

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107 See Harris, *Despatch*, p.153, and Kohan, *Works and Buildings*, p.283

108 R.A. Freeman, *Airfields of the Eight*, p.8

airfields had a 2,745m long by 225m wide concrete surface, roughly equivalent to 64.36 kilometres of main road'<sup>109</sup>. Finally, in early 1945, three Bomber Command stations had runways widened from 45 m to 90 m in width and lengthened by one third, from 1,830 m to 2,745 m. The cost of these extensions for each station was £1,750,000, another £5,250,000 on the overall bill<sup>110</sup>.

The calculations made here lead to an estimate of the cost for building Bomber Command's airstrips and pavement of something in the order of £151,500,000. This cost does not include the £99,000,000 spent on building airfields for Bomber Command that the Air Ministry later transferred to the United States Army Air Forces<sup>111</sup>. Nor does it take into account the cost of repairing and maintaining these airstrips once they became operational.

Having now established the approximate size of Bomber Command's pavement it is necessary to identify the cost associated with building all of the facilities and services required to house and support the 59 different functions carried out on such an airfield<sup>112</sup>.

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109 Kohan, *Works and Buildings*, p.284

110 Kohan, *Works and Buildings*, p.160

111 Kohan, *Works and Buildings*, p.286

## **Airfield Lighting and Traffic Control**

In order to keep a logical progression this section will describe the various facilities required for a bomber station by working from the airstrip out and starting with the lighting systems used on those airstrips. In 1939, Bomber Command had no airstrip lighting and did not foresee a need for more than a rudimentary system. Following the initial losses inflicted by the German defenders over the North Sea and the need to change from day to night operations lighting became an urgent requirement. As the war continued and the complexity and size of Bomber Command's operations increased, the complexity and size of the aerodrome lighting systems increased as well.

The vital importance of effective aerodrome lighting and control systems came from the need to prevent the unnecessary loss of valuable aircraft due to such simple accidents as running off the taxiway into soft wet earth. Within Bomber Command, Harris estimated that the wastage rate of aircraft within the boundaries of its own airfields was as high as one aircraft damaged per 227 flying hours<sup>113</sup>. Airfield accidents were so bad that by March 1942, the Air Ministry standardised airfield markings and lighting, local landing and taxiing procedures and the creation of a central air traffic control organisation under the control of Bomber Command. At the beginning of 1942, the intended increase in the operational intensity proposed by Harris was under threat from the simple fact that it took one

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112 Higham, *Bases of Air Superiority*, p.50

113 Harris, *Despatch*, p.187

hour to land 12 aircraft, or six minutes per aircraft<sup>114</sup>. Harris states that this was due to the primary consideration given to safety and the poor lighting and radio communications available to pilots. By 1944, the timing for landing an aircraft had dropped by 66 percent to two minutes, which was essential if the large number of aircraft being despatched were to land and accidents on and near the airfields kept to manageable levels. Harris contends that without these improvements in lighting and air traffic control the bomber offensive ‘could never have achieved the scale it did’<sup>115</sup>.

When the war started in 1939 the RAF used a ‘primitive form of flare path, composed of small battery fed electric lamps laid out on the grass by hand’<sup>116</sup>. This early flare path could be ‘supplemented in poor visibility by paraffin flares of the road-mender variety’<sup>117</sup>. A massive and clumsy floodlight was also available for use<sup>118</sup>. By May 1944, 95 percent of all Bomber Command airfields were equipped with Drem Mark II airfield lighting, 75 percent had sodium funnels, 71 percent had SANDRA searchlights<sup>119</sup>, 52 percent had sodium flare-paths and 45 percent had SBA and contact lighting<sup>120</sup>. The effort required to quickly assimilate the lessons of war operations and to design, engineer,

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114 Harris, *Despatch*, p.186

115 Harris, *Despatch*, p.185

116 Harris, *Despatch*, p.186

117 Harris, *Despatch*, p.186

118 Harris, *Despatch*, p.186

119 Harris, *Despatch*, p.186. This was a cone of search lights shone by the Army Anti-Aircraft defences over an airfield to guide in returning aircraft.

120 Harris, *Despatch*, p.186

manufacture and install these lighting systems in less than four and a half years was a remarkable achievement and it produced a remarkable system which is still the standard today.

Similarly, the 'Hooded' contact lighting system that replaced the battery-operated contact lighting remains the track lighting system used at airports today. This type of lighting works off mains electricity and the cables to supply this electricity had to be buried under the existing pavement. This was one other reason why so much existing pavement had to be lifted and replaced during the war and this modification added to the cost of building airstrips and paved areas. All 131 Bomber Command airfields had Hooded Contact Lighting installed before the end of the war in 1945<sup>121</sup>. The contact lighting system consisted of individual hooded lights placed every 61m on the airstrip itself and every 91m on taxiways and boundary roads<sup>122</sup>.

In 1941, a new form of guidance lighting, the Mark I and Mark II Drem<sup>123</sup> systems came into operational use at 80 Bomber Command stations<sup>124</sup>. The Mark II Drem system comprised landing strip contact lights, outer circuit lights, funnel

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121 Higham, *Bases of Air Strategy*, p.50

122 Sharp, Shaw and Dunlop, *Airport Engineering*, p.113

123 Drem lighting consisted of dim lights aligned with the curving approach to a landing strip that allowed pilots to make safer approaches at night. The system was named after Drem Aerodrome in East Lothian, where 602 Squadron developed it. See J. Tully-Jackson and Ian Brown, 'Drem Aerodrome', <http://www.eastlothianatwar.co.uk/Drem.htm>, 28th February, 2004

124 Higham, *Bases of Air Strategy*, p. 51

lights, totem poles, Glim and floodlights, fog funnels<sup>125</sup>, angle of approach indicators, taxiing track lights, dispersal signs and portable Glim lights etc., all controlled from the Watch Office of a station<sup>126</sup>. A further 21 Bomber Command stations received the MK III Drem system in order to limit the number of aircraft being damaged by running off the taxiways and hard standing onto soft ground. The Mark III system provided different lighting on the inside and outside of tracks, illuminated dispersal signs, and closer spacing of lights on curves. With the arrival of the USAAF arrival ID beacons flashing a two letter code and radio beacons were then needed so returning aircraft could identify their group and home airfields<sup>127</sup>. All of these lighting systems developed for use on RAF airfields, particularly Bomber Command's airfields, became the standard lighting system for post-war airfields all over the world<sup>128</sup>.

The importance of effective lighting to bomber operations cannot be over-emphasised. Amongst the problems facing Bomber Command were flying congestion and aircraft accidents on or in the immediate vicinity of airfields. Good lighting and traffic control systems were vital to limit the impact of this congestion on operations<sup>129</sup>. Surprisingly, the underlying cause of these problems

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125 The fog dispersal systems operated by burning oil and a single dispersal system burned several tons of oil per minute. See Memo from Prime Minister to CAS dated 7 Oct 43, reproduced in Sir W. Churchill, *Closing the Ring*, History of the Second World War Vol IV, p.517

126 Harris, Despatch, p.153; Sharp, Shaw and Dunlop, *Airport Engineering*, pp. 110-115; Higham, *Bases of Air Strategy*, p.51 and Froesch and Prokpsch, *Airport Planning*, pp. 140-150

127 Higham, *Bases of Air Strategy*, p.50

128 Froesch and W. Prokpsch, *Airport Planning*, pp. 140-150

129 Harris, *Despatch*, pp. 156-157

was a lack of space. There were not enough suitable locations for bomber airfields in the British Isles leading to a concentration of such stations in South Yorkshire, Lincolnshire, Huntingdonshire, Cambridge and Norfolk<sup>130</sup>.

The congestion caused by the concentration of Bomber Command's stations into the mid-eastern seaboard of Britain was made worse by the training and testing flights that aircraft were required to undertake as well as the operational sorties that formed the primary reason for the whole organisation. Harris lists the installation of the Mark II Drem system along with advances in flying control and the provision of the three emergency airstrips at Woodbridge, Manston and Carnaby as helping to overcome this problem. This problem was so severe at some stations that their airfield circuits overlapped leading to the relegation of such airfields to training activities<sup>131</sup>.

The problem of congestion increased as the size of the aircraft fleet available to Bomber Command increased. A significant part of the problem lay in the movement of an aircraft from its parking area along a taxiway to the end of a runway for take off<sup>132</sup>. Sir Arthur Harris believed that 32 to 45 aircraft was a reasonable number of aircraft to operate from a single station<sup>133</sup>. By 1942, the average time allocated to each heavy bomber to complete its take off was 45 seconds. If nothing went wrong, the shortest period of time in which 32 aircraft

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130 Harris, *Despatch*, pp. 156-157

131 Harris, *Despatch*, p.157

132 See Froesch and W. Prokosch, *Airport Planning*, p.93

could get clear of a runway was 24 minutes<sup>134</sup>. With the adoption of bomber stream tactics the need to reduce the time taken to get aloft became even more important. Landing was, as already discussed, even more problematic with 32 aircraft taking more than 90 minutes to land. This should have meant more casualties due to damage, fatigue and injury amongst returning aircraft and crews<sup>135</sup>. That it did not was due to the efficiency with which Bomber Command and the Air Ministry's Works Directorate met the challenges posed by the rapidly changing face of the strategic air offensive.

In 1943, 23 aircraft were damaged for every 10,000 flying hours in Bomber Command. By 1944, the rate had fallen to 15 aircraft and by 1945 only eight aircraft were being damaged for the same period of flying<sup>136</sup>. These figures look good when viewed by themselves, but they need to be seen against the 1,170 percent growth in traffic density on Bomber Command's airfields that over the same period. Under these conditions, the improvements in safety achieved by Bomber Command are startling and they show a level of professionalism and organisation that few military forces have been able to achieve. This improvement also demonstrates that Britain was highly capable in operating military forces during World War II.

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133 Harris, *Despatch*, p.157

134 Higham in *Bases of Air Strategy* gives a time of 45 seconds for take-off. Given that the average Bomber Command station had up to 45 aircraft this meant, providing no accidents or delays occurred, that all aircraft could be airborne in 33.75 minutes.

135 Harris, *Despatch*, p.157

## **Air Traffic Control**

The congestion that afflicted Bomber Command as it grew between 1942 and 1945 posed significant threats to the ability of Bomber Command to sustain the strategic air offensive. For Bomber Command the loss of an aircraft and crew was serious and it did not matter whether enemy action or accident caused the loss. Bomber Command had more control over the causes of accidents than it did over German defences and it expended a lot of effort in addressing these causes.

The answer to the problem of a vast increase in operational intensity and the need to concentrate large force over enemy targets was the effective control of airspace. Prior to 1942, operational intensity and tactics did not require an extensive system of air traffic control and, although there was a rudimentary system, it did not play a critical role until 1942. After February 1942, the introduction of the bomber stream led to the problem of landing these aircraft. One answer to this problem was the airfield lighting systems discussed above. A second was getting aircraft back to the vicinity of their home airfield and landing them in a rapid and orderly manner. To accomplish this, the Air Ministry established a system of air traffic control by extending the authority of the Flying Control Organisation (FCO) and placing it under the command of the C-in-C Bomber Command.

The Air Ministry established the FCO in 1939 as an all-command, RAF wide entity designed to assist aircraft in distress<sup>137</sup>. Bomber Command took over the FCO, as it was the largest user of the skies and airfields in Britain. The FCO became part of Bomber Command by having its Central Flying Control (CFC) function moved to the HQ at High Wycombe<sup>138</sup>. This was necessary because the FCO was the only organisation with the necessary structure and facilities capable of carrying out both local and nation wide air traffic control<sup>139</sup>.

Local air traffic control was the responsibility of the Flying Control Staff (FCS) at each station and it was their job to get returning aircraft down in as quick and orderly a manner as was possible<sup>140</sup>. The need for a system covering the entire British Isles and surrounding seas was due to the unpredictable nature of British weather, which could result in local fog or rain conditions leading to the diversion of a large number of aircraft to stations that could accept landings. This required the national level CFC at High Wycombe. Communication from the airfield FCS and the CFC went through a Group FCS (G-FCS) so that when aircraft from an airfield within a Group needed to divert to airfields outside of that Group the CFC coordinated it. If the diversion was to an airfield within the same Group then the G-FCS controlled the activity<sup>141</sup>.

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137 Harris, *Despatch*, p.185

138 Harris, *Despatch*, p.185

139 Harris, *Despatch*, p.185

140 Harris, *Despatch*, p.185

141 Harris, *Despatch*, p.185

## **Emergency Assistance to Aircraft in Distress**

Despite the re-orientation of the FCO to general air traffic control, priority went to assisting aircraft in distress<sup>142</sup>. The importance of providing this assistance lay in the necessity of maintaining aircrew morale. The risks faced by Bomber Command aircrew were significant enough and the men flying these operations needed to know that everything possible would be done to get them back alive. Any failure to supply such assistance would have almost certainly entailed a dramatic and sustained drop in morale amongst aircrew. Due to a lack of accurate figures, it is difficult to evaluate the contribution that the FCO made to the strategic air offensive and the crews of Bomber Command. Sir Arthur Harris places a high value on the value of the FCO. He reports that the number of Bomber Command aircraft that the FCO assisted to a safe landing numbered ‘many thousands’ and that many Bomber Command aircrews owed their lives to the efficiency of this organisation<sup>143</sup>. The actual numbers involved were very high and 11,250 Bomber Command aircraft in some degree of distress were to land at the three emergency runways at Carnaby, Woodbridge and Manston<sup>144</sup>. Added to this achievement was the planning of 95,000 diversions of which 20,000 actual diversions occurred<sup>145</sup>.

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142 Harris, *Despatch*, p.188

143 Harris, *Despatch*, p.188

144 Harris, *Despatch*, p.189

145 Harris, *Despatch*, p.189

Sir Arthur Harris attributes the success achieved by the FCO and its management of air traffic control to the 'wide inter-command' nature of the FCO and the close co-operation of an extensive range of civilian and other service agencies<sup>146</sup>. It took 2,700 personnel to man the FCO and they saved the equivalent of 31,250 distressed aircraft, at an approximate value of £625 million<sup>147</sup>, from crashing on return and they controlled 660,000 take-offs and landings by achieving a 300 percent increase in the speed of control between 1942 and 1945<sup>148</sup>. Harris rightly states that 'without the FCO to get the bomber force safely onto the ground again on its return, the massive scale of the offensive could never have been achieved'<sup>149</sup>. The evidence fully supports this claim.

### **Camouflage**

Once constructed an airfield required accommodation for aircraft and people and the estimated 59 different activities that were undertaken on a Bomber Command station<sup>150</sup>. Amongst these buildings were barracks, messes, communal buildings (cinemas, churches etc.), institutes, hangars, workshops, stores, ground staff facilities, administrative buildings, sick quarters, mechanical and electrical installations, wireless stations, operational planning areas, control towers, fire

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146 Harris, *Despatch*, p.189

147 This estimate achieved by multiplying the number of aircraft by the average price of £20,000 for a bomber aircraft in 1943/44 as noted in the Ministry of Aircraft Production, *Price Books*.

148 Harris, *Despatch*, p.189

149 Harris, *Despatch*, p.189

150 Higham, *Bases of Air Strategy*, p.50

stations, vehicle parks, water supply, sewage, roads and other services. The need for dispersal and camouflage increased the cost of providing these amenities.

Although the Director of Works had identified a need for a national camouflage scheme in 1935, very little happened until 1939 when the Air Ministry appointed the artist, Norman Wilson RA, as an Honorary Air Commodore with the responsibility of establishing a national camouflage scheme and applying it to RAF establishments. There was a lot of work for Hon. Air Commodore Wilson.

In 1938, the RAF establishment had had one officer charged with the management of camouflage. By 1942, Air Commodore Wilson commanded 330 officers and 1,000 men involved in the planning and application of camouflage schemes for the RAF<sup>151</sup>. In the same year, Wilson's men used 22 million gallons of paint, 6,700,000m<sup>2</sup> of steel wool and untold amounts of Stadistall slag chips and, until Malaya fell, large amounts of scrap rubber. All of this work was to disguise the bomber stations and runways from the air<sup>152</sup>. The cost of this activity was £8,750,000<sup>153</sup>, of which Bomber Command's proportion would have been approximately £6,037,500. This figure excludes the construction of a number of dummy airfields, which contributed to the war effort by attracting 443 out of the 877 enemy air attacks carried out against RAF airfields<sup>154</sup>.

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151 Higham, *Bases of Air Strategy*, p.53

152 Higham, *Bases of Air Strategy*, p.53

153 Higham, *Bases of Air Strategy*, p.53

154 C. Dobson, *Fields of Deception, Britain's Bombing Decoys of World War II*, Methuen, London, 2000, p.127

## **Accommodation**

The provision of accommodation for aircraft was one problem that continued to plague Bomber Command throughout the war<sup>155</sup>. Accommodation shortages existed in all areas of Bomber Command and affected domestic facilities and sleeping accommodation for personnel, as well as workshops and hangars for aircraft. Interestingly, Harris claims the hangar problem was finally resolved in 1944, but the personnel problems increased in the later months of 1944 ‘as the casualty rates decreased’<sup>156</sup>. The reason for the decline in casualty rates is well known. The ending of the hangar shortage probably lies in the fact that a considerable number of Type T hangars were built on Bomber Command stations for the storage of Horsa Gliders which were expended in the invasion of Europe<sup>157</sup>, leaving the hangars to be utilised by the squadron and base repair organisations.

## **Accommodation for Aircraft**

The average hangar accommodation provided on a Bomber Command airfield depended on when the airfield had been built. Pre-war stations such as Binbrook (see map 2 below), were designed like airports with all of their service accommodation clustered at the end of a taxi circuit leading off the landing strips.

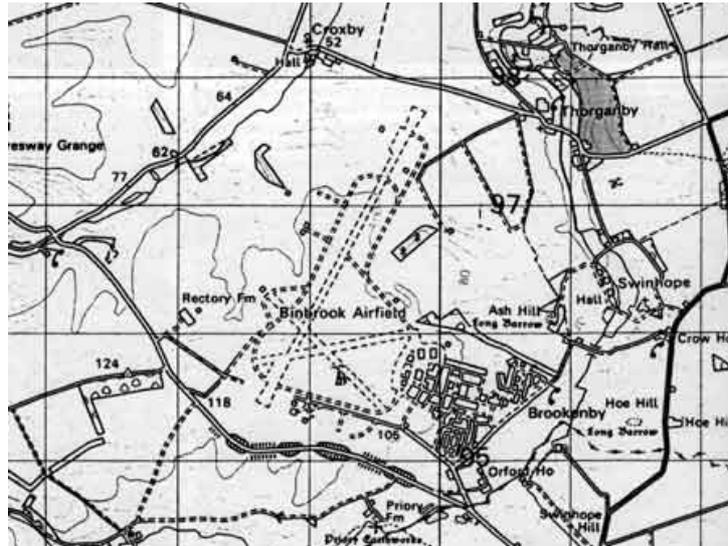
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155 Harris, *Despatch*, p.157

156 Harris, *Despatch*, p.157

157 Ministry of Defence, *www.RAF.MOD/BomberCommand/station*

The advent of German air attack on RAF bases forced the re-consideration of this approach so that the dispersal of buildings and services became essential.



**Fig. 5.7: Binbrook Airfield**

**Courtesy: MOD.RAF**

The pre-war stations also had 5 Type C hangars. The Air Ministry had designed these hangars for the smaller Battles, Blenheims and Wellingtons of the pre-war period. The Type C hangar was 45.7m wide by 91.4m long and had doors up to 10.7m high which had gravel filling up to 6m high<sup>158</sup>. This size of hangar could take a Lancaster wingspan but the height of the hangar remained a problem in terms of fitting lifting devices above such a large aircraft.

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158 Higham, *Bases of Air Strategy*, p.51



**Fig. 5.8: Type C Hangar at Binbrook; Courtesy of D. McKenzie, Airfield Research Group**

Another problem created for the Directorate of Works by the Air Staff was the small size of the early hangars. The small size of early hangars had arisen from an Air Staff requirement that hangars needed to be light to allow easy transportation. The first of these hangars, the Bellman or Type B, designed in 1938, was 29m wide by 55m long and, at this size; it was totally inadequate for the heavy bombers then coming off the drawing boards and into the testing stages of their development. Of the 101 stations described on the RAF Bomber Command Commemoration site 51 had Type B hangars<sup>159</sup>. This gives some indication of the extent of the accommodation problems that beset Bomber Command.

With the advent of the heavy bombers, a larger temporary hangar was required and Teesside Bridge and Engineering Works Ltd. developed these. The Type T hangar had two variants, a Type I and Type II. These hangars were 35.1m wide

by 73.2 m long and 7.6 m high and some 906 were erected<sup>160</sup>, of which 199 Type T2 are listed as having been built on 76 Bomber Command stations<sup>161</sup>. Although a number of these were for storing Horsa gliders for the invasion, there is little doubt that Bomber Command made at least partial use of their resources, particularly after the Horsas had made their one-way trips to the continent. The standard fit-out of hangars for a Class A airfield was two T2 type hangars plus one Type B. If so, then the 131 airfields operated by Bomber Command would have required approximately 200 Type T hangars.



**Fig. 5.9: Type T2 Hangar at Sculthorpe;      Courtesy of Airfield Research Group**

This fits closely with the listing of 199 hangars published on the RAF's Bomber Command Commemoration page. Also listed are 52 Type B hangars, 16 Type J

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159 Ministry of Defence, [www.RAF.MOD/BomberCommand/stations](http://www.RAF.MOD/BomberCommand/stations)

160 Higham, *Bases of Air Strategy*, p.52

161 Ministry of Defence, [www.RAF.MOD/BomberCommand/stations](http://www.RAF.MOD/BomberCommand/stations)

and 84 Type C<sup>162</sup>. The numbers above equate to 38,933,544 m<sup>3</sup> for the storage of aircraft in Bomber Command. The breakdown of this figure shows 3,905,200 m<sup>3</sup> in Type T hangars, 630,344 m<sup>3</sup> in Type B and 34,398,000m<sup>3</sup> in Type C.

### **Miscellaneous**

In order to conduct bomber operations a large number of ancillary facilities ranging from control towers to fire stations to bomb dumps and petrol, oil and lubricant (POL) stores were required. Chapter 7 details the subject of POL, its manufacture, supply, storage and use. This leaves a brief description of the types of ancillary services and structures that the Air Ministry provided to Bomber Command's stations.

Each operational station required a control tower and these housed not only the Flying Control Organisation elements on the airfield but also the watch office and the control systems for the lighting systems. In a number of these towers, there was also facility for a radio control room. However, the radio facility was often housed remotely from the tower, in a van or hut of its own. In addition to the tower, there were buildings for the necessary fire tenders and ambulances so that aid to crashed and injured crews could be quickly despatched onto the landing strip. An example of a control tower is shown here;

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162 Ministry of Defence, [www.RAF.MOD/BomberCommand/stations](http://www.RAF.MOD/BomberCommand/stations)



**Fig. 5.10: Control Tower** Courtesy: Airfield Research Group



**Fig. 5.11: Control Tower** Courtesy: Airfield Research Group



**Fig. 5.12: Air Ministry Fire Section Building circa 1939-42 Courtesy of D. McKenzie, 2001**

Not all operational facilities and activities could be housed on the actual site of Bomber Command's airfields. The most obvious of these were the POL and bomb stores. Bomb stores had to be placed in isolated areas, preferably in open countryside at a good distance from other structures. This ensured that any accidental explosion in a store could not seriously harm the station, surrounding buildings or civilian houses. In 1936, the Air Ministry estimated that the RAF would use 98,000 tons of incendiaries and general-purpose bombs and storage for this amount of ordnance was put in place. The estimate resulted in Bomber Command stations having 12 by 12-ton stores giving a maximum storage capacity of 144 tons<sup>163</sup>. The problem was that actual usage rapidly overtook the 1936 figures leaving most of Bomber Command's stations with insufficient bomb

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163 Higham, *Bases of Air Strategy*, p.52

storage and handling facilities<sup>164</sup>. Over the peak period of the strategic air offensive, Bomber Command's average monthly consumption of bombs was more than 3,841 tons per month in 1942, 12,759 tons in 1943, 42,275.5 tons in 1944 and 37,204 tons in 1945<sup>165</sup>. The amount of bomb storage supplied to Bomber Command and to all elements along the supply links never met the needs of the campaign. The above figures indicate the dependency of the strategic air offensive on the continuous supply of ordnance in sufficient quantity to maintain the weight of attack decreed by Harris and his staff.

### **Human Accommodation**

For Sir Arthur Harris, another significant problem facing Bomber Command throughout the war was the lack of what he called 'domestic accommodation'. This included messes, kitchens, recreational facilities and sleeping accommodation. Towards the end of the war, this problem worsened as casualty rates fell whilst the number of replacement aircrew remained at the level that the Air Staff had estimated as being required. Life for the average member of Bomber Command during the war never approached the level of deprivation suffered by the millions of men who served in front-line army formations and would not stand any comparison of the conditions, which were the norm for the front-line infantry. Nevertheless, the life of Bomber Command aircrew was not

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164 Higham, *Bases of Air Strategy*, p.52

165 Harris, *Despatch*, p.47

easy; the normality of life between missions can only have accentuated the shock of the myriad deaths that these men experienced.

Prior to the war the RAF had prided itself on providing above average domestic accommodation for what it saw as above average servicemen. The concept was that being a member of the RAF entailed being at the front of modern living and this included living conditions for all personnel. Even the British Arts Council had been involved in ensuring that the buildings erected by the Air Ministry conformed to the Art Council's standards for the countryside. This resulted in pleasant redbrick buildings that suggested something Georgian in their appearance.



**Fig. 5.13: Officers Mess**    **Courtesy: Ashley Bailey Collection, 2001**

The problem was, nice buildings took too long to build and with the increased urgency of the expansion scheme, the RAF had to put up with Nissan Huts and other prefabricated buildings. In order to meet this demand the Air Ministry built 3,110,000m<sup>3</sup> of pre-fabricated huts on RAF stations to meet the accommodation needs for personnel<sup>166</sup>. Higham provides figures of 84,711m<sup>2</sup> of hut floor space supplied to the RAF in 1939, 432,922m<sup>2</sup> in 1940 and 3,051,209m<sup>2</sup> in 1941 giving a total of 3,568,842m<sup>2</sup> over the three years<sup>167</sup>. The actual amount of huts supplied to Bomber Command is not available, but as much as 60 percent or 2,145,900m<sup>3</sup>, of this hutting may have gone to Bomber Command.



**Fig. 5.14: Nissan Hut**      **Courtesy of the Airfield Research Group.**

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166 Kohan, *Works and Buildings*, p.287

167 Higham, *Bases of Air Strategy*, p.47

Initially most of this hutting was wooden<sup>168</sup>. The intention behind using wood was, surprisingly, to minimise the impact of such accommodation on the local countryside, presumably in an attempt to stay within the Arts Council's standards. Higham estimates that the Air Ministry spent approximately £4.5 million on the provision of this hutting between 1935 and 1939<sup>169</sup>. By 1939, shortage of timber plus the need to construct large amounts of accommodation quickly led to the development of the Nissan Hut, shown above.

Even the provision of accommodation for personnel was not a simple task. Sleeping accommodation had to be placed well away from the airfield because of the noise created by a busy airfield and because of the need to protect personnel from the risks associated with enemy air attacks and crashes of damaged or badly handled aircraft upon their return from flights. On the other hand, the messes and kitchens needed to be close to the airfield so that personnel did not have to travel far to eat during working hours. This necessary dispersion made the bicycle king and imposed further inefficiencies upon the smooth operation of stations. The most obvious impact of the dispersal of domestic accommodation was that it required larger areas of land than those within the boundaries of the station. For example, at Alconbury the Air Ministry requisitioned Alconbury House and built 18 personnel accommodation blocks near this location and to the South of the A14 road towards Little Stukeley<sup>170</sup>.

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168 Higham, *Bases of Air Strategy*, p.52

169 Higham, *Bases of Air Strategy*, p.52

170 RAF and Bomber Command Association, [www.raf.mod.uk/bombercommand/stations](http://www.raf.mod.uk/bombercommand/stations)

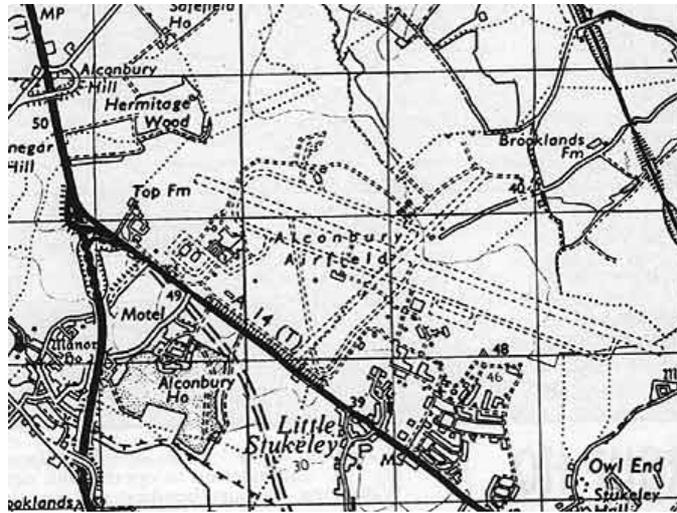


Fig. 5.15: Little Stukeley

Courtesy: MOD/RAF

At other stations, personnel were billeted into requisitioned housing or were billeted upon the local population. It is not known with any precision how many Bomber Command personnel found themselves housed in requisitioned buildings or billeted in other people's homes. Because of the lack of data on requisitioned housing, the figures provided here do not take into account the cost of this activity. Also unknown is the amount of accommodation that was taken up by those married personnel who officially or unofficially moved their wives and families to the vicinity of their stations. This latter activity was often at the personal cost of the service member because Bomber Command did not approve of having wives close to the stations where their husbands were serving<sup>171</sup>.

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171 R. Morris, *Guy Gibson*, Penguin Books, Harmondsworth, 1995, p.82

By 1944, the average Bomber Command station had living accommodation provided for around 2,300 personnel<sup>172</sup> and with a total of 131 stations being in the Command during 1944 it is estimated that there was sufficient accommodation for over 301,000 persons. This figure is well above the estimate of 250,000 provided by Sir Arthur Harris (see Chapter 8)<sup>173</sup>. The reason for this discrepancy may simply be that each Bomber Command station had a significant number of personnel assigned to it who did not officially come under Sir Arthur Harris's command. If so, this means that the manning of Bomber Command was substantially above the figures provided via the official strength states for the Command.

One substantial group that falls into this category were the navvies employed on stations to extend or refurbish damaged roadways, hard standings and airstrips. In 1942, large numbers of navvies and construction personnel, all of whom required housing in the local area, were working on 29 of Bomber Command's operational airfields<sup>174</sup>. There is little information available on whether they were billeted in Bomber Command facilities, or were billeted out by their own organisation or found their own accommodation. Whichever method was used it imposed a cost directly attributable to Bomber Command but which is almost impossible to measure at this time.

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172 Figure compiled from Ministry of Defence, *www.RAF.MOD/BomberCommand/stations*, 16<sup>th</sup> march 2004

173 Harris, *Bomber Command*, p.268

174 Kohan, *Works and Buildings*, p.298. For example, when Lakenheath was upgraded in 1945 over 1,000 navvies were billeted on the local population in addition to the RAF personnel living on the



**Fig. 5.16: Airmen's Restaurant**

**Courtesy: D. McKenzie, 2001**

As well as providing somewhere to sleep, the Air Ministry had to supply the various categories of RAF personnel with somewhere to eat, entertain and occupy themselves. As is still the case in all military organisations, there was a clear distinction between officers, non-commissioned officers and ordinary serving members. In addition, there was strict segregation of female and male personnel. This separation increased costs and, because each individual facility was of a reduced size, it limited any benefit that could be gained from the increased economy of scale that larger centralised messes would have allowed.

On each station, the Air Ministry had to provide boilers, cookers, ovens, cold-rooms and storage for handling, cooking and serving up to 7,000 meals per day. The cost of providing these meals came to around £8,000 per month for an

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station. See, RAF and Bomber Command Association, <http://www.raf.mod.uk/bombercommand/stations/s40.html>, 16<sup>th</sup> March 2004

average Bomber Command station<sup>175</sup>. Over the period 1942 to 1945, it is possible, using an average of 112 operational stations, to estimate a total food bill for Bomber Command of £36,736,000.00. Added to this is roughly between £6 - £10 million for the period 1939 to end of 1941 giving a total of between £43 and £47 million for feeding alone.

### **Water and Sewerage**

Putting aside the management of storm water runoff from the airfield, each bomber station had to have a water system capable of supplying a small town and providing the water necessary to wash down the aircraft. In addition to water, these stations also needed to remove copious amounts of dirty water and sewage through their own disposal systems. Each of these stations used an average of 140-150,000 litres of water per day to supply the 2,300 personnel and to provide for other functions, such as fire fighting and the washing down of aircraft<sup>176</sup>. In relation to fire fighting, each station had to maintain a fire reservoir of about 380-760,000 litres. At the peak of operations in 1943, the daily water consumption for Bomber Command's airfields would have been approximately 74,670,000 litres. This figure does not include the requirements for HQs or ancillary depots or off-station support operations. Higham states that in 1939 the RAF used 20,500,000

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175 *War Savings*, Vol 5., No.11, Wings for Victory Issue, 2 Feb. 1943, p.25

176 Higham, *Bases of Air Strategy*, pp. 57-58

litres per day rising to 182,000,000 litres per day in 1945 of which RAF reservoirs supplied 54,600,000 litres<sup>177</sup>.



**Fig. 5.17: Water Tower** Courtesy of Airfield Research Group

To supply this amount of water the RAF built reservoirs on stations, sunk bore holes and drew on local water supplies via the mains. Little information is available on the percentage of airfields that drew upon the local water mains but Higham does report that the Air Ministry had to sink 800 boreholes to provide RAF stations with water. It is probable that a large number of these bore holes were for Bomber Command stations. Interestingly, only 1 percent, or 8, of these bore holes ran dry<sup>178</sup>.

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177 Higham, *Bases of Air Strategy*, p.50

178 Higham, *Bases of Air Strategy*, p.61

As well as supplying water to airfields, the Air Ministry had to ensure that dirty water was disposed of via an effective sewage system. Bomber Command stations were forced to have their own sewage systems. This was due to the simple fact that they tended to be built a reasonable distance from local communities and therefore from the sewage systems serving those communities. To meet the need of up to 2,300 personnel the Air Ministry Directorate of Works designed a standardised system utilising humus tanks and drying beds<sup>179</sup>. This standardised system was mass-produced and the components shipped to stations where the building contractors assembled and installed them during the construction phase. The initial designs were not capable of handling the increased population of the larger Class A stations and a completely new sewage system had to be developed and installed as part of the upgrades<sup>180</sup>.

Once again, it is virtually impossible to identify the cost associated with the construction of individual sewage systems for bomber airfields. The lack of records and the fact that such works were often part of the overall contracted price of the station makes isolating information very difficult. It is also unclear how many stations were connected to mains water and sewage and whether any accounts were raised for these services. The evidence to date suggests not.

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179 Higham, *Bases of Air Strategy*, p.50

180 Higham, *Bases of Air Strategy*, p.5

## **Electricity**

Electricity came to play a major role in the operations of Bomber Command and it was not until the end of 1943 that the electricity grid began to meet Bomber Command's minimum power requirements, or so at least Sir Arthur Harris claims<sup>181</sup>. The Directorate of Works had known of the need to provide for the supply of electrical power to RAF stations prior to the war<sup>182</sup>. However, as in many other cases, such as camouflage mentioned above, knowing something would be needed was not the same as knowing how much of that thing will be needed. So it was with electrical power. At the start of the war, the average RAF station had the necessary electrical supply to provide power to its accommodation blocks and hangars but that was all. With the move to night operations and the growing attrition rate from airfield accidents more effective and complex lighting and other control systems were required. All of these required dependable electricity supplies and this led to a need to supply cabled power supplies beyond the area previously occupied by barracks, messes, hangars and offices.

As well as the need to power lighting and supply the needs of living and working areas, the increasing complexity of the aircraft led to a massive increase in the level of industrial capacity needed to carry out routine maintenance and repair of operational aircraft. Power was needed for the heavy lifting equipment being installed in hangars so that the multiple engines and other parts of large aircraft

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181 Harris, *Despatch*, p.153

182 Higham, *Bases of Air Strategy*, p.67

could be winched onto and off aircraft. The ability of the power supply to keep pace with this expansion in machinery remained an area of substantial difficulty for Bomber Command right up until the end of the war<sup>183</sup>.



Fig. 5.18: No. 4 Squadron Servicing Hanger

Courtesy of [www.raf.mod.uk](http://www.raf.mod.uk)

Amongst the specialised work undertaken with the Command was metalwork, to replace areas of structural damage on aircraft, spark plug cleaning, battery recharging, engine removal and rebuilding and tyre removal and repair. These operations required power, as did the supporting activities like machining, fitting and turning, compressing air, and so on. It is not surprising that the demand for electricity grew so substantially over the period 1939-1945. On an average Bomber Command station, electrical demand could vary between 600 kW and could peak at 2,500 kW but sometimes the load could reach 5,000 kW at a peak<sup>184</sup>.

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183 Harris, *Despatch*, p.158

184 Higham, *Bases of Air Strategy*, p.67

The electrical power requirements of bomber stations, as with the majority of RAF stations, was drawn from the national grid, which was, given the shortage of fuel, the most economical way of obtaining the necessary electrical power.

Whatever the level of actual consumption, the lack of accurate records makes it impossible to estimate the value of the electricity consumed in carrying out the strategic air offensive. Indeed, it has been impossible to identify whether the Air Ministry received accounts for any electricity usage during the war or whether the supplying authorities wrote off this cost.

## **Conclusion**

The 131 bomber stations that Britain built for Bomber Command were a fundamental part of the strategic air offensive, as fundamental in fact as the aircraft and the aircrew that flew from them. It is odd, to say the least, that the history of the strategic air offensive has for so long overlooked the vital importance of this infrastructure and failed to appreciate the effort, skill and wealth that building the bomber stations required. As Sir Archibald Sinclair told the House of Commons, it was one of the greatest engineering works undertaken in modern Britain and without it Bomber Command could not have conducted the strategic air offensive.

The airfield construction programme constrained the growth of the strategic bomber offensive as much as the availability of heavy bombers. Even if the

Lancaster and Halifax had been available in 1940 their numbers could have grown only as fast as airfields were built for them. As the heavy bomber aircraft arrived in Bomber Command at the 1942 the airfield construction programme was struggling to keep up with the needs of Bomber Command. Only in mid-1943 were adequate numbers of large airfields available to allow significant increases in the weight of the attack that Bomber Command could deliver using its increasing number of heavy bomber aircraft.

The complexity that night bombing by large formations imposed on the operation of airfields was another factor of which the pre-war planners were unaware. The heavy losses suffered by Bomber Command aircraft over the North German coast in 1939 demonstrated the strength of the defences that could be brought to bear on attacking bombers. The Air Staff had thought that Bomber Command would be able to win sufficient control of the air to operate in daylight and that any night operations would be supplementary to the main daytime effort. As a result, the original plans identified a need for a preponderance of basic airfields. This presented a major problem when Bomber Command's entire operational effort moved to night raiding and there were inadequate lighting systems and only rudimentary air traffic control, which could not cope with the demand placed upon them.

A further problem was that the weight of attack required to inflict substantial damage on Germany had also been vastly underestimated by the Air Staff. This led to a demand for larger and heavier bombers that could carry the required

weight of bombs the necessary distances to Germany proper. These larger and heavier aircraft changed the whole specification for a bomber station leading to a complete overhaul and upgrading of existing stations and the expansion of proposed stations. All of this change came at a cost.

The initial lack of large all-weather airfields and air traffic systems was due to the Air Staff's decision to make France their doctrinal enemy for planning purposes. Just as this decision adversely affected the design and development of the RAF's aircraft in the mid-1930s, so it also affected the design of airfields. The use of France as the 'planning enemy' had occurred in the early 1920s and was, at that time, a logical assumption. The problem for the Air Staff was the lead times involved in setting specifications for aircraft to operate against France and then designing, developing and building the operational aircraft. It was not until the early 1930s that the strategic assumptions of the Air Staff changed to reflect the German threat and it took almost ten years for the appropriate aircraft to become operational. The same problem affected the design and development of airfields. The grass strips that would enable small bombers to launch daytime air raids on France could not cope with night time operations by large numbers of heavy bombers in all weathers.

The total cost of the airfield-building programme, including the provision of buildings, was £247.3 million. This price includes £155.5 as the cost of building and paving airstrips, £36.4 million for buildings and £6.04 million for camouflage of those facilities and indirect costs of £53.4 million for lost crops. The £247.3

million added to the £1.4957 billion for the development of the aircraft industry and the purchase of aircraft used by Bomber Command during World War II makes the total cost of the strategic air offensive at this point £1.7430 billion.

## Chapter 6

### ARMAMENTS

On 12<sup>th</sup> of July 1941, Winston Churchill sent a memo to his close associate and scientific advisor, the Paymaster General, Lord Cherwell, telling him that ‘the criterion of bomber strength is the weight of bombs deliverable per month on the reasonably foreseeable targets in Germany and Italy’<sup>1</sup>. The offensive demanded by Churchill and carried out by Bomber Command and the USAAF killed between 250,000<sup>2</sup> and 400,000 German civilians and injured approximately 420,000<sup>3</sup>. It also destroyed 20 percent (3,600,000) of Germany’s pre-war housing stock<sup>4</sup>, rendering 7,500,000 people homeless<sup>5</sup>.

The subject of this chapter is the cost of manufacturing, handling and accurately dropping high explosive and incendiary bombs during the strategic air offensive. The analysis will begin with a description of the types of bombs, pyrotechnics and mines developed for strategic bombing. Under this heading both conventional and non-conventional ordnance will be described, as will the arrangements made by Britain to develop and manufacture the Mustard Gas bombs which, in April 1943,

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1 PRO CAB 120/299, Memo Churchill to Lord Cherwell, 12th July, 1941

2 United States Strategic Bombing Survey, ‘The Economic Effects of the Air Offensive Against German Cities’, *United States Strategic Bombing Survey*, Area Studies Division Report, Report 31, War department, Washington, January 1947, p.3

3 Horst Boog, Harris – A German View, in Harris, *Despatch on War Operations*, ed by S. Cox, Frank Cass and HMSO, London, 1995, p.xxxvii

4 British Bombing Survey Unit, *The Strategic Air War Against Germany*, p.69

Churchill offered to use against the German civilian population if the Germans used Mustard Gas against the Soviet Forces on the Eastern Front<sup>6</sup>.

The analysis will also endeavour to identify the percentage of British bombs that failed to operate as expected. The subject of ordnance failure was a significant complaint made by Sir Arthur Harris in his post-war report on the offensive<sup>7</sup>. Harris's complaints over unreliability of bomb fuses is acknowledged in the Air Staff reply to his criticisms and this suggests that there was a significant problem associated with British bombs that may have led to a significant percentage of them failing to explode<sup>8</sup>.

The analysis also extends to identifying the amount of money that the British government invested in expanding armaments manufacture for Bomber Command. The financial assistance provided to armaments firms was small by comparison to that made available to the aircraft industry, none the less, it added to the total cost of the strategic air offensive. Included in this analysis will be the costs of developing and providing the aircrafts defensive systems including machine guns, turrets and small arms ammunition supplied to all aircraft at government expense.

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5 *USSBS*, Report 31, p.3

6 PRO CAB 120/858, Head of State Telegram to Marshal Stalin, T.540/3, 18th April, 1943

7 Harris, *Despatch on War Operations*, pp. 91-97

8 Air Staff Memorandum on the Despatch by Air Chief Marshal Sir Arthur Harris, GCB, OBE, AFC on Bomber Command's Operations 1942/1945, *The Despatch on War Operations, 23rd February, 1942 to 8th May, 1945*, Frank Cass, London, 1995, p.209

The most important sources on the extent of bombing and the damage inflicted on Germany are the 208 reports of the United States Strategic Bombing Survey (USSBS), which the USAAF compiled at the end of World War II. The Air Staff also attempted to conduct a similar survey but Churchill stopped it because he saw it as a waste of time<sup>9</sup>. As a result, the British Bombing Survey Unit (BBSU), which the Air Ministry established in 1945, produced a report, which was unable to conduct much independent research, and is therefore heavily reliant upon the USSBS reports. A second problem associated with the BBSU report was that Sir Solly Zuckerman played a significant role in its preparation and writing. Zuckerman was a central player in the wartime argument over the validity of attacking cities, oil or transport targets. He advocated very strongly for transportation and it is likely his partisan views have overly influenced the findings of the BBSU<sup>10</sup>.

The lack of resources put into the BBSU makes the USSBS the most significant body of data available on strategic bombing. The USSBS had 1,159 civilian and service personnel, who were able to enter Germany in early 1945 with the follow-up elements of the western Allied ground forces<sup>11</sup>. The major motive for commissioning the USSBS was to collect evidence on the effectiveness of strategic bombing to bolster the argument of US air force commanders for the establishment of an independent air force in the United States. The political

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9 S. Cox, 'Introduction: An Unwanted Child-The Struggle to Establish a British Bombing Survey', *The Strategic Air War Against Germany, 1939-1945*, The Official Report of the British Bombing Survey Unit, Frank Cass, London, 1998, p. xvii

10 Zuckerman, *From Apes to Warlords*, p.282

imperatives of the USAAF had an impact upon the subsequent reports. J.K. Galbraith claims that the USAAF leadership attempted to modify the findings of the Area (Urban) Studies Reports. In his 1981 autobiography, Galbraith describes how senior USAAF officers attempted to influence the findings of the economic reports<sup>12</sup>. However, the reports remain the most detailed body of research ever collected on the effectiveness of air warfare and they clearly show that air power, as a whole, made a significant contribution to the allied victory. However, the USSBS findings on the strategic air offensive were less clear and indicated that such an offensive was substantially less effective than air force commanders had expected.



**Fig. 6.1: Exploding Bombs**

**Source: Crown Copyright**

The histories of the strategic air offensive have very little to say about the design, development and manufacture of the explosive ordnance used by Bomber

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11 *United States Strategic Bombing Survey*, Garland, New York, 1976

12 J. K. Galbraith, *A Life in Our Times: Memoirs*, Houghton Mifflin, Boston, 1981

Command to inflict destruction upon Germany. Like airfields and fuel, few historians have devoted attention to how Britain produced the ordnance for strategic air war. There appears to be an acceptance that the effectiveness or otherwise of Britain as a modern technological power between 1939 and 1945 can be simply measured by looking at the amount of man-hours it took to construct one pound of aircraft structure weight. As with airfields, the amount of ordnance that would be needed to inflict substantial damage on Germany had been seriously underestimated.

Between September 1939 and May 1945, Bomber Command despatched a total of 988,281 tons of bombs and sea mines to targets on the Continent or in the seas around the Continent. The economic cost of producing these bombs, mines and pyrotechnics has never been subjected to examination and nor has the effectiveness of the investment been closely examined. To date, the most extensive work on the production and distribution of ordnance to the RAF has been confined to the *Despatch on War Operations*, written by Sir Arthur Harris and the official histories, particularly *The Design and Development of Weapons*, written by M. Postan, D. Hay and J.D. Scott<sup>13</sup>. Of these two sources, Sir Arthur Harris's is the most revealing and useful. In his report, Harris details the technical development of bombs, pyrotechnics, mines and other ordnance and describes the technical difficulties encountered in using these weapons. Postan, Hay and Scott allocate no space to the production of the explosive and pyrotechnic devices used

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13 Postan, Hay and Scott, *Design and Development of Weapon*, p.200

in the strategic air offensive and nor do they discuss the apparent significant problems associated with poor fuse design.

The chapter will also draw upon the little information that is available from the official records, held at the Public Record Office in Kew and from the Royal Air Force Museum, Hendon. The official records provide information spread throughout a number of files from departments and ministries who held joint responsibility for the production and distribution of explosive ordnance. The most important of the ministries involved were the Ministry of Supply, Admiralty, the Air Ministry and the Ministry of Aircraft Production. The official documentation provided comprehensive information on the manufacture of ordnance over the first nine months of World War II. This reflects the close co-ordination of the war effort by the Chamberlain Cabinet. However, these reports stopped in May 1940, when the newly elected Prime Minister, Sir Winston Churchill, wound up the committees.

Churchill concentrated as much power in his hands as he could. The promotion and demotion of the Chancellor in and out of the War Cabinet suggests Churchill was limiting the influence of Treasury on wartime decision-making. Churchill relegated Treasury from its central position in policy formulation to a supporting role. Treasury represented the greatest threat to the way in which Churchill was conducting the war. That is, he made decisions based upon military necessity and regardless of the long-term consequences that these would pose to Britain.

Churchill, as Prime Minister and Minister of Defence, with advice from the service

Chiefs of Staff and the service ministers, handled all military operations, foreign affairs, major shipping issues, production issues and imports, as well as serious internal economic or social issues,<sup>14</sup>.

The Lord President's Committee handled home affairs and domestic economic issues and the Ministry of Production, along with the Supply Ministers and their staffs, handled the general issues of the supply programmes with the Defence (Supply) Committee coming in on major questions. The War Cabinet discussed foreign policy, major military policy, and any social, economic, or production questions that the Lord President or the Ministry of Production could not deal with alone.

The evidence suggests that significant technical problems with British bombs seriously undermined the effectiveness of the strategic air offensive. If this is so, a significant proportion of the £2.7 billion that Britain spent on creating the equipment and infrastructure for Bomber Command was wasted. Bomber Command dropped 955,044 tons of bombs during the war and suffered 73,741 casualties, including 55,500 dead. It cost one casualty for every 12.9 tons dropped and one aircrew killed for every 17.2 tons<sup>15</sup>. If only 10 percent of all bomb tonnage dropped by Bomber Command failed to operate, it means that 95,500 tons of bombs and the resources put into dropping them on Germany were completely

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14 D.N. Chester, 'The Central Machinery For Economic Policy', In *Lessons Of The British War Economy*, p.13

15 Calculation based on casualty statistics provided in Middlebrook and Everitt, *Bomber Command War Diaries: An Operational Reference Book, 1939-1945*, Midland Publication Company, Leicester, 1996, p.708

wasted. If the percentage of failure was closer to 30 percent, over a third of Bomber Command's wartime effort was wasted. And this does not take into account the bomb tonnages dropped on open countryside due to inaccuracy.

The evidence suggests that much more than 10 percent of British bombs failed to explode properly. The Air Staff would have considered a 10 percent failure rate for explosives during operations as high but within expected limits. The strength of Harris's criticism, plus the Air Staff's acceptance of a significant problem, suggests that the failure rate was much higher than 10 percent<sup>16</sup>. The Air Staff acknowledged Harris was correct and that problems did exist, due to 'an incorrect outlook in the inter-war period', which resulted in a 'state of affairs too deep seated to be rectified without the most far reaching measures'<sup>17</sup>. The Air Staff do not state who was to blame<sup>18</sup>. The implication of what Harris revealed in his official despatch and the Air Staff's reply to these criticisms shows that the reliability of British bombs was a significant concern and that this lack of reliability cost money and lives during the campaign.

### **Types of Ordnance Used**

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16 Air Staff Memorandum on the Despatch by Air Chief Marshal Sir Arthur Harris, GCB, OBE, AFC on Bomber Command's Operations 1942/1945, *Despatch*, p.209

17 Air Staff memorandum, *Despatch*, p.209

The ordnance used by Bomber Command during World War II fell into four categories: bombs, including high explosive and incendiary; sea mines; pyrotechnics; and small arms ammunition for the defensive armaments of the bombers. The supply of Bomber Command's ordnance was co-ordinated by the Armament Section of the Command, but the design, development and supply of this ordnance lay with the Ministry of Supply and Admiralty, with the Air Ministry, with the Ministry of Aircraft Production being subordinate to the first two ministries.

The centralisation of all munitions production in the Ministry of Supply was a direct result of the munitions shortages that had plagued the British during the First World War. The Government found that the centralisation of munitions production in one ministry reduced much confusion and inefficiency. As a result, the principle authority for the production of explosive fillings and munitions was given to the Ministry of Supply, whilst the Admiralty retained control of the production of maritime munitions, such as mines, torpedoes and gun ammunition. Likewise, the Air Ministry retained responsibility for the design and development of aerial munition casings, such as bombs and incendiaries. However, the Ministry of Supply controlled the production of explosive fillings and the manufacture of casings, fuses and explosive pistols (detonators). It appears from the records that responsibility for the design, development and production of

aerial munitions was a co-operative venture between the Air Ministry, MAP and the Ministry of Supply or Admiralty. This division of responsibility may have played some part in the problems that afflicted the bomb types supplied to Bomber Command that Harris complained about in Despatch<sup>19</sup>.

Between September 1939 and July 1945 the British armaments industry produced 948,217 tons of high explosive bombs and 270,363 tons of incendiaries<sup>20</sup>. Of them, 758,408 tons of HE and 196,256 tons of incendiaries were despatched on Bomber Command aircraft<sup>21</sup>. In percentage terms, this means that Bomber Command consumed 80 percent of the HE bombs and 72.6 percent of the incendiary bombs manufactured in Britain throughout the period of the war. The size of this consumption is staggering, as Bomber Command was only one of six RAF combat forces operating worldwide. The size of Bomber Command's allocation of HE bomb production underscores how important the strategic air offensive was to Britain.

### **Bombs – High Explosive**

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19 Harris, Despatch, p.91

20 Central Statistical Office, *Statistical Digest of the War*, p.146

21 Harris, *Despatch*, p.47

Throughout World War II Bomber Command used 17 different types of explosive and incendiary bombs<sup>22</sup>. These devices ranged from the 4 lb incendiary to the 22,000lb (9.82 ton) bomb, designed by Barnes Wallis, and shown here below. At the beginning of World War II, the bombs used by the RAF were essentially the same as those used in 1918, as the planners assumed that sufficient damage would be inflicted using high explosive (HE) bombs<sup>23</sup>. The experience of the Blitz in 1940 and experiments conducted by Solly Zuckerman challenged the early assumptions that HE bombs alone would be effective<sup>24</sup>. As the war progressed, the Air Ministry scientific advisors found that blast effect rather than penetrative power was more important in destroying buildings. The importance of this development was that blast bombs, which had lighter containers and heavier explosive loads, were easier and cheaper to manufacture than were heavily cased armoured piercing types. A further improvement was in the filling of bombs with new chemical explosives that provided more power per given weight. The developmental work on new explosive mixtures was the responsibility of the Ministry of Supply and the Air Ministry therefore depended upon the researchers at the Royal Ordnances Factories and the chemical industry for the necessary improvements in explosives.

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22 Harris, *Despatch*, pp. 92-93

23 British Bombing Survey Unit, *The Strategic Air War*, p.48

24 PRO AIR 2/8655, Minutes of the 25<sup>th</sup> Meeting of the Bombing Committee, 5<sup>th</sup> February 1941 and S. Zuckerman, *From Apes to Warlords*, p.45



**Fig. 6.2: Cookie** Source: Crown Copyright

The earliest bombs used by Bomber Command used an explosive mix called ‘Amatol’, a mixture of TNT and ammonium nitrate<sup>25</sup>. ‘Amatol’ was replaced by a newer and more effective explosive filling called RDX (cyclo-trimethylene-trinitramine) which was later mixed with ‘Amatol’ to produce ‘Amatex’.

‘Amatol’ was also mixed with TNT and aluminium powder to form ‘Torpex’ and ‘Minol’, the latter being used as the explosive filling of Bomber Command’s high explosive bombs from July 1943 onwards<sup>26</sup>. Of these fillings, RDX/TNT and Minol were the most commonly used. The blast of these HE bombs knocked down structures, destroyed roofs and smashed in windows and doors<sup>27</sup>. This allowed the smaller incendiary devices to penetrate inside structures and set them on fire. Most of the killing was done by these small four and thirty pound incendiaries.

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25 Zuckerman, *From Apes to Warlords*, p.45

26 Harris, *Despatch*, p.94

27 British Bombing Survey Unit, *The Strategic Air War Against Germany*, p.48

Although incendiaries only constituted 20.5 percent of all bomb tonnage dropped by Bomber Command during the entire war period, they were the most important type of bomb in creating damage<sup>28</sup>. The massive bomb tonnages dropped by Bomber Command on German military targets in France from March 1944 onwards has skewed the figures. Until March 1944, incendiary bombs accounted for 40 percent of all bomb tonnage dropped by Bomber Command. After this time incendiaries dropped in percentage terms because they were not used against hardened military targets. As a result, the proportion of high explosive bombs increased in proportion to incendiaries<sup>29</sup>.



**Fig. 6.3: Grand Slam**      **Source: Crown Copyright**

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28 Harris, *Despatch*, p.47

29 British Bombing Survey Unit, *The Strategic Air War Against Germany*, p.21

In looking at the cost of bombs, the existing data makes it hard to identify accurately the precise cost of particular bombs during the war, but it appears that, on average, it cost the British Government £1.00 per 23.4 lb of HE bomb weight purchased. At this price, the total value of high explosive bombs despatched to targets by Bomber Command during the strategic air offensive was £72,599,749.



**Fig. 6.4: Incendiaries and a 4,000 lb HE Bomb**

**Source: Crown Copyright**

In one case, that of the 4,000 lb bomb, it is recorded by the Air Ministry that 402 of this particular type of bomb, the equivalent of 723.6 tons, were dropped during 1941<sup>30</sup>. Using the Figure 6.5 below, the cost of the 402 x 4,000 lb HC bombs would have been £65,526 for that year. The following year Bomber Command

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30 PRO AIR 14/1951, Bomber Command Quarterly Review, No. 1, Sept 1942

despatched a total of 13,860 tons of all types of bombs to targets and 4,000 lb HC bombs made up 52.6 percent of this total with 4,055<sup>31</sup> of these bombs despatched at a total cost to the Exchequer of £660,965.

### **High Explosive Bomb Types Used By Bomber Command 1939-1945**

<b>Bomb Type</b>	<b>Cost</b>	<b>Usage</b>
500 lb Medium Capacity (MC)	£23.00	Moderate
1,000 lb MC	£50.00	High
4,000 lb MC	£135.00	Low
12,000 lb MC	£550.00	Low
22,000 lb MC	Approx £950.00	Very Low
ANM44, 58 and 64 500 lb (US)	-	Moderate
ANM 59 and 64 1,000 lb (US)	-	Moderate
2,000 lb Armour Piercing (AP)	£138.00	Low
SAP Bombs	£49.00	Very Low
2,000 lb HC	£100.00	High
4,000 lb HC	£163.00	Very High
8,000 lb HC	£355.00	Very High
12,000 lb HC	£585.00	High
4,000 lb General Purpose (GP)	£100.00	Low
Upkeep	-	Dams Raids
Johnnie Walker	-	Used once on Tirpitz
CS Bomb	-	Used once or twice

**Fig. 6.5:** Source: Sir A. Harris, *Despatch* pp.92-95 and Source: *War Savings, Wings for Victory* Issue, February, 1942, pp.25-27

### **Bombs – Incendiary**

The use of incendiary bombs mixed with high capacity, blast effect bombs was an idea that the British took from Germany, who, in turn may have gotten the idea

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31 PRO AIR 14/1951, Bomber Command Quarterly Review, No. 1, Sept 1942

from Douhet's writings<sup>32</sup>. On 23<sup>rd</sup> September 1941, the Air Staff produced a report detailing the effectiveness of German incendiary attacks on Britain and recommending that incendiaries be a central feature of Bomber Command attacks<sup>33</sup>. In November 1941, the Chief of the Air Staff informed Churchill of the effectiveness of fire-raising attacks<sup>34</sup>. Portal proposed the first trial fire attack be carried out in December 1941, when it was hoped that clear weather conditions and a full moon would coincide<sup>35</sup>. The success of the incendiary saw increasing numbers of this type of bomb used. In 1941, approximately 12 percent of the total bomb loads despatched consisted of incendiary bombs. The following year, 42 percent of bombloads, 5,821 tons, was incendiary devices<sup>36</sup>.

Sir Arthur Harris and the Director of Bombing Operations at the Air Ministry, Air Commodore Sydney Bufton, have both remarked upon the importance of the incendiary bomb, particularly the 4lb bomb<sup>37</sup> although the British Bombing Survey Unit's report found the usefulness of the 4lb J bombs 'controversial'<sup>38</sup>. This disagreement probably relates to the wider debate on area bombing, pursued by Harris, and precision bombing favoured by Solly Zuckerman. Bomber Command's incendiary bombs were not accurate and were only effective when

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32 British Bombing Survey Unit, *The Strategic Air War*, p.48

33 S.O. Bufton, 'Notes on Staff College Lecture Review of bombing Policy 1940/1943', *Bufton Papers*, Churchill College Cambridge.

34 PRO CAB120/393, Minute from CAS Portal to Prime Minister, 5th November 1941

35 PRO CAB120/393, Minute from CAS Portal to Prime Minister, 5th November 1941

36 PRO AIR 14/1951, Bomber Command Quarterly Review, No. 1, Sept 1942

37 Harris, *Despatch*, p.94 and S.O. Bufton, 'Notes on Staff College Lecture Review of bombing Policy 1940/1943', *Bufton Papers*, Churchill College Cambridge.

38 British Bombing Survey Unit, *The Strategic Air War Against Germany*, p.49

dropped on cities. Zuckerman, who had considerable influence on the British Bombing Survey Unit's findings, tended to dismiss the usefulness of an inaccurate weapon like the 4 lb incendiary whereas Harris did not. In carrying out attacks on cities using incendiaries, Bomber Command was responding to 'Incendiary Plan Unison' issued on 25<sup>th</sup> October 1941<sup>39</sup>. The first fire attack using incendiaries as the major component of bomb loads occurred on the night of 28th March 1942 against the city of Lubeck and this particular attack, was, unlike its predecessors, a very successful one<sup>40</sup>.

Of the total percent of bombs despatched by Bomber Command during the war 20.5 percent (196,256 tons) were incendiary bombs. This figure is smaller than the 42 percent quoted above for 1942, but is due to the dilution of bomb tonnages caused by the large amounts of HE bombs used during 1944 against military targets prior to the Normandy Invasion and to the numerous operations conducted against the flying bomb sites in Northern France and the Low Countries.

By 1944, the percent of total incendiary bomb load in a city attack by Bomber Command was around 70 percent<sup>41</sup>. Even so, the figure of 20 percent of total tonnage represents approximately 86 million individual bombs weighing either 4 or 30 lbs. The efficacy of incendiary bombs was such that Sir Arthur Harris's

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39 Bufton, 'Notes on Staff College Lecture Review of bombing Policy 1940/1943', *Bufton Papers*, Churchill College Cambridge.

40 Bufton, 'Notes on Staff College Lecture Review of bombing Policy 1940/1943', *Bufton Papers*, Churchill College Cambridge.

41 Air Studies Division Report: The Economic Effects of the Air Offensive Against German Cities, *USSBS*, p.5

declared the 4 lb incendiary bomb was ‘the mainstay of the Command throughout the war’<sup>42</sup>. The estimate of the financial cost of obtaining these bombs would suggest that Harris’s claim is accurate.

Based on an estimated price of 2s/9d per pound for incendiaries the cost to Britain of manufacturing incendiary bombs for Bomber Command was approximately £73 million<sup>43</sup>. The cost of individual incendiary bombs ranged from 2s/9d for a 4 lb incendiary to 15s 0d for a 4 lb Magnesium Incendiary Bomb and £3.00 for the 30 lb Incendiary Bomb<sup>44</sup>. This means that incendiary bombs cost slightly more than 50 percent of the total cost of £145.6 million spent on bombs by Britain during the entire period of the campaign. This supports the claims made by Harris that the incendiary bomb was the most significant type of munition deployed by Bomber Command. The heavy reliance of Bomber Command on highly inaccurate incendiaries shows that fire-raising was a major weapon in the strategic air offensive.

### **Bombs - Special Arrangements**

In the 1930s, there was widespread fear in most countries that combatant nations would use chemical warfare, in the form of Mustard Gas, against the civilian population of their enemy. There is no doubt that the British Government shared

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42 Harris, *Despatch*, p.94

43 *War Savings*, Wings for Victory Issue, Vol. 3, No. 11, Feb 1943, p.26

44 *War Savings*, Wings for Victory Issue, Vol. 3, No. 11, Feb 1943, p.26

this fear and was concerned that Germany would use chemical weapons in attacks against British cities. In the months leading up to war, these fears led to mass issuing of gas masks to the civilian populations of Britain, France and Germany and the preparation of stocks of Mustard Gas for use against Germany.

British preparations for strategic air war included the production and stockpiling of chemical weapons as early as 1939. The First Report of the Air Ministry on Supply and Production details the payment of £4,500 to T& J Daniels for the extension of their Gas Bomb Case manufacturing capacity<sup>45</sup>. This suggests that the Air Ministry either held stocks of chemical weapons, most probably Mustard Gas, or was expecting the imminent delivery of such weapons. Further evidence of Britain's plans for chemical warfare includes Air Commodore Sydney Bufton, the personal papers of the Director of Bomber Operations Policy at the Air Ministry during World War II<sup>46</sup>, telegrams sent by Churchill to Stalin in April 1943<sup>47</sup> and Churchill's, *History of the Second World War*<sup>48</sup>.

British policy on the use of mustard gas was that it would use these weapons only if the enemy used them first. The draft documents in Bufton's private papers only ever envisaged retaliatory gas attacks on Germany. The plans assumed that 'the respective governments have directed the unrestricted use of gas against all types

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45 PRO CAB 68/1, Supply and Production, First Report By The Air Ministry, 23rd September 1939 and PRO CAB 68/3, Supply and Production, Fourth Report By The Air Ministry, 9th December 1939

46 Bufton, BUFT 3/51, Plan for Retaliatory Gas Attack on Germany, Feb 45

47 PRO CAB 120/858, T.540/3, 18th April, 1943

of objectives in Germany'<sup>49</sup>. The wording of the draft plans indicates that planning for the use of chemical warfare continued throughout the war and that the retaliatory nature of such warfare remained official Air Ministry and government policy.

The closest that Britain came to using mustard gas during World War II was in April 1943, when British Intelligence sources reported rumours circulating in Spain of a German intention to use Mustard Gas against Russian troops on the Eastern Front<sup>50</sup>. Churchill passed this tenuous information to Stalin in a telegram dated the 18<sup>th</sup> April 1943<sup>51</sup>. Stalin replied within one day of Churchill's telegram stating, 'your information on the intention of the Germans to use gas on our front is corroborated also by our own information'<sup>52</sup>. The speed with which Stalin answered Churchill's telegram suggests Churchill had caught him off-guard. It is difficult to accept that the Russian would have kept secret from the British information that Germany was planning to use mustard gas against the Red Army. Stalin agreed with Churchill that they should inform the German Government through intermediaries that the Allies had found out about their intention to use gas on the Eastern Front and that this would result in retaliatory gas attacks by Bomber Command on Germany. Stalin told Churchill that, 'It goes without saying that I fully support your intention to warn Hitler and his Allies and threaten

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48 Churchill, *The Hinge of Fate*, pp. 174, 273

49 *Bufton Papers*, 3/51, Plan for Retaliatory Gas Attack on Germany

50 PRO CAB 120/858, Head of State Telegram to Marshal Stalin, T.540/3, 18th April, 1943

51 PRO CAB 120/858, T.540/3, 18th April, 1943

52 PRO CAB 120/292 Telegram, 19th April 1943

with a powerful chemical attack in case they make a gas attack on our front<sup>53</sup>.

The episode suggests that Britain had the means of conducting bombing attacks using mustard gas and that Churchill was quite prepared to launch such attacks against German cities, if the need should arise.

Mustard gas was not a stand-alone weapon. The Air Staff estimated that such an attack would require 25 percent HE bombs and 75 percent mustard gas bombs to be effective against German cities<sup>54</sup>. The HE bombs would break windows and doors to allow the poison gas to enter buildings and do its damage. Despite all of the planning and preparation for the offensive use of mustard and other gasses, the European powers did not resort to chemical warfare. Despite not using such weapons, Britain did plan to use poison gas against the civilian population of Germany, if the need arose.

### **The Efficiency of Bombs**

The extent of concern with the efficiency of Britain's aerial bombs is obvious from the harshness of Sir Arthur Harris's criticisms of the designers involved and by contrasting this with his praise of the Admiralty design staff working on sea mines that Bomber Command laid. In his criticism of the shortcomings of the armaments designers, Harris specifically singles out the service and civilian staff of the Air Ministry and the Ministry of Aircraft Production, whom he called

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53 PRO CAB 120/292<sub>2</sub> Telegram, 19th April 1943

54 *Buften Papers*, 3/51, Plan for Retaliatory Gas Attack on Germany

‘incompetent’<sup>55</sup>. He urged a ‘drastic overhaul of the design personnel’ in order to safeguard the national security of Britain<sup>56</sup>. By comparison, he praised the work of the Admiralty on the design, development and manufacture of sea mines, which were ‘without exception’ successful and efficient<sup>57</sup>.

Harris’s comparison is a little unfair. The success of the Admiralty in the area of sea mines was due to the tight control exercised by the Mine Warfare Branch of the Royal Navy at HMS Vernon and to the fact that sea mines that had been operationally deployed could be retrieved and examined. It was not possible for the designers within the Air Ministry and the MAP to obtain similar insights because as Bomber Command dropped most of its bombs in the dark, there was little opportunity to obtain accurate observation of their performance or direct effect. And obviously it was not possible for the Air Ministry and MAP bomb designers to retrieve and examine aerial bombs.

What is apparent from the complaints is that the fundamental problem with British aerial bombs appears to have been in the area of trigger and fuse design. The No. 30 tail pistol (detonator), which was widely used in all medium calibre bombs throughout the war, is a good example of the difficulty Bomber Command had in obtaining operational feedback on bombing attacks. Bomber Command only became aware that the No. 30 pistol had severe problems when its crews

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55 Harris, *Despatch*, p.91

56 Harris, *Despatch*, p.91

57 Harris, *Despatch*, p.91

undertook daylight-bombing operations in the autumn of 1944. During this period, bomber crews were appalled to see bombs dropped from accompanying aircraft explode as they left the aircraft<sup>58</sup>. Subsequent investigations found that the nut on the striker spindle was binding and forcing the spindle onto the detonator. In the dark, this fault had not been obvious and crews, if they survived, would have assumed that the explosion was German flak. Attempts to fix the problems did not entirely prevent these premature detonations and the designers had found no fix for the problem before the war ended. It is therefore reasonable to suspect that a large percent of the medium sized bombs using the No. 30 Pistol failed and, worse, they may have been responsible for the destruction of the aircraft that carried them.

The failure of the No. 30 Pistol was not unique. Harris describes the No. 37 Long Delay Fuze Mark IV, introduced at the beginning of 1943, as having ‘several dangerous features which resulted in the loss of lives of many of our own personnel and the destruction of a number of aircraft’<sup>59</sup>. Harris also states that with the anti-tampering device fitted, 15 percent of these fuzes failed rendering the bomb a dud, which would fail to explode<sup>60</sup>. This fuze was, until May 1944, the only long delay fuze available to Bomber Command and, like the No. 30 Pistol, its problems were never rectified.

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58 Harris, *Despatch*, p96

59 Harris, *Despatch*, p.96

60 Harris, *Despatch*, p.96

In May 1944, Bomber Command began to take delivery of two new long delay fuzes, which unlike the No.37 fuze, had no anti-tampering device. These new fuzes were the No. 53 Pistol and the No. 53a one-hour delay pistol. These fuzes suffered the same problems as the No. 37 pistol. They caused a number of accidents and losses within the command. Sir Arthur Harris considered them both dangerous and unreliable<sup>61</sup>. Other fuzes used within Bomber Command included the No. 845, which was designed to be fitted to the nose of general purpose and medium capacity bombs. This fuze also had an anti-tampering device that ‘was apt to become live when it should have remained safe’<sup>62</sup>. Harris banned the 845 when one of them blew up an entire bomb dump in the autumn of 1943<sup>63</sup>. The 848 fuze, used in the 4.5-inch photographic flash, was unreliable and was replaced by the 849 fuze, which was reliable. The 42 fuze, used in pyrotechnics including target indicators, flares and incendiary bomb clusters throughout the air offensive, gave ‘considerable trouble’; the M111 fuze, used in 4.5 inch photographic flares, also suffered a high proportion of failure<sup>64</sup>. In all, Harris only praises the No. 44 Pistol and the 860 and 867 Barometric fuzes introduced in 1943<sup>65</sup>. Of the 11 fuzes most commonly used by Bomber Command, nine were ineffective, dangerous or unreliable. This suggests the failure rate of British bombs was much higher than the 15 percent suggested for one type of fuze by

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61 Harris, *Despatch*, p.96.

62 Harris, *Despatch*, p.96

63 Harris, *Despatch*, p.96

64 Harris, *Despatch*, pp. 96-97

65 Harris, *Despatch*, p.96

Harris and it may be that up to 30 percent of all British bombs failed to operate correctly because of bad fuzes<sup>66</sup>.

The major problem afflicting British bombs may have been unreliable fuzing systems; however, there were other problems as well. The next most important problem that Bomber Command encountered involved contained design and construction. The lightness of the high capacity HE bomb containers relative to their overall weight meant that a knock or bump would produce damage. The heaviness of these bombs also made handling difficult, particularly when it is realised that many bomber stations had only hand operated winches and muscle power to move these bombs. The result was that poor aerodynamics and damage to bombs during transportation, storage and handling plagued the Command<sup>67</sup>.

Harris ascribed the problem to poor design and, by implication, a lack of effective co-ordination between the operational squadrons and the designers<sup>68</sup>. The importance of bomb casing design was a case in point. The design of new bombs or the redesign of existing bomb types had a major impact on the capacity of Bomber Command to handle them. The problem was that whilst bomb designers designed bombs for a particular job of destruction, no one was co-ordinating the design and manufacture of the equipment needed to move and lift these bombs into the aircraft. The result was that Bomber Command had to expend

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66 Harris, *Despatch*, p.96

67 Harris, *Despatch*, pp. 91-99

68 Harris, *Despatch*, pp. 91-99

considerable time and resources in designing derricks and manual handling systems that would allow ground staff to move and position bombs in aircraft<sup>69</sup>.

For example, how did the ground crew load the new 12,000 lb bomb into a Lancaster? The answer appears to have been that they used a lifting device called 'Lorraine' and 'brute strength' to lift bombs weighing 5.3-tons into place<sup>70</sup>.

Throughout World War II, the standard way of moving HE bombs was by rolling them along the ground<sup>71</sup>. The manual handling of heavy bombs in this way resulted in injury to personnel and damage to bomb casings, which would have made them even more inaccurate than they already were. Even the mud thrown up by the uncovered wheels of the bomb trolleys as they crossed the open fields that separated the bomb dumps from the airfields may have caused failures by getting into the fusing systems and coating the bomb containers.

A rigorous programme of experimentation and testing of ordnance may have prevented this problem from continuing as long as it did. The extent of the Air Ministry's experimental programme did not go much beyond testing the effects of blast bombs and armoured piercing bombs on buildings. The responsibility for such testing lay with the Aeroplane and Armament Experimental Establishment (AAEE). The problem that faced the AAEE was the availability of bombing ranges, all of which were in almost constant use by the Operational Training

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69 Harris, *Despatch*, p.97

70 Harris, *Despatch*, p.97

71 Harris, *Despatch*, p.96

Units and the availability of heavy bombers and crews to take part in the testing<sup>72</sup>. The jealous retention of heavy bombers, bombs, aircrew and bombing ranges by Bomber Command may have prevented the AAEE, from successfully investigating and correcting the problems associated with bomb pistols and fuzes. Ironically, Harris's jealous conservation of his available force may have allowed the ineffective bombs he so vehemently criticised to remain in service for so long.

Prior to the war, the AAEE had suffered from significant internal problems of its own. A Group Captain commanded the organisation, which consisted of a Performance Test Squadron and an Armament Squadron, supported by a small civilian scientific team led by the Chief Technical Officer. The rank of the commanding officer was relatively junior, making it difficult for him to argue with superiors for access to resources, or for the establishment of a more rigorous programme of testing<sup>73</sup>. On top of this, the AAEE a long-standing dispute between the civilian scientists and the RAF officers made the effectiveness of the AAEE questionable.

The cause of the conflict lay in the way in which the AAEE evaluated aircraft and their armaments. The professional RAF officers were opposed to the scientists' insistence on quantitative methods at the expense of pilot observation and opinion<sup>74</sup>. As with all such internecine squabbles most of the AAEE's efforts

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72 Postan, Hay and J. Scott, *Design and Development of Weapons*, pp. 465-467

73 Postan, Hay and J. Scott, *Design and Development of Weapons*, pp. 465-467

74 Postan, Hay and J. Scott, *Design and Development of Weapons*, p.467

went into winning the argument and this reduced the capacity of the organisation to contribute to the testing of bombs prior to the outbreak of war in 1939<sup>75</sup>. The outcome of these failures was that there was no systematic evaluation of bomb types and therefore no way of identifying and correcting problems. The failure of the Air Ministry to ensure a rigorous research project in bomb design and appraisal was a significant lapse.

Whatever the cause, there is little doubt that Bomber Command was unhappy with the quality of the bombs and other ordnance that they were supplied by the Air Ministry and MAP design organisations. The testing of armaments that was undertaken did not identify significant failures in bomb types and ignored the impact of design changes on bomb transportation, storage and handling. All of which were areas of significant concern to the Command throughout the war<sup>76</sup>. The likelihood is that somewhere around 30-40 percent of all of ordnance did not function effectively; that is they failed to explode at the right time. If this is so, it is reasonable to suggest that faults, particularly defective fuses, made useless somewhere between £43.7 million and £58.2 million worth of ordnance. It also wasted the sacrifices made by many of the men who flew these bombs to their targets.

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75 Postan, Hay and J. Scott, *Design and Development of Weapons*, p.467

76 Harris, *Despatch*, pp. 91-99

## **Bombing Accuracy**

A further negative effect on the returns achieved by the investment made by the British Government lies in the lack of accuracy of night bombing. Bomber accuracy in 1943 meant that only 15 percent of the despatched load fell within a one-mile radius from the selected point of attack<sup>77</sup>. Effectively, this meant that only 37,168 tons of bombs fell within one mile of the target area whilst 210, 618 tons was thinly scattered outside this area<sup>78</sup>. At the end of 1942, £20,161,723 worth of British bombs had been scattered ‘thinly’ over the outskirts of a number of German cities.

Accuracy improved as navigational equipment got better and as the German defenders lost territory on which their early warning radar systems had operated. Towards the end of 1944, 75 Lancasters carrying a bomb load of 70 percent incendiaries and 30 percent HE could achieve the same level of destruction as a 750 Lancaster force in 1943 because, by late 1944, they were able to drop 93 percent of their bombs into an area of one mile in radius<sup>79</sup>.

## **Pyrotechnics**

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77 McIsaac, David, ‘Area Studies Division Report, The Economic Effects of the Air Offensive Against German Cities’, *USSBS*, p.5

78 McIsaac, David, ‘Economic Effects of the Air Offensive Against German Cities’, *USSBS*, p.5

One of the major problems that afflicted Bomber Command in its operations was visibility and the highly inaccurate nature of blind bombing. As we have already noted, the accuracy achieved by Bomber Command over Germany was such that a large proportion of the resources expended in conducting the strategic air offensive fell on empty countryside. After the war, the Air Ministry found that 55 percent of the bomb tonnages dropped missed the aiming point by more than 2,000 yards<sup>80</sup>. The major problem facing Bomber Command was one of target identification and marking and the major means of overcoming this problem was the development of ever more sophisticated pyrotechnics.

The development of pyrotechnics was a natural development stemming from the traditional military use of flares to illuminate the battlefield. The initial pyrotechnic was the 4.5 inch reconnaissance flare. The use of such a flare posed a number of problems ranging from the poor illumination of ground targets to blinding glare from the burning flare that prevented the bomber crew from seeing the ground.

By 1942, Bomber Command took steps to improve the effectiveness of its target identification and marking systems. The impetus was the acceptance by the Air Staff of the Butt Report of August 1941. Mr. Butt's investigation of photographic

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79 McIsaac, David, 'Economic Effects of the Air Offensive Against German Cities', *USSBS*, p.5

80 McIsaac, David, 'Area Studies Division Report, The Economic Effects of the Air Offensive against German Cities', *USSBS*, p.9.

evidence found that in Germany only 30 percent of bombs fell within five miles of their target. In the Ruhr, where air defences were more substantial, only 10 percent of bombs fell within the five-mile radius of the intended target<sup>81</sup>. Despite Butt's evidence, improvement was slow. In November 1941, Sir Charles Portal, the Chief of the Air Staff, wrote to Churchill telling him that examination of the night photographs taken over the last three months did not 'disclose any improvement' on the results in June and July which Butt had examined. Portal placed the blame on the weather, which was 'consistently bad'<sup>82</sup>.

The result of the Butt Report was an increase in the resources put into designing and developing effective navigational aids and targeting pyrotechnics. According to Harris, between early 1942 and May 1945, Bomber Command used over 40 different types of flare and marker bombs in a large variety of colours. The need for such a large number of different devices lay in a pyrotechnic version of the electronic warfare that the combatants were conducting. As soon as Bomber Command used a set of colours in a marker bomb or target indicator, the German defenders would simulate it to divert the bomber attack onto decoy targets set up in open fields. As Harris says, 'throughout the period that followed there was a race between the Development Branches in this country, and those of the enemy'<sup>83</sup>.

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81 Overy, *The Air War*, p.110

82 PRO CAB 120/393, Memorandum from CAS to Prime Minister, 5th November 1941

83 Harris, *Despatch*, p.104

The first of the true ‘marker’ bombs was the 2,800 lb ‘Pink Pansy’. This bomb, sometimes mistakenly described as a 4,000 lb bomb, because it used the same container as the 4,000 lb HC bomb, was one of the more effective markers. The problem for the German defenders was that they could not simulate the pink colour obtained when this bomb burst. Another advantage of the ‘Pink Pansy’ was its lighter weight which was achieved by using a lower density benzol, rubber and phosphorus filling<sup>84</sup>. The ‘Pink Pansy’ was quickly followed by ‘Sky Markers’, coloured flares and stars, which were used by aircraft carrying Oboe, the first generation of ground sensing radar. Sky Markers were followed by the Target Indicator (TI) bomb, which was first used during a raid on Berlin on the night of 16/17 January 1943.

The contents of a TI were to be widely varied in an effort to prevent the German defenders from decoying the attacking forces. The TI bomb was a highly aerodynamic weapon that was able to release its packages of pyrotechnic candles of differing colours. A single TI bomb could mark an area of approximately 100 yards diameter and differing fuse settings on the candles allowed some to ignite as others burnt out<sup>85</sup>. As time went by, Bomber Command used larger 1,000 lb TI bombs to swamp the decoy efforts of the Germans, who had become highly proficient at simulating the effects of the existing British systems<sup>86</sup>.

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84 Harris, *Despatch*, p.104

85 Harris, *Despatch*, p.104

86 Harris, *Despatch*, p.105



**Fig. 6.6: Night Raid** Source: [www.mod/raf/bomber/command](http://www.mod/raf/bomber/command)

Other pyrotechnic devices used by Bomber Command included the ‘Spot’ bomb, which the Pathfinder aircraft dropped to mark turning points on the ground for the following bomber stream and a number of smoke bombs, which bombers used to mark targets during daylight raids conducted towards the end of the war. There were a number of photoflashes including the 4.5 inch Photographic Flash, Mark II, the 848 fuze and the Tri-Cell Chute. These illuminated targets so that the attacking bombers could take photographs<sup>87</sup>.

The research conducted to date has failed to identify the cost of particular pyrotechnics. This may be a result of the highly specialised nature of these armaments and the fact that they were not subjected to larger production runs, being manufactured using a variety of different components drawn from existing bomb and explosive production. An example of this is the use of the 4,000 lb bomb casing for the 2,800 lb ‘Pink Pansy’<sup>88</sup>. Given the constantly changing fillings contained within these pyrotechnic bombs it is likely that the cost per unit

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87 Harris, *Despatch*, p.106

88 Harris, *Despatch*, p.104

produced was much higher than the cost of an equivalent HE bomb or incendiary. Despite this, it is unlikely that the overall cost of pyrotechnics would have been anything near that of HE or incendiary bombs due to the relatively low number of pyrotechnics used per air raid. The likelihood is that the total cost of these devices would have been around £10 million for the entire period of the war. Given the lack of reliable information, this figure is an informed guess.

### **Manufacturing Ordnance - Bomb Cases**

The manufacturing of bombs was broken up during the war into three major operations: first, the manufacture of the bomb containers; second, the manufacture of the explosive contents; and, third, the manufacture of the fuses, which operated the bombs. Of these three operations, the simplest was manufacturing the bomb cases and the MAP dispersed this work amongst the 25 companies listed in Figure 6.7 below<sup>89</sup>.

There is little doubt that the 27 firms listed below received financial aid from both the Air Ministry and, later in the war, the MAP. The evidence available indicates that six firms obtained financial assistance totalling £2,058,900 for the construction of new buildings and plant for the making of bombs<sup>90</sup>. The firms involved included ICI Ltd., which received £395,250 for the construction of a

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89 PRO AVIA 10/211, Bomb Subcontracting Firms.

90 PRO CAB 68/1, Supply and production First report by the Air Ministry, W.P.(R)(39) 16, 23<sup>rd</sup> Sept 39, and CAB 68/3

new bomb-making factory at Kilmarnock in Scotland and £23,000 for machine tools for incendiary bombs at the Linlithgow incendiary bomb plant<sup>91</sup>. The supply of machine tools indicates that as well as the manufacture of explosive filling, ICI was also involved in the manufacture of bomb casings, most probably the incendiary type.

### **Bomb Manufacturing Firms**

Baldwin Ltd	P.R. Jackson and Company
Binns and Speight	Jarrow Metal Industries
Briggs Motor Bodies	N.C. Joseph
Castle Engineering	Kryn and Lely
Gattons and Company	Littlewoods Mail Order Stores
G. Coles and Sons	F.H. Lloyd and Company
Corfield and Buckle	Magnesium Castings and Products
Dobson and Barlow	Magnal Products
Enfield Furniture Manufacturers	E. Nicklin & Sons
Machine Products	Platt Bros. & Company
J. Firth and J. Brown	Steel Company of Scotland
Hadfields	Suckling Pty Ltd
ICI Ltd.	Trojan Ltd. Pty.
Vickers Armstrong	

**Fig. 6.7:**

**Source: PRO AVIA 10/211, 7.6.40**

Three other firms, Machine Products of Cardiff, Hadfields Ltd of Sheffield and Jarrow Metal Industries Ltd received government funding of similar size to that given to ICI. Two of these companies, Machine Products and Hadfields, were giving funding to establish 'shadow factories' with Machine Products receiving £306,000 and Hadfields £715,000<sup>92</sup>. Jarrow Metal Industries Ltd got £461,000

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91 PRO CAB 68/1, Supply and production First report by the Air Ministry, W.P.(R)(39) 16, 23<sup>rd</sup> Sept 39,

92 PRO CAB 68/3, Fourth Monthly Report on Supply and Production by Air Ministry, 19<sup>th</sup> Dec 1939

for the extension of plant and buildings for the production of Semi –Armour Piercing (SAP) bombs<sup>93</sup>. Jarrow Metal Industries received further funding of £56,000 in May of 1940 to meet a shortfall of 10,750 in 500 lb SAP bomb component sets. Jarrow obtained this money to enable it to increase their production from 1,050 sets of components per month to 7,500 sets per month<sup>94</sup>. Vickers Armstrong received £118,500 for the production of SAP bombs and Baldwins Ltd of London received £29,150 to increase monthly production of 250 lb and 1,000 lb bombs to 5,400 and 1,800 respectively<sup>95</sup>.

Of the £2 million given to bomb manufacturers, over £1 million was for the construction of two ‘Shadow Factories’. If the finance for the Shadow Factory scheme is left out of the analysis then the remaining £600,000 divided amongst three companies gives an average amount of government financial assistance of £200,000 per company. This very rough estimate suggests the government supplied around £5 to £7 million in financial aid to bomb manufacturers in order for them to increase their production levels. This estimate is qualified by the fact that the funding applies to such a small cross section of the munitions industry.

The second process in the making of a bomb is the manufacture of explosives and the filling of the bomb containers with this explosive. Between 1939 and the second quarter of 1945 the British chemical industry produced 485,078 tons of

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93 PRO CAB 68/3, Fourth Monthly Report on Supply and Production by Air Ministry, 19<sup>th</sup> Dec 1939

94 PRO CAB 68/6, Seventh Monthly Report, Supply and Production, Air Ministry, 16th May, 1940

95 PRO AVIA 10/211, Bomb Firms, 7<sup>th</sup> June 1940

explosive filling for HE aircraft bombs<sup>96</sup>. This represents 51.1 per cent of the total weight of HE bomb production of 948,217 tons in Britain between September 1939 and July 1945<sup>97</sup>. Bomber Command used the vast majority, 80 percent, of this production during the strategic air offensive.

In September of 1939, the Air Ministry reported to Cabinet that the filling organisation already developed would be 'adequate to meet revised requirements' with the exception of incendiaries<sup>98</sup>. This shortfall in incendiaries was to be met by ICI Ltd with financial assistance from the government as already noted above. The other type of bombs reportedly suffering technical problems were the SAP and Anti-Submarine (AS) bombs, whose fuse fittings were not watertight leading to a failure of these weapons<sup>99</sup>.

The chemical industry was the centre of production for the explosive fillings used in all bombs and other explosive ordnance. The explosive fillings favoured by the Air Ministry were those such as RDX/TNT, Torpex and Minol<sup>100</sup>, which provided large blast with lower density and therefore less weight. The Ministry of Supply rather than the Air Ministry or MAP managed explosive filling production and this led to some disputes over priorities assigned to aerial bomb production. Over all though, the relationship was quite good with the sole exception of the concerns

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96 Central Statistical Office, *Statistical Digest of the War*, p.146

97 Central Statistical Office, *Statistical Digest of the War*, p.146

98 PRO CAB 68/1, Supply and production First Report by the Air Ministry, 23<sup>rd</sup> Sept 39,

99 PRO CAB 68/1, Supply and production First Report by the Air Ministry, 23<sup>rd</sup> Sept 39,

100 Harris, *Despatch*, p.94

about the reliability of the fusing mechanisms. The Air Ministry did provide a little funding to some of the manufacturers of chemical explosives particularly ICI Ltd and Athol G. Allen Ltd, who received £5,000 to extend their TNT plant<sup>101</sup>. Other than these few figures, there is little in the Air Ministry or MAP files relating to the financial costs of manufacturing high explosive fillings. Given the predominant role played in this area by the Ministry of Supply, this is not surprising.

The other area in which the Air Ministry took a significant interest was the production of magnesium, which was used in the production of aircraft alloys and the filling for incendiaries, flares and illumination bombs. The Army and Royal Navy also used magnesium in their pyrotechnics but their needs were much less than those of Bomber Command<sup>102</sup>. In late 1939, the Air Ministry had estimated its future demand for magnesium as being up to 15,000 short tons per year<sup>103</sup>. The 4lb incendiary bomb, which was dropped in its millions over Germany, was a magnesium bomb that burned at a high intensity. This bomb and the 30 lb incendiary bomb constituted 26 percent (196,256 tons) of the total bomb tonnage dropped by Bomber Command during the offensive<sup>104</sup>. In order to supply the necessary magnesium for these bombs the Air Ministry, MAP and the Ministry of Supply had to ensure an increasing supply of magnesium from domestic and foreign sources. In 1939, two firms Murax Ltd and Magnesium Elektron Ltd,

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101 PRO CAB 68/1, Supply and Production First Report by the Air Ministry, 23<sup>rd</sup> Sept 39

102 PRO CAB 68/5, Supply and Production Sixth Report by the Air Ministry, 13<sup>th</sup> Feb 40

103 PRO CAB 68/2, Supply and Production Second Report by the Air Ministry, 10<sup>th</sup> Oct 39

were provided with £987,000 for the expansion of their production facilities<sup>105</sup>.

As national production of magnesium was in the order of 5,000 short tons per year<sup>106</sup>, the Air Ministry's concerns about this particular raw material are entirely understandable.

The £500,000 provided to Murex Ltd. went to increase production at the company's facilities by 4,000 tons per year<sup>107</sup>. The £487,000 given to Magnesium Elektron Ltd was to increase their production to about 5,000 tons per year<sup>108</sup>. Despite these payments, the increase in magnesium supplies was to take nearly two years as the amount of magnesium produced in Britain during 1940 was only 6,100 tons, whilst consumption in the same year was 13,800 tons<sup>109</sup>. The shortfall of 7,700 tons made good by importation from the United States and the recovery of magnesium from scrap<sup>110</sup>. By 1941, British magnesium production has lifted to 10,900 tons before peaking at 23,100 tons in 1943<sup>111</sup>.

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104 Harris, *Despatch*, p.47

105 PRO CAB 68/3, Supply and Production Fourth Report by the Air Ministry, 19<sup>th</sup> Dec 39

106 PRO CAB 68/1, Supply and production First report by the Air Ministry, 23<sup>rd</sup> Sept 39, and Central Statistical Office, *Statistical Digest of the War*, p.109

107 PRO CAB 68/2, Supply and Production Second Report by the Air Ministry, 10<sup>th</sup> Oct 39

108 PRO CAB 68/6, Supply and Production Ninth Report by the Air Ministry, 16<sup>th</sup> May 40

109 PRO CAB 68/6, Supply and Production Ninth Report by the Air Ministry, 16<sup>th</sup> May 40 and Central Statistical Office, *Statistical Digest of the War*, p.109

110 PRO CAB 68/6, Supply and Production Ninth Report by the Air Ministry, 16<sup>th</sup> May 40

111 Central Statistical Office, *Statistical Digest of the War*, p.109

The major ingredient of incendiary bombs, flares, photoflashes and target indicators was magnesium powder<sup>112</sup>. In 1940, the Air Ministry estimated that annual production of this material was about 450 tons whilst the Ministry's requirements were 1,000 tons for 1940 rising to 2,000 tons by 1941<sup>113</sup>. The shortfall in finely ground magnesium powder, used in incendiary bombs and pyrotechnics, led to a further payment of £159,000, with £85,000 going to Murex and £74,000 to Magnesium Elektron<sup>114</sup>. The Air Ministry also pressured the Ministry of Supply to increase imports of raw magnesite and to increase domestic production of magnesia using dolomite clay and seawater.

**British Magnesium  
Production and Consumption  
1939-1945 (Short Tons)**

Year	Production	Consumption
1939	5,000	
1940	6,100	8,000
1941	10,900	13,800
1942	18,100	20,800
1943	23,100	36,100
1944	18,100	36,000
1945	6,800	8,600
<b>Total</b>	<b>88,100</b>	<b>123,300</b>

Table 6.8: Source: *Statistical Digest of the War*, p109

The total Air Ministry investment in the development of productive capacity for magnesium appears to have been £1,114,000 split between Murax and

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112 PRO CAB 68/5, Supply and Production Sixth Report by the Air Ministry, 13<sup>th</sup> Feb 40

113 PRO CAB 68/5, Supply and Production Sixth Report by the Air Ministry, 13<sup>th</sup> Feb 40

114 PRO CAB 68/6, Supply and Production Ninth Report by the Air Ministry, 16<sup>th</sup> May 40

Magnesium Elektron<sup>115</sup>. The only other expenditure being £52,400 paid for 42 additional presses, each capable of making 1,200 4.5” flare candles per month in order to meet an expected monthly demand for up to 50,480 such flares<sup>116</sup>. The total Air Ministry and MAP funding of pyrotechnic production therefore appears to have been £1,166,400.

A final cost that can be added to the equation is the cost of transporting the 955,044 tons of ordnance from its places of manufacture to the airfields where it was loaded onto the aircraft that were to attempt to deliver it to the target. Based on an average journey of approximately 120 miles at a total cost of 1s/6d per ton-mile charged by railways during, the period the cost would have been around £8.6 million.

### **Machine Guns**

With the sole exception of the Mosquito and the Photo-reconnaissance Spitfires, every aircraft operated by Bomber Command carried a defensive armament of .303-inch Browning machine guns. These weapons were a gas operated, blow back system and were widely used by the RAF and the Royal Navy during World War II. Sir Arthur Harris describes the .303inch Browning as having ‘performed most reliably throughout the war’ whilst on page 107 he describes the

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115 PRO CAB 68/1, Supply and production First report by the Air Ministry, 23<sup>rd</sup> Sept 39, PRO CAB 68/3, Supply and Production Fourth Report by the Air Ministry, 19<sup>th</sup> Dec 39, PRO CAB 68/5, Supply and Production Sixth Report by the Air Ministry, 13<sup>th</sup> Feb 40 and PRO CAB 68/6, Supply and Production Ninth Report by the Air Ministry, 16<sup>th</sup> May 40

ineffectiveness of the .303inch Browning against the heavily armoured German fighters which were also equipped with cannon that out-ranged the .303 inch<sup>117</sup>. This discrepancy may simply be that, whilst outranged and ineffectual, the Browning operated reliably, unless it froze in the low temperatures encountered at the altitude the bomber formations flew<sup>118</sup>.

Despite being happy with the reliability of the .303-inch Browning machine gun, Sir Arthur Harris's more fulsome description of the ineffectiveness of these weapons is a more telling statement about the usefulness of this defensive armament. The problems faced by Bomber Command crews in defending themselves against air attack were enormous. The ability of the crew to detect an approaching enemy fighter relied on the observation of that fighter in the dark. Anecdotal evidence in a number of wartime memoirs written by ex-aircrew repeatedly make the point that evasion and not firepower was the primary means of defence against German fighters<sup>119</sup>.

The manufacture of machine guns for the RAF had been a concern for the Air Ministry in the immediate lead-up to the war in 1939. Of particular concern was the supply of the .303 inch Browning machine guns, which were to be the armament of both bomber and fighter aircraft. The standardisation of the direct

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116 PRO CAB 68/6, Supply and Production Ninth Report by the Air Ministry, 16<sup>th</sup> May 40

117 Harris, *Despatch*, pp. 107-111

118 Harris, *Despatch*, p.109.

fire weapon promised higher production levels sooner rather than later. The problem was that the selection of the .303-inch Browning had a major impact upon the design of aircraft, which later reduced their effectiveness in combat. For example, the use of the .303-inch Browning allowed Reginald Mitchell to keep the wings of the Spitfire very thin and aerodynamically efficient. When it was realised that the .303-inch weapons were not capable of inflicting the necessary damage on German aircraft in the few seconds that a closing target was available, the replacement of the .303-inch Browning with 0.5-inch machine guns or cannon required a redesign of the airframe. For the bombers, the .303-inch Browning Machine Guns did not offer much in the way of protection; however, the 0.5-inch guns festooned over the Boeing B-17 did not provide adequate protection either.

The Air Ministry obtained its supplies of .303-inch machine guns from three major arms manufacturers, B.S.A. Guns Ltd, Vickers Armstrong<sup>120</sup> and the Royal Ordnance Factory at Enfield<sup>121</sup>. In order to meet the expected demand, B.S.A. Guns Ltd. was given £1,100,000, Vickers Armstrong £500,000 and the Royal Ordnance Factory £540,000 (approximately)<sup>122</sup> in financial assistance by the Air Ministry to purchase machine tools for manufacture of Browning and Vickers K machine guns at B.S.A's Birmingham and Redditch plants and Vickers Crayford

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119 For examples see A. Cooper, *Air Battle of the Ruhr*, Airlife Publishing Ltd., Shrewsbury, 1992, pp.23-24 and J. Currie, *Battle Under the Moon: The Documented Account of Mailly-le-camp, 1944*, Air Data Publications, Wilmslow, 1995, pp.86-87.

120 PRO CAB 68/3, Supply and Production Fourth Report by the Air Ministry, 19<sup>th</sup> Dec 39.

121 PRO CAB 68/4, Supply and Production Fifth Report by the Air Ministry, 12<sup>th</sup> Jan 40.

122 PRO CAB 68/4, Supply and Production Fifth Report by the Air Ministry, 12<sup>th</sup> Jan 40.

and Openshaw plants<sup>123</sup>. This total of £2,100,000 does not include the cost to the Government of relocating one of B.S.A. Browning machine gun production plants into a 2.2 million square foot underground facility.

**Estimated Cost Of Machine Guns For Bomber Command**

<b>Aircraft Type</b>	<b>Number of Guns</b>	<b>Gun Type</b>	<b>Number Built</b>	<b>Total Machine Guns</b>	<b>Total Cost (£)</b>
Lancaster	8	.303 inch	7,373	58,984	2,654,280
Halifax	7	.303 inch	6,176	43,232	1,945,440
Stirling	8	.303 inch	2,731	21,848	983,160
Wellington	8	.303 inch	11,460	91,680	4,125,600
Hampden	4	.303 inch	1,453	5,812	261,540
Blenheim	5	.303 inch	2,450	12,250	551,250
Whitley	5	.303 inch	1,812	9,060	407,700
Boston	8	0.5 inch	270	2,160	97,200
Fortress	10	0.5 inch	109	1090	49,050
Manchester	8	.303 inch	200	1,600	72,000
Ventura	9	.303 inch	406	3,654	164,430
Liberator	8	0.5 inch	785	6,280	282,600
Mitchell	5	0.5 inch	537	2,685	120,825
<b>Totals</b>				<b>268,921</b>	<b>£11,715,075</b>

Fig. 6.9: Source: Based on data extracted from Hornby, *Factories and Plant*, pp.252-255 and *Statistical Digest of the War*, p.144

Added together, the above financial aid cost the British Government £6.6 million, of which Bomber Command probably accounted for £3.4 million. The costs of purchasing the guns for Bomber Command added a further £11.7 million to the bill bringing the cost of supplying machine guns to Bomber Command to somewhere around £15.1 million. This estimate is reasonably accurate as a total of 509,190 .303-inch Browning machine guns were manufactured in Britain between 1937 and 1945<sup>124</sup> and, as shown in Figure 6.9 above, the aircraft designed and built

123 PRO CAB 68/3, Supply and Production Fourth Report by the Air Ministry, 19<sup>th</sup> Dec 39.

124 Central Statistical Office, *Statistical Digest of the War*, p.142

for the strategic air offensive accounted for a total of 268,921, or 51.1 percent, of this production.

### **Small Arms Ammunition**

At the beginning of the war in September of 1939, there was real concern in the Air Ministry that they might not be able to secure the amounts of .303-inch small arms ammunition (SAA) that would be required<sup>125</sup>. The reason for this concern was the dependence of the Air Ministry on the Ministry of Supply for this type of ammunition. This dependence probably provoked fears that the Army would consume most of the output of less than five million rounds per week. The concern of the Air Ministry lay in the fact that it estimated that it would need eight million rounds of .303 SAA per week<sup>126</sup>. These initial concerns came to nothing and production kept pace with consumption with Britain producing 9.4 billion rounds of ammunition between 0.22 and 0.45 calibres, the vast bulk of which was .303 inch<sup>127</sup>. At an average cost of 1.8 pence, the total cost of this ammunition production was equivalent to £70,500,000<sup>128</sup>.

Bomber Command was not a large user of Small Arms Ammunition (SAA). The major SAA used within Bomber Command was .303 inch linked in belts of 1,000

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125 PRO CAB 68/3, Supply and Production Fourth Report by the Air Ministry, 19<sup>th</sup> Dec 39.

126 PRO CAB 64/2, Production and Supply, Second Monthly Report, 10th Oct 39.

127 Central Statistical Office, *Statistical Digest of the War*, p.142

128 Figure derived from costs given in *War Savings*, Wings for Victory Issue, p.26 and Central Statistical Office, *Statistical Digest of the War*, p.147

rounds using a sequence of seven armoured piercing, two incendiary and one tracer<sup>129</sup>. The average number of rounds taken by each aircraft appears to have been about 10,000 and the cost of this was £70.00 per aircraft<sup>130</sup>. The only real measure of the cost of this type of armaments is £722,470, which is £70.00 for the SAA carried in each of the 10,321 aircraft lost by Bomber Command through accident or enemy action. The total cost involved is small by comparison with the value of the bombs and pyrotechnics examined above.

There is little doubt that the amount of SAA used by Bomber Command significantly exceeded the above figure. SAA was an expense item and once issued was generally not required to be returned. An unknown amount of SAA was lost in aircraft that crashed or were shot down. Training and test firing of weapons in the lead-up to raids would also have used substantial amounts of SAA, but again the approximate amounts can only be guessed at. Within Bomber Command, the need to keep air gunners proficient meant that range practices were a frequent activity. This type of training would have been far more intensive within the Operational Training Units than within the frontline operational squadrons. But, even within frontline squadrons such training was undertaken. The amount of SAA used in this activity would have greatly surpassed that used in operations.

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129 Harris, *Despatch*, p.112

130 *War Savings*, Wings for Victory Edition, p.26

On operations, most SAA ended up being declared out-of-date or was fired off during the test firing of guns. Ironically, Bomber Command's aircraft used very little ammunition fighting off enemy fighters. The limited range of the .303-inch Browning machine guns made them ineffectual against German night fighters armed with long-range cannon<sup>131</sup>. German tactics also served to limit the effectiveness of Bomber Command defensive armaments as the most common German attack technique, which involved firing into the undefended bottom of a bomber, frequently meant that the defensive armaments could not engage enemy fighters during an attack. It was also a common practice among bomber crews to refrain from firing their defensive weapons because the evasive manoeuvres of the aircraft made aiming difficult and the flashes from the firing guns only served to show the fighter where the bomber was.

Once airborne and formed into formation the bomber stream would have set course for their assigned target. This course took them over either the English Channel or the North Sea. Once over water it was a standard practice for each air gunner to fire a two second burst from their guns to check that these weapons were operational. This testing was a standard operational procedure designed to reassure the crew that their weapons were operational following pre-operational maintenance and loading by the ground crew armourers. In addition to the risk of malfunction due to poor maintenance, the Browning .303-inch machine guns used in Bomber Command had a tendency to freeze up and become inoperable at high

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131 Harris, *Despatch*, p.107

altitude. This problem was to remain with Bomber Command throughout the war<sup>132</sup>.

<b>Estimated Ammunition Consumption in Testing</b>						
<b>Aircraft Type</b>	<b>Number of Guns</b>	<b>Gun Type</b>	<b>Cyclical Rate of Fire per Minute</b>	<b>Rounds per 2 Second Burst</b>	<b>Number of Sorties</b>	<b>Total Rounds</b>
Lancaster	8	.303 inch	600	160	152,192	24350720
Halifax	7	.303 inch	600	140	82,773	11588220
Stirling	8	.303 inch	600	160	18,440	2950400
Wellington	8	.303 inch	600	160	47,409	7585440
Mosquito	-				39,795	
Hampden	4	.303 inch	600	80	16,541	1323280
Blenheim	5	.303 inch	600	100	12,214	1221400
Whitley	5	.303 inch	600	100	9,858	985800
Boston	8	0.5 inch	600	160	1,609	257440
Fortress	10	0.5 inch	600	200	1,340	268000
Manchester	8	.303 inch	600	160	1,269	203040
Ventura	9	.303 inch	600	180	997	179460
Liberator	8	0.5 inch	600	160	662	105920
<b>Total</b>					<b>51,019,120</b>	

**Fig. 6.10: Ammunition Consumption in Testing**

The best estimate for the amount of SAA used in test firing guns is obtained by multiplying the number of rounds fired per second by the number of guns carried per aircraft and then multiplying the figure derived by the number of sorties per aircraft type. This gives a total of just over 51 million rounds for testing alone.

At a cost per round of 1.8pence<sup>133</sup>, the total cost of SAA used by Bomber

Command is £3,826,434. Added to the amount of SAA estimated to have been lost in crashes above the total cost of the SAA consumed in these two ways was

132 Harris, *Despatch*, pp. 107, 109, 111

133 Figures derived from costs given in *War Savings*, Wings for Victory Issue, p.26

£4,548,904. This estimate of the cost of the SAA consumed by Bomber Command is a gross underestimate, as it does not take into account the financial costs incurred because of training activities and the destruction of out-of-date stock. Unfortunately, the lack of records on ammunition expenditure rates make it very difficult to ascertain where the SAA was expended and how much was used.

A further level of financial cost that has been left out of this analysis is the capital investment that the British Government made in the establishing and operating of the Royal Ordnance Factories that produced SAA. In the practice of the time, officials did not factor in the cost of such productive infrastructure into the pricing of the product. Thus the £7.10.0 cost of 1,000 rounds of .303 inch will invariably not reflect the capital investment or even the value of some of the labour that was expended in producing it. It is likely that the true financial cost of SAA was many times that suggested here; however, there is no way that this cost can be identified.

## **Turrets**

Unlike machine guns, the cost of aircraft turrets was included in the price of the finished aircraft supplied by the aircraft manufacturer to the RAF. As was done with other parts of the industry supplying aircraft and equipment to the RAF, the makers of turrets received generous financial assistance from the Air Ministry to enable them to increase their production to meet the expected demands of war.

Throughout World War II Bomber Command used two principal types of turret, the Fraser-Nash, developed by Parnell Aircraft Company, and the Boulton-Paul, developed by the Boulton-Paul Aircraft Company. Three other firms, Brockhouse Engineering Company Ltd, Joseph Lucas Ltd and the Daimler Company were utilised by the Air Ministry and the MAP to produce turrets. Brockhouse and Daimler formed a group led by the Parnell Aircraft Company and the Joseph Lucas Group worked under the supervision of Boulton Paul. The only other company involved in the production of turrets who received government financial assistance was Integral Auxiliary Gears Ltd. and they received £14,000 for machine tools to increase the output of the oil pumps used in the Fraser-Nash and Boulton-Paul turrets<sup>134</sup>.

The total amount of government money provided to the five turret manufacturers was £2,930,000. Of this amount Parnell obtained £990,000<sup>135</sup>, Joseph Lucas £862,000, of which £540,000 was the cost of building a new turret factory at Pontypool in South Wales<sup>136</sup>, Boulton Paul received £319,000 to extend their factory at Wolverhampton<sup>137</sup>, Brockhouse £584,000 to extend their works at

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134 PRO CAB 68/5, Supply and Production Seventh Report, 8th March, 1940

135 PRO CAB 68/5, Supply and Production Seventh Report, 8th March, 1940

136 PRO CAB 68/2, Supply and Production, Third Report by the Air Ministry and CAB 68/3, Supply and Production, Fourth Report by the Air Ministry

137 PRO CAB 68/3, Supply and Production, Fourth Report By the Air Ministry, 19<sup>th</sup> Dec 39

Southport<sup>138</sup> and Daimler obtained £175,000 for a plant at Birtley in Northumberland<sup>139</sup>.

The turrets supplied to Bomber Command were, at the time, the most modern aircraft defensive systems in the world. The power for these turrets was either hydraulic or electro hydraulic and it was noted by Bomber Command that the Boulton Paul electro-hydraulic turret was seven to 13 times less likely to be damaged by enemy fire than the purely hydraulic systems made by Parnell<sup>140</sup>. Problems with the turrets included poor heating, which resulted in both air gunners and their guns becoming victims of cold at high altitude. There were also problems with the small size of the access doors which, particularly in rear turrets, hindered easy entry and escape. The size of the tail turret also meant that the gunner could not wear his parachute and together, these problems made trapping a common hazard for tail gunners. A further problem was that the rear turret door would not open unless the gunner could position the turret in a particular position. If the electrical or hydraulic systems were damaged whilst the turret door was misaligned, the gunner could not escape the aircraft. Difficulties with the design of turrets continued until the end of the war and in November of 1944, in an attempt to obtain a better turret, Bomber Command, at Sir Arthur Harris's direction, placed orders with Rose Brothers Ltd. for turrets. This attempt to have

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138 PRO CAB 68/3, Supply and Production, Fourth Report By the Air Ministry

139 PRO CAB 68/6, Supply and Production, ninth Report, 16<sup>th</sup> May 40

140 Harris, *Despatch*, p.109

the Rose Turret financed by the MAP was successful<sup>141</sup>, but by the time the prototypes were available the end of the war was at hand and the Rose turret did not play any real part in the strategic air offensive.

## **Conclusion**

The supply of munitions to Bomber Command allowed it to despatch 955,044 tons of bombs of all types to targets on the continent at an estimated total cost of about £183,032,304. These munitions included H.E. and incendiary bombs, pyrotechnics and the machine guns and small arms ammunition, used to defend the aircraft from German fighters. The above estimate of the financial cost of these munitions to Britain is very conservative. It does not take into account the bombs and ammunition used in testing and training of bomber crews. Similarly, it passes over the significant costs incurred in transporting, storing and managing bombs and ordnance, until Bomber Command used it on operations. Even without these added costs being included, the cost of a ton of bombs during the strategic air offensive was £196.85.

The value that the British Government obtained was much less than has been previously identified. Approximately 30 percent of this tonnage, that is 286,513 tons, may have been defective due to significant problems that existed with fuzes through the entire air offensive. In monetary terms, this means that almost

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141 Harris, *Despatch*, p.109

£56,400,123 was wasted. Added to this is the fact that until December 1943 only 15 percent of the 247,786 tons of bombs dropped by Bomber Command fell within a one-mile area in enough concentration to inflict the level of damage required. The cost of the 85 percent of bombs that Bomber Command thinly spread around the outskirts of the target city was £41,457,988. These figures suggest that as much as £98 million, about 52 percent of the total estimate of £183 million paid for Bomber Command's ordnance may have been lost due to defective equipment and inaccurate bombing. These calculations make the strategic air offensive a very costly exercise and one whose returns appear to look extremely meagre. By contrast, Richard Overy argues that the strategic air offensive played a significant role in defeating Germany by diverting essential manpower and weapons from the fighting fronts to the defence of the homeland<sup>142</sup>. The total cost of the strategic air offensive, including the cost of aircraft, airfields and ordnance used, amounts to £1.926 billion.

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142 See R. Overy, *Why the Allies Won*, pp.101-133

## *Chapter 7*

### FUEL, OIL AND LUBRICANT: THE COST

Joseph Stalin is reported to have said ‘The war was decided by engines and octane’<sup>1</sup>. In my analysis of petrol, oil and lubricant (POL), one of the major technical advantages that the Allies enjoyed over Germany in terms of air power was the availability of high-grade petroleum products, particularly 100-Octane plus petrol. The ability of the Allies to manufacture large quantities of high-grade petroleum products provided their aircraft with a performance edge that German engineers, despite their great proficiency, could never make up. In light of this, Stalin’s identification of the interplay between engines and octane was correct.

Britain had identified high-grade petroleum as a strategic resource of great importance well before the outbreak of World War II. The performance advantage that 100-octane petrol gave to aircraft was such that Britain put in place special arrangements for obtaining high-octane fuels from the United States and had spent considerable sums of money attempting to establish a domestic manufacturing capacity in Britain and the Empire. The contention of this chapter is that high-grade petroleum products were a significant cost for Britain. In establishing the full cost of these products, the analysis provides a description of the development of high-octane, particularly 100-Octane, fuel and the advantages

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<sup>1</sup> Joseph Stalin quoted in R Goralski and R. W. Freeburg, *Oil and War: How the Deadly Struggle for Fuel in WW II Mean Victory or Defeat*, William Morrow, New York, 1987p.68

it provided to users. The evidence suggests that 100-octane fuel was one of the major advantages that British aircraft like the Spitfire enjoyed over their German opponents.

The analysis of the cost of obtaining the supplies of high-octane petrol, the oil and lubricants that Bomber Command needed for its aircraft shows that it was a strategic resource and it was expensive to obtain. Bomber Command was a major user of 100-octane fuel and other high-grade petroleum products. The cost of POL used by Bomber on operations has been relatively easy to establish. In attempting to provide the most accurate estimate of the cost of the POL used by Bomber Command in carrying out the strategic air offensive this analysis will identify the value of POL used in operations and in training. It will also provide an estimate of the value of the POL destined for Bomber Command but lost at sea, as well as the cost of the ships sunk while carrying it. The economic losses incurred in shipping POL into Britain for the strategic air offensive are legitimate costs of the offensive and need to be assigned against it, if a true evaluation of cost is to be ascertained.

The files of both the British and United States governments and those of the oil companies contain a wealth of information on petroleum supply during the war. A most important source is the *Statistical Digest of the War* published in 1951 by the Central Statistical Office<sup>2</sup>. It provides the data upon which the British

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2 Central Statistical Office, *Statistical Digest of the War*, HMSO, London, 1951

government based many wartime decisions. The information contained in the *Statistical Digest* was rounded out with information on prices and shipping costs obtained from the archives of British Petroleum Amoco, held at their historical section in London and at the University of Warwick. This archive contains information on the prices of the different grades of petrol imported into Britain and contains unpublished information relating to the precise amounts of fuels imported, the shipping and insurance charges and the exact figures for the wartime exchange rates between the £sterling and the \$US.

Aside from the above official records and the *Statistical Digest of the War*, a few early works describe the supply of POL to the Allies during the war. The first of these is Brian Bond's *Peace, Plenty and Petroleum*, published in the United States in 1944<sup>3</sup> and J. Frey and H.C. Ide's 1946, *A History of the Petroleum Administration for War, 1941-1945*, published by the United States Department of the Interior<sup>4</sup>. It describes the administrative, logistical and technical aspects of the expansion of American domestic oil production and refining during the war. The wealth of detail covers production, transportation, and the way the United States Government organised the supply of petroleum products including aviation fuel sent to Britain.

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3 B.T. Brooks, *Peace, Plenty and Petroleum*, the Jacques Cattell Press, Pennsylvania, 1944

4 J. Frey and H. Chandler, *A History of the Petroleum Administration for War 1941-1945*, United States Government Printing Office, Washington, 1946

The first British work on petroleum is D.J. Payton-Smith's 1971 volume of the official history, *Oil: A Study of War-Time Policy and Administration*, which deals with the way in which the British Government managed its oil resources<sup>5</sup>. It also contains interesting information on technical developments in the petroleum industry. Other secondary works include Ronald Cooke and Roy Conyers Nesbit's *Target: Hitler's Oil – Allied Attacks on German Oil Supplies, 1939-1945*, which provides an examination of the technical aspects of oil refining and the importance of high-octane fuel for aircraft and the military attacks against German oil production by the Allies<sup>6</sup>. R Goralski and R.W. Freeburg's 1987 study, *Oil and War*, on the technological advantages provided by access to high-grade petroleum<sup>7</sup>. All of these works have as a central theme the importance of how access to large quantities of high-grade oil supplies gave the western Allies a major technological advantage over Germany. Finally, Daniel Yergin's extremely readable, *The Prize: The Epic Quest for Oil, Money and Power*<sup>8</sup> is a general history of the world oil industry and provides a few pages devoted to the production and supply of petroleum during World War II.

The strategic air offensive was highly dependent upon Britain having access to large stocks of high-grade refined petroleum. The problem for Britain was that she had no domestic production of any significance and she was therefore

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- 5 D.J. Payton-Smith, *Oil: A Study of War-Time Policy and Administration*, HMSO, London, 1971
- 6 R. Cooke and R. Conyers Nesbit, *Target: Hitler's Oil – Allied Attacks on German Oil Supplies, 1939-1945*, William Kimber, London, 1985
- 7 Joseph Stalin quoted in Goralski and Freeburg, *Oil and War*, p.68

dependent on imports. This presented the British government with two problems; the first was paying for the petroleum and the second was getting it past the German U-Boat fleet. The history of 100-Octane fuel in World War II is a story of technological prowess, industrial power, sacrifice and luck. During World War II, neither side enjoyed a decided advantage in terms of the technological proficiency of their aircraft. All of the major powers, Germany, Britain, the United States, USSR and Japan, were capable of producing advanced and effective aircraft. The advantage that the western allies enjoyed was that they had better fuel.

### **Technical Advantage and the Role of High Grade Aviation Fuel**

The official historians of the United States Petroleum Administration, J. Frey and H.C. Ide, describe 100-Octane fuel as ‘the superfuel’ that provided the speed, power, range, climb and manoeuvrability, ‘all of the things, that meant the victory margin in combat’<sup>9</sup>. They did not include the added advantages of less wear and tear on engines, which, in a total war, amounts to a significant advantage when factories and repair organisations are stretched to meet the demands of the fighting air force. In order to understand the advantages provided by operating on 100 as against 87 octane fuel it is necessary briefly to discuss what octane means and what high (100 plus) octane does.

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8 D. Yergin, *The Prize: The Epic Quest for Oil, Money and Power*, Simon and Schuster, New York, 1993

9 Frey and Ide, *A History of the Petroleum Administration*, p.193

The octane rating of a fuel is a number used to describe how quickly petrol burns. In octane the lower the number, the faster the fuel burns and with the lower octanes, the fuel explodes or detonates rather than burns. The higher the octane number the slower the fuel burns. The practical result is that a high-octane fuel burns relatively slowly in a spreading flame front, which starts at the point of ignition at the points of the spark plug within an engine cylinder. As a consequence the forces generated by the burn are more evenly distributed and uniformly transferred to the moving pistons, resulting in a more efficient transfer of energy from the fuel to the engine. Engines using 100-Octane fuels therefore obtain better power per gallon than if they used fuel with lower octane ratings.

In lower octane fuels, the explosion or detonation of the fuel produces an uneven flame front, which causes unequal distribution of temperature within the cylinder. It results in hot spots, which damage the metal of the cylinder and lead to uneven heating causing a weakening of metals that in turn led to a decrease in the life expectancy of the engine. For a high performance engine, high-octane fuel is vital if the best power output is to be obtained from the engine. 100-Octane fuel provides approximately 20 percent better performances in acceleration, climb and load carrying capacities than can be obtained by using 87-Octane fuel in the same engine<sup>10</sup>. In consequence, where the engineering of German and Allied aircraft was equally effective, 100-Octane gave the Allied aircraft a 20 percent advantage.

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10 Brooks, *Peace, Plenty and Petroleum*, p.91

William Burton began the developmental work on high-octane fuel in 1916 when he designed the thermal cracking process, which Standard Oil Indiana used to double the yield of gasoline from its refineries from 17.5 percent to 35 percent<sup>11</sup>. Although thermal cracking of crude oil was an economical way of producing fuel for motor vehicles, it was uneconomical for high-grade aviation fuels<sup>12</sup>. The next big advance in the economic production of large quantities of the higher-octane came in the early 1930s, when Eugene Houdry invented the catalytic cracking process<sup>13</sup>.

Although there were some minor problems with the efficiency of the process, Houdry's catalytic process of 1935 allowed the first commercial release of 100-Octane fuels in the United States<sup>14</sup>. Warren Lewis and Edwin Gilliland, who jointly developed the fluidised-bed catalytic cracking of petroleum, quickly resolved the remaining technical problems with the Houdry method, and Sun Oil moved quickly to built the first large scale catalytic cracking plant at its Marcus Hook refinery in 1937<sup>15</sup>. It gave the United States a significant lead in the commercial production of anti-knock fuels.

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11 Petroleum Institute, <http://www.petroleum.co.uk/index.cfm?PageID=678>, 15th February, 2003

12 Goralski and Freeburg, *Oil and War*, pp. 42-43

13 Petroleum Institute, <http://www.petroleum.co.uk/index.cfm?PageID=678>, 15th February, 2003

14 Petroleum Institute, <http://www.petroleum.co.uk/index.cfm?PageID=678>, 15th February, 2003

15 Petroleum Institute, <http://www.sunocoinc.com/aboutsunoco/sunhistoryf.htm>, 15th February, 2003

The impact of these advances was that 100-Octane immediately became the fuel of choice for aero-engines and designers, such as Roy Fedden, who had worked hard to ensure that they altered their existing engine designs to take full advantage of the power available from this new fuel. By the late 1930s it was claimed in America that the use of 100-Octane was ‘fairly widespread’<sup>16</sup>. This claim reflects a difference in the way the Americans measured Octane rather than any widespread use of the very high-grade fuel. What the Americans called 100-Octane was actually equivalent to the 87-Octane that was widely used throughout Britain and Europe<sup>17</sup>. In the late 1930s, the United States petroleum industry was only beginning to establish significant production of true 100-Octane fuel and this fuel was still as rare there as it was in Europe<sup>18</sup>.

The demand for 87-Octane fuel expanded rapidly and, in 1937, a contributor to an issue of the *SAE Journal* quoted Captain F.D. Klein, of the Materials Division of the United States Army Air Corps (USAAC), wrote that the USAAC would be purchasing approximately 2,841,000 gallons of 100-Octane [87-Octane] fuel before July 1937<sup>19</sup>. The Army would draw this fuel from the total United States supply of 155,000,000 gallons (3,690,476 barrels), which sources expected the industry to produce that year. The *SAE Journal* also quoted Standard Oil, the

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16 R.N. Du Bois and V. Cronstadt, High Output in Aircraft Engines, *SAE Journal*, Vol 40, No. 6, June 1937, p.225

17 Gunston, *Fedden*, p.100

18 PRO CAB 67/8, Memorandum by the Secretary of State for Air, 5th November 1940

19 Du Bois and Cronstadt, *SAE Journal*, p.225

major player in this market, as saying that it would be ‘possible for United States production of 100-Octane fuel to quickly reach 340,000,000 gallons per year’<sup>20</sup>.

In Europe, work on high-octane fuel was also underway, principally at Shell in Holland<sup>21</sup>. In Britain, Roy Fedden at Bristol used 100-Octane fuel in 1927 to power the Bristol Mercury engine during bench testing sprints<sup>22</sup>. In Britain, 100-Octane petrol was regarded as an experimental fuel and it is likely that the fuel used by Fedden at Bristol was either obtained from Shell or made by chemists using the Burton thermal cracking method<sup>23</sup>. The average octane rating of the fuel used in RAF aircraft of this period varied from 69 to 77 octanes<sup>24</sup>. By 1934, the new 87-octane petrol, DTD.230, was available in Britain and engine manufacturers, such as Bristol and Armstrong Siddeley, who hoped to supply the RAF with engines, began the process of re-designing their engines to suit the new fuel.

British engine designers knew of the imminent arrival of 100-Octane fuel and had begun to re-design their engines to burn this fuel. Roy Fedden kept himself well informed on the developments in fuels that were occurring abroad and it is likely that other engine manufacturers also kept a close eye on these developments.

Fedden was a frequent visitor to the United States and, given the popularity of his

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20 Du Bois and Cronstadt, *SAE Journal*, p.225

21 Yergin, *The Prize*, p.383

22 Gunston, *Fedden*, p.100

23 Gunston, *Fedden*, p.100

air-cooled rotary engines in that market, he had good access to American colleagues and their technical innovations. In 1937, Fedden gave a paper to the Society of American Engineers (SAE) where he described some of the changes that were occurring in the industry. Interestingly, he made special note of the negative impact of the high cost of 100-Octane fuel at 2s/6d and fuel oil 1s 2d per gallon<sup>25</sup>.

### **The American Connection**

In September of 1939, the British Secretary of State for Mines reported to the War Cabinet that the United States oil market was ‘deluged with inquiries from all over the world, including Italy’<sup>26</sup>. He was happy to report to his colleagues that the American sellers were ‘holding off’, probably in the hope, that prices would rise and he hoped that they would sell their fuel to Britain<sup>27</sup>. Despite the efforts of Britain to plan for her own POL needs through the development of domestic refining capacity and the construction of refineries in Trinidad, Calgary, Canada and in the Middle East, it became obvious that she would have to rely upon the United States for supplies of POL, especially 100-Octane petroleum.

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24 R. Fedden, ‘Next Decade’s Aero-engines will be Advanced But Not Radical’, *SAE Journal*, Vol. 31, No. 3, p.380

25 R. Fedden, ‘Trend of Air-Cooled Aero-engines – The Next Five Years’, *SAE Journal*, Vol. 41, No. 3, October 1937, p.437

26 PRO CAB 68/1, Supply and production First report by the Air Ministry, 23<sup>rd</sup> Sept 39

In 1939, British plans to access American supplies of petroleum faced a significant hurdle in that Britain was a defaulting debtor on the war loans she had raised from the United States during World War I, and was unable to obtain credit from the United States for war stores, including POL. In order to obtain the necessary supplies of POL the British government was forced to liquidate her holdings in the western hemisphere. The Americans took full advantage of this to obtain significant British assets at very low prices. The cost of POL that is measured in this chapter does not include the monetary value of these transactions, all of which represented a loss of real wealth and a significant loss of prestige as Britain went ‘cap-in-hand’ to the United States in order to obtain the POL she needed.

This problem of payment was to continue until the introduction of the Lend-Lease Act by the US Congress. The major advantage of it was that Britain gained access to supplies of American petroleum, without having to pay in dollars. Before the Lend-Lease Agreement, Britain had to pay the United States for supplies of petroleum which was a significant drain of wealth, as the account was paid in US dollars or gold. The efforts of the British Government to build cracking plants in the British Isles and at Trinidad and Azerbaijan may have been justified to some extent by a desire to locate some POL production within the sterling sphere in order to protect holdings of dollars and other foreign currencies. The concerns of the British government were well based and by 1940 the national

debt was \$21 billion, a significant proportion of which was due to her importation of petroleum products from the United States<sup>28</sup>.

The United States recognised Britain as a supplicant partner very early in the war<sup>29</sup>. The Americans based their decision to support Britain in 1939-1940 on a careful evaluation of their national interests and the damage to those interests if Britain and France were defeated<sup>30</sup>. As the war progressed, many United States Government officials believed that the United States Administration was too lenient in dealing with Britain. In 1943, these rumblings increased dramatically as British Gold and United States dollar reserves built up to around \$2.5 billion. Secretary of the Treasury, Morgenthau, strongly advocated that the President place a limit of \$US1 billion on Britain<sup>31</sup>. Although President Roosevelt sent a letter to Churchill requesting that he 'look at the matter', the tone of the letter is relaxed and intimates that he was asking Churchill to investigate only because he had to<sup>32</sup>. Roosevelt's relaxed attitude was firmly supported by the State Department and the Lend-Lease Administration. Despite this, there is no denying the status of Britain as a supplicant.

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28 Hancock and Gowing, *British War Economy*, pp. 546-545

29 Lord Cherwell, Memo to Prime Minister 12th November, 1943, British Diplomatic Files, Box 36, *F.D. Roosevelt Digital Archive*, a330oo01

30 Cover Letter to Summary of Intelligence Report 3rd March 1939, *FDR Digital Archive*, Box 37, A339U03

31 Cherwell, *FDR Digital Archive*, a330oo01

32 President Roosevelt, Letter to Prime Minister of Great Britain, 22 Feb, 44, Box 36, *FDR Digital Archive*, a331d04

In the first year of the war, Britain imported from the United States over 12 million tons of POL<sup>33</sup>. The supply of 100-Octane to Britain was of increasing concern as the fuel was now recognised as a necessity for operational aircraft and the three British plant, Heysham, Trinidad and Thornton, were still under construction at the end of 1940<sup>34</sup>. The estimated cost of the Thornton plant alone was £9 million and, by October 1940, the Government had already paid out £1.2 million of this amount. It was expected that Britain would need in 1942 to find 600,000 tons of 100-Octane from non-British sources, with at least 350,000 tons of this coming from the United States, which was the ‘main outside source of supply’<sup>35</sup>.

At the beginning of the war it was not certain that the American oil industry could expand its production to meet the demand for 100-Octane. In 1938, United States production of 100-Octane was approximately 22,178 barrels per day<sup>36</sup>. By 1940 it had doubled to 40,000 and five years later had reached approximately 514,000 barrels per day, an increase of over 2000 per cent on the 1938 figure<sup>37</sup>. The cost of this achievement was \$925 million of which the US government provided loans of only \$245 million. The US government spent a further \$233 million on cracking plant, which the industry then leased and

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33 Chart in *FDR Digital Archive*, Safe, Box 5, a68c02

34 PRO CAB67/8, Memorandum by the Secretary of State for Air, 5th November 1940

35 PRO CAB67/8, Memorandum by the Secretary of State for Air, 5th November 1940

36 Cronstedt and Du Bois, *SAE Journal*, p.225

37 Frey and Ide, *A History of the Petroleum Administration*, p.455

operated<sup>38</sup>. A further \$7.3 million went to the industry to compensate some companies for extraordinary construction expenses and the industry supplied the balance of \$439.7 million<sup>39</sup>.

From 1942 to August 1945, total Allied production of 100-Octane equalled 410,578,170 barrels of which British domestic and Commonwealth production contributed 56,613,340 barrels, 13.78 percent of the total. Following Pearl Harbor the United States seriously addressed the problem of meeting the massively increased demand for 100-Octane.

The lack of domestic crude oil supplies and the difficulty of importing crude oil limited Britain's domestic manufacturing capacity, making an uninterrupted supply of this strategic commodity a highly problematic outcome during most of the Second World War. Over the period of World War II, Britain manufactured 6.4 percent of her total aviation and motor spirit needs from the indigenous raw materials that she could access<sup>40</sup>. In 1940, the Air Ministry estimated that the force they were aiming for would consume 850,000 tons of 100-Octane per annum<sup>41</sup>. At the time, when 53 percent of Britain's 100-Octane fuel (4,380 barrels per day) was being supplied by the United States, there were substantial

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38 Frey and Ide, *A History of the Petroleum Administration*, p.193

39 Frey and Ide, *A History of the Petroleum Administration*, p.193

40 Central Statistical Office, *Statistical Digest of the War*, pp. 91-92

concerns that British requirements for 100-Octane could be adversely affected by United States Government decisions. A further problem was that United States 100-Octane fuel normally rated only 90-octane against the British standard and imports of this fuel from the United States needed testing before they were accepted into British stocks<sup>42</sup>.

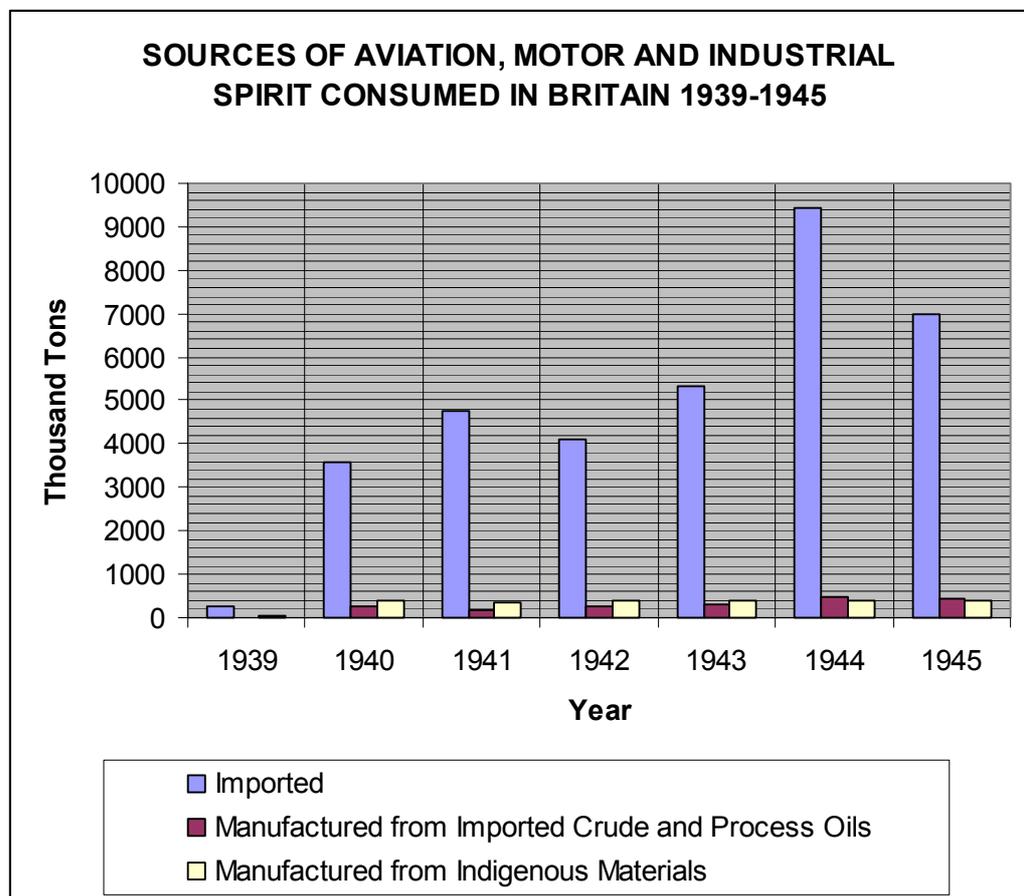


Fig.:7.1:

Source: *Statistical Digest of the War*, pp. 87-90

41 PRO CAB 67/8, Memorandum by the Secretary of State for Air, 5th November 1940

42 PRO CAB 67/8, Memorandum by the Secretary of State for Air, 5th November 1940

Faced with these problems, Britain intended to develop her production of the essential fuel. It is not surprising that the primary impetus for the building of domestic catalytic cracking facilities came from the Air Ministry<sup>43</sup>. It was hoped Britain would be able to manufacture up to 700,000 of the 850,000 tons of 100-Octane required annually to conduct the air war<sup>44</sup>. Production was spread across nine plants, three in the UK, one in the Caribbean and the Middle East and two in the Dutch East Indies. The biggest plant was to be Thornton with a proposed capacity of 200,000 tons per annum with the Heysham, Billingham and Stanlow plants adding a further 220,000 tons annually<sup>45</sup>. Another 130,000 tons would be available from Trinidad and Abidjan in the Middle East and 150,000 tons were to come from Standard Oil in Aruba, Palembang and Pladjoe in the Dutch East Indies<sup>46</sup>. The total, including Thornton, would constitute around 700,000 tons per annum, leaving only 150,000 tons of 100-Octane to be sourced from the United States. Most of these plans failed.

The production of aviation grade fuel in Britain was regarded by the industry and by the Government as being uneconomical and the decision not to pursue the expensive hydrogenation plants was taken quite early in the war. The British Government was not particularly attracted to this idea even in the dark days of

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43 PRO CAB 67/8, Memorandum by the Secretary of State for Air, 5th November 1940

44 PRO CAB 67/8, Memorandum by the Secretary of State for Air, 5th November 1940

45 PRO CAB 67/8, Memorandum by the Secretary of State for Air, 5th November 1940

46 PRO CAB 67/8, Memorandum by the Secretary of State for Air, 5th November 1940

1940, when the need for 100-Octane was critical<sup>47</sup>. The only plant that was to become operational was Stanlow, and this produced a minute quantity of 720 barrels of 100-Octane a day<sup>48</sup>.

By December 1939, the British government had spent £15.8 million on the development of domestic 100-Octane production<sup>49</sup>. By October 1940, the cost had risen to approximately £18 million, after an increase of £2 million in construction costs at Thornton<sup>50</sup>. All of the money spent on Heysham and Thornton was lost, as neither plant was ever completed. The £8.5 million given to ICI for the building of a 100-Octane plant at Billingham also failed as the plant never produced any 100-Octane fuel. As a result, the British Government spent around £18 million in unsuccessful attempts to provide the RAF with domestically manufactured 100-Octane fuel.

The benefits of 100-Octane fuel need to be offset against the very real cost of the fuel and other petroleum products to Britain during World War II. Prior to the outbreak of the war the British government identified 100-Octane fuel as a strategically important product. In order to ensure an uninterrupted supply, Britain began building modern cracking plants in the United Kingdom and in Trinidad and in Azerbaijan. The development of cracking plants in Britain and

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47 PRO CAB 67/8, Memorandum by the Secretary of State for Air, 5th November 1940

48 Goralski and Freeburg, *Oil and War*, p.44

49 PRO CAB68/3, Supply and Production, Fourth Report By the Air Ministry, 19<sup>th</sup> Dec 39

the Empire were an insurance policy in case of a failure of the supply of high-grade petroleum from the United States, which Britain always saw as being the primary source of the high-grade fuels they would need.

### **The Problem of Transportation**

Of the almost 91 million tons of POL imported into Britain during the war, 42.55 percent (38,684,000 tons) was aviation and motor spirit<sup>51</sup>. Of this latter figure 33.13 percent (12,817,848 tons) was aviation fuel of which the Air Ministry received 90.68 percent (11,624,409 tons)<sup>52</sup>. Of the amount delivered to the Air Ministry, 77 percent (8,960,295 tons or 2.243 billion gallons) was 100-Octane plus fuel<sup>53</sup>. As a proportion of total fuel imports into Britain during the war, 100-octane fuel accounted for about 9.8 percent. Getting this fuel to Bomber Command entailed considerable cost both in shipping losses amongst the tankers and in the freighting of the POL through the sorely stretched inland transportation system.

From the outbreak of war until November 1943, the United States used a fleet of 50 US registered tankers to operate a shuttle along the east coast, which ensured that oil for Britain was available at the northern ports. The tankers for this service along the United States coast were a cost that has not been counted here though it

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50 PRO CAB 67/8, Memorandum by the Secretary of State for Air, 5th November 1940

51 Central Statistical Office, *Statistical Digest of the War*, pp. 93-94

52 Central Statistical Office, *Statistical Digest of the War*, pp. 93-94

could be included as part of the cost because these ships were completely removed from any other service<sup>54</sup>. This system of transportation between the Gulf and the terminals along the North Atlantic seaboard of the United States shortened by 1,500 miles the distance that British tankers had to steam in order to pick up their cargoes<sup>55</sup>. The probable reason for this system was to reduce the risk to United States coastal shipping posed by German U Boats operating against British tankers steaming in American coastal shipping lanes. The annual cost of the scheme was approximately £1.13 million for handling, storage, freight and insurance<sup>56</sup>. The total cost for the four years 1940 to the end of 1943 would have been approximately £4.52 million.

In 1943, the 'Big Inch' oil pipeline<sup>57</sup>, which terminated in New York, removed the need for the shuttle system of tanker transport<sup>58</sup>. Under an agreement with the American Government, the British could draw on the United States Navy's petroleum pool, which the Americans had established at the New York terminal of the 'Big Inch'<sup>59</sup>. The use of this system included a surcharge for transportation, handling and storage, which increased from 7s/5d per ton in early

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53 BP Archives, 'Deliveries into Consumption', *ARC 7439*, 4th Sep 39 to 31st Dec 1945

54 Frey and Ide, *A History of the Petroleum Administration*, p.85

55 Frey and Ide, *A History of the Petroleum Administration*, p.85

56 BP Archive, 'Special Items of Cost' *ARC 7439*

57 The threat from German submarines to the US oil tanker routes along the eastern seaboard led the US Government to build the 'Big Inch' and 'little Inch' pipelines between Aug 42 and Mar 44 to deliver crude oil from the Texas oil refineries at Houston and Port Arthur to terminals in New York, New Jersey and Philadelphia. [www.tsha.utexas.edu/handbook/online/articles/view/BB/dob8.html](http://www.tsha.utexas.edu/handbook/online/articles/view/BB/dob8.html)

58 BP Archive, 'Special Items of Cost' *ARC 7439*

59 BP Archive, 'Special Items of Cost' *ARC 7439*

1944 to £1.16s per ton shipped in the first two quarters of 1944 before dropping to £1.8s/3d in early 1945<sup>60</sup>. The surcharge applied to all petroleum products with the exceptions of tar oils, aviation fuels and paraffin wax, all of which were military stores<sup>61</sup>.

The Americans completed the first leg of the 'Big Inch' pipeline as German U Boats moved into American coastal shipping lanes and began to inflict serious losses on shipping tankers and other coastal vessels. The rate at which the Germans sank American coastal shipping was so high that it led to a significant fall in the amounts of crude oil reaching the refineries along the Atlantic seaboard. The unwillingness of the United States Navy to impose a convoy system on their coastal trading fleet exacerbated the problem and allowed the German U Boats a free rein to sink many more ships than they otherwise would have. Poor communications security on American ships and the refusal of a number of coastal cities, like Miami, to impose a blackout allowed U Boat commanders to more efficiently locate and destroy American vessels<sup>62</sup>.

The U Boat offensive along the United States Atlantic coast was very successful with POL shipments from the Gulf to United States East Coast ports falling from under 450 million barrels a year in 1941 to around 60 million barrels in 1943<sup>63</sup>.

The situation was so serious that Churchill wrote to Roosevelt in March 1942,

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60 BP Archive, 'Special Items of Cost' *ARC 7439*

61 BP Archive, 'Special Items of Cost' *ARC 7439*

62 Goralski and Freeburg, *Oil and War*, pp. 106-110

expressing deep concern at the immensity of the shipping losses<sup>64</sup>. The threat posed to the Allied oil stocks by the success of the U Boats was serious and there were East Coast refineries in the United States which suffered a 37 percent decrease in the size of their crude oil runs<sup>65</sup>. This drop then passed downstream, resulting in shortages of aviation and other fuels. Perhaps paradoxically, whilst the production of refined POL fell on the United States East Coast, it piled up at Gulf Coast refineries to such an extent that they even considered reducing production at those plants<sup>66</sup>. For a short period, Germany's U-boats had seriously reduced the flow of petroleum supplies to the Allied war effort.

Once POL had arrived at Baltimore or New York, it was loaded onto tankers bound for Britain. Until the United States entered the war in December 1941, they were mostly British tankers or non-US tankers operating on behalf of Britain as United States tankers refused to enter the zone of hostilities<sup>67</sup>. In the six years between 3<sup>rd</sup> September 1939 and 30<sup>th</sup> September 1945, Britain gained 1,727,000 gross tons of tankers of over 1,600 gross tons whilst losing 2,063,000 gross tons of these vessels to enemy action and misadventure<sup>68</sup>. The German U Boats claimed 88.6 percent of all the tonnage sunk.

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63 Goralski and Freeburg, *Oil and War*, p.110

64 Goralski and Freeburg, *Oil and War*, p.111

65 Frey and Ide, *A History of the Petroleum Administration*, p.217

66 Frey and Ide, *A History of the Petroleum Administration*, p.217

67 BP Archive, 'Special Items of Cost' *ARC 7439*, undated tables

68 Central Statistical Office, *Statistical Digest of the War*, p.177

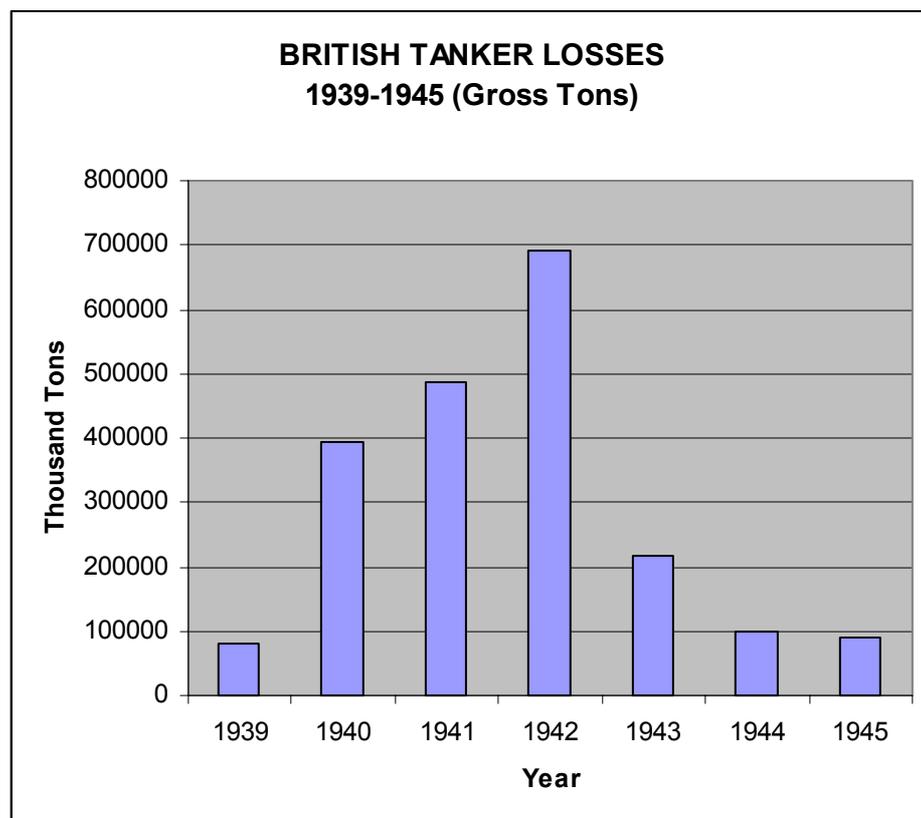


Fig. 7.2:

Source: *Statistical Digest of the War*, p. 180

The remaining losses were due to misadventure, scrapping and the transfer of vessels to other flags. Given that aviation fuel comprised 14.1 percent of all POL imported into and manufactured by Britain during the war, it is reasonable to suggest that 14 percent of all tanker losses, 280 vessels, were carrying aviation fuel of which 69.65 percent would have been 100-Octane fuel<sup>69</sup>. At an average capacity of 4.5 million gallons of fuel per tanker, a rough estimate of the loss is about 1.26 billion gallons (5.8 million tons) of 100-Octane<sup>70</sup>. At an average wartime cost of 2s/6d<sup>71</sup> per gallon, this puts the overall cost in the region of £166

69 BP Archive, Deliveries into Consumption, *ARC7439*

70 Goralski and Freeburg, *Oil and War*, p.106

71 BP Archive, 'Selling Prices, Aviation Spirit (per Gallon)', *ARC 7439*

million worth of 100-Octane fuel lost. Of this amount, 37.91 percent, £62.93 million (470 million gallons) can be written off against Bomber Command and the strategic air offensive.

The estimate of £62.93 million in lost 100-Octane fuel does not take into account the cost of the lost shipping and other resources. During the war the average cost of a tanker was somewhere around £405,000<sup>72</sup>. This figure, the cost of a single Liberty ship, is conservative, as these mass-produced American ships were much cheaper than many pre-war built tankers. If the 280 tankers that sank whilst transporting 100-Octane fuel are multiplied by the figure above, the cost of the shipping lost is about £113 million. Using the same calculations as for the 100-Octane fuel, the percentage of the loss that can be made against Bomber Command is 37.91 percent, valued at £42.8 million.

Once a loaded tanker had crossed the Atlantic, the fuel was transferred to the inland transportation system. The distribution of POL in Britain was achieved by using a mixture of small coastal tankers, rail and road transportation. On arrival, rail wagons, lorries, coastal tankers and barges were used in a unified system to

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72 United States Maritime Service Veterans, 'Liberty Ships Built by the United States Maritime Commission in World War II', <http://www.usmm.org/libertyships.html>, 19th November, 2002 It is also of interest to note that the famous United States Liberty Ship was not an American invention. A British design, the original plans were made by a British shipbuilder, J.L Thompson and Sons Ltd.<sup>72</sup>. Thompson's original design was for a ship called the *Dorington Court* and it used much of the welding and plate techniques that were to epitomise the American ship building industry during World War II. The design was passed to the United States as part of a British Government order for 60 mass produced ships and it was hoped that Thompson's design would ensure a standardised product that could be quickly built. This is further evidence of the weakness of Correlli Barnett's claims that British shipbuilders were not technologically capable of producing cheap, mass produced shipping.

move POL from ports and oil terminals to its destinations<sup>73</sup>. The immediate effect of the war on these operations was the movement of the bulk of tanker traffic from the east coast of the United Kingdom to the west coast and an increase in costs as the two-day voyage from Hull to Aberdeen increased to eight days<sup>74</sup>. The records consulted provide no insight as to why the trip times increased so dramatically, but it is a reasonable assumption that the increase was due to fear of enemy action and mines.

In examining the figures available for inland transportation of POL it is difficult to separate from the railway statistics the amount of POL transported in the consolidated freight miles. It is clear that such loads were moved an average of 57.3 miles<sup>75</sup>. Robin Higham suggests that the railways increased the amount of POL freighted per month from 250,000 tons in 1938, to 350,000 tons in 1943<sup>76</sup>. He also reports that the Air Ministry increased its holding of railway tanker wagons from 350 in 1939 to 500 in March 1941<sup>77</sup>. What is of note though is that road transport appears to have played a major role in the distribution of POL throughout the United Kingdom during the war. This conclusion is based upon the fact that 93.36 percent of all general haulage goods vehicles and 18 percent of the total licensed (registered) vehicles were petrol or oil tankers (see Figure 7.3

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73 PRO CAB 68/1, Supply and Production First Report, 23<sup>rd</sup> Sept 39

74 PRO CAB 68/2, Supply and Production Second Report, 10<sup>th</sup> Oct 39

75 Central Statistical Office, *Statistical Digest of the War*, p.190

76 Higham, *Bases of Air Strategy*, p.32

77 Higham, *Bases of Air Strategy*, p.33

below)<sup>78</sup>. This figure does not include such vehicles operated by the armed services or by civilian companies operating under defence contracts.

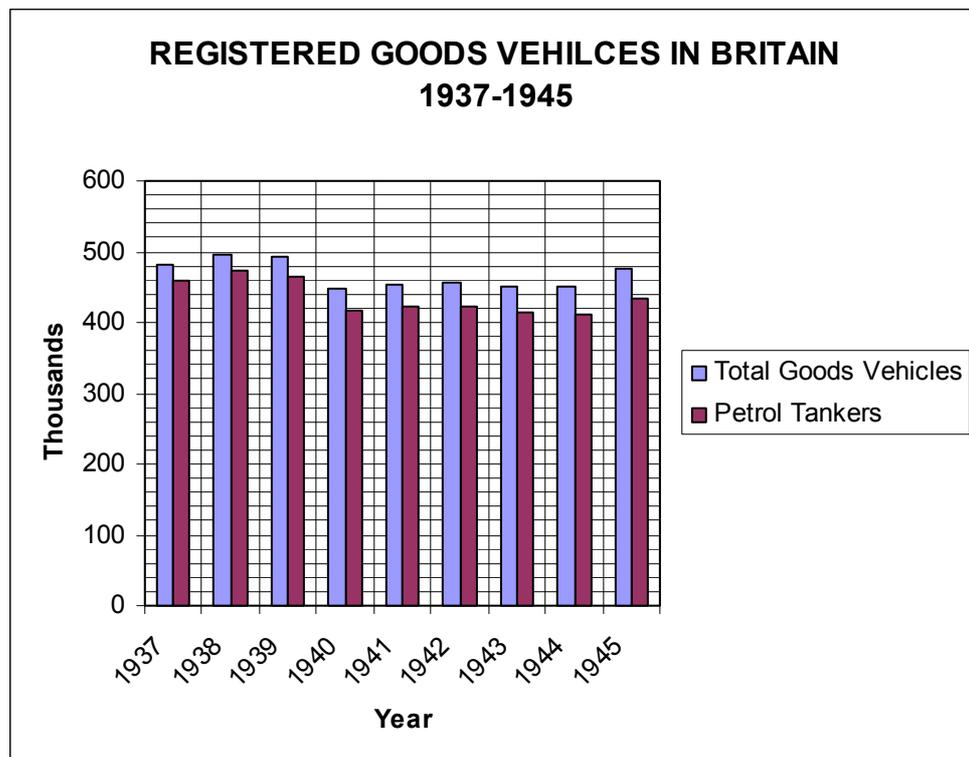


Fig.7.3:

Source: *Statistical Digest of the War*, p. 191

The road haulage industry was one of the more successful industries in fending off government controls during the war. The road freight companies avoided direct government control of its activities until March 1943, when a number of the larger firms were nationalised and the Minister for War Transport took direct control of the 25,000 vehicles that operated over distances greater than 60 miles<sup>79</sup>. The road haulage industry was the only significant part of the transportation network to resist centralised government control for so long.

78 Central Statistical Office, *Statistical Digest of the War*, p.191

79 Hancock and Gowing, *British War Economy*, pp. 486-487

## **Bomber Command and POL**

The total amount of POL used by Bomber Command during the strategic air offensive is almost impossible to ascertain with any degree of accuracy. Despite this, it is possible to identify the approximate amount of POL used on operations, as there are records of the fuel loads used for various aircraft types flying to Berlin, Milan and the Ruhr. In order to arrive at a workable estimate, these known fuel loads were divided by the number of engines on the particular aircraft and an estimate of the fuel usage per engine per mile was identified. These estimated figures were then applied to the total number of engines used in the aircraft despatched on operations to these targets and to other targets of similar distance from the United Kingdom. This enables us to roughly estimate the total amount of fuel expended over the various target areas attacked by Bomber Command.

In 1935, as the size of planned operational aircraft and the likelihood of war increased, the Air Staff decided to review the whole process of managing POL within the RAF. At this time, operational RAF stations in the United Kingdom held 87-octane fuel in 12,000-gallon tanks with a maximum of four such tanks, or 48,000 gallons, per storage pit<sup>80</sup>. The system could only dispense 60 gallons per minute for the refuelling of aircraft<sup>81</sup>. Refuelling an aircraft with a fuel capacity of 2,500 gallons would have taken 41 minutes and with 42 such aircraft operating

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80 Higham, *Bases of Air Strategy*, p.53

81 Higham, *Bases of Air Strategy*, p.53

from a Bomber Command base it would have taken 22 hours to refuel the usual number of 32 aircraft that routinely operated from these bases<sup>82</sup>.

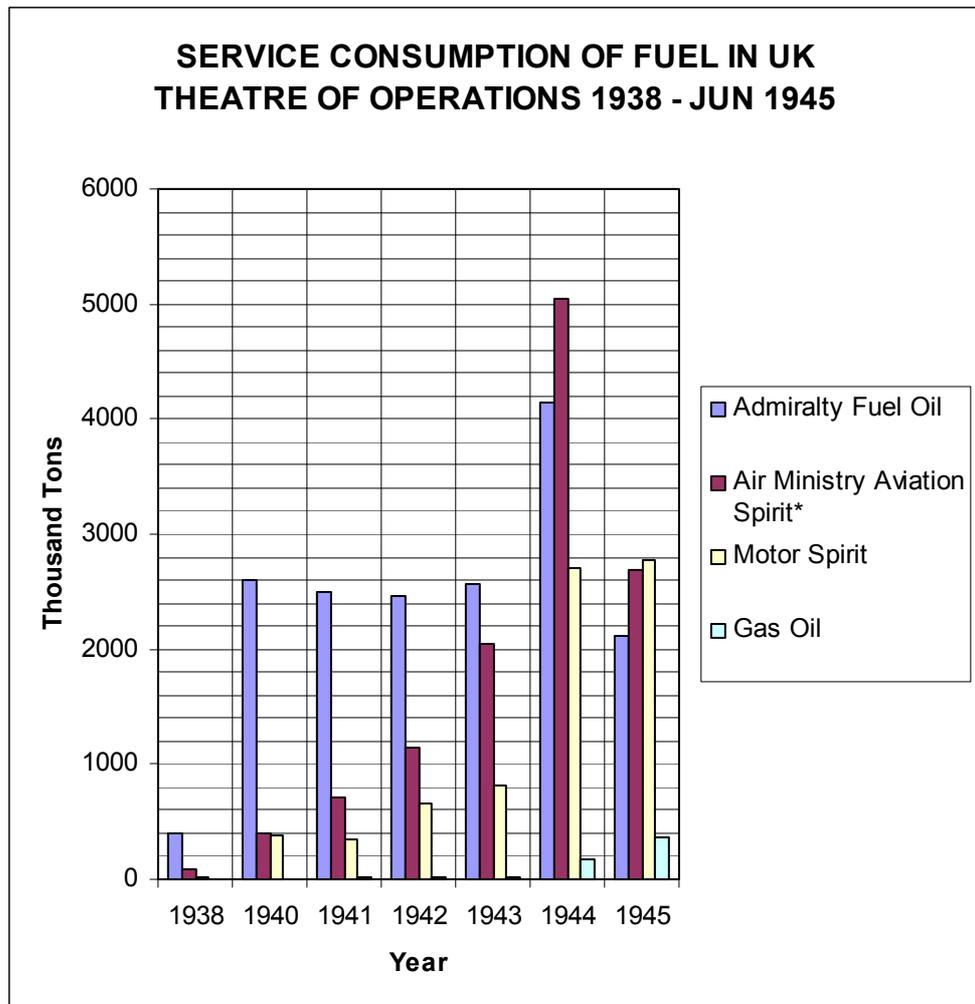


Fig.7.4:

Source: PRO CAB 68/6-9

Because of a 1935 review, the Air Ministry retained the 12,000-gallon tanks but fitted these with pumps that could pump 90 gallons per unit. The same review also increased the number of installations to a maximum of three dispersed sites

82 Harris, *Despatch*, p.157

with their own blast and splinter proof bunds<sup>83</sup>. This increased the amount of petroleum held on a station to a maximum of 72,000 gallons<sup>84</sup>. Engine oil of approximately 5 percent of petrol holdings, up to a maximum of 5,000 gallons, was also held at each bomber station<sup>85</sup>. This oil was still dispensed using hand pumps with mechanical pumps attached to vehicles being slowly introduced over the next three or so years.

### **Operational Consumption of POL**

From the 3<sup>rd</sup> of September 1939 to the 14<sup>th</sup> of August 1945, the POL supply organisations delivered somewhere between 2.5 and 2.7 billion gallons of aviation fuel to the Air Ministry at an estimated total wholesale cost of £295 - £357 million<sup>86</sup>. Information on the amount of POL, including 100-Octane is contained in a number of primary and secondary sources and although these figures are only partial records of usage, they do provide a workable body of data from which more general and useful figures can be extrapolated. The main sources consulted here have been the fuel loadings listed in the AIR files<sup>87</sup> at the Public Record Office in London and a set of figures obtained from private sources by Norman Franks<sup>88</sup>.

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83 Higham, *Bases of Air Strategy*, p.53

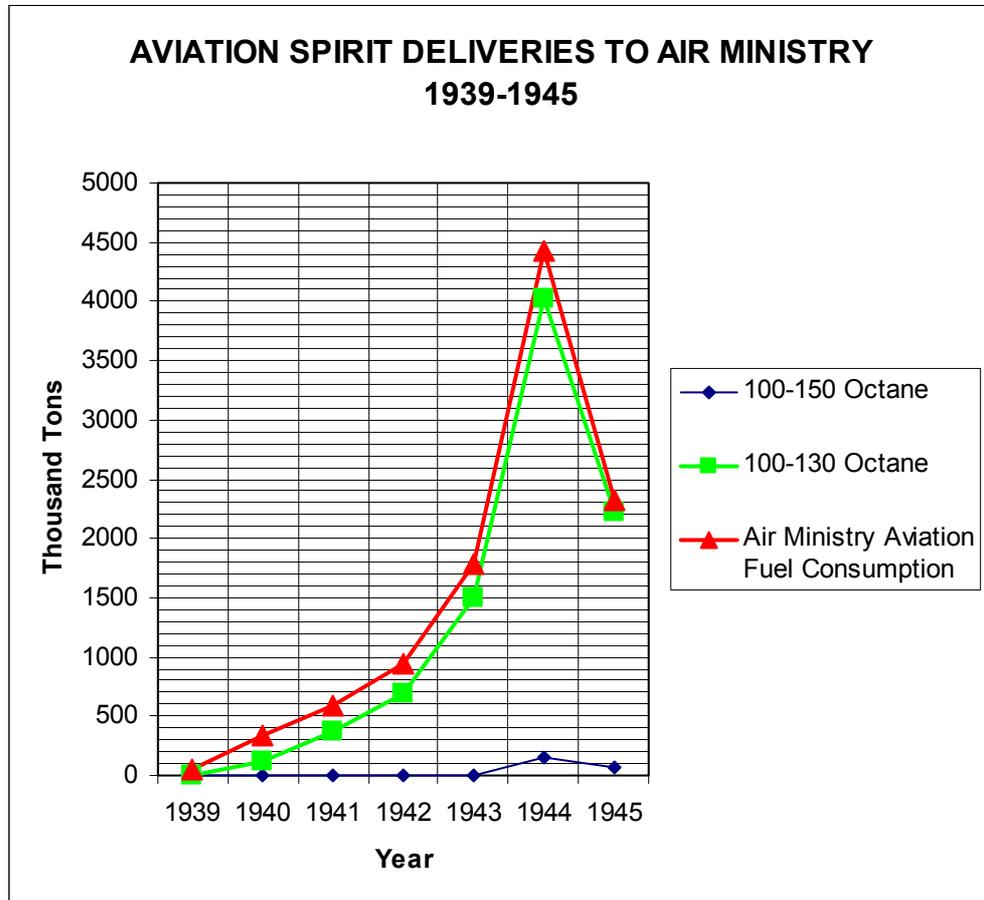
84 Higham, *Bases of Air Strategy*, p.53

85 Higham, *Bases of Air Strategy*, p.53

86 The lower set of figures come from the BP Archive, *ARC 7439*, Deliveries into Consumption and Selling Prices and the higher set from PRO *CAB 69/6*, *CAB 69/7* and *CAB 69/8*

87 PRO AIR *14/1951*, Bomber Command Quarterly Review, No.8, Jan-Mar 1944

88 Franks, *The Lancaster*, pp.10-11



**Fig.7.5:**

*Source: BP Archive, ARC 7439*

Analysis of the available data shows that the average fuel load for a four-engined bomber flying to Berlin, Cologne or Hamburg with a bombload between 7,500 lbs and 10,000 lbs was around 2,000 gallons of 100-Octane fuel. In addition, these particular aircraft also used 70 gallons of engine oil and five gallons of coolant each constituting a total of 2,075 gallons of POL and coolant per aircraft. The usefulness of the above data did not lie in the gallons per mile flown, but rather in calculating the fuel needed to lift a given weight of bombs.

In planning an operation against a target on the continent, the two variables in the loads carried by individual aircraft lay in the tonnage of bombs or mines carried or the amount of POL used to lift that bomb load. The amount of machine gun ammunition remained the same at 10,000 rounds of .303 inch per aircraft. As well the crews remained the same two for a Mosquito, or seven for a Halifax or Lancaster and their consumables such as food, coffee and oxygen did not alter either. Thus, on any raid the amount of fuel required to lift the empty aircraft remained almost constant. What changed was bomb load over distance against weather.

In analysing fuel statistics for this chapter the most striking realisation was not the performance obtained by a particular fuel whether in terms of miles per gallon or power produced, it was the actual weight of fuel needed to fly a bomber from Britain to a target in Germany. The 2,075 gallons of 100-Octane fuel that a Lancaster bomber required to reach a Berlin is another figure until it is realised that it represents a mass or weight of nine and a half tons of fuel<sup>89</sup>. Suddenly, with this one conversion, the imperative of Bomber Command's demand for petrol, oil and lubricant becomes stark. It indicates that strategic bombing was an avid consumer of energy in the shape of aviation fuel.

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89 PRO AIR 14/1951, Bomber Command Quarterly Review, No.8, Jan-Mar 1944

Bomber Command's heavy consumption of POL is highlighted in a statistical analysis contained within a secret report compiled by the Command conducted in early 1944<sup>90</sup>. The secret report discussed the resources consumed in launching a thousand bomber raid on Germany and, given the date of this report, it is more than likely that the raid it was describing was the series of attacks on Hamburg that took place in July 1943<sup>91</sup>. The report details that the raid consumed two million gallons of 100-Octane fuel along with 70,000 gallons of engine oil and 5,000 gallons of coolant. Converted to mass, these gallon amounts equate to 9,216.5 tons of petrol, 325 tons of engine oil and 23 tons of engine coolant, a total of 9,564.5 tons. This was the POL required to transport 4,500 tons of bombs, 10 million rounds of machine gun ammunition, 15 million litres of oxygen, 8,000 pints of coffee, 27 tons of food and approximately 7,000 airmen to their target in Germany<sup>92</sup>. The wholesale price of the 100-Octane fuel for one four engined bomber was £275 and £275,000 for the entire fleet of attackers.

More interesting even than the financial cost is the tantalising insight the figures reveal into the relationship between the tonnage of bombs and the tonnage of fuel consumed. The 4,500 tons of bombs that were despatched to the target used 9,216.5 tons of 100-Octane fuel, a ratio of over 2 tons of 100-Octane per one ton of bombs lifted to this target. This ratio of around 2 tons of 100-Octane fuel per ton of bombs despatched to German and Italian targets is very close to the

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90 PRO AIR *14/1951*, Bomber Command Quarterly Review, No.8, Jan-Mar 1944

91 PRO AIR *14/1951*, Bomber Command Quarterly Reviews

92 All figures derived from PRO AIR *14/1951*, Bomber Command Quarterly Reviews

average figure of 2.34 tons per ton of bombs despatched that can be extrapolated from the data supplied by Norman Franks<sup>93</sup>.

<b>Fuel Loadings for Lancaster Bomber</b>			
<b>Target</b>	<b>Bomb Load in lbs</b>	<b>100-Octane Fuel Load in Gallons*</b>	<b>Fuel Required to lift One Ton of Bombs</b>
Essen	9,160 (4 Ton)	1,500 (6.8 Ton)	1.7 Ton
Hamburg	9,160 (4 Ton)	1,500 (6.8 Ton)	1.7 Ton
Berlin	10,200 (4.5 Ton)	1,743 (7.9Ton)	1.7 Ton
Nurnberg	8,260 (3.7 Ton)	1,800 (8.1 Ton)	2.2 Ton
Berlin	5,360 (2.4 Ton)	1,900 (8.6 Ton)	3.6 Ton
Berlin	7,960 (3.5 Ton)	2,062 (9.37 Ton)	2.7 Ton
Milan	7,600 (3.4 Ton)	2,062 (9.37 Ton)	2.7 Ton

**Fig.7.6:** Source: N. Franks, *The Lancaster*, pp. 10-11

\* Fuel loads were varied by the planned route to be taken as well as metrological conditions.

The figure above shows that it took an average of 2.3 tons of fuel to lift one ton of bombs or mines<sup>94</sup>. If the 988,281 tons of bombs and mines despatched by Bomber Command between 1939 and 1945 is multiplied by 2.3 it gives a figure of 2,274,304 tons of 100 octane fuel used to fuel the aircraft despatched on operations by Bomber Command during the war<sup>95</sup>. This result is 149,790 tons higher than the figure of 2,124,514 tons obtained by multiplying average fuel consumption per mile by the number of engines by total distance to a target. The closeness of the results derived by using two completely different analytical techniques provides a high degree of confidence that Bomber Command used

93 Franks, *The Lancaster*, pp. 10-11

94 It needs to be borne in mind that the estimates here are rough estimates only as the fuel loadings for an aircraft varied with the planned height and route of the attacking force and fuel consumption was adversely affected by head winds and other climatic factors. As Figure 7.6 above shows the fuel loadings for a Lancaster flying to Berlin varied from 7.9 to 9.37 Tons.

95 Harris, *Despatch*, p.50

approximately 2.2 million tons of 100-Octane fuel during World War II. This is 25 percent of all 100-Octane issued to the Air Ministry and 17 percent of all grades of aviation spirit used by Britain at home or shipped from Britain to overseas theatres of operation<sup>96</sup>.

In order to arrive at a total financial cost for the 100-Octane that Bomber Command used on operations, it is necessary to convert tons to gallons and 2,174,218 tons equals 475,891,107 gallons. This amount of fuel multiplied by the average wholesale cost of 2s/8d per gallon<sup>97</sup> during the war, gives a total expenditure of £62,752,139, or almost £63 million as the cost of the 100-Octane fuel used by Bomber Command for its various offensive operations.

The analysis of the data shows that Bomber Command attacked approximately 501 enemy targets by either mining or bombing. Of these targets 32 percent (161) had more than 500,000 gallons of fuel expended in the process, whilst 17 percent (86) had more than one million gallons used against them and 1.1 percent of cities (Berlin, Cologne, Duisburg, Essen, Hamburg and Stuttgart) had more than 10 million gallons used in attacks against them. The total amount of 100-Octane expended against this one percent of all targets, the six cities listed above, was 100,428,142 gallons, or 21 percent of all fuel committed to Bomber Command operations. The cost to Britain was £13.2 million out of the almost £63 million spent on obtaining 100-Octane fuel for the strategic air offensive.

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96 BP Archive, *ARC 7439*, undated.

97 BP Archive, *ARC 7439*, undated

In addition to the fuel used, there is also the engine oil, which was used at a ratio of 15.5 gallons per ton of bombs carried. It suggests that the amount of oil consumed by Bomber Command during the strategic air offensive between 1939 and 1945 would have been approximately 15.3 million gallons. The amount of oil, based on the 1937 price of 1s/2d per gallon<sup>98</sup>, would have cost £893,570. The overall price for POL consumed by Bomber Command between September 1939 and June 1945 is therefore somewhere around £63,645,709.

### **Non-Operational Usage**

The operational activity consumed only part of the 100-octane fuel used by Bomber Command during the strategic air offensive. A significant amount of this fuel was also used in training aircrew, moving diverted aircraft and in simply maintaining and testing aircraft after maintenance. In addition, there needs to be some evaluation of the cost incurred through simple leakage, spillage and contamination of 100-octane fuel. Aviation fuel in particular has to comply with very high standards of purity, as water or other contaminants can result in multiple engine failures and the loss of an aircraft. The importance of ensuring aviation fuel is free of contamination was a major aspect of aircraft operations and any fuel storages that were contaminated had to be disposed of and this represented a cost.

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98 Fedden, *SAE Journal*, Vol 41, No. 3, October 1937, p.437

The history of the strategic air offensive is devoid of research on the Air Ministry's management of POL and the official records contain very little information, probably because the bulk of the records would not have been maintained after the fuel had been issued and accounted for. The lack of sources makes it difficult to analyse the cost of managing this resource. It also makes it difficult to estimate the amount of POL used on supporting activities such as training, testing and maintenance. This thesis will attempt to provide useful estimates by averaging the amounts of POL used for these activities.

The first area of activity of operational support is the diversion of returning bombers from their home airfield to other airfields from which they would later have to relocate themselves. These diversions were not cost-free activities as the relocation of a diverted aircraft from one airfield to its home base imposed a cost in POL. The question is how big this cost was. Between early 1942 and VE day Bomber Command made plans to divert 95,000 aircraft and approximately 20,000 of these aircraft were diverted<sup>99</sup>. The main reason for such diversions was, as Sir Arthur Harris put it, 'The fickle nature of British weather', which included low cloud, rain, sleet, snow and fog<sup>100</sup>.

Although it has been impossible to identify any records detailing how much POL was required to relocate a four-engined bomber over a reasonably short distance,

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99 Harris, *Despatch*, p.188

100 Harris, *Despatch*, p.187

it is unlikely that Bomber Command would let any bomber aircraft take off with less than 250 gallons on board. Given that the bulk of the anecdotal evidence supplied by those who served as aircrew in Bomber Command shows that pilots and crews made every effort to land at their home airfield, it is most likely that a diverted aircraft returning from an operation would be very low on fuel indeed. Therefore, it is safe to assume that most of these aircraft would have taken on around 250 gallons of 100-Octane fuel at the airfield at which they finally landed. It is also probable that these diverted aircraft would not have used much more than half of this amount of fuel in the flight back to their own airfields. If such diversions consumed 100 gallons of fuel, it is probable that around 2 million gallons of 100-Octane costing of £263,916 were used in returning diverted aircraft to their home airfields.

Even where Bomber Command had installed fog dispersal systems, the cost in oil remained high. The fog dispersal systems operated by burning oil and it took several tons of oil per minute to successfully disperse fog<sup>101</sup>. So even when fog could be cleared from an airfield using these systems, it cost an untold amount of oil to accomplish. It has not been possible to estimate the amount of fuel oil used up in this way.

Training also consumed substantial amounts of fuel, although it is extremely difficult to identify any data dealing with such usage. Bomber Command had

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101 Memo dated 7 Oct 43 from Prime Minister to CAS, Sir W. Churchill, *Closing the Ring*, p.115

developed its own extensive training system for new crews and for crews re-training to fly the new heavy bomber aircraft. Keeping the training organisation for heavy bombers within the Command was sensible as it allowed heavy bombers to be carefully husbanded so that very few valuable aircraft types, such as the Lancaster, were diverted from their operational roles. It also allowed Bomber Command to call upon the aircraft of the Heavy Conversion Units (HCUs) and Operational Training Units (OTUs) when there was a need to maximise the size of the attacking force. It also prevented other commands siphoning off these valuable aircraft and their skilled air and ground crews for other purposes.

The size of the resources dedicated to training within Bomber Command indicates the importance that the Command placed on keeping this activity well within the authority of the Command. Despite this implied level of importance it is as difficult to estimate as POL usage on diversions is the amount of this fuel used in the more prolific support activities of training crews to fly heavy bomber aircraft in the Operational Training Units (OTUs) and Heavy Conversion Units (HCUs) that were an intrinsic part of Bomber Command. The average length of this training was five months and the number of hours spent flying a four-engined bomber at an HCU alone was between 40 and 45 hours, the equivalent of seven to seven and a half round trips to Berlin for every crew that undertook this training<sup>102</sup>.

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102 Harris, *Despatch*, p.166

Another very useful indicator, in trying to establish the probable amount of fuel used for training within Bomber Command, is the comparative strengths of the training and operational squadrons. In 1943, only 40.5 percent of all aircraft in the Command were in operational squadrons. The remainder were in HCUs, OTUs or in the miscellaneous category of aircraft doing photo-reconnaissance, supply drops to the resistance or fighters used to simulate attacking Germans for the trainees in the HCUs<sup>103</sup>.

The relationship between training and operations is shown in Figure 7.7. In January 1944, the number of aircraft available in operational squadrons fell, reducing the percent of operational aircraft to 38.5 percent of all aircraft available in the Command<sup>104</sup>. The fall most probably reflected the serious losses inflicted on Bomber Command during the Battle of Berlin at the end of 1943.

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103 Harris, *Despatch*, p.161

104 Harris, *Despatch*, p.160

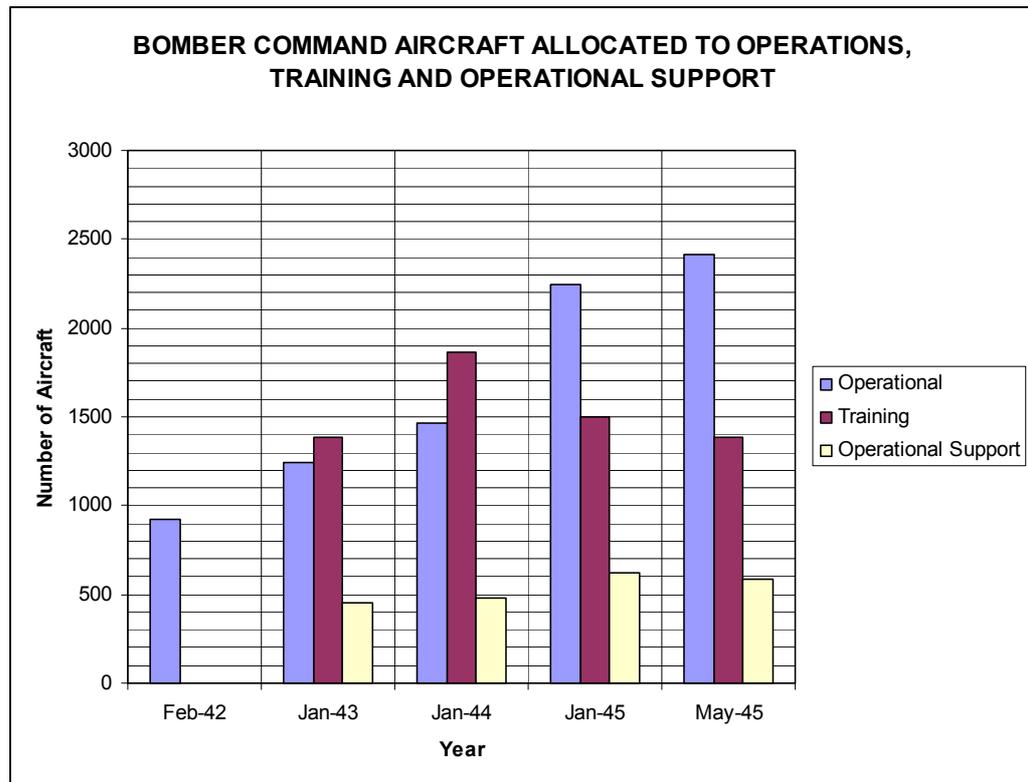


Fig.7.7:

Source: Sir A. Harris, *Despatch*, pp. 45, 160-161

At the time, as can be seen on Figure 7.7 above, there was a widening gap between the number of aircraft available for training and the number of aircraft on charge to operational squadrons. The situation changed from June of 1944, when Bomber Command switched its focus from the heavily defended cities of Germany to operations in support of OVERLORD. With the subsequent collapse of the German front in France and the capture of much of the early warning radar system upon which the German defences depended, the level of attrition on operational squadrons was reduced leading to a reduction in the demand for trained crews.

In January 1945, the percentage of operational aircraft had increased to 51.4 percent, before peaking at 55.1 percent in May of that year. This growth in the number of operational aircraft in Bomber Command most likely reflected the increased survivability of the bombers as the German defences collapsed under the weight of the ground attack and the loss of their fuel supplies and fighter forces in the war of attrition that was being fought out in the skies over Germany.

The resources dedicated by Bomber Command to training were substantial but there is no easy way of quantifying them. It is likely that the amount of POL used in training was between half to three quarters of those dedicated to operations. In calculating the amount of POL consumed by training, it is assumed that every effort would have been made to keep the training overheads as low as possible and therefore the estimates are placed at approximately 50 percent of the total costs of the operational activities. The 40-45 hours of flying that was required of a pilot during HCU training would have consumed an estimated 14,000 gallons of aviation fuel. This figure if multiplied by the 15,714 pilots that are estimated as having undergone this training gives a total of 220 million gallons of 100-Octane fuel as being used in HCU training. This figure is estimated to be under 50 percent of the amount of fuel used on operations. This amount of fuel would have cost £29,030,305 and when added to £446,500 for engine oil, would give a cost of £29.5 million as the total cost of the POL used on HCU training. Given that this estimate does not include the amount of POL used for OTU training it is likely that it is an underestimate of the actual cost.

Other support activity not included in the fuel usage figures identified so far include such things as the testing of engines on the ground and aircraft in the air, as well as the costs associated with the delivery of aircraft from the factories directly to Bomber Command airfields. Test flights for the Hampden cost £11-12, whilst those for a Wellington were from £17-18<sup>105</sup>. The running of engines on test beds and all of the other activity associated with maintaining over four thousand aircraft would have a substantial cost in fuel and oil alone. But, again there are no figures to inform us on this point and it must be accepted that a cost was paid, although it is impossible to accurately tell what it might have been. The best estimate is that it cost around £10 per aircraft delivered to Bomber Command. The total cost of this activity would have been £362,840 with £162,840 spent on delivering the Halifax, Lancaster and Stirling heavy bombers and £200,000 for the remaining 11 types used within the Command.

The last general area of that needs to be described is wastage through the loss of fuel from a variety of causes such as leakage (the loss of fuel volume whilst in storage), spillage (the loss of fuel volume during handling operations), evaporation, theft and contamination. Although it is impossible to quantify the amount of fuel lost through wastage, it is important to consider its impact as a cost factor. Not only does fuel wastage cost money, but it imposes other costs as well particularly if it leaks or spills into the environment. Even under war conditions the Air Ministry had to take account of the impact of its activities on the local

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105 Ministry of Aircraft Production, *Price Books*

environment. There would not be many farmers who would be happy with fuel containing large quantities of lead being spread over their lands.

Contamination of the fuel itself is another major problem, particularly as the safe operation of aircraft demands fuel of the highest quality. Any contamination of aviation fuel stocks by dirt, water or other substances makes it instantly unusable in an aircraft. As with leakage and spillage, there are no figures detailing the extent of fuel lost through contamination. This leaves an estimate for the loss of fuel through wastage and this is being done in the absence of even a staff-planning figure used to prepare the Air Ministry fuel requirements. As a result, I argue that a figure of 5 to 10 percent for total wastage for POL is not unlikely and given the emergency nature of much of the distribution and storage systems used during World War II, it is most likely that the wastage rate was closer to 10 percent than to five. At five percent of total POL used this wastage would be somewhere around 200,000 tons (43,400,000 gallons) at a cost of roughly £5.7 million.

## **Conclusion**

Without access to high quality petroleum products supplied through the United States and the Middle East, Britain could not have successfully prosecuted the war. The resources dedicated to producing petroleum and petroleum products and to transporting them across the world were very large and are a strong indication of how important petroleum was to the war effort. However, Britain and the

United Nations were able to enjoy access to the highest quality petroleum because of the generosity and technical prowess of the United States.

As an island nation Britain had to fight a long and protracted battle in the Atlantic to ensure that her lifelines of fuel, food and armaments were kept open. Amongst the most important of the cargoes that were despatched was the POL that the tankers carried. The Germans understood this and the U Boat captains sought out tankers above all other ships. During World War II, Britain imported or manufactured a total of 90,902,800 tons of POL for her war effort and people<sup>106</sup>. These POL imports provided chemicals to make explosives, asphalt to pave airfields, bunker oil for ships, packing wax for protecting food and ammunition from the environment and of course, the petrol to drive the engines of the armed services. Of this petrol, the most important was the 12,817,848 tons of aviation fuel brought in or manufactured for the aircraft of the RAF, Admiralty and War Office<sup>107</sup>. The amount is 14.1 percent of the total POL imported or manufactured for all uses during the war by Britain. Of these 12.8 million tons of aviation fuel imported or manufactured, 69.65 percent (8,960,295 tons)<sup>108</sup> was 100-Octane fuel needed for the fighters of Fighter Command and the bomber aircraft of Bomber Command, the latter of which is the subject of this thesis.

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106 Central Statistical Office, *Statistical Digest of the War*, pp. 87-92

107 BP Archive *ARC7439*, undated

108 BP Archive *ARC7439*, undated

Having looked closely at the data relating to the use of POL in Britain during the war it has been possible to identify with relative accuracy that Bomber Command used around 24.2 percent (2,174,218 tons) of 100-Octane plus fuel in its strategic air offensive against Germany. The cost of this expenditure was £63 million. Added to this is the cost of training and the other necessary support activities that had to be undertaken to conduct the air offensive. Subsidiary activity, such as diverting returning aircraft, training of aircrews, testing and maintaining aircraft and the simple handling of POL all resulted in the use or loss of this fuel. The cost of diverting returning aircraft may have been £263,916; the cost of training, £29,000,000; the cost of testing and maintenance, a conservative £362,840; and then the cost of wastage, £5,723,375. All together, a total cost of £99 million pounds has been estimated for the consumption of POL within Bomber Command.

The other indirect costs that must be taken into account include the cost of the shipping lost whilst transporting aviation fuel and petroleum products to Britain. A percentage of this loss is attributable to the strategic air offensive, because Bomber Command would have taken a percentage of the fuel in these tankers. The cost of the 100-Octane fuel lost at sea that would have been issued to Bomber Command is estimated to be £62.93 million and the value of the sunken tankers carrying it £42.83 million. The total cost of these losses £105.7 million.

Added together the above figures for the use of 100-Octane fuel together with the value of losses in both fuel and ships come to an impressive total of

£223,653,125. This now gives us a total figure of £2.149 billion for the aircraft, infrastructure, ordnance and petrol, oil and lubricants used by Bomber Command in the strategic air offensive against Germany.

## *Chapter 8*

### MANNING THE OFFENSIVE

The men and women who served in Bomber Command were the most important element in the successful creation of the strategic air offensive against Germany. Yet the raising, training and work of these men and women has been largely ignored in the histories of the campaign. This chapter focuses on the cost of manpower for the 2,074 days of Bomber Command's offensive. In order to cost manpower, the analysis deals with Britain's efforts to obtain, train and maintain the necessary skilled manpower for Bomber Command. The effort involved proved to be very great and it led to the development of a worldwide recruiting and training scheme that consumed massive resources to provide the aircrew and ground personnel who made up Bomber Command during the war.

The first step in analysing the cost of manpower involved in the strategic air offensive is to identify the approximate size of that manpower. The most widely accepted figures for these are 125,000 aircrew and 'never...more than 250,000' given by Sir Arthur Harris in his book *Bomber Offensive*<sup>1</sup>. The analysis produced here confirms Harris's figure of 125,000 aircrew as being reasonably accurate but it shows his suggestion of 250,000 for the total size of Bomber Command as

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1 Sir Arthur Harris, *Bomber Offensive*, pp. 267-268

being 100,000 higher than the establishment figures for manpower authorised by the Air Ministry at the height of the strategic air offensive in 1943 and 1944<sup>2</sup>. In analysing the cost of manpower in the strategic air offensive I have retained Harris's estimate for aircrew but used the Air Ministry establishment figures of approximately 150,000 for the total size of Bomber Command.

I have also chosen not to include the possibility that up to 300,000 personnel worked on Bomber Command Stations. This last figure comes from an analysis of the accommodation provided at bomber stations. Each of Bomber Command's stations had accommodation for an average of 2,300 personnel. However, it cannot be known whether all of this accommodation was used or if the difference for accommodation provided and the numbers of personnel posted onto Bomber Command's strength was due to a large number of support personnel being present who were subordinate to or commander by other organisations.

With a reliable estimate of the size of Bomber Command, it has been possible to identify the approximate financial costs incurred by Britain in paying, recruiting, training and maintaining this workforce. Each of these is analysed in turn in order to provide an estimate of the cost involved. The result is that the direct cost to Britain of supplying, training and maintaining manpower for Bomber Command was a little under £647 million, making this the second most expensive activity undertaken to carry out the strategic air offensive against Germany. The

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2 PRO *AIR* 8/699, Letter from AMP to C-in-C Bomber Command 31 July 1943 and PRO *AIR* 8/699, Letter from AMP to C-in-C Bomber Command 31 July 1944

identification of the size of the Command's manpower during the war and the direct financial cost involved are a considerable contribution to the existing history of Bomber Command.

The histories dealing with the subject of manpower in Bomber Command are few in number. Of those available, Harris's *Despatch on War Operations* (1945) and *Bomber Offensive* (1947) are fundamental works for historians working in this area. Harris is the only writer who provides a cost for training a single Bomber Command aircrew. My analysis suggests that Harris's estimate of £10,000 to train one member of an aircrew is excessive and the true cost was probably under £5,000. Nevertheless, he is the only source in a position to know what the true costs may have been who has offered a consolidated cost of training.

Other useful sources are F. J. Hatch's volume of the Canadian Government's Official History of the British Commonwealth Air Training Plan (BCATP), *Aerodrome of Democracy*<sup>3</sup> (1983) and the Australian J. Herington's two volume Official History, *Air War against Germany and Italy 1939-1943* (1954) and *Air Power Over Europe 1943-1945* (1963)<sup>4</sup>. Hatch describes the Royal Canadian Air Force's operation of the BCATP (as the Canadians called the Empire Air Training Scheme (EATS)) and its contribution to Allied victory.

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3 E.J. Hatch, *Aerodrome of Democracy: Canada and the British Commonwealth Air Training Plan, 1939-1945*, Canadian Government Publishing Centre, Directorate of History, Department of National Defence, Ottawa, 1983

4 J. Herington, *Australia in the War of 1939-45, Air, Air War Against Germany and Italy 1939-1943*, Australian War Memorial, Canberra, 1954 and *Air Power over Europe, 1943-1945*, Australian War Memorial, Canberra, 1963

Hatch and Herington provide essential information on the size, complexity and costs of training aircrew for service in Bomber Command and, unlike the British official historians Sir Charles Webster and Noble Frankland, they were uninvolved in the British controversy over the effects of wartime bombing. Of the two Commonwealth historians, Herington provides the frankest appraisal of casualty rates, survivability and the way in which the RAF and Air Ministry recruited, trained and administered service personnel. In particular, Herington is the only British Commonwealth official historian to blame Bomber Command's casualty rates as being responsible for what he called the 'phenomenal turnover' of aircrew<sup>5</sup>. Webster and Frankland took a more careful approach to these subjects, which is unsurprising perhaps given the sensitivity of many serving and ex RAF officers who were hostile to the idea of an official history being written outside the control of the Air Ministry and the Air Staff<sup>6</sup>. Perhaps because of this, Webster and Frankland have focussed more on the military aspects of the strategic air offensive and have not expended much time or space on the discussion of manpower, training and administration.

Because of the large role played by the Dominions in providing and training personnel for the RAF, Australian and Canadian writers dominate the subject. The Australian, John McCarthy, was the first to examine critically the impact of EATS on Australia's own defence. McCarthy is the most prolific writer dealing

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<sup>5</sup> Herington, *Australia in the War of 1939-45*, p.456 n.3

with manpower in the RAAF and has produced two articles, and a book on the subject<sup>7</sup>. In ‘The Defence of Australia and the Empire Air Training Scheme’ (1974)<sup>8</sup>, McCarthy concluded that the Australian Government had put at risk the nation’s own national interest by sending airmen to serve in the RAF under the EATS agreement with Britain. He is also one of the first historians to examine the subject of how Bomber Command handled psychological problems amongst aircrew and how the RAF used the administrative categorisation of ‘Lack of Moral Fibre’ (LMF) to punish men whose nerve failed them on operations.

The subject of psychological stress and air operations had attracted some earlier attention. Two senior RAF medical officers, Air Marshal Sir Charles Symond and Wing Commander Denis Williams, published , *Psychological Disorders in Flying Personnel of the Royal Air Force 1939-1945*<sup>9</sup> (1947), an early study on flying stress. It is perhaps surprising that there was little interest amongst historians in this subject. McCarthy’s fine study, ‘Aircrew and Lack of Moral Fibre in the Second World War’, (1984)<sup>10</sup> examined the punishment for perceived cowardice in the RAF and particularly in Bomber Command. Mark Wells has

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6 N. Frankland, *History at War*, Giles de la Mare, London, 1998, pp. 87-92

7 J. McCarthy, The Defence of Australia and the Empire Air Training Scheme, *Australian Journal of Politics and History*, Vol XX, No 3, December 1974; J. McCarthy, The “Surrender” of Aircrew to Britain 1939-1945, *Journal of the Australian War Memorial*, No 5, October 1984; J. McCarthy, *A Last Call of Empire, Australian Aircrew, Britain and the Empire Training Scheme*, Australian War memorial, Canberra, 1988

8 John McCarthy, The Defence of Australia and the Empire Air Training Scheme’ in the *Australian Journal of Politics and History*, of December 1974

9 Sir C. Symonds’s and D.J. Williams, *Psychological Disorders in Flying Personnel of the Royal Air Force 1939 to 1945*, HMSO London, 1947

10 J. McCarthy, Aircrew and ‘Lack of Moral Fibre’ in the Second World War, *War and Society*, Vol 2, No. 2, Sept 1984, pp. 85-101

added to this body of work with *Courage and Air Warfare: The Allied Aircrew Experience in the Second World War* (1995)<sup>11</sup> which compares the ways in which the RAF and USAAF managed the psychological selection of aircrew and any subsequent emotional stress.

The relatively small number of histories dealing with this subject has led to a far greater reliance in this chapter on primary sources. The most important of these is the *Statistical Digest of the War* (1951)<sup>12</sup>, compiled by the Central Statistical Office. Other sources include the files in the Public Record Office (PRO) in London. The analysis in this chapter draws heavily on the figures identified in the PRO files and the *Statistical Digest of the War* to estimate the financial costs of recruiting, selecting, training and maintaining the personnel who served in Bomber Command. The chapter produces a low total estimate of slightly under £647 million for manpower in Bomber Command during the strategic air offensive. It was too difficult to assess precisely the amount of money spent by the British government in the payment of additional monies for rank, trade skills, married status and so forth. Therefore, the wages component of the estimate is low as it adopts a lowest available daily payment for RAF service personnel of 3s/6d to calculate the cost of wages in Bomber Command during the war. Even with such a reduced amount, the analysis here shows the cost of manpower as being second only to the cost of aircraft and aircraft factories.

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11 M.K. Wells, *Courage and Air Warfare: The Allied Aircrew Experience in the Second World War*, Cass Series: Studies in Air Power, Frank Cass, London, 1995

12 Central Statistical Office, *Statistical Digest of the War*, HMSO, London, 1951

## **The Size of Bomber Command**

In order to establish the financial cost of manning Bomber Command the first step is to calculate the exact numbers of personnel assigned to the Command during World War II. It is a difficult task to accurately identify precisely the number of individuals within Bomber Command at a given point in time. Unlike aircraft and airfields, the number of service personnel within a military organisation like Bomber Command changed on an almost hourly basis as personnel continuously moved into and out of the organisation during the war. Such movements were part of the friction of war and reflected the death, wounding and capture of personnel by the enemy. It also reflected the transfer of personnel to other theatres of operations or to other commands within the RAF, as well as the constant flow of individuals onto training courses and even out of Bomber Command at the end of their two tours of duty.

My analysis of personnel suggests that the strength of Bomber Command never rose to 250,000 men and women and that 125,000 men served as aircrew within the Command during World War II<sup>13</sup>. Sir Arthur Harris provides the source for both statistics and whilst a figure of 125,000 for aircrew appears plausible, the figure of 250,000 as an upper limit to the strength of Bomber Command is most probably a significant overestimate<sup>14</sup>. The evidence for this is in the Air Ministry

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13 Harris, *Bomber Offensive*, p.268

14 Harris, *Bomber Offensive*, p.268

files which give an establishment size of under 150,000 for Bomber Command at the height of the strategic air offensive<sup>15</sup>. In July 1943, the official establishment of Bomber Command was 147,923 positions of which Bomber Command claimed only 91,564 (61.9 percent) were filled<sup>16</sup>. The Air Ministry rebutted these claims by pointing out that 139,195 of the 147,923 positions were filled and that the percentage shortfall was only 5.9 percent<sup>17</sup>.

In mid 1944, the Director General of Manpower noted that Bomber Command had an establishment of 143,171 positions of which 135,607 personnel were posted in the Command<sup>18</sup>. The establishment figures clearly show that between July 1943 and July 1944 the size of Bomber Command fell by 3.22 percent, whilst the size of the RAF increased by 2.14 percent, from 1,148,600 to 1,173,200 over the same period<sup>19</sup>. The reduction in the absolute size of Bomber Command probably reflects the need of the RAF to supply increasing numbers of personnel to the tactical air forces required to support the invasion of Europe in 1944 and they indicate that Bomber Command did not enjoy continual growth throughout the war.

The figures also show that between 1943 and 1944 Bomber Command contained an average of 12.53 percent of the RAF's total manpower. If this average is truly

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15 PRO AIR 8/699, Letter from AMP to C-in-C Bomber Command 31 July 1943 and PRO AIR 8/699, Letter from AMP to C-in-C Bomber Command 31 July 1944

16 PRO AIR 8/699, Letter from AMP to C-in-C Bomber Command 31 July 1943

17 PRO AIR 8/699, Letter from AMP to C-in-C Bomber Command 31 July 1943

18 PRO AIR 8/702, Letter from AMP to C-in-C Bomber Command 31 July 1943

indicative of Bomber Command's relative share of RAF manpower, it provides a basis for charting the relative strength of the Command throughout the period of the war by calculating it at 12.53 percent of total RAF strength<sup>20</sup>. The results are shown in Figure 8.1 below.

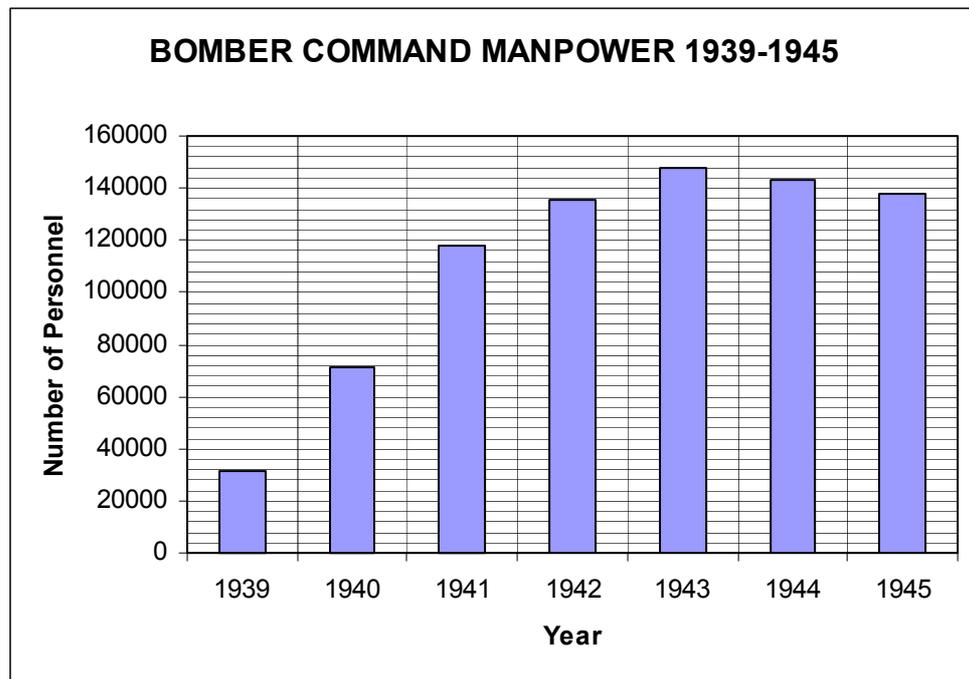


Fig. 8.1: Total Strength Bomber Command September 1939 to June 1945 Source: PRO AIR 8/702, Letter from AMP to C-in-C Bomber Command 31 July 1943 and Central Statistical Office, *Statistical Digest of the War*, p.9.

As can be seen from Figure 8.1, at no time during World War II did Bomber Command's strength ever approach 250,000 as Sir Arthur Harris hints at in his history of the offensive<sup>21</sup>. It is possible that Harris inadvertently overstated the

19 Central Statistical Office, *Statistical Digest of the War*, p.9, Tab 10

20 Note that the figure for 1939 is the September quarter figure and, with the exception of the figures for July 1943 and 1944, all establishment figures are estimated as 12.53 percent of total RAF manpower listed in Central Statistical Office, *Statistical Digest of the War*, p.9, Tab 10

21 Harris, *Bomber Offensive*, p.268

size of Bomber Command by more than 100,000 personnel, but unlikely, as he was intimately involved in promoting the claims that Bomber Command was undermanned<sup>22</sup>. It is hard to be sure about the reason for so large an overestimate but a possible explanation may lie in RAF sensitivity over the very high casualty rates suffered by Bomber Command.

The casualty figure for Bomber Command is estimated by Richard Overy as being 79,172, 25, a few more than the 79,147 reported by Harris in his official report<sup>23</sup>. Overy's breakdown of the casualties shows that more than 72.7 percent (57,582) of them were deaths, 11.57 percent (9,162) wounded and 16.2 percent (12,867) made prisoner of war<sup>24</sup>. The high proportion of deaths relative to wounding and capture is very uncommon in military operations and indicates that service in Bomber Command during World War II was a highly dangerous undertaking.

If the casualty figure of 79,172 is considered as a percentage of the 147,923 establishment positions in Bomber Command in July 1943, it represents a total casualty rate of 53.4 percent, of which almost three quarters were killed<sup>25</sup>. The members of Bomber Command who suffered most were the aircrew. They accounted for 97.2 percent of the deaths, 45.8 percent of the wounded and 98.3

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22 See PRO AIR 8/699, Letter from AMP to C-in-C Bomber Command 31 July 1943 and PRO AIR 8/699, Letter from AMP to C-in-C Bomber Command 31 July 1944

23 Overy, *Bomber Command, 1939-1945*, p.204 and Harris, Despatch, p.61

24 Overy, *Bomber Command, 1939-1945*, p.204

25 PRO AIR 8/699, Letter from AMP to C-in-C Bomber Command

percent of the prisoners of war<sup>26</sup>. Aircrew losses were disproportionately large within Bomber Command with 61.45 percent (76,817) of the 125,000 aircrew becoming casualties and 44.45 percent (55,573) being killed<sup>27</sup>. These figures are most probably an under-estimate as they do not include those aircrew removed from flying duties due to psychological breakdown. In human terms, the cost of the strategic air offensive was very high indeed. John Herington, the Australian official historian, estimates that Bomber Command lost 10 percent of its fighting men every week<sup>28</sup>. The average figure, when adjusted for actual losses, suggests that Herington's estimate may be not too far from the truth.

#### **DEATHS IN BOMBER COMMAND**

<b>Country</b>	<b>Aircrew Killed</b>	<b>Percent of Total Dead</b>
United Kingdom	38,462	69.3
Canada	9,919	17.8
Australia	4,050	7.3
New Zealand	1,679	3.0
Poland	929	1.7
Other Allied Air Forces	473	0.9
South Africa	34	0.06
Other Dominions	27	0.04

Fig.8.2:

Source: R. Overy, *Bomber Command*, pp.204-208

The Australian official history tells us that 4,050 Australia airmen were killed whilst serving in Bomber Command. This figure constituted 7.3 percent of

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26 Overy, *Bomber Command, 1939-1945*, p.204

27 Overy, *Bomber Command, 1939-1945*, p.204

28 Herington, *Air War against Germany and Italy*, p.456

Bomber Command's losses<sup>29</sup> but 10.2 percent of all Australian military deaths suffered during World War II<sup>30</sup>. It is a stark insight into the size of the risk faced by the men serving as aircrew in Bomber Command. This finding supports McCarthy's contention that the Australian Government may have placed the national interest at risk by being so liberal in providing personnel for the RAF through EATS<sup>31</sup>. In New Zealand's case, a similar situation is found with 1,679 RNZAF servicemen killed in Bomber Command, a loss equating to 14.2 percent of the 11,824 New Zealanders killed by enemy action during World War II<sup>32</sup>.



**Fig. 8.3: Wellington Aircrew** Source: [www.raf.mod.uk/bombercommand](http://www.raf.mod.uk/bombercommand)

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- 29 Australian War Memorial, [www.awm.gov.au/atwar/statistics/world\\_wars.htm](http://www.awm.gov.au/atwar/statistics/world_wars.htm), 20th February 2003 and Middlebrook and Everitt, *Bomber Command War Diaries*, p.710
- 30 Australian War Memorial, [www.awm.gov.au/research/infosheet/war\\_casualties.asp](http://www.awm.gov.au/research/infosheet/war_casualties.asp), 20th February 2003
- 31 It can be claimed that RAAF personnel gained valuable operational experience from serving in the European theatre. However, the value of flying Lancaster bombers over heavily defended German cities had little relevance to the types of operations conducted in the Pacific.
- 32 R. Kay, New Zealand Section, *Oxford Companion to the Second World War*, Oxford University Press, Oxford, 1998, p.801

Casualty figures are one of the areas where Sir Arthur Harris is imprecise. In his memoirs, he cites a figure of ‘some 60,000’ casualties and a total manning somewhere below 250,000<sup>33</sup>. In the *Despatch on War Operations* Harris provides two different figures, 57,786 in the text and 79,147 in a table<sup>34</sup>. The loss of 60,000 casualties out of a force of 250,000 constitutes a 24 percent casualty rate which, while quite high, is less perturbing than the actual casualty rate of 61.45 percent (76,817 out of 125,000) suffered by Bomber Command aircrew. The earlier differences over Bomber Command’s manning and casualties figures may have been caused by an understandable reluctance to advertise the true size of aircrew losses in the strategic air offensive.

## **Recruitment**

Between 1919 and 1939, the RAF was a small technically trained force of professional officers and other ranks. The RAF retained a large number of men who had served in its ranks during World War I and who carried their experience across when the new service formed in 1918. During the interwar years, the Air Ministry handled recruitment into the RAF for officers and other ranks. The Air Ministry recruited candidates for positions according to their social and educational background. What made the RAF different from the other services was its recruitment of middleclass young men who had completed the upper

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33 Harris, *Bomber Offensive*, p.33, and p.61

34 Lund, ‘The Industrial History of Strategy’, *The Journal of Military History*, p.77

levels of their secondary education and who could cope with the technical training they would receive in the RAF as apprentices<sup>35</sup>.

As the likelihood of war increased towards the end of the 1930s, the Air Ministry and the British Government were aware that they would have to look to the white Dominions of the Empire for manpower, particularly for aircrew. In order to convince the white Dominions that they should provide air force recruits the Air Ministry developed the concept of the Empire Air Training Scheme (EATS).

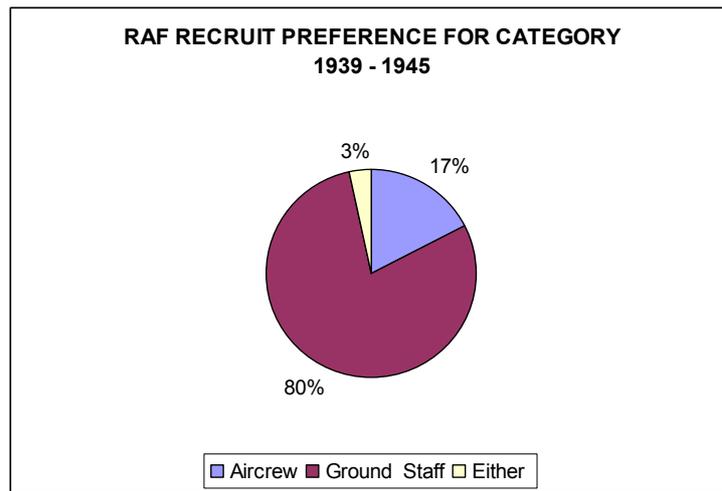


Fig. 8.4: Source: PRO AIR 41/65 (90532) 301, September 1945

Under the EATS Agreement, Australia, Canada and New Zealand were committed to supplying the RAF with aircrew, and, to a lesser extent, with ground staff as well. Other than Canada, which had to provide the ground staff for the British Commonwealth Air Training Plan (BCATP), the other signatories were unable to supply significant numbers of ground staff, leaving Britain to supply the

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35 Lund, 'The Industrial History of Strategy', *The Journal of Military History*, p.77

bulk of the ground staff for the war in Europe, South Asia and the Middle East<sup>36</sup>. The Empire Air Training Scheme became the aircrew-training organisation for Britain first and then for the Empire.

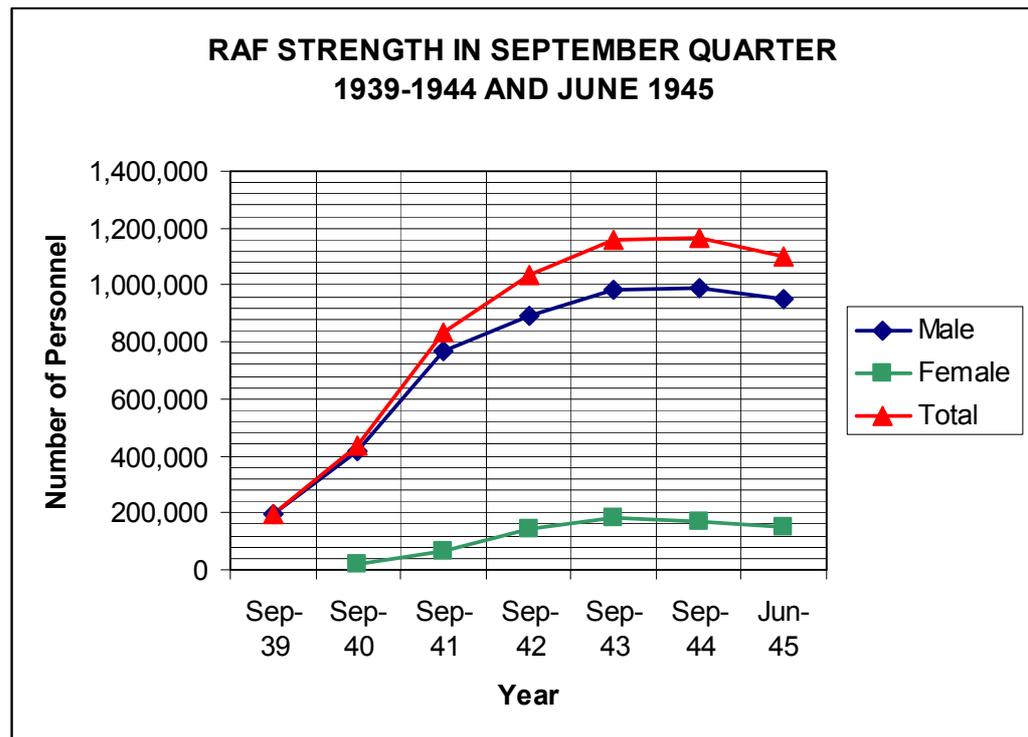


Fig. 8.5:

Source: *Statistical Digest of the War*, p.9

Within Britain, as Figure 8.6 shows, recruitment of personnel for the RAF peaked in early 1940 with aircrew recruitment rising to its highest level in October of that year. The significance of these figures is that they clearly show that manpower was a significant limitation on the expansion of both the RAF and Bomber Command. The lateness of the recruitment spike means that very few personnel would have been ready for active service in squadrons before late 1941. The

36 PRO AIR 8/280, Office Memorandum, Mission to Canada in Connection with Dominion Air Train Scheme, 27<sup>th</sup> Oct 39

delay in expanding Bomber Command's striking power to late 1942 is therefore not simply due to the late arrival of heavy bombers or to the lack of sufficient airfields but also to a significant lack of trained personnel.

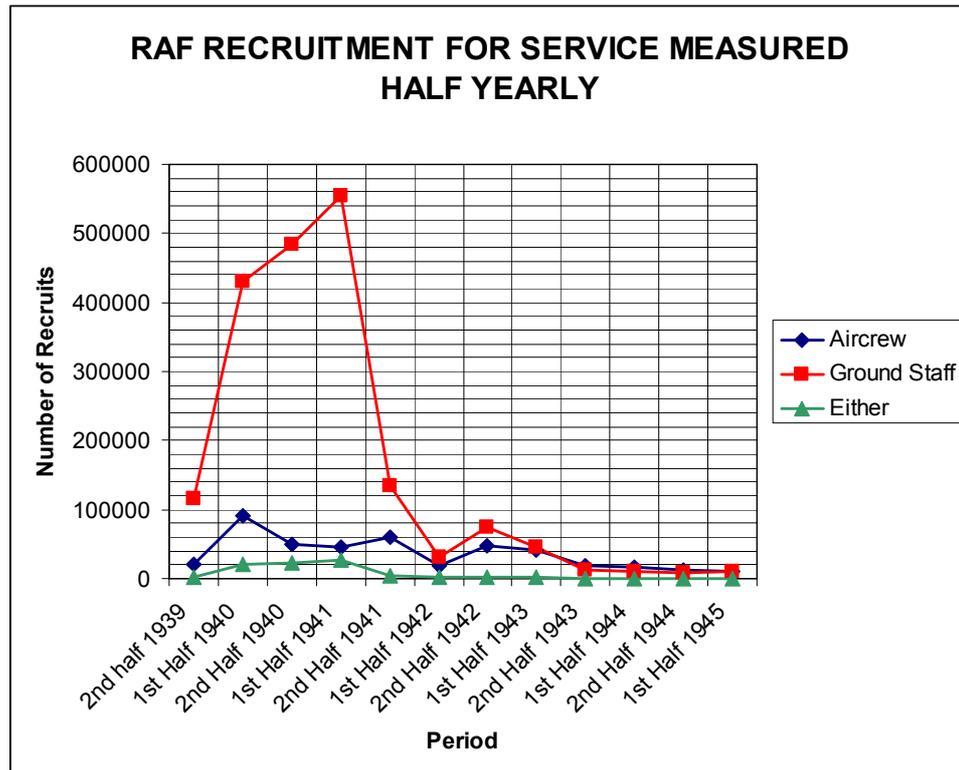


Fig. 8.6:

Source: PRO AIR 41/65 (90532) 301, September 1945

A further problem for the RAF was that 80 percent of all volunteers for service wanted to be ground crew and only 17 percent expressed a clear preference for aircrew<sup>37</sup>. By mid 1941, the pool of enthusiastic older volunteers had emptied and, from that time, none older than 20 expressed a preference for service as aircrew<sup>38</sup>. The RAF and Bomber Command could only draw upon those young

37 PRO AIR 41/65, Notes on Recruitment Advertising, Mar 41

38 PRO AIR 41/65, Notes on Recruitment Advertising, Mar 41

men reaching their 18<sup>th</sup> birthday to provide replacement. The change in the demography of the recruit base probably explains why after April 1943 more men volunteered for aircrew than ground crew.

A further indication of a reduction in the available pool of manpower was the rapid increase after mid 1941 in the number of women enlisting into the Women's Auxiliary Air Force (WAAF). Although they could not serve in aircrew, women provided a significant proportion of the RAF's workforce rising from 3.97 percent in September 1940 to 15.5 percent in September 1943<sup>39</sup>. The figures for the recruitment of women clearly show a marked increase from mid 1941, the time when the numbers of male recruits dropped markedly. The Air Ministry made a serious effort to fill its manpower needs from the female population of the United Kingdom. Aircrew recruitment was heavily reliant on volunteers coming from the Empire but even these sources saw a decline in recruits volunteering for aircrew with Canada showing a definite drop and it is likely that both Australia and New Zealand experienced a similar drop in volunteers for aircrew service.

In the early stages of World War II, the Royal Australian Air Force (RAAF) and the Royal New Zealand Air Force (RNZAF) were more than able to meet their commitments to supply aircrew for the RAF. However, these EATS participants had much greater difficulty in supplying sufficient ground staff. In Australia, in September 1940, the Australian CAS reported to his British equivalent that 2,000

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39 Central Statistical Office, *Statistical Digest of the War*, Table 10

aircrew trainees were already under training while about 7,300 young men were still awaiting enlistment<sup>40</sup>.

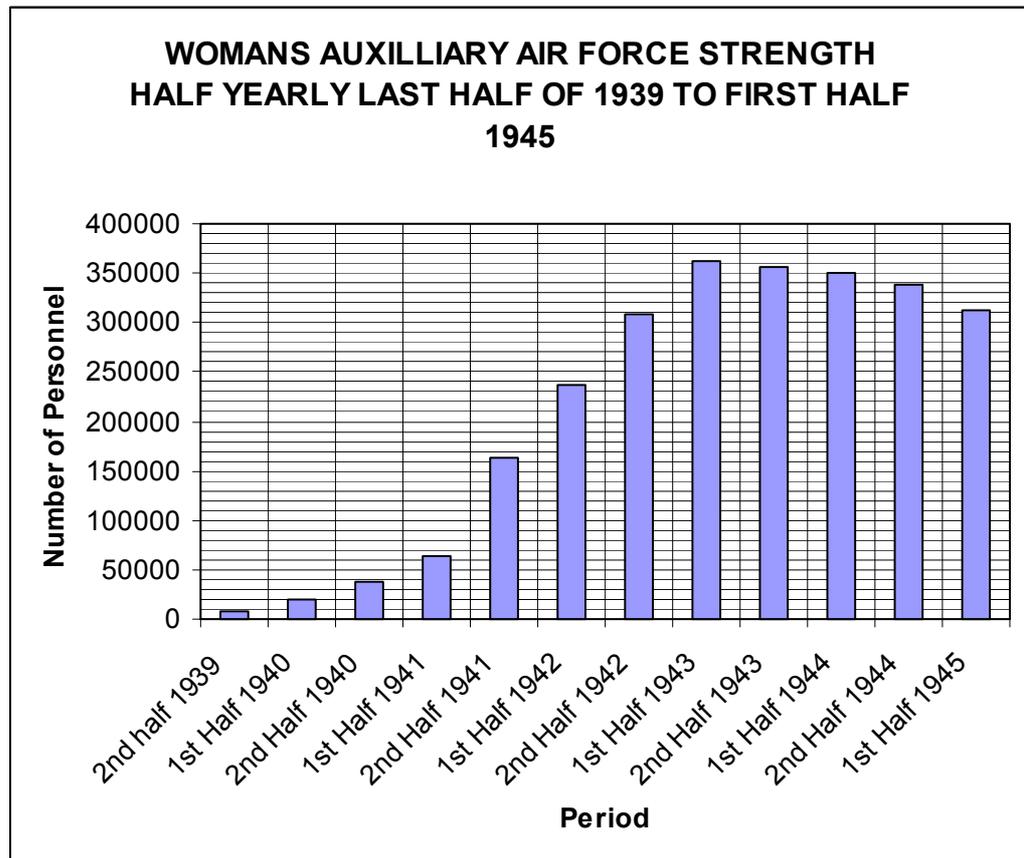


Fig. 8.7 Total Strength WAAF

Source: *Statistical Digest of the War*, p.9

In Canada, the authorities made additional efforts to increase recruitment, including an aggressive campaign to recruit United States citizens for service as pilots and aircrew<sup>41</sup>. Despite being illegal, the recruitment of United States citizens for service in the RCAF and RAF appears to have enjoyed the blessing of

40 PRO AIR 2/1608, Letter from Australian CAS, 16<sup>th</sup> Sep 40

41 Dunmore, *Wings for Victory*, p.256

the USAAF. General Hap Arnold, the then Chief of the United States Army Air Corps, and the later commander of the United States Army Air Forces during World War II, suggested that the Canadians make use of men who had been ejected from USAAF pilot training because they had been ‘fractious’, went in ‘for low stunt flying’, got ‘drunk one time’, or had been discovered as being ‘married’<sup>42</sup>. Arnold believed these men, who were the ‘kind I’d want to keep’, had the United States being fighting a war would be of value to Britain<sup>43</sup>. Despite Arnold’s helpfulness in arranging the recruitment of pilots, the Canadians faced the legal problem of how they could protect United States citizens who had volunteered for service. The United States authorities had already demonstrated a distinct lack of understanding for the men and women who had volunteered to fight in Spain and the Canadian Government was keen to ensure that none of their recruits would be subjected to the \$US2,000 fine or risk losing their United States citizenship because they were deemed to have ‘expatriated’ themselves<sup>44</sup>.

In order to minimise these risks the Canadian Government dropped the loyal oath so that US citizens did not have to swear allegiance to King George. The Canadians also trod carefully so avoid aggravating Washington by being too obvious in their recruitment of aircrew and the system of recruitment that the Canadians developed for United States citizens became quite complex. The process for recruiting a US citizen involved failing them as candidates for the

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42 Dunmore, *Wings for Victory*, p.256

43 Dunmore, *Wings for Victory*, p.256.

44 Dunmore, *Wings for Victory*, p.256.

RCAF but offering them employment in a Canadian association called The Dominion Aeronautical Association, which then supplied pilots for the RAF and RCAF<sup>45</sup>. The United States Government finally reacted to the Canadian activity when the State Department issued a note stating that the Canadian activities were an embarrassment and were to stop. Roosevelt forced the State Department to drop the matter and the Canadians continued their activities, but far more cautiously.

The cost of recruiting United States citizens for service in the RCAF and the RAF is unknown, but *Newsweek* reported that by March 1940 there were 2,000 United States volunteers on the RCAF list already<sup>46</sup>. In spring of 1943, the Canadians were looking for another 2,500 volunteers<sup>47</sup>. Amongst the costs identified for this activity were those of staffing the recruiting system in the United States, establishing the framework for accepting these volunteers into the RCAF and the payment of their expenses, including a \$5.00 per day food allowance<sup>48</sup>. The total amount of this activity is difficult to estimate, but if each American recruit received three days of payments, the total amount involved for 2,742 recruits would have been \$CAN41,130.00.

Added to this activity is the cost of advertising and propaganda, which included the Hollywood film production '*Captains of the Clouds*', starring James Cagney.

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45 Dunmore, *Wings for Victory*, p.258.

46 Newsweek, 16 March 1940, quoted in S. Dunmore, *Wings for Victory*, p.242

47 Dunmore, *Wings for Victory*, p.259

Warner Brothers made this film at the suggestion of the head of the RCAF's advertising section. The objective of the production was to promote the EATS and the strategic air offensive, and was a box office success returning a profit<sup>49</sup>. All of the EATS signatories actively sought volunteers through advertising and these cost money. From November 1940 to March 1941, the Air Ministry spent £125,000<sup>50</sup> on advertising to attract 15,805 recruits for aircrew. The campaign attracted 11,000 individuals from which the Air Ministry only expected 3,000 to be successful as aircrew. The cost of recruiting an aircrew candidate in 1941 is estimated at £11.7s/2d and the cost for one aircrew member £41.13s/2d. Applied to the 125,000 aircrew who served in Bomber Command, the cost of advertising alone would have been £5,207,500.

In Australia, Canada and New Zealand, where similar recruiting activity was undertaken, advertising was placed in newspapers and on billboards. The Canadian Government also employed World War I ace, Billy Bishop, to lead a recruitment campaign, which found 72,835<sup>51</sup> men for aircrew training and a further 33,352 personnel to staff the BCATP<sup>52</sup>. The recruitment organisation within the Canadian EATS had 450 establishment positions of which 105 were

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48 Dunmore, *Wings for Victory*, p.259

49 Dunmore, *Wings for Victory*, pp. 259-273

50 PRO AIR 41/65, Notes on Recruitment Advertising, Mar 41

51 Heide, Rachel L., 'The British Commonwealth Air Training Plan: How Canada's Contribution to the Second World War Affects Us Today', [www.vac-acc.gc.ca/general/sub.cfm?source=history](http://www.vac-acc.gc.ca/general/sub.cfm?source=history)

[/secondWar/bcatp/page4](#), 20th February 2003

52 Dunmore, *Wings for Victory*, p.50

civilian<sup>53</sup>. Obtaining sufficient personnel in a country where there was no conscription was a formidable task and the success of the EATS relied heavily upon the efforts of the recruiters and marketers. A significant proportion of this activity is directly attributable to the cost of the strategic air offensive.

### **Selection**

To become a member of an aircrew the potential recruit had to satisfy the selection requirements of the Air Ministry. These covered educational, psychological and physical attributes and barrier testing. Aviation Candidates Selection Boards oversaw the process of selection during the initial interview and testing of potential candidates. The types of tests administered were specified in the Air Ministry's pamphlet, *Member of Aircraft Crews – Conditions of Entry and Service*<sup>54</sup>. This document also informed the potential recruit of salaries and conditions of service and was the Air Ministry's contract with the recruit.

In 1940, the required educational standard for aircrew candidates was an upper secondary level general and technical education<sup>55</sup>. For ground staff, a relatively high level of education was also required<sup>56</sup>. By November 1943, for aircrew candidates, who the selection boards considered suitable in all other respects,

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53 PRO AIR 8/280, Office Memorandum, Mission to Canada in Connection with Dominion Air Train Scheme, 27<sup>th</sup> Oct 39, Table F, p.57

54 PRO AIR 2/4620, RAF Members of Aircraft Crews – Conditions of Entry and Service

55 Lund, 'The Industrial History of Strategy', p. 77

56 Lund, 'The Industrial History of Strategy', p.77

there were ‘No rigidly fixed educational standards’<sup>57</sup>. The Air Ministry even paid these men to undertake ‘a course of broad educational character prior to the initial period of ground training’, so that they would qualify for aircrew<sup>58</sup>. How many men undertook the pre-employment education is unknown, but the Air Ministry referred to the usefulness of this policy in most of the documents it produced relating to aircrew selection.

There is anecdotal evidence to support a drop in the standards applied by selection boards. For example, Jim Lovelace of Sydney, Nova Scotia, failed a medical in January 1940 because he could not blow hard enough to maintain a column of mercury at the required height for the required period. In May of that year, as France collapsed, he was passed fit by a medical officer who told him ‘Well I suppose they’ll be needing you now’<sup>59</sup>. Other Canadians, such as Wally Loucks of Ontario, used influence to by-pass the educational requirements by successfully lobbying his local MP to gain entry to the RCAF<sup>60</sup>.

The normal method for joining the RAF aircrew was for men to enlist in the ranks of the RAF Volunteer Reserve for training as a member of an aircraft crew. Entry was open to any man, regardless of profession or education and even men from reserved occupations, or those with a deferred call-up into other services, could

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57 PRO AIR 2/4620, Members of Aircraft Crews– Conditions of Entry and Service, November 1943

58 PRO AIR 2/4620, Conditions of Entry and Service, November 1943

59 Dunmore, *Wings for Victory*, pp. 51-52

60 Dunmore, *Wings for Victory*, pp. 51

volunteer<sup>61</sup>. Direct appointments to commissions for flying duties would only occur in exceptional circumstance, with most commissions in General Duties coming from the ranks. Once enlisted, the Air Ministry or its colonial counterparts reserved their right to first claim on the individual by placing them on deferred service with no emoluments<sup>62</sup>.

In Britain, and in line with age requirements for service in ground and naval combat units, potential candidates for aircrew service had to be over 17 years and three months of age before they could register for enlistment. They could only undertake training when they had reached the age of 18 years<sup>63</sup>. The upper age limit varied with the job category with 39 years of age for air gunners, 31 years for pilots and 33 years for navigators, air bombers or wireless operators<sup>64</sup>.

Waivers were available for candidates who had special qualifications, but the selection board had to recommend these exemptions<sup>65</sup>.

Once recruited, the individual was committed to serve for an indefinite period until the end of the 'present emergency'<sup>66</sup>. For those candidates who were to serve in Bomber Command this meant serving till the end of the war and for aircrew it meant serving in combat until they had completed the required number

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61 PRO AIR 2/4620, Conditions of Entry and Service, November 1943

62 PRO AIR 2/4620, Conditions of Entry and Service, November 1943

63 PRO AIR 41/65, Notes on Recruitment Advertising, March 1941

64 PRO AIR 2/4620, Conditions of Entry and Service, November 1943

65 PRO AIR 2/4620, Conditions of Entry and Service, November 1943

66 PRO AIR 2/4620, Conditions of Entry and Service, November 1943

of operational tours after which, they were re-categorised into training or administrative postings within the RAF or its sister services in the Empire.

### **Training Aircrew**

Sir Arthur Harris proudly asserts that the cost of training each member of an aircrew in Bomber Command was £10,000, 'enough to send ten men to Oxford or Cambridge for three years'<sup>67</sup>. He claimed that 'the education of a member of a bomber crew was the most expensive in the world'<sup>68</sup>. There is no reference in Harris's book as to where he sourced the figure, nor is there any reference in the files to this or to any other estimate for the overall cost of training a member of a bomber crew. If Harris is accurate, the cost of training 125,000 men as aircrew was £1.25 billion, which is a very great cost for the 18 months it took to train an aircrew member<sup>69</sup>.

The training undertaken by all volunteers for RAF service began with a standardised period of four weeks. Once it was completed, recruits were categorised into a mustering (trade), the only restriction on categorisation was that the RAF could not force ground crew volunteers into aircrew trade against their wishes. For aircrew, subsequent training varied depending on the job the candidate was given. The course for an air gunner was 18 weeks long and for air

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67 Harris, *Bomber Offensive*, p.98

68 Harris, *Bomber Offensive*, p.98

69 Overy, Richard, *Bomber Command, 1939-1945*, p.148

gunner/wireless operator, 22 weeks<sup>70</sup>. Navigators received the longest training with a course of 58 weeks duration<sup>71</sup>. The length of training also varied due to the need to move students from one course to another around the globe and because of the impact of factors such as bad weather. Problems arising from co-ordinating the courses for the five different trade types also often imposed delay and confusion. This resulted in the cost of aircrew training being higher than planned<sup>72</sup>. As a result, the cost of training salaries for 125,000 aircrew graduates was over £20 million based upon an average training salary of six shillings per person per day over the estimated 18 months it took to train a bomber crewmember<sup>73</sup>.

Once trainees had completed their initial training, they went for more advanced training with Training Command and advanced operational training with the Heavy Conversion Units (HCU) and Operational Training Units (OTU) within Bomber Command. All operational training involved training pilots to fly the four-engined aircraft in the Heavy Conversion Units (HCUs) and then training the entire crew in an OTU. It was at the OTU stage that crews formed up and completed the final stage of their training as a team before posting to an operational squadron.

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70 PRO AIR 2/8181, Agreement On EATS Payments, 31<sup>st</sup> Mar 43

71 PRO AIR 2/8181, Agreement On EATS Payments, 31<sup>st</sup> Mar 43

72 PRO AIR 2/8181, Agreement On EATS Payments, 31<sup>st</sup> Mar 43

73 Harris, *Bomber Offensive*, p.98

The concentration of heavy conversion training and operational training of crews remained within Bomber Command because this prevented other commands poaching experienced crews and heavy aircraft. It also provided Bomber Command with a reserve to bolster the front line squadrons. Sir Arthur Harris made use of this capability to launch the highly publicised thousand-bomber raids of 1942 and 1943.

The training of personnel for Bomber Command was one of the more demanding activities that confronted the Air Ministry and RAF in the early years of World War II. Training the numbers necessary to meet the demands of the RAF and Bomber Command was beyond the resources of the United Kingdom. It was also physically impossible to fit a training organisation of the size of the EATS into the geographical area of the UK. Space limitations were not only due to the threat posed by the Luftwaffe, as described in Chapter 5 above, but as well the United Kingdom could not fit in more airfields than already existed.

### **The Empire Air Training Scheme**

The solution to the problems of geographical space, manpower shortages, and enemy threat was the Empire Air Training Scheme (EATS). By the early 1930s, the Air Ministry had put forward the idea of an Empire training scheme and had been fostering it through providing training to air force personnel from Australia, Canada and New Zealand. The white Dominions of the Empire were justifiably

suspicious about establishing a training scheme the main purpose of which appeared to be the air defence of Britain.

Resistance to the Air Ministry's overtures varied. The Canadians proved the most reluctant. The Canadian government took seven months to consider a British Air Ministry offer to extend short service commission positions to RCAF members in the same way as they had been for RAAF and RNZAF pilots. In June 1935, the Canadians finally consented to a limited scheme<sup>74</sup>. In Australia, the Chief of the Air Staff (CAS) put off approaches from his British counterpart because he was unsure of the 'extent of to which our Prime Minister, Treasurer and Minister for Defence...are convinced of the necessity for accelerated defence provision'<sup>75</sup>.

The British Air Ministry finally obtained Australian participation following their agreement to provide 40 Anson aircraft to the RAAF<sup>76</sup>. In a letter dated 29<sup>th</sup> May 1939 to the Chief of the Air Staff (CAS), Sir Cyril Newall, the Australian CAS, Air Vice-Marshal S.J. Goble, mentions the expansion of the RAAF and thanked Sir Cyril for the loan of the 40 Anson aircraft to tide Australia over until Beaufort Bombers became available<sup>77</sup>.

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74 Dunmore, *Wings for Victory*, p.24

75 PRO AIR 2/1608, Letter 4th March, 1937 from Air Board, Commonwealth of Australia to sir Edward Ellington, CAS

76 PRO AIR 2/1608, Letter 29th May 1939 from Air Board, Commonwealth of Australia to Sir Cyril Newall, CAS The willingness of the Australian government to tie support for Britain to trade, specifically the purchase of the 1939 wheat crop, is discussed in D. Day, *The Politics of War*, Harper Collins, Sydney, 2003, p.31

77 PRO AIR 2/1608, Letter 29th May, 1939 from Air Vice-Marshal Goble to sir Cyril Newall, CAS

The Australians appeared satisfied to obtain free aircraft among other benefits. Goble also made special mention of the RAAF's happiness in being able 'to buy British' and that the Air Ministry's action in tying the sale of the Beaufort and Bristol aircraft to Sunderland Flying Boats for the RAAF and QANTAS 'really clinched the deal'<sup>78</sup>. The marginal notations and underlining on the document, presumably done by Newall himself, indicates that British Air Staff were mainly interested in the progress of the new air training school at Wagga Wagga in New South Wales and in the undertaking given by the RAAF to 'concentrate earlier on service training'<sup>79</sup>.

In New Zealand, the negotiations slowed over who was to pay for what. The Air Ministry, unsure of what the New Zealand Government was demanding from Britain, was cautious but appears to have been happy to supply New Zealand with 100 Tiger Moth aircraft at half price plus another 24 obsolete Oxfords and Ansons at no charge<sup>80</sup>. A telegram of 8<sup>th</sup> April 1939 from the British High Commissioner to New Zealand reports that, in addition to the 100 Moths, New Zealand might be looking for a capital grant of £1,550 per student for 220 cadets for short service commissions as pilots<sup>81</sup>. There was concern within the Air Ministry that the public payment of such a grant might set an unwelcome precedent and bring Treasury into the negotiations on the re-armament and war expansion

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78 PRO AIR 2/1608, Letter 29th May, 1939

79 PRO AIR 2/1608, Letter 29th May, 1939

80 PRO AIR 2/3028, Minute 10th May, 1939

81 PRO AIR 2/3028, Minute 10th May, 1939

programme<sup>82</sup>. The Air Ministry believed that the £1,550 asked for by the New Zealanders was ‘very much less’ than what it would cost to fully train a pilot in Canada and they recommended an increase in assistance to New Zealand of £150.00 per student<sup>83</sup>. The rationale was that the original £1,550 figure was to pay for New Zealand providing elementary and intermediate training whereas they would now be providing fully trained pilots<sup>84</sup>.

Of the four significant contributors of manpower to Bomber Command, Canada, led by Prime Minister MacKenzie-King, was the most cautious. A complex set of political considerations confronted the Canadians including the sensitivity of the French Canadian population, memories of the suffering of the trenches of World War I and real concerns about Canada’s capacity to finance another major war<sup>85</sup>. Despite his best efforts to avoid his nation’s full-scale commitment to defend Britain in another major European war, MacKenzie-King was unable to prevent Canada becoming a major contributor to Britain’s war effort.

Discussions between Britain and Canada began in earnest in May 1938, when a British delegation led by the British industrialist and Air Ministry advisor, J.B. Weir, arrived in Ottawa to negotiate the establishment in Canada of air training schools for RAF pilots<sup>86</sup>. The Air Ministry gave Weir the authority to commit

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82 PRO AIR 2/3028, Minute 10th May, 1939

83 PRO AIR 2/3028, Minute 10th May, 1939

84 PRO AIR 2/3028, Minute 10th May, 1939

85 Dunmore, *Wings for Victory*, pp. 14-29

86 Dunmore, *Wings for Victory*, p.29

Britain to pay for the building of initial air training schools and the supply of training aircraft, spares and other equipment. The Canadians would provide the locations for the training schools and the personnel to operate them. MacKenzie-King discussed the proposals with Weir but remained non-committal and Weir returned to Britain with little more than an undertaking from the Canadians to consider the proposals in more detail. It was not until November 1939 that MacKenzie-King finally agreed that Canada would play the major role in the training of aircrew for the Commonwealth by managing the BCATS<sup>87</sup>.

Britain made a second attempt in October and November 1939 by sending Lord Riverdale to Ottawa to negotiate an agreement on the Empire Air Training Scheme with Australia, Canada and New Zealand. Riverdale, a leading British industrialist with good links in Canada, was to obtain Canadian agreement to manage EATS and to provide RCAF personnel for service in or alongside the RAF in Europe. The focus on Canada aggravated relations with the Australian and New Zealand delegations who threatened to return home unless they were involved in the bi-lateral meetings. The acrimonious nature of these meetings exasperated Lord Riverdale who seemed at a loss in understanding the reservations of the other nations involved<sup>88</sup>.

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87 Dunmore, *Wings for Victory*, p.39

88 PRO AIR 8/280, Office Memorandum, Mission to Canada in Connection with Dominion Air Train Scheme, 27<sup>th</sup> Oct 39

The significant issue was money. The Australian, Canadian and New Zealand governments were eager to avoid any commitments to the large expenditures which the scheme seemed to entail. Lord Riverdale's instructions also included a direction to ensure that the Dominions paid a good proportion of the estimated cost of \$CAN607, 000,000 over three years<sup>89</sup>. The British offered to pay \$CAN187, 000,000 for equipment and freight, whilst Canada would bear \$CAN68, 000,000 for the cost of initial ground and elementary flying training. The remaining \$CAN354, 000,000 was to be split between Canada (\$CAN285, 000,000), Australia (\$CAN39, 931,000) and New Zealand (\$CAN28, 603,200)<sup>90</sup>.

<b>Personnel Requirements for BCATP</b>				
<b>Schools, HQs and Depots</b>	<b>Officers</b>	<b>Airmen</b>	<b>Civilians</b>	<b>Works Pers</b>
Commands, Groups and other HQs	288	603	134	
Initial Training	39	393		36
Service Flying	752	11,376	64	320
Air Observer	250	2,470		100
Bombing and Gunnery	450	6,920		150
Elementary Flying	351	4,134		130
Wireless	96	1,284		80
Air Navigation	126	1,278		40
Repair Depots	51	141	1,308	36
Equipment Depots	66	228	3,318	60
Technical Training	41	627		30
Records Office	14	277		
Recruit Depots	28	424		40
Recruiting Organisation	134	211	105	
<b>Totals</b>	<b>2,686</b>	<b>30,366</b>	<b>4,929</b>	<b>1,022</b>

**Fig. 8.8: Manning of BCATP**

Source: PRO AIR 8/280, Oct 39, pp.52-57

89 PRO AIR 8/264, Enclosure , Fourth Report from Lord Riverdale to the Secretary of State for Air

90 PRO AIR 8/264, Enclosure , Fourth Report from Lord Riverdale to the Secretary of State for Air

A further complication was MacKenzie-King's determination to ensure that Canadian personnel would not serve in a European war. EATS appealed to him because it allowed Canada to support Britain without having to commit large numbers of combat forces to a war in Europe. MacKenzie-King does not appear to have grasped that the British intended that EATS included Canada running the BCATS in Canada and supplying volunteers to serve within the RAF in Europe<sup>91</sup>. Eventually, Canada gave way on EATS and agreed to the use of Canadian flyers in combat under RAF command.

<b>Flying Schools Established Under EATS</b>						
<b>School Type</b>	<b>UK</b>	<b>Australia</b>	<b>Canada</b>	<b>NZ</b>	<b>Others</b>	<b>Total</b>
Initial		2		1		3
Elementary	13					13
Service Flying			18			18
Air Observer			10			10
Bombing/Gunnery			10			10
Wireless			1			4
Navigation			2			2
<b>Total at May 1942</b>	<b>13</b>	<b>2</b>	<b>41</b>	<b>1</b>		<b>60</b>
<b>Total 1939-45</b>	<b>153</b>	<b>26</b>	<b>92</b>	<b>6</b>	<b>62</b>	<b>333</b>

Fig. 8.9:

Source: PRO AIR 8/280, Oct 39, pp.52-57

By the end of the war, the Canadian BCATP had expanded well beyond the size initially agreed in Ottawa. Of the 333 flying schools established under EATS, 92 were in Canada. Approximately 136,849 men graduated from these schools to serve in the RAF and Bomber Command<sup>92</sup>. The final cost of the BCATP

91 Dunmore, *Wings for Victory*, p.39

92 Heide, Rachel L., 'The British Commonwealth Air Training Plan: How Canada's Contribution to the Second World War Affects Us Today', [www.vac-acc.gc.ca/general/sub.cfm?source](http://www.vac-acc.gc.ca/general/sub.cfm?source)

reflected the increase, being much larger than expected at \$CAN2.2 Billion in 1945<sup>93</sup>. Of the cost, Canada contributed \$CAN1.6 Billion<sup>94</sup> plus a further \$CAN425 million in March 1946, when Britain defaulted on its payments and the Canadian Government cancelled Britain's unpaid debt<sup>95</sup>.

Canada's work on training aircrew for EATS was large but did not surpass the United Kingdom's own domestic training effort on behalf of the RAF and Bomber Command. The United Kingdom training establishment had 153 EATS schools, by far the largest number of EATS schools. These schools trained 80,000<sup>96</sup> aircrew and Flight Engineers, along with the vast majority of the ground staff used in Bomber and the other RAF Commands. Canada had the next largest training organisation with 92<sup>97</sup> schools. Australia had 26, South Africa 25, Southern Rhodesia, 10, India, nine, New Zealand and the Middle East each had six, five in the USA and one in the Bahamas<sup>98</sup>. The 333 flying schools trained 300,000 aircrew graduates<sup>99</sup>, with 136,849 in Canada, 80,000 in the United Kingdom and 83,151 amongst the others.

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=*history/secondWar/bcatp/page3*, pp. 4, 8, 13 April, 2003 and S. Dunmore, *Wings for Victory*, p.346

93 Heide, Rachel L., 'The British Commonwealth Air Training Plan', *www.vac-acc.gc.ca*, 13 April, 2003

94 Heide, Rachel L., 'The British Commonwealth Air Training Plan', 13 April, 2003

95 Heide, Rachel L., 'The British Commonwealth Air Training Plan', 10<sup>th</sup> January 2004

96 Overy, *Bomber Command*, p.142

97 In its website at *www.vac-acc.gc.ca/remembers*, 2004, the Canadian Department of Veterans Affairs claims 100 EATS aerodromes in Canada. However, the documentary evidence shows only 92 such schools and this figure is used by Dunmore in *Wings for Victory*, p.346 It may be that the Canadian Government operated further aerodromes under EATS which were not schools as such.

98 Dunmore, *Wings for Victory*, p.346

99 Dunmore, *Wings for Victory*, p.346 and Overy, *Bomber Command*, p.142

Australia provides the best example of flying training provided via EATS outside Britain and Canada. The RAAF had the third largest number (26) of EATS flying schools. By 1941, these schools had trained 3,074 pilots, observers and air-gunners. During this period a further 676 Australian pilots were trained in Rhodesia<sup>100</sup> and then later served in Europe. Of the 3,074 Australians trained in Australia before 1942, only 359 remained in Australia for home defence and 51.7 percent subsequently served in Bomber Command. This figure indicates that Australia was doing more than its fair share for the defence of the United Kingdom.

<b>Aircrew Trained in Australia 1939 – 1942</b>		
<b>Category</b>	<b>Number Trained</b>	<b>Number Subsequently Transferred to Bomber Command</b>
Pilot	1,142	731
Observers	678	210
Wireless Operator/AG	1,001	400
Air Gunner	253	248
<b>Total</b>	<b>3,074</b>	<b>1,589</b>

**Fig. 8.10:** **PRO AIR 14/4, Jan 42, p.432**

The most reliable figure on the financial cost of the EATS comes from Canadian Government sources, which are rightly proud of the effort expended by their country in managing the largest part of the EATS outside of the UK. Since the end of World War II, the Canadian Government has calculated the cost of the

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100 PRO AIR 14/4, Statistics on Personnel, Aug 44

BCATP element of EATS at \$CAN2.2 billion, of which Canada paid about \$CAN1.6 billion.<sup>101</sup> This works out as a cost per aircrew graduate of \$CAN16,076, or £4,019.00 per student, not including salary and expenses, such as the cost of transporting thousands of service personnel around the world. The total cost of the 300,000 EATS graduates was £1.2 billion of which Bomber Command's bill was £502,375,000.

<b>Australian EATS Schools</b>		
	<b>Established as of Sept 1940</b>	<b>Target</b>
Initial Training School	2	3
Elementary Training School	6	7
Wireless Air Gunner School	1	2
Service Flying School	2	6
Bombing Gunnery School	1	3
Air Observers School	1	2
Air Navigation School		3
<b>Total</b>	<b>13</b>	<b>26</b>

**Fig. 8.11:**

**Source: PRO AIR 2/1608, 16 Sep 40, p54**

### **Ground Staff Training**

With the approach of war and the rapid expansion, the RAF could not rely on its traditional sources to meet the demand for training. Existing training establishments like Halton could not hope to train sufficient technical tradesmen.

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101 Heide, Rachel L., 'The British Commonwealth Air Training Plan: How Canada's Contribution to the Second World War Affects Us Today', [www.vacc.gc.ca/general/sub.cfm?source=history/secondWar](http://www.vacc.gc.ca/general/sub.cfm?source=history/secondWar)

Prior to 1939, recruits for ground staff could enter the RAF directly as unskilled or semi-skilled tradesmen. Younger applicants could apply to enter as apprentices and received their training at establishments like Halton. These establishments had a reputation for providing demanding training and produced the technically qualified NCOs that the Air Ministry saw as essential for the future of the RAF. In the case of Halton, the Air Ministry regarded it as a national training centre for both the RAF and the aircraft industry<sup>102</sup>.

The training at Halton was three years in length and committed the student to a return of service obligation of twelve years<sup>103</sup>. The career path led the graduate into the RAF and from there to the aircraft industry. Between 1920 and 1938, over 12,000 students graduated from Halton, more than the total number of aviation engineering technicians that were to be found working in the German aircraft industry, Reich Air Ministry and in the Luftwaffe in the years prior to the outbreak of World War II<sup>104</sup>.

During World War II, the large majority of ground staff in the RAF and Bomber Command was British. Australia, Canada and New Zealand were unable to provide large numbers of personnel for ground crew<sup>105</sup>. These nations did not possess large-scale aircraft industries and they had a small pool of qualified manpower. Indeed, the shortage of suitably skilled manpower appeared early in

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102 Lund, 'The Industrial History of Strategy', *The Journal of Military History*, p.77

103 Lund, 'The Industrial History of Strategy', *The Journal of Military History*, p.77

104 Lund, 'The Industrial History of Strategy', *The Journal of Military History*, p.77

Canada and Australia. Soon after the conflict had begun, both countries experienced shortages of skilled men to train as ground crew and this problem persisted with on-going negotiations between the EATS partners until 1943<sup>106</sup>. In September 1940, Australia had enlisted 18,144 ground staff and had a backlog of 5,968 men waiting to enlist. The lack of skilled RAAF instructors was made up by using civilian technical schools to meet the need<sup>107</sup>.

Whatever the technical competency of these new members of the RAAF, Australia's CAS reported that the 'type offering is, generally speaking, quite good'<sup>108</sup>. Due to the on-going shortage of skilled ground staff, Australia refused to release large numbers of RAAF ground crew for service overseas other than in the Middle East and the Pacific. A similar situation applied in Canada and New Zealand. Britain had to provide the majority of the necessary personnel to fill the RAF's needs for manpower.

Ground staff made up the vast majority of Bomber Command's strength during the war. Between July 1943 and July 1944, when the average strength of Bomber Command was 147,923, the number of aircrew was probably around nine percent, or 13,904<sup>109</sup>. Based upon this calculation, the July 1943 figure for ground staff

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105 Herington, *Air War Against Germany and Italy*, p.536

106 PRO AIR 2/8181, Agreement on EATS Payments, 31<sup>st</sup> Mar 43

107 PRO AIR 2/1608, Letter from Australian CAS 23rd April, 1940

108 PRO AIR 2/1608, Letter from Australian CAS 16th September, 1940

109 Aircrew figures derived by multiplying the number of crews assigned per squadron by the number of squadrons using particular aircraft types listed on the strength of Bomber Command in Harris, *Despatch*, pp. 146-149

numbers in Bomber Command would have been around 134,000. The problem the historian faces here is that ground crew personnel moved in and out of Bomber Command as readily as aircrew. Qualified and experienced technicians were in demand throughout the whole of the RAF: they were required in Bomber, Coastal and Fighter commands as well as in the Middle and Far East. When the Air Ministry transferred aircraft such as the Whitley and Wellington from Bomber Command to Transport Command or the Middle East, the qualified and experienced maintenance ground crew were transferred with them. The result was a steady stream of technical personnel away from Bomber Command.

In *Bomber Offensive*, Harris asked his readers to imagine ‘what it is like to work in the open, rain, blow or snow, in daylight and through darkness, hour after hour, twenty feet up in the air on the aircraft engines and airframes...’<sup>110</sup>. This is one of the few times that the work of the men and women of the RAF’s ground crews received any acknowledgment. Harris in fact believed sincerely that his ground crew deserved a campaign medal, and he is right. Between 3<sup>rd</sup> September 1939 and 8<sup>th</sup> May 1945, 1,870 men and women died serving in Bomber Command, almost one for every day of the war. A further 759 ground crew were seriously wounded or injured and 78 were listed as missing or prisoners of war before being returned safe<sup>111</sup>. Although the ground staff of Bomber Command never left the United Kingdom there is no doubt that they suffered from the same discomforts

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110 Harris, *Bomber Offensive*, p.268

111 Overy, *Bomber Command*, p.204 See also Harris, *Despatch*, p.61

and dangers encountered by logistical and support personnel overseas, all of whom received the appropriate campaign medals.

## **Wages**

Under the EATS agreement the wages, salaries, allowances and expenses incurred by aircrew serving under RAF command were a British liability<sup>112</sup>. A significant problem for Treasury and the Air Ministry was the higher salary levels of RAAF, RCAF and RNZAF personnel compared to their British equivalents. Either from a desire to keep the cost down or as an attempt to maintain equality in pay within squadrons, the British government insisted that all dominion personnel within the RAF receive the same rate of pay as their British equivalents<sup>113</sup>. This required the Dominion governments to withhold a component of the salary of their service personnel serving within the RAF. The individual would then receive the outstanding salary when they left the RAF and returned to their national air force.

It was a silly idea that took no account of the accounting dilemmas caused by the death of an airman. The result was an accounting nightmare as nations, such as Australia and Canada, attempted to estimate payments to the families of men who died on active service. The Australian Government found the difficulties in reconciling the amount of back pay demanded and the amount justified by the documentary records just too difficult to manage. The problems persisted until

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112 PRO AIR 2/8181, Agreement On EATS Payments, 31<sup>st</sup> Mar 43

113 PRO AIR 2/8181, Agreement On EATS Payments, 31<sup>st</sup> Mar 43

the matter came to a head in late 1942 and the RAAF, like the RCAF, reverted to their own pay-book system and ignored the Air Ministry's complaints<sup>114</sup>.

Britain's liability for the salaries and costs of Dominion airman began as soon as a student airman had departed his own nation for service with, or in conjunction with, the Royal Air Force. This liability continued up till the day preceding the date of their arrival back in their home nation, Britain had to meet the cost of all wages and expenses. Britain's liability was for the wages bill of the 147,165 aircrew graduates who undertook this training outside of their home nation. The estimated total cost to Britain was £24.26 million of which £13,350,000 belongs to Bomber Command<sup>115</sup>. The £24.26 million estimate only relates to the wages element of the bill and does not reflect further costs in terms of allowances and expenses incurred. It is therefore reasonable to assume that the total cost to Britain would have been substantially higher than these figures suggest.

The other problem facing the historian is the paucity of information available on the numbers of aircrew that served in Bomber Command. It is impossible at this time to allocate a proportion of the training wages of these individuals to Bomber Command because of the absence of records relating to the actual size of the Command during the period of the strategic air offensive. The calculation I have

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114 Herington, *Air War Against Germany and Italy*, p.537, n.8

115 This figure has been calculated by assuming an average wage of 6s/0d per day for an average period in training of 12 months for the 125,000 non-Canadian students. A percent of 41.6 percent of the resulting cost is allocated to Bomber Command on the basis that the Command absorbed 41.6 percent (125,000 out of 300,000) of all aircrew graduates from the EATS and other schemes during the course of the war.

used is based upon an estimate of probable personnel levels extrapolated from the July 1943 and 1944 figures. This approach suggests a figure of 56,515 for the size of Bomber Command in December 1941 rising to 183,172 in June 1945.

The calculation for Bomber Command's wage bill for the war is obtained by multiplying the base daily wage rate of 3s/6d by the average strength of Bomber Command per year<sup>116</sup>. The base daily wage is the amount paid without taking into account allowances, payment for rank or qualifications, or any other financial payments such as the higher rates paid to Canadian and Australian servicemen.

The average annual base wage bill for Bomber Command over the period of World War II was £6.7 million, a total of £39.1 millions for the five years and ten months of the conflict. This is a substantial underestimate, as it does not take into account. However, it provides a starting point for estimating the cost of wages to Bomber Command. Added to the £13.35 million cost in training wages for aircrew the figure obtained for wages in Bomber Command is £52.47 million.

The attempt to identify a precise cost for wages in Bomber Command, as opposed to the cost of wages for EATS students, is fraught with difficulty. The usefulness of the figures derived for 1943 until 1945 is that they given an indication of the wages bill when Bomber Command was at peak size. This does not give a sound total for the strategic air offensive. A further personnel cost that is not included in

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116 PRO AIR 2/9155, Service Pay and Allowances, 19<sup>th</sup> Apr 44

wages is the cost of feeding and clothing the men and women who served in Bomber Command. Luckily, in this case, there are some sound figures available.

### **Food and Clothing**

The provision of meals to the men and women of Bomber Command was another significant cost incurred in the conduct of the strategic air offensive. Each member of the Command required the usual three cooked meals per day. The RAF differed a little from the other services in that flying personnel were entitled to better rations than were other Britons. In particular, by wartime standards, they received a generous ration of eggs and meat. The RAF believed such a diet was essential to allow them to meet the rigors of flying in European conditions. In addition to the three normal meals per day, RAF messes had to contend with supplying food throughout a 24-hour period. The foodstuffs were of a light meal variety and consisted of the ubiquitous tea and sandwiches or cake for ground crew. Aircrew received coffee, soup and sandwiches for their flights.

The cost of feeding was about £8,000 per month for an average RAF station<sup>117</sup>. Based upon this figure, the overall cost of feeding Bomber Command during World War II was £48.62 million. Even though this looks like a very high cost, it is not. At an average strength of 130,000 personnel in the Command over the 2,074 days of the war, the cost per meal would have been 1s/2d. This is a more

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117 *War Savings*, Wings for Victory Issue, p.25

useful figure than it may at first appear. The fact that the food bill worked out on the number of Bomber Command stations can return a legitimate cost per meal when divided by the estimated average number of personnel serving within the Command over the war, suggests that a total cost of £48.62 million is a reliable estimate.

The provision of uniform and clothing was another cost met on behalf of Bomber Command. There were two issues of clothing, the everyday uniforms provided to all members of the Command and specialist clothing, such as personal protective clothing for ground trades and flying clothing for aircrew. All personnel in Bomber Command received a basic issue of over thirty items of uniform and other kit. This covered everything from trousers to coats, pyjamas, sewing kits and steel helmets<sup>118</sup>. The cost of it all was £11 6s/3d<sup>119</sup> per person, which gives a conservative figure of £3,113,542 for all of the personnel estimated to have served in Bomber Command. The breakdown of the cost is £1,525,000 for equipping an estimated 120,000 ground staff plus another £1,588,542 for equipping the 125,000 aircrew who passed through Bomber Command. Dominion forces equipped their own personnel with an initial set of uniform clothing. As it was Bomber Command that obtained the benefit from this issue, it is legitimate to assign the full cost to the Command.

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118 *War Savings*, Wings for Victory Issue, p.27

119 *War Savings*, Wings for Victory Issue, p.25

As well as the normal uniform items, Bomber Command issued aircrew with specialised flying kit including electrically heated waistcoats, jackets and suits, plus gauntlets, silk gloves, flying boots, helmets and a variety of other specialised items. The cost for each issue was £36 9s/0d.<sup>120</sup>, at a total cost of £4,556,250 for the 125,000 aircrew of Bomber Command. All together, the cost of initial clothing and flying kit to Bomber Command personnel was £7,669,792. This amount does not reflect the added expenses of loss, breakages and the replacement of items such as socks, underwear and shirts.

The above calculations suggest that it cost approximately £56.28 million to feed and clothe the personnel of Bomber Command during the strategic air offensive. This figure appears to be reliable having been calculated using two different criteria. It shows that the food bill was one of the more significant on-costs of maintaining the members of Bomber Command.

## **Conclusion**

The purpose of this chapter has been to describe the effort that went into recruiting, training and maintaining the men and women who served in Bomber Command during World War II. The analysis highlights the size of the undertaking that was required to staff Bomber Command with the trained personnel it needed to carry out the strategic air offensive. Next to the building of

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120 *War Savings*, Wings for Victory Issue, p.26

factories for the aircraft industry, and the purchasing of aircraft from that industry, the recruitment, selection, training and maintenance of personnel was the most significant cost incurred by Bomber Command during the strategic air offensive.

The total cost of providing Bomber Command with the 125,000 aircrew and 300,000 ground staff was approximately £646.87 million. Of this amount, around £5.2 million went on advertising and £20 million on training wages for aircrew.

The proportion of the EATS expenditure that can be attributed to Bomber Command is £502.37 million and a further £108.75 million for operational wages, food and clothing. The estimate of cost here does not include expenditure on travel and other incidentals. Nor does it include allowances or higher rates of pay for flying duties, rank or other qualifications. It also does not address the actuarial issues involved in the economic loss caused by the early death of 57,143 young men. The total price of £646.87 million for manpower is at the lower end of the possible estimates and it is highly likely that the upper end of the cost would be more than £1 billion.

In addition to identifying a reliable estimate for the cost of manpower in Bomber Command, the analysis conducted in this chapter has shown that the availability of trained manpower was as significant a problem in expanding Bomber Command as was the availability of heavy bomber aircraft and airfields. The importance of understanding this fact is that it substantially undermines the superficial argument that the British government could have substantially sped up the strategic bomber offensive if it had committed the necessary resources to the

development and production of suitable aircraft in the 1930s. Even if the government had been able to get the aircraft, it still would have had to build the airfields, and recruit and train the necessary personnel. Due to the dislocation that acquiring and building airfields and the force necessary to carry out strategic bombing inflicted on the lives and activities of the wider community neither of these activities was achievable within a peacetime context. Therefore, even if the Lancaster had been ready in 1939, it is highly likely that Bomber Command would still have had to wait until late 1941 for the airfields to be built and the recruits enlisted in 1940 to start flowing in sufficient numbers to man the squadrons.

The large influx of recruits into the RAF in the first two years of the war placed great strains on the RAF and its training establishments in the United Kingdom and placed strains on the Empire Air Training Scheme throughout the Commonwealth. Overall, though, the system coped and the Air Ministry trained sufficient aircrew and ground staff to allow Bomber Command to absorb the introduction of the heavy bombers in 1942. The year 1942 saw not just the arrival of the heavy bomber but also the construction of sufficient airfields and the arrival of sufficient trained personnel to allow the development of a truly strategic air offensive.

A further contribution that this research makes to the history of the strategic air offensive is that it identifies that the official operating strength of Bomber Command remained below 150,000 personnel. Bomber Command constituted

about 12.5 percent of total RAF strength during World War II making it one of the largest formations within the RAF. It must be noted though, that the findings here do not mean that less than 150,000 personnel were needed to conduct the strategic air offensive against Germany. The findings in this chapter simply relate to the official posted strength of Bomber Command and take no account of the myriad of RAF and other personnel employed by other functional commands or organisations whose work directly supported Bomber Command and its air offensive. The lack of information on the percentage of time dedicated by these personnel to supporting the strategic air offensive makes it impossible to estimate a cost and therefore there is no valuation of this activity in this analysis. The estimates of cost provided in this chapter must be regarded as being very much on the low side.

## *C o n c l u s i o n*

The strategic air offensive formed a major part of Britain's wartime military activity during World War II and for this reason alone it has attracted the attention of historians. The histories of the air offensive have centred on two major areas of interest. The first has been the debate about the morality of bombing cities and civilian populations and the second has revolved around the relative technical and economic proficiency of Britain's aircraft industry and air force during the war. In both areas, the historical record has dedicated a significant amount of attention to the impact of the strategic air offensive on Germany but with much less attention on estimating the offensive's impact on Britain. The purpose of this thesis is to help address this imbalance by investigating the financial cost to Britain of carrying out the strategic air offensive against Germany during World War II.

My study began with a brief overview of the strategic air offensive and the background to the intellectual rationale underlying a belief in this form of warfare. The survey showed Britain conducted the air offensive against Germany in line with a profound belief in the power of air attack to demoralise a civilian population and, by doing so, cause some sort of social collapse which would force an enemy government to surrender. The intellectual basis for this belief was a naïve acceptance of the concepts developed by early imaginative writers such as H.G. Wells and the more serious, but no less imaginative writers, like Douhet,

Mitchell and de Seversky. The examination of the intellectual approach of the British Air Staff showed a strong disinclination to scrutinize objectively strategic bombing. Other than an adherence to the value of offensive action, there was no unified British theory on how the RAF would conduct a strategic bombing campaign. The present view that the ruminations of military thinkers such as Douhet, Mitchell, de Seversky and Trenchard somehow produced theories of air warfare is problematical. Certainly, the evidence evaluated in this work shows that military men were thinking carefully about how aircraft could be used in war but there was little effort to take the next step and rigorously test the assumptions that they were making.

The outcome for Britain was that she entered World War II with a set of assumptions masquerading as a theory of air warfare. The failure to evaluate the improvements in defensive power of fighters supported by radar stands out as an example of this. Even more of a failure was the inability of the Air Staff to identify the exact weight and types of bombs and to test the bombs to check they were effective in the roles given to them. Based on such a flawed process, it is unsurprising that Bomber Command went to war with a single-mindedness that was eventually to lead to the widespread bombing of German cities. It was also perhaps the reason why the Air Staff pursued such bombing even as there was growing evidence that these attacks were not accomplishing the expected

outcomes. The hope was that victory was only just a few raids away is a strong indication of a lack of a clear idea on how strategic bombing would work<sup>1</sup>.

Understanding the way the offensive developed is important as it allows a fuller understanding of how military operations were constrained by the economic activity undertaken to implement them. The first thing learnt from this approach was that the slow growth in the striking power of Bomber command was not only due to the slow delivery of heavy bombers. The growth in Bomber Command's striking power after early 1942 came about as heavy bombers, airfields and manpower became available in sufficient numbers to allow an increase in bombing activity. The ability of Bomber Command to conduct its attacks relied on an enormous infrastructure, which was extremely costly to provide in wartime and politically impossible to provide in peacetime. This is something overlooked by many writers on the subject of Britain's preparedness for war in 1939.

The subsequent chapters of this thesis show how Britain spent £2.78 billion on the strategic air offensive. This amount represents around 10 percent of the £28.7 billion that the British government spent during World War II and 12.19 percent of the £22.8 billion Britain spent on defence<sup>2</sup>. The £2.78 billion cost of Bomber Command's campaign was also 5.57 percent of Britain's total National Income

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1 Harris, *Bomber Offensive*, p.263

2 Central Statistical Office, *Statistical Digest of the War*, Table 173, Central Government Expenditure (Exchequer Issues), p.195

for the entire war period<sup>3</sup>. Even on the basis of the figures I have provided, the strategic air offensive was one of the most expensive military campaigns undertaken by Britain in World War II.

The aircraft designed and developed in Britain's factories were the means by which the RAF was to accomplish their victory over the enemy. In the examination of the British aircraft industry carried out in Chapter Three, the evidence shows that Britain dominated the world's aircraft industries through licensing production and joint venture operations. In addition, her domestic aircraft industry was probably the largest exporter of aircraft until well into the 1930s<sup>4</sup>. These findings support the contention of A. Robertson<sup>5</sup> and David Edgerton that Peter Fearon and, later, Correlli Barnett exaggerated their claims of British backwardness in aircraft production. During the 1920s and 1930s, British aero-engine manufacturers dominated the American aircraft industry and there is little doubt that many British ideas were incorporated into aircraft design in the United States just as American ideas were incorporated into British designs. The transfer of technology continued to the advantage of the United States, which not only obtained licences to manufacture Merlin engines, but gained access to the cavity magnetron valve and the entire British nuclear research programme.

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3 Central Statistical Office, *Statistical Digest of the War*, Table 180, National Income, p.200  
Figure does not include approximately £3.5 billion in depreciation

4 S.N. Broadberry, *The Productivity Race: British Manufacturing in International Perspective, 1850-1990*, Cambridge University Press, Cambridge, 1997, pp. 235-238

5 A. Robertson, 'The British Airframe Industry and the State in the Interwar Period: A comment', *Economic History Review*, Vol 28, 1975

As World War II approached, Britain was preparing to fight the strategic air offensive envisaged by the Air Ministry and the Air Staff. The technological capacity was available and the expansion of aircraft production and heavy bomber aircraft was being organised. What the Air Staff had not foreseen was the extent of the infrastructure that would be necessary to allow the aircraft to operate in the numbers required to carry out the offensive. Partially, this appears to have resulted from Air Staff over confidence in the effect of bombing upon civilian populations, but it also resulted from over confidence in the capacity of bomber aircraft to penetrate enemy airspace. The result was that large numbers of heavy bombers were required and these needed airfields, complex navigation, and air-traffic control systems in order to enable their safe operation at night. As Chapter Five shows, airfields and their availability placed a significant brake on the speed at which Bomber Command could expand. Even where the airfields were available, their size had to be increased to fit the needs of the larger aircraft that were coming into service and they needed more sophisticated traffic management systems.

With the aircraft and infrastructure dealt with, the final areas examined were the consumables, such petroleum and ordnance. Of these, petroleum was the most pressing due to the need to import almost 95 percent of all the high-octane fuels and high-grade oils used by Bomber Command. However, ordnance was also to prove highly problematic and it is likely that a high percentage of British aerial bombs were faulty. The faults appear from the evidence to have been in the fuzing systems of the bombs. Either these fuzes failed to explode or they

exploded the bombs prematurely. The extent of the problem is unknown but the attention given to it by Sir Arthur Harris and the Air Staff suggests that faulty fuses may have affected a significant percentage of the bombs dropped.

Of the £2.78 billion that Britain spent in carrying out the strategic air offensive, £223.86 million went to the aircraft industry for the expansion of their production through the building of new factories and plant. To this cost must be added £1.5 billion paid for the bomber aircraft that served in Bomber Command. The aircraft required airfields costing £222.15 million, fuel and oils costing another £223.65 million and ordnance, which added another £183 million. On top of the expenditure on equipment and facilities was £636.34 million on wages and salaries. The financial costs identified in each of the chapters were arrived at using modern accrual accounting methods. The result has been a more accurate estimate of the total financial cost and the proportion of the cost that each major area of activity consumed.

Knowing the financial cost of the strategic air offensive allows a more useful evaluation to be made of the value of the offensive. Now historians can begin to compare the impact of strategic bombing on Germany with the cost of that bombing to Britain. It is now possible to see how the strategic air offensive affected Britain. The full implications of this remain to be teased out, but the work here suggests that Britain derived very little long-term benefit from the £2.78 billion spent on mounting the bombing of Germany. In the first three quarters of 1945, the production of bomber aircraft fell by 52 percent on the levels

for the same three quarters of 1944<sup>6</sup>. The slump in production continued and within a few years, the British aircraft industry would make increasing demands on British wealth in a futile effort to maintain Britain as a leading aircraft manufacturer.

Bomber Command's airfields also represented a poor return on investment. Unlike shipping ports, bomber airfields did not provide a generic set of services to civilian and military craft. With the end of the war the British government retained very few of Bomber Command's airfields and, with the major exception of the new bomber station at Heathrow, they were not attractive as civilian passenger terminals. The vast majority of these airfields were simply decommissioned and left to deteriorate. The cost of ripping up and disposing of the extensive runways and taxiways was too high for the government immediately after the war. Even today, a significant number of these disused airfields remain and continue to displace agricultural activity. The cost of the post-war economic losses sustained by the continued dislocation of agriculture has not been included in the calculations made in this thesis.

Having identified that the strategic air offensive cost £2.78 billion it is now possible to place a financial value on the investment it took to achieve the outcomes of the bomber attacks launched against enemy targets in Europe. It is now possible to show that it cost approximately £7,131.00 for each of the 389,809

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<sup>6</sup> Central statistical Office, *Statistical Digest of the War*, Table 130, p.152

operational sorties flown by Bomber Command aircraft during World War II and the average cost of each of the 6,259 bomber raids launched by Bomber Command was £444,160.00. The average cost per ton of bombs dropped was £2,911.00<sup>7</sup>. It cost Britain £5,914.00 to kill a German civilian by bombing. Of course, this last figure is questionable because there is no way of separating out those killed by American and Russian air attacks from those killed by Bomber Command. It does mean that the actual cost of each civilian killed was substantially more than the figure offered here.

Financially, the strategic air offensive was an expensive undertaking as the analysis in this thesis has confirmed, and the financial costs were not the only costs associated with the strategic bomber offensive. Bomber Command suffered 79,172 casualties comprising 57,143 fatalities 9,162 wounded and 12,867 prisoners or missing amongst its aircrew and ground staff<sup>8</sup>. The strategic air offensive carried out by Bomber Command resulted in the deaths of a considerable proportion of the 410,000 German and 60,000 Italian civilians killed by Allied bombing raids<sup>9</sup>. The ratio of enemy killed was 5.65 per Allied aviator<sup>10</sup>. The damage inflicted on Germany is only one side of the balance sheet. The other side contains the costs to Britain imposed by developing Bomber

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7 Figures derived by dividing £2.78 billion by the figures in Middlebrook and Everitt, *Bomber Command War Diaries*, p.707 and Harris, *Despatch*, p.51

8 Overy, *Bomber Command 1939-1945*, p.204

9 Overy, *Bomber Command 1939-1945*, p.202

10 Based on 57, 143 dead in Bomber Command and 26,000 dead suffered by the USAAF 8th Air Force reported in US Air Force, Museum, [www.wpafb.af.mil/museum/history/wwii/veday.htm](http://www.wpafb.af.mil/museum/history/wwii/veday.htm), 23 March, 2003

Command to the point where it could inflict damage on Germany. By using an accrual method of accounting, the analysis has been able to tease out a little more precisely and in a little greater depth the actual cost to the British of the multitude of goods and services that the strategic air offensive consumed. The importance of the analysis and its findings lie in the balancing out of the perception that the strategic air offensive inflicted damage on the German war effort without causing any damage to the British war effort. The facts as identified by my analysis show that the strategic air offensive imposed an enormous cost on Britain and that it was a cost that she could ill afford. It shows that the damage inflicted on Germany came at a very high price and it lends weight to the idea that the strategic air offensive bombing against Germany was a major contributor to Britain's post-war impoverishment.

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