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Royal Air Force Air Power Review

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Sopwith Camel of 46 Squadron fitted with four 25lb Cooper bombs under the fuselage, 16 December 1917. It has a flight commander's pennant fitted to the rudder.

Armourers fit rocket-projectiles to the under-wing racks of a 247 Squadron Hawker Typhoon IB at B6/ Coulombs, Normandy, on 16 June 1944.

Airmen with 10 Squadron RFC pictured at an airfield in Belgium, c. 1917/18.

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Air Chief Marshal Sir Arthur Tedder, Deputy Supreme Commander Allied Expeditionary Force, pictured in early 1945.

Lancaster B.III, LM446/PG-H, above an overcast sky in early February 1944, a few days after being received by 619 Squadron at Coningsby, Lincolnshire. The aircraft was lost during an attack on the Gnome-Rhone engine factory at Gennevilliers, France, during the night of 9/10 May 1944.

Foreword

By Squadron Leader Paul Baroni

Welcome to *Air Power Review*, Summer 2014. This edition again sees an interesting and diverse blend of articles and viewpoints on both contemporary and historical air power matters. The APR Editorial Board was especially pleased to be able to choose two insightful papers on the First World War with this summer marking the centenary of the start of the first 'Total War' back in August, 1914. It can be argued that no form of warfare has witnessed such a dramatic, exponential development over the course of a century as that of air power. The improvised, aerial reconnaissance role carried out by our forebears in the early days of the Great War, to the submission of RAF Officer Cadet Whittle's first jet engine patent was separated by a period of just 15 years. Radar, integrated air-defence systems and long-range ballistic missile technology were prevalent by the 1940s with space exploration, precision guided munitions and stealth technology quickly following in the second half of the 20th Century. As such, from the very outset, air power practitioners, strategists and government treasuries alike, have always been forced to contend with the challenges of balancing cost with mass, proven capabilities with emergent technologies, not to mention competition for resources with land and maritime forces. On the theme of the First World War, readers may be interested to know that the RAF Museum (in-conjunction with the RAF Centre for Air Power Studies), will be holding a conference entitled From *'Shooting the Front' to Combat ISTAR – The Evolution of Aerial Intelligence and Reconnaissance* in April next year – more details and a call for papers are at the back of this publication.

Our edition starts with Air Vice-Marshal (Retd) Peter Dye's article 'The Bridge to Air Power-Aviation Engineering on the Western Front 1914-1918'. The author examines the importance of logistical organisation and the critical impact it had on successful air operations in this theatre during the First World War, arguing that logistical expertise was the foundation of air superiority during this period. Citing the flair and aptitude of the Royal Flying Corps (RFC) logistic staffs, headed-up by Brigadier-General Robert Brooke-Popham, Dye highlights their deft recognition of the key demands of 'three-dimensional warfare' during the nascent stages of military air power. Dye goes on to highlight the enormity of the RFC's logistical enterprise, which saw thousands of personnel supporting high-tempo, enduring air operations around the clock, unseen from the frontline and with direct dangers of its own. Parallels with more recent operations in Iraq and Afghanistan are evident to the reader, which serves to reinforce the author's thesis that those logistics principles developed on the Western Front during the First World War provided the blueprint for Royal Air Force success in the Second World War, and, indeed, were the foundation for the principles and practices of today's air power logistic professionals. Dye concludes his paper by discussing the interdependency of logistics and air power, stating that 'logistics was the bridge between the nation's economy and air power' throughout the war and that this relationship endures today.

Building on the First World War theme, an article by Sergeant Paul Marr (an RAF Weapons Systems Operator by trade) entitled 'Haig and Trenchard: Achieving Air Superiority on the Western Front', looks at the influence that these two celebrated senior officers had on the development of British air power during the conflict. Examining the body of critical thought on Haig and Trenchard, the author acknowledges the criticism that both generals have received for their employment of unsuitably offensive tactics on the modern, mechanised battlefield of the First World War. Providing a balanced, thoughtful perspective, Marr suggests that Haig and Trenchard were successful in their introduction and 'methodical' development of military air power during the conflict, against a backdrop of unprecedented operational complexity. Despite suggestions of a dogmatic, sometimes overly rigid approach to the effective employment of air power in the First World War, the author succinctly captures how both Haig and Trenchard were pivotal in creating a model of an independent air force that was to be emulated by many – including Germany - over the inter-war years.

Moving through these inter-war years, and the development of air forces, our next article is written by Trevor Nash, a PhD candidate at the University of Birmingham. 'Fit for Purpose? An Analysis of Operational Training in Bomber Command 1934-1944' examines how the RAF built a modern, effective and innovative Bomber Force in the lead-up to the Second World War. Again, parallels between today and the 1930s are clear – a backdrop of austerity, a popular rejection of military intervention and competition for scarce government defence spending, had threatened the development of air power in the run-up to this period. With little appetite for investment of public money in the Service, the RAF was forced to think carefully about how it trained and developed its strategic bombing arm, resulting in some ground-breaking, innovative ideas and solutions that laid the ground for the RAF to expand from training just 300 pilots per year in 1934, to 22,000 by the end of 1941. Changes weren't just to the organisation of training structures – in the shape of the new flying training system, the introduction of synthetics and simulation – but they also focused on the ethos and identity of a newly created service. As is the case for air forces today, Nash highlights how the need to drive efficiency, value and flexibility remained the dominant planning factors for the RAF during a period that saw a reversal of a policy of cuts and reduction in numbers, as the European strategic landscape changed over the course of the 1930s.

Our final article in this edition is co-authored by Ian Horwood, Niall MacKay and Christopher Price. Horwood and Price are historians at York St John University and MacKay is a mathematical physicist at the University of York. Their article, 'Concentration and Asymmetry in Air Combat: Lessons for the Defensive Employment of Air Power' marks a break from the preceding articles in that it combines a scientific, operational research methodology with a historic analysis of air campaigns, including the Battle of Britain and the air war within the Falklands Conflict. Using a

fascinating approach, the authors assess whether the use of defensive air power, to deny air supremacy or defend surface targets was correctly employed in a series of different campaigns. Horwood, MacKay and Price point to an asymmetry in air combat - between attack and defence - carefully separating the concepts of mass and concentration. In doing so, they demonstrate how defensive concentration is not dependent on numbers in order to be effective, as long as a deterrent effect is produced on multiple opponents. Western air forces, in particular, have had the relative benefit of operating against generally outmatched opponents (in the case of Gulf War II and Libya), or in counterinsurgency campaigns where the enemy has no air power capability. The lesson for current and future operations is clearly evident as modern air forces consider the requirement to be able to operate in a fully contested air environment – something not seen in the conflicts of the past decade.

This edition's articles are followed by a *Viewpoint* from Air Commodore Alistair Byford, Assistant Commandant (Air), Joint Services Command and Staff College (JSCSC) at the UK Defence Academy, Shrivenham. 'How Well Do We Understand Air Command and Control?' offers an examination of how airmen understand and apply the principles of Command and Control (C2) in their unique environment. The author suggests that there has been a tendency towards intellectual complacency in the RAF when it comes to Air C2, citing a dependence on the US to exclusively provide the C2 framework and context on recent operations. Pointing to the risks that this approach brings if the RAF is to retain its freedom of independent action, Byford proposes a new model of 'centralised control – adaptive execution' to substitute the current, one size fits all, mantra of 'centralised control – decentralised execution'. In doing so, the RAF will regain the flexibility and the ability to adapt to the operational circumstances and context that it is presented with.

APR Summer 2014 concludes with two book reviews, the first of which is David Kilcullen's recent publication, *Out of the Mountains: The Coming of the Age of the Urban Guerill*a. Kilcullen, is a former Australian Army Officer turned academic and strategic advisor to the US Government and is considered an expert in counterinsurgency. RAF Regiment Flight Sergeant Wayne Lovejoy offers a critique of his insight into the future character of conflict against a backdrop of four projected megatrends – population growth, urbanisation, littoralisation and networked connectivity. Although not air power specific, this book offers an important analysis of what the future operating environment may look like in the next 20 to 30 years. *Out of the Mountains* appears on the Chief of the Air Staff's Reading List 2014, a collection of 10 books that span air power, leadership, strategy, future conflict and technology. Recently published, an electronic copy of the Reading List can be found on our website – airpowerstudies.co.uk. Our final offering is a review by Dr David Jordan of Tony Blackman's *Vulcan Boys – From the Cold War to the Falklands: True Tales of the Iconic Delta*

V-Bomber. Blackman traces the development and introduction of the Vulcan into RAF Service and examines its varying roles and operational achievements over the course of 3 decades of flying on the front line. Dr Jordan does point out that *Vulcan Boys* is not strictly an academic read but it does provide a valuable insight into the RAF, service culture and air power practitioners during the Cold War period.

Notes on Contributors

Air Vice-Marshal Peter Dye served for 36 years in the Royal Air Force. Commissioned in 1972, he served in a variety of engineering related appointments as well as training and personnel policy. He joined the Royal Air Force Museum in 2008, as Deputy Director General and Director Collections. He was appointed Director General in June 2010. Awarded a Portal Fellowship in 2007, Peter researched the Royal Flying Corp's Logistic Organisation on the Western Front for his PhD. He has written numerous articles over the years, many published in the Royal Air Force Air Power Review and the United States Air Force Logistics Journal, ranging from Logistics and the Battle of Britain to Expeditionary Air Operations in German East Africa.

Sergeant Paul Marr joined the RAF in 1997 as an aircrew Sgt and was trained as a WSOP (EW) or Weapons Systems Operator specialising in Electronic Warfare. During the period 1999-2006 he flew as a rear crew member on the Nimrod MR2 as part of 206 and 120 Sqns in support of operations in a number of theatres worldwide whilst based at RAF Kinloss. Between 2006 and 2009 Sgt Marr was employed as an Intelligence Briefing Officer in A2 before returning to flying duties in 2009. His flying tour was cut short when both the Nimrod MR2 and MRA4 aircraft were withdrawn from service in 2010. Since this time Sgt Marr has been employed as part of the United Kingdom Maritime Air Operations Centre (UKMAOC) team facilitating Allied Maritime Patrol Aircraft operations within the UK AOR. He recently completed his Masters in Air Power: History, Theory and Practice at the University of Birmingham.

Trevor Nash is the Consultant Editor of Jane's Training & Simulation Systems. He has a BA (Hons) in Modern History from the Open University and a MA in Air Power Studies from the University of Birmingham. He is currently undertaking PhD research, also at the University of Birmingham.

Ian Horwood is a historian at York St John University who has previously worked at the University of Missouri-Columbia and Pennsylvania State University. His principal interests are in US military history, air power history, and the wars in Indochina. His monograph Interservice Rivalry and Airpower in the Vietnam War is published by the US Army Combat Studies Institute.

Niall MacKay is a mathematical physicist at the University of York who also works in operational research and combat modelling, on which he collaborates with colleagues at the US Naval Postgraduate School. He has previously worked at Cambridge, Durham, Kyoto and Sheffield universities.

Christopher Price is a historian at York St John University who has previously worked at the Universities of York and Liverpool. His main areas of interest are financial, economic and military history in the twentieth century. His book Britain, America and Rearmament in the 1930s: The Cost of Failure is published by Palgrave Macmillan.

The Bridge to Air Power - Aviation Engineering on the Western Front 1914 - 1918

By Air Vice-Marshal (Retd) Peter Dye

The development of the British air weapon on the Western Front during the First World War represented a radical and unprecedented change in the way that national resources were employed in exploiting a technological opportunity to achieve tactical and operational advantage. Logistic competence was the precondition for air superiority and the 'modern style of warfare' – indirect, predicted artillery fire. The Royal Flying Corps' logistic staffs, led by Brigadier-General Robert Brooke-Popham, demonstrated considerable agility in meeting the demands of three-dimensional warfare. Sustaining adequate numbers of frontline aircraft required substantial numbers of skilled and semi-skilled personnel, located largely beyond the battle zone, operating at a continuously high tempo while coping with rapid technological change and high wastage. These elements formed a complex, dynamic and integrated network that was also partly self-sustaining, in the form of salvage and repair, with the ability to compensate for shortfalls in aircraft and aero-engine production as well as unpredictable demand. The logistic principles developed on the Western Front provided the foundation for Royal Air Force success in the Second World War and anticipated the management practices that underpin today's global supply chain – as well as demonstrating the enduring interdependence of logistics and air power.

This article has been drawn from the author's PhD, undertaken as a Portal Fellow. The full PhD can be accessed via Birmingham University's eTheses Repository and the British Museum's EThOS.

Introduction

We take for granted the existence of a global economy underpinned by a complex supply chain connecting distributed manufacturing, via an extensive international transportation network, to worldwide markets. Engineering lies at the heart of these activities, creating and supporting products while responding to rapidly changing customer requirements. This is not just a one way process, but increasingly involves recycling to meet 'green' as well as financial imperatives. Operating at a tempo determined by the marketplace, where fashion is sometimes as important as technological advances, the regular introduction of new products is critical to commercial success.

Although we may believe that this picture is a recent one, I would argue that its essential characteristics can be found in the maelstrom that was the First World War. The 'Great War' has long been recognised as an industrial war that consumed vast amounts of materiel, and where logistic superiority gave the Allies an overwhelming advantage.[1] The outbreak of war in 1914 has been described as marking the end of the first phase of globalisation, but it is equally possible to see it as the culmination of a process triggered by the Industrial Revolution that only came to an end with the Great Depression.[2] In sustaining military operations in the face of high attrition and rapidly evolving technology, processes and systems were developed that underpin today's global economy. This was best exemplified in the conduct of the air war where air superiority could only be achieved through a relentless struggle that pitted machine against machine in a seesaw process that saw neither side achieve an overwhelming technical or tactical advantage.

To explore this idea further, I will look in particular at the arrangements created to support the Royal Flying Corps (RFC) on the Western Front and how a huge engineering and supply network provided a war-winning capability – in the form of three dimensional warfare – that underpinned Allied success.[3]

The involvement of engineering in the war zone is hardly a recent development. Vegetius records that engineers and craftsmen were integral to the Roman Legion and that their presence in camp was essential in the fabrication and repair of weapons and armour - as well as in the construction of buildings and the undertaking of siege works.[4] What was unprecedented in the British Air Services, and the RFC in particular, was the scale of the engineering effort - such that over 90% of the total strength of the RFC on the Western Front comprised logistic (engineering and supply) personnel and only a very small proportion (some 8%) were assigned combat roles.[5] This was in sharp contrast to the BEF where 60% of personnel were assigned to the teeth arms.[6]

As the intensity and extent of the air war grew, the RFC developed operations management techniques that anticipated best practice in contemporary supply chains.[7] Demand forecasting, rough-cut planning, postponement, mass customisation, lean manufacturing, distributed production, reverse logistics, integrated supply chain management and disruptive innovation

all found their place on the Western Front. Although unprecedented, these techniques drew partly on the advances in advanced manufacturing and mass production achieved over the previous century, including standardisation, interchangeability and the employment of scientific management.

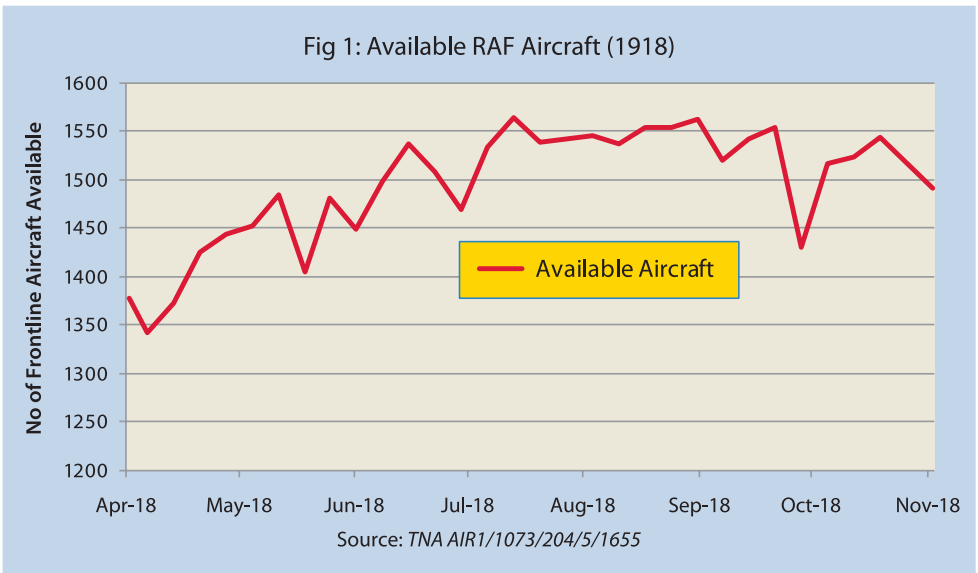
Scientific management is concerned with the organisation of work and the management of the worker. It is closely associated with 'Taylorism' and the measurement of performance, but in its broadest sense comprises the planning of industrial activity and the setting of standards of efficiency.[8] These ideas emerged in the USA at the turn of the century and are credited with transforming manufacturing. It has been suggested that scientific management made little progress in the UK prior to the First World War but the picture is less straightforward.[9] Admittedly, scientific management did not advance rapidly or uniformly across all industries, but the management of mechanisation advanced rapidly in the years immediately prior to the First Word War. Alongside this development was the tentative introduction of commercial methods in military affairs. The impetus for these changes stemmed from the South African War and major failures in the procurement and distribution of supplies by the War Office.[10] The solution was the creation of the 'soldier business man', to facilitate the manipulation of material resources through cost accounting.[11] One of the more visible results was a training programme for logistic officers overseen by the London School of Economics, under the leadership of Sir Halford Mackinder. Starting in 1907, this initiative paved the way for the employment of business experience in the management of logistics during the First World War.[12] The techniques and processes employed by the RFC to manage an increasingly complex and extensive supply chain should be seen, therefore, against this background and the reforms in Army administration introduced by Haldane in the decade prior to the outbreak of war.

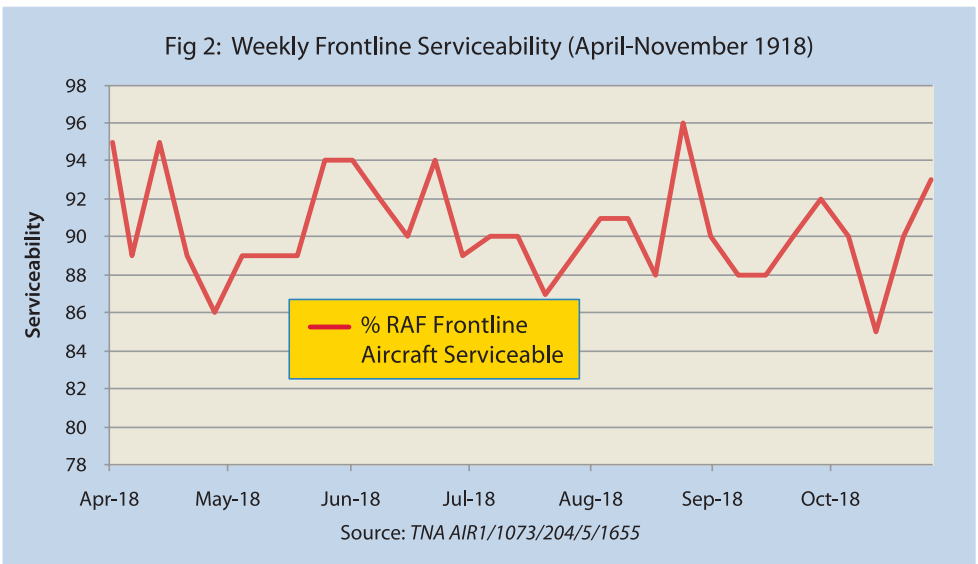
The RFC's achievements on the Western Front have sometimes been regarded as an interesting experiment that contributed little of direct military value to the war's outcome but offered some pointers to the role of air power in the Second World War.[13] This rather simplistic view overlooks two important points. Firstly, that aviation was both the precondition and precipitant for the advent of three-dimensional warfare on the Western Front; the integration of air and ground forces to deliver accurate, predicted, indirect fire at distance.[14] Without the RFC's ability to achieve air superiority this simply could not have happened and it is quite possible that the stalemate of trench warfare would have endured. Secondly, although the RFC's contribution to the advent of modern warfare was undoubtedly significant, indeed essential, the means of achieving this outcome was unprecedented, if not revolutionary. One of the most interesting aspects of early military aviation was how much its organisation owed to contemporary business practice and the way that it developed as a national endeavour rather than as a distinct activity - outside mainstream society or civilian experience.

RFC Operations on the Western Front

The RFC (and RAF)'s achievements on the Western Front were substantial and a key factor in the BEF's ultimate success. The metrics for 1918 are undoubtedly impressive.[15] In the last ten

months of the war the RAF: flew 484,000 hours; engaged 12,000 hostile batteries for destruction; destroyed 1,150 gun pits and damaged 3,500; took 256,000 photographs; dropped 321,000 bombs and fired 321,000 rounds. In delivering these outputs, over 7,000 aircraft were struck off charge – lost to enemy action, crashes or simply worn-out.[16] Even so, aircraft availability (the number of aircraft available to the frontline squadrons to undertake operational tasks), remained largely constant through 1918 (**Fig. 1**). Serviceability also remained high, at over 80% (**Fig. 2**), reflecting excellent technical skills and ready access to tools, equipment **and** spares.[17]





The RFC Logistic System

The RFC's logistic system on the Western Front was part of a global system that acquired, handled, distributed and maintained large quantities of technically advanced equipment across four continents. This was not simply a supply chain but incorporated engineering and repair activities that modified, reconstructed and configured aircraft and engines to meet the frontline's changing needs. The entire system was motorised, indeed, the RFC was the first organisation in the British Army to be fully motorised, and drew on an extensive transportation network, including sea, rail and inland waterways, to deliver equipment, spares and consumables to airfields and depots.[18] Although the RFC was a small proportion of the BEF, it had to manage an unprecedented inventory against a highly volatile and unpredictable demand.

By 1918, and the formation of the Royal Air Force (RAF), the RFC's inventory on the Western Front was substantial,[19] comprising: 1,500 frontline aircraft; 3,000 aircraft and 5,000 engines on charge; 12 aircraft and 16 engine types; and 40,000 separate line items (stock control units). This highlights a key challenge faced by the RFC. To sustain a single squadron on the frontline the supply chain had to hold as many aircraft again and three times as many engines. Although engine wastage was lower than aircraft wastage, there were many more arisings (from wear, defects or damage) meaning that at any one time there were as many engines under repair as fitted to frontline aircraft.

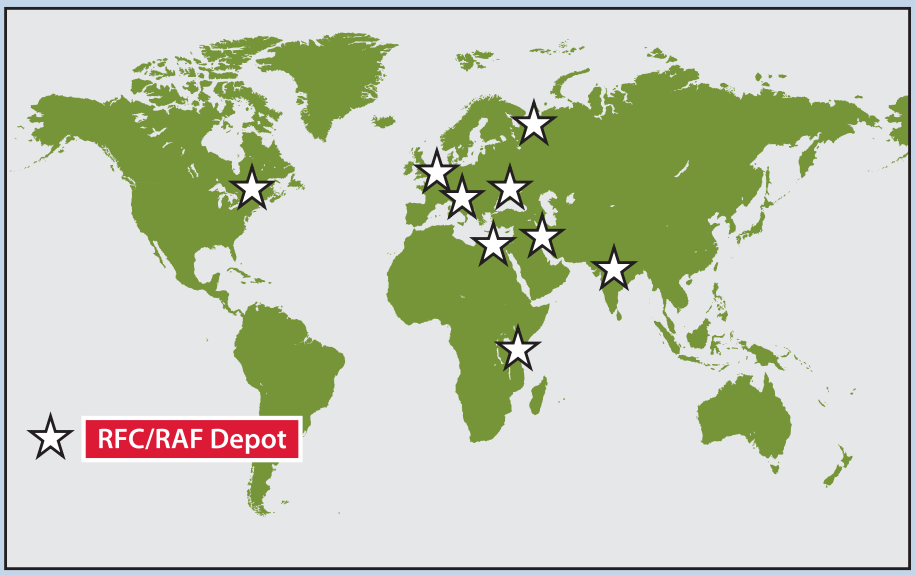
The range and quantity of the RFC's inventory was unprecedented for its time. The largest inventory previously seen was probably that managed by Sears Roebuck, who pioneered mail order and introduced the concept of central warehousing and integrated order control in Chicago at the end of the nineteenth century. The RFC's inventory on the Western Front comprised twice as many line items as the Sears-Roebuck Catalogue (20,000) and anticipated the immense range of spares required by the RAF during the Second World War (813,000). Even today, the RAF's inventory (although below its peak of 1.4 million line items at the end of the Cold War) remains impressive – reflecting the inherent complexity of military air systems. In fact, the inventory range managed by the RFC compares favourably with a modern supermarket chain, albeit without the advantages of automated data processing or the internet, that holds around 50,000 line items.[20]

The efficient and effective handling of a large and complex inventory should not be taken for granted. The problems faced by the Tank Corps in implementing robust stores handling practices and sustaining adequate levels of availability underscore the RFC's relative proficiency in coping with both the mass and detail of industrial warfare.[21] The RFC's inventory was largely held by depots located up to 30 miles from the front line, supported by a range of smaller forward issuing units closer to the operational squadrons. The depots' role was to: hold and issue inventory; erect aircraft; repair aircraft and aero-engines; install special to type equipment; modify equipment; salvage aircraft and aero-engines. Supplying the depots was very much a global business. Although the special steels and forgings came from the UK, as did some of the wood (such as ash), most of the raw materials required in the manufacture of aircraft and

engines had to be imported. This was also true of aluminium, fabric, dope, petroleum products and castor oil – all essential to the industry. Such was the demand for aircraft that licensed production was also required – either British designs built by foreign manufacturers (in France and the USA) or foreign designs built by British manufacturers. This still proved inadequate and substantial numbers of aircraft and engines had to be purchased overseas – primarily from France. Indeed, in 1916 the British Government funded an entire aero-engine plant in France to mass produce the Hispano-Suiza design for both countries.[22] Much of the work of the depots involved the preparation, modification, standardisation and reconstruction of aircraft and engines. Some of this was pre-planned, to avoid disruption to production lines, but the majority of work was in response to operational experience or to repair aircraft and engines damaged in combat or through accidents.

The RFC was active in every theatre of the First World War, from France to Italy and the Middle East. Flying aircraft at any distance from the home base represented a major logistic challenge, especially under climatic extremes. Supply and repair depots were established around the world to support and sustain air operations (**Fig. 3**). The bulk of the RFC's overseas effort was focussed on the Western Front where the frontline required a constant supply of aircraft, engines, stores and consumables (including fuel, oil, bombs and ammunition). By 1918, the scale and tempo of this operation was considerable,[23] and involved: 50,000 personnel (3% BEF); 7,000 vehicles (12% BEF); 79 airfields, and six depots that received 1,000 ton stores and 1,500,000 gal fuel each month while issuing 900 aircraft.

Fig 3: Global Distribution of Depots 1914 - 1919



The high number of vehicles employed by the RFC gave its supply chain substantial 'velocity' – the speed at which items could move within the logistic system. Motorisation, that is the use of motor vehicles in support of operational functions, permeated every part of the RFC organisation from the depots to the frontline squadrons. Additional vehicles were allocated to specialist tasks (such as carrying ammunition) while others were held as a strategic reserve to deploy as required. This sophisticated transportation system, allied to a substantial inventory, allowed the front line's needs to be met quickly and effectively under a wide range of conditions.

Modern Supply Chain

The parallels between the challenges faced by the RFC on the Western Front and modern supply chains are significant. Today's global market is characterised by: uncertainty; rapid obsolescence; volatile demand; and complexity.[24]

Uncertainty characterised the supply of aircraft and engines on the Western Front throughout the entire war. Wastage varied greatly from month to month - driven not only by operational tempo and enemy action but also by the weather, landing accidents, unreliability and obsolescence. The pace of aeronautical development during the First World War, the 'constant tactical factor',[25] was so rapid that obsolescence became a major problem. Failure to provide aircraft and engines with adequate performance to match continuing improvements in the German Air Service's fighting abilities compromised the RFC's ability to achieve air superiority and led to a substantial increase in wastage. The 'Fokker Scourge' in 1915/1916 and 'Bloody April' in 1917 are the most obvious examples of why quality mattered as much as quantity. The regular replacement of older aircraft types or time-expired machines was an important feature of the RFC's logistic system on the Western Front, although many of these could, and were, recycled for employment on the Home Front in training or air defence duties.

Demand volatility forced the RFC to postpone product configuration – to respond more rapidly to changing customer needs. This required the creation of a generic inventory (or strategic reserve) that could be readily modified to meet demand. Postponement saved time and allowed production to be optimised as well as reducing overall stock levels. By creating an in-theatre repair facility – in the form of the RFC's engine and aircraft depots – equipment could be held forward close to the squadrons awaiting final configuration. The depots' reconstruction programmes were planned in advance but amended in light of the actual supply position and real demand. Without the depots and their ability to create additional aircraft and engines (beyond new supply from England) more aircraft would have had to be held in reserve to maintain the same levels of availability.

The complexity of the RFC's supply chain arose because of the need to balance mass-production (and the standardisation of design) with technical development.[26] Complexity within the supply chain creates unpredictable effects and uncertain demand. There are two broad categories of complexity: sources of network complexity (the number of squadrons, aircraft

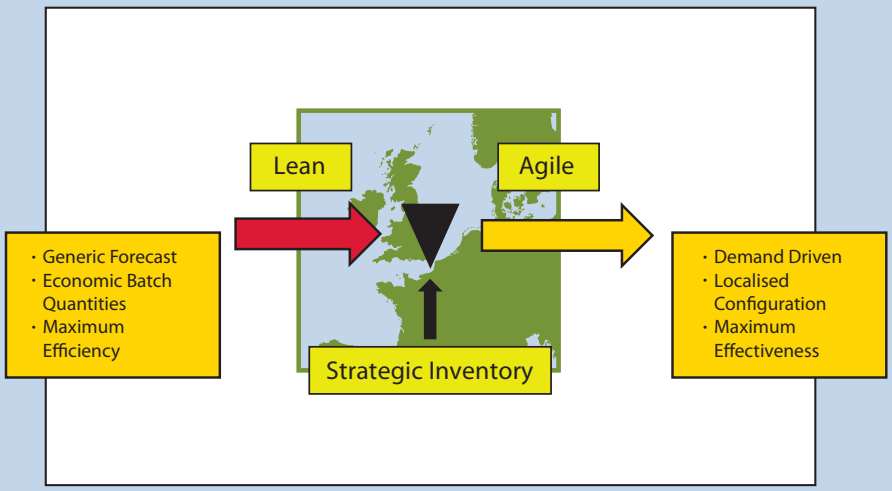
firms, engine firms and logistic units); and sources of information complexity (lead times, aircraft types, inventory range and operational roles).[27] By 1918, sources of network complexity on the Western Front were 25 times greater than 1914, while sources of information complexity were more than 400 times greater.[28]

The Effectiveness of the RFC Logistic System

The key challenge in any supply chain is to meet customer demand. However, since production generally takes longer than the customer is prepared to wait it is necessary to hold inventory. During the First World War it generally took an average of 34 weeks to take a new aircraft from design to mass production and some 64 weeks for an engine.[29] Once a particular type was in production, contracts had to be set some 25-30 weeks ahead of the required delivery. In other words, the Western Front's supply needs (in aircraft and aero-engines) had to be estimated somewhere between 9-12 months ahead of actual demand. These lead times grew during the course of the war.

The relationship between supply (in the form of production capacity and inventory) and demand can be represented as a fulcrum – demand is balanced by a combination of capacity and inventory. If the fulcrum can be moved closer to the customer, demand can be satisfied by a smaller inventory and/or less capacity. This can be achieved either by increasing product velocity or by improving the demand horizon. In fact, this is exactly what the RFC implemented in France. By creating a network of depots and forward supply parks, the frontline's demands were rapidly met – either from the immediate strategic reserve or by erecting cased aircraft. At the same time, the repair and reconstruction programme

Fig 4: RFC Decoupling Point



focused on making good the shortfall. The RFC's depots represented what is now known as the 'decoupling point' – the point in the supply chain where supply meets demand.[30] Upstream of this point, the Ministry of Munitions was able to manage the production of new aircraft as efficiently as possible; while downstream the emphasis was on effectiveness rather than efficiency. In effect, the depots marked the transition from a lean to an agile system (Fig 4, see page 17). This is known as a 'hybrid' system and is now recognised as 'best practice' in supply chain management.

Logistic Innovation

To achieve these outcomes and sustain the frontline, the RFC had to create a system based on little previous experience and no existing model. This demanded flexibility, intellectual honesty and a willingness to innovate. The RFC's senior leadership, in the form of Major-Generals Hugh Trenchard and Geoffrey Salmond, provided the necessary strategic direction but day to day responsibility for sustaining front line availability and serviceability fell to Brigadier-General Robert Brooke-Popham who managed the RFC's logistic arrangements in France for most of the First World War.[31] At his direction, the RFC introduced a wide range of techniques and processes that still find their place in modern supply chains, including: demand forecasting; rough-cut planning; strategic inventory; postponing configuration; mass customisation; hybrid (lean/agile) approach; distributed production; reverse logistics; integrated supply chain management; and disruptive innovation.

At the heart of the RFC's logistic system was the process of predicting future demand. This was based on calculated wastage (determined by a combination of experience, seasonal variation and operational tempo), the planned size of the frontline and the required level of reserves. These routine forecasts were used to set long-term production contracts, allocate shipping space and plan the level of in-theatre repair. A key step in the planning process was the creation of a monthly forward plan defining the quantity and type of future aircraft deliveries up to three months ahead. This allowed the War Office and HQ RFC to adjust in-theatre plans to match actual, as opposed to planned, production. The difficulty of determining detail demand (as opposed to global demand) was resolved by holding a stock of ready to repair aircraft that could be rebuilt quickly to meet shortfalls in deliveries or higher than anticipated wastage rates. By creating a strategic reserve and placing it at the decoupling point, the RFC was able to switch production or alter products at short notice. The effectiveness of these arrangements depended heavily on the efficient recycling of aircraft and engines. Salvage parties ensured that almost every crashed aircraft on the Allied side of the frontline (more than 95%) was retrieved either for rebuilding or breaking down into individual spares.

In addition to rebuilding aircraft, the RFC's depots were also responsible for the final configuration of all aircraft prior to frontline delivery. This included installing wireless and photographic equipment and completing urgent modifications, such as the fitting of bomb racks to fighters during the German spring offensive, and the embodiment of routine modifications not undertaken during manufacture to avoid slowing production rates. By focussing on the

manufacture of standard designs, and outsourcing the airframe to non-aviation companies, skilled in wood-working and piece metal working, the Ministry of Munitions was able to accelerate production rates. Final assembly was undertaken at home-based Aircraft Acceptance Parks where separately sourced high-value components (such as engines and instruments) were installed and the completed aircraft test flown. The depots represented the supply chain fulcrum – the point where supply meets demand and where 'lean' meets 'agile'. Downstream of the depots the frontline units 'pulled' aircraft and aero-engines, whereas upstream the Ministry of Munitions 'pushed' aircraft and aero-engines.

HQ RFC demonstrated considerable skill in managing the supply chain as a single entity, balancing new production and repair to meet the frontline's daily needs in aircraft, engines and spares. This involved a number of techniques, including varying the balance between air and sea delivery (to meet volatile demand volumes) while altering the detail of in-theatre repair and salvage programmes to meet changing demand by aircraft type. The agility of the entire organisation was such that new units could be rapidly created to meet the needs of mobile warfare (such as the deployment of advanced stores distributing sections during the Hundred Days Campaign) or existing processes altered to meet operational circumstances (such as the decision to move from a 'pull' to a 'push' system in delivering stores during the German spring offensive).

The RFC waged a continuous battle, in the form of sustaining innovation, to counter the enemy's technological and tactical advances, such as modifying artillery observation aircraft to lay smokescreens or drop small arms ammunition. It also engaged in disruptive innovation, such as the decision in 1917 to transfer the two-seat F.E.2 from daylight operations – where it was increasingly struggling against improved German fighters – to the night-bombing role. This required a whole series of changes, including the creation of dedicated night-flying training units in the UK (together with specially modified dual-control machines) and an extensive modification programme – navigation lights, night-flying instruments, new multiple bomb-racks and structural changes to carry larger bombs – to reconfigure the aircraft for its new role. As a result, rather than being withdrawn, the F.E.2 remained an important part of the frontline until the end of the war, providing an invaluable tactical bombing capability. In essence, the RFC created an entirely new 'market' for a mature product that would otherwise have been discarded – together with the associated production capabilities, infrastructure, spares, aero-engines and operational knowledge.

Conclusions

The contribution of the RFC's logistic system in supporting air operations on the Western Front was significant and, in many ways, revolutionary. Air power demanded very different logistic arrangements compared to previous military requirements. Sustaining the frontline required substantial numbers of skilled and semi-skilled personnel, located largely beyond the battle zone, capable of functioning at a continuously high tempo while coping with rapid technological change and substantial wastage. These support elements formed part

of a complex, dynamic and integrated network with the capacity to handle uncertainty while responding rapidly to unexpected demands. It was also partly self-sustaining, in that salvage and repair made a significant contribution to maintaining a continuous supply of aircraft and aero-engines. Van Creveld's assertion that the First World War was the first time in warfare that it was logistically easier to stay put than to move is an interesting observation but obscures a more important point.[32] The scale and intensity of fighting on the Western Front required all combatants to create complex networks capable of rapidly distributing large volumes of material that flowed both ways. What was significant about the First World War was that, whether the armies moved or not, their supplies were always on the move and none more so than the resources needed to sustain air power.

The RFC's logistic system was modern both in its needs and in the processes developed to meet these needs. In this effort, a variety of logistic techniques were pioneered (supply chain integration, strategic warehousing, velocity management, postponement and make-to-order, new product introduction, international sourcing, hybrid and reverse logistics) that now provide the basis for global supply chain logistics management. The RFC, led by a new breed of soldier-technocrat, who combined military values, managerial competence and business skills, was the epitome of an 'entrepreneurial military organisation', characterised by intellectual honesty, imagination and the courage to exploit historical failure.[33] The outcome was a new style of warfare that wove together 'industrial mobilization, national resources, morale and operational art'.[34] The RFC's logistic system on the Western Front was the bedrock for this achievement, delivering strategic success, facilitating 'modern warfare' and anticipating the management practices that now form the global supply chain – an immense legacy for a small military organisation that flourished for just five years at the beginning of the last century. In providing the foundation for air operations, and sustaining the RFC's efforts to achieve air superiority, logistics was the bridge between the nation's economy and air power.[35] It is a relationship that continues to this day.

Notes

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[15] *TNA AIR1/9/15/1/32/1* – Work in the Field, Consolidated Weekly Statements.
[16] *TNA AIR1/926/204/5/915* – Aeroplane and Engine Casualties, *TNA AIR1/998/204/5/1242-1243* – Duplicate Returns. The 1917 total was inflated to some extent by the front-line replacement programme that saw most squadrons re-equip with new types.
[17] *TNA AIR1/1073/204/5/1655* – Weekly Returns.
[18] Employing Liddell Hart's definition of 'motorization', as distinct from 'mechanization' – the employment of armoured fighting vehicles. B. Liddell Hart, *Thoughts on War* (London: Faber & Faber, 1944), p. 160.
[19] *TNA AIR1/926/204/5/915* – Aeroplane and Engine Casualties and *TNA AIR1/998/204/5/1242* – Duplicate Returns.
[20] Sears Roebuck 1912 Catalogue. Air Historical Branch, *Maintenance* (London: Air Ministry, 1954), p. 160. J. Reichert, *IKEA and the Natural Step* (Washington: World Resources Institute, 1998), p. 5. A. Eaves & B. Kingsman, 'Forecasting for the Ordering and Stock-holding of Spare Parts', *Journal of the Operational Research Society* (2004) 55, pp. 431-437. *DSDA Annual Report & Accounts 2008-2009* (London: Stationary Office, 2010), p. 15. Tesco Annual Report & Accounts 2011 (Cheshunt: Tesco plc, 2011), p. 28.
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Haig and Trenchard: Achieving Air Superiority on the Western Front[1]

By Sergeant Paul Marr

This article will examine the influence of Haig and Trenchard on the development of British air power during the First World War. Haig and Trenchard have both been criticised for employing unrealistic offensive tactics unsuited for the modern battlefield of the First World War. This article will demonstrate that in spite of popular perceptions to the contrary, Haig and Trenchard developed British air power methodically, logically and efficiently. However, Haig and Trenchard applied their offensive policies too rigidly at times, which had dire consequences for many British airmen, and for this they are deservingly criticised. Nevertheless in the shadow of these tragedies what is sometimes ignored is that by 1918 the Royal Air Force was highly efficient at the operational level and contributed significantly to the effectiveness of the British Expeditionary Force and eventual victory.

Introduction

The First World War saw the introduction and development of 'virtually every important manifestation' of modern air power roles.[2] Yet study of the air operations on the Western Front themselves, and the relationships between army commanders and their air leaders, still require academic scrutiny.[3] Haig's reputation as a 'technophobe,' at first glance, appears to preclude him as an area of study for the air power historian.[4] This impression is reinforced when, as late as 1914, Haig is reputed to have said:

> *"I hope none of you gentlemen is so foolish as to think that aeroplanes will be able to be usefully employed for reconnaissance purposes in war. There is only one way for a commander to get information by reconnaissance, and that is by the use of cavalry".*[5]

When considered with Trenchard's reputation as a 'stubborn and uncaring commander, who squandered the lives of his men,' the collaboration between Haig and Trenchard seems an unhealthy combination for the development of British air power during the First World War.[6] However, when studying air power during this period, particularly with regard to Haig, by consulting the actual 'actions' and 'written opinions' of those involved, a clearer perception of events may be obtained.[7] This paper therefore, will examine the considered actions and written opinions of Haig and Trenchard, in order to trace their combined influence and effect on the development of British air power during the First World War.

The literature surrounding Haig is divisive in the extreme, and there is no indication that a consensus is near at hand.[8] Tim Travers argued that Haig failed to adapt to the realities of the modern battlefield, and that his reluctance to heed advice from subordinates led to the offensives of the Somme and Passchendaele being pursued longer than was appropriate.[9] Gerard De Groot supported this when he argued that Haig's inability to adapt to new technology was responsible for him sending thousands of soldiers to 'a futile death.'[10] In Haig's defence, J.M. Bourne argued that Haig's ability to adapt new technologies and tactics into an effective cohesive doctrine, under pressure from his own government, the pressures of coalition warfare, and whilst overseeing the expansion of the army, was 'an administrative triumph.'[11] Gary Sheffield believed that Haig was one of the most significant and most successful British Generals.[12] His achievements have never been equalled, before or since 'in British military history,' and yet his record as a war time commander has been condemned in Britain.[13] Trenchard is condemned by association. Arthur Gould Lee's assertion that Trenchard's offensive policies during the First World War were as 'irrational as Haig's unyielding adherence to attrition,' links Trenchard's reputation to Haig's.[14] This view is supported by Tami Davis Biddle who described Trenchard as Haig's 'disciple.'[15]

In order to understand Haig, and by extension Trenchard, it is necessary to place them in 'the historical context in which they belong.'[16] Their shared belief in the efficacy of offensive operations in the pursuit of military goals ensured that Haig held Trenchard in high regard.[17] This belief was not peculiar to Haig and Trenchard in the years leading up to the First World War.

The development of technologies such as national railways, barbed wire and the machine gun, increasingly conferred the advantage in military operations to the defender. In spite of the evidence, there was a perception in Europe that the 'attackers would hold the advantage on the battlefield.'[18] This led to a belief that 'conquest was relatively easy' and the growth, of what Stephen Van Evera called, 'the cult of the offensive.'[19] Travers argued that prior to the war, the British Army also exhibited the symptoms of an 'unrealistic cult of the offensive.'[20] Therefore, Haig and Trenchard's belief in the offensive will be shown to be consistent with the prevailing attitudes of the times they lived in. Perhaps a more pertinent consideration is the short history upon which Trenchard and Haig had to draw upon when developing their air policies. Richard Overy argued that in order to develop doctrine effectively, five factors must be considered: Impact of politics; technology; experience; efficient review procedures; and the 'eccentricity factor.'[21] Trenchard believed that air power was 'an offensive and not a defensive weapon.'[22] In light of the limited experience on which Trenchard had to draw, this premise, as a doctrinal springboard, will be compared to more modern ideas on air power to assess its validity.

The paper will then show that Haig and Trenchard developed British air power methodically and logically according to a mutually agreed military role. The most significant role played by air power during the First World War was as an auxiliary to the artillery arm.[23] Insightfully Haig wanted his air service to provide his artillery with targeting information and other vital battlefield intelligence.[24] Haig was happy to leave the details of how to achieve this effect to Trenchard, and gave him a relatively 'free hand' to develop the Royal Flying Corps (RFC) in France.[25] Trenchard believed that for an air force to be successful it must first gain and then maintain air superiority.[26] The factors he considered essential to winning air superiority were; 'material and supply, training, tactical employment of aircraft and the morale of the fighting and ground personnel.'[27] It will be demonstrated that Trenchard developed the RFC in France in accordance with these principles, and his policies were consistently supported by Haig.

Finally, the RFC and later the RAF contribution to events in France during 1918 will be examined to demonstrate the effectiveness of Haig and Trenchard's policies. An in depth discussion regarding the legacy effect of Haig and Trenchard's policies on the strategic air campaign of 1918 is considered to be beyond the scope of this paper. What will be shown here is that the RAF, at the operational level, 'added considerably to the potency' of the British Expeditionary Force (BEF) and proved that air power had become integral to the conduct of war.[28] As the men who built the air service, Haig and Trenchard deserve 'some of the credit' for this success.[29]

Origins of the Relentless Offensive

Haig and Trenchard have been criticised for the tactics they deployed and the policies they pursued during the First World War.[30] Bourne characterises the popular image of Haig as the 'ambitious cavalryman' who, because of a limited understanding of tactics and strategy, caused the needless death of 'hundreds of thousands of men.'[31] Trenchard also received criticism for pursuing his offensive policies with a 'single-mindedness that bordered on stubbornness' regardless of the 'losses incurred.'[32] When studying history, in this case air power history, Peter

Gray emphasised 'the need to situate events in their own context.'[33] This is particularly apposite when applied to Haig and Trenchard's development of British air power during the First World War. There is some confusion as to when the two men met. Trenchard himself maintained that their first meeting took place in December of 1914, whereas Boyle, his biographer, placed the meeting in early January 1915.[34] What is more important than the date in this case, is that it marked the start of what was to 'prove an interesting and fruitful relationship'[35]

Trenchard was born in 1873 in Taunton and as a youth he proved to be an indifferent student. He eventually however, qualified for the militia in 1893 and was subsequently commissioned in to the Second Battalion of the Royal Scots Fusiliers.[36] He proved to be a keen sportsman and was diligent in his duties. By the time he met Haig Trenchard had served in India, Nigeria and had seen active service in South Africa during the Boer war, where he had been wounded. At the age of 39 Trenchard qualified as a pilot and joined the RFC in 1912.[37] Haig was born in 1861 in Edinburgh. As a youth 'he did not shine at his lessons,' nevertheless he managed to secure a place at Oxford.[38] Although he eventually left university without a degree, this was due to a residency issue and not because of academic failure; in any event, 'possession of a degree' provided no material 'benefit' in the army he was joining.[39] Haig saw no advantage to completing another term at Oxford, deciding instead to take a place at Royal Military College Sandhurst in 1884, where he graduated first in his class in December of that year.[40] Haig was ambitious and diligent; he became a serious student of soldiering however, he also took the time to partake in Edwardian past times such as polo and hunting. He served in India, attended Staff College and saw active service in the Sudan campaign and the South African Boer war.[41] Although over a decade separated Haig and Trenchard in age, their past times and careers show them to be typical examples of Edwardian officers of that time.[42] To understand Haig and Trenchard in the context of their times, it is necessary to explore the prevailing attitudes of their times.

During the years leading up to the First World War a number of technological innovations, such as the machine gun, barbed wire and railways, tipped the balance firmly in favour of the defence in warfare.[43] Yet despite this 'nearly all statesmen perceived that it favored the offense' during this period.[44] This dichotomy resulted in the growth of a phenomenon which has become known as the 'cult of the offensive.'[45] As a consequence there was a belief in European States that wars would be short.[46] The belief in the short war was not, however, universal. Von Moltke himself was hopeful that the Schlieffen Plan would work however, he feared that the resulting war could 'drag on for years, wreaking immeasurable ruin.'[47] Whilst in Britain, the General Staff answered the Government's question as to the probable length of a war against Germany with the quiet warning, 'it would not be safe to calculate on the war lasting less than six months.'[48] Nevertheless, despite a tacit acknowledgment of the strength of the defensive in warfare, all of the European major Powers had adopted 'elaborate and inflexible offensive war plans' by 1914.[49] Commentators disagree as to the extent the 'cult of the offensive' contributed to the start of the First World War.[50] However, a lengthy examination on this topic is beyond the scope of this paper the purpose of the discussion here, is merely to illustrate the pervasiveness of offensive ideologies across Europe prior to 1914.

In Britain the preference for the offensive could also be detected during this period. Travers stated that in the years leading up to the First World War the British Army adopted 'an unofficial doctrine or cult of the offensive' which was closely related to the 'concept of the psychological battlefield.'[51] Whilst Travers was critical of Haig, the main recipient of his condemnation was the army as an organisation.[52] According to Travers, the British 'cult of the offensive' was based on three tenets: the influence of fire-power on the battlefield, a primitive concept of Social Darwinism which doubted the reliability of the working classes under fire, and the belief that warfare was 'structured, ordered, and therefore potentially decisive.'[53]

Elements of Travers 'British cult of the offensive' can be detected in Haig and Trenchard's attitudes. Haig's acceptance of the structured battle can be seen in his writings before the war. In *Cavalry Studies* Haig stated 'there are four phases in a battle,' the introduction, engagement, supreme effort and finally, the 'taking advantage of victory,' or indeed retreat.[54] De Groot suggests that *Cavalry Studies* demonstrated Haig's inability to appreciate the influence of technology on the battlefield, because of Haig's belief that 'The role of the cavalry on the battlefield will always go on Increasing.'[55] If, as Sheffield suggests, the word 'cavalry' is changed to 'mobile troops' the relevance of Haig's argument is placed in a more balanced context.[56] After the war in his final dispatch Haig argued that the war should be seen as one continuous battle where the losses incurred during the supreme effort were inevitably high as this was where 'the price of victory' was paid.[57] He also affirmed his commitment to the offensive pre-war when he wrote: 'it is the "offensive" which alone can bring a war to a speedy termination.'[58] After the war he stated, 'decisive success in battle can be gained only by a vigorous offensive.'[59] His belief in moral qualities was illustrated when he stated, 'success in battle depends mainly on *moral*, and a *determination* to conquer.'[60]

Trenchard's preference for the offensive is revealed in his 'Future Policy In The Air' of 1916. This memorandum was written in the wake of the battles of Verdun and the Somme; it encapsulated Trenchard's thoughts on the employment of aircraft and defined the RFC's air policy.[61] In it Trenchard stipulated the British air effort should be one of 'relentless and incessant offensive.' He went on to state, as an offensive weapon, the effect of aircraft 'cannot be too highly estimated.' He believed that the moral effect of an aircraft on the enemy was, 'out of all proportion to the damage which it can inflict.'[62] According to Trenchard the only logical policy to be followed in the air was 'to exploit this moral effect of the aeroplane on the enemy.'[63] Haig and Trenchard were by no means the only British officers to believe so emphatically in offensive operations. In 1915 the General Staff had concluded 'that to obtain a decisive result a sustained offensive on a large scale is necessary.'[64] As late as January 1918 Robertson, then Chief of the Imperial General Staff (CIGS), during a meeting of the Supreme War Council stated 'the offensive was in fact the best form of defensive.'[65] To criticise Haig and Trenchard because of their offensive beliefs would be unfair, as has been shown their belief in the offensive merely 'reflected their commitment to the Edwardian martial culture' prevalent at the time.[66]

A more pertinent question would be whether their shared belief in the offensive was prejudicial to the development of the air arm? At first blush the evidence suggests not. A

brief examination of the development of air power theory indicates that air power has been seen as an offensive weapon from the First World War to the present. During the First World War, according to Maurice Baring, the German air service believed that the offensive strategies employed by the British should be emulated. He stated that in January 1917 General von Bulow was moved to say, 'we must exchange *defence* for *offence*, and do to the English what they are doing to us.'[67] This would appear to confer legitimacy to Haig and Trenchard's offensive policies. However, as Trenchard's assistant for many years, Baring's perspective may have been influenced by his admiration for Trenchard.[68] In Italy, the inter-war years saw Giulio Douhet offer a vision of future air power which admitted 'of no defense only offense.'[69] Heavily biased towards the Italian strategic position during the inter-war period, Douhet nevertheless concluded that air power had to be employed offensively to be successful.[70] John Slessor, whom Phillip Meilinger characterised as 'one of The Royal Air Force's most brilliant thinkers,' came to similar conclusions.[71] Slessor maintained the 'moral' advantage in the air campaign can only be realised 'by an instant and unremitting *offensive*.'[72] More recently the latest publication of 'UK Air and Space Doctrine' stated 'offensive action is inherent to air power.'[73] In this light, Haig and Trenchard's bias towards the offensive use of air power was almost intuitive. Intuition however, should not be the foundation upon which doctrine is developed. According to Overy, the essential ingredient to the creation of 'effective doctrine' is experience; he stated emphatically that it 'does not emerge in a vacuum.'[74] By 1914 barely eleven years had elapsed since the Wright Brothers had recorded the world's first successful flight in a powered aircraft therefore there was little in the way of historical experience upon which doctrine could be based.[75]

Although air power was in its infancy, the Army had been experimenting with aircraft since at least 1907; Andrew Whitmarsh stated that by 1914 the army in fact 'saw aircraft not as a 'useless and expensive fad' but as a vital weapon system.'[76] Although defeated in the 1912 Army Manoeuvres, Haig's comments regarding the performance of aircraft were positive and thoughtful. In addition to stating that the overall performance of aircraft had been good, he also pointed to the need for close cooperation between Army Headquarters and the flying corps. He warned against an over reliance on the information provided by aircraft. Finally, he also noted the perennial problem of distinction between friendly and enemy aircraft.[77] The opposing commander, Lieutenant General Grierson, was even more positive. Grierson believed the use of aircraft had proved to be 'an unqualified success' going so far as to state that the aircraft had 'revolutionised the art of war.' He also suggested that the elimination of enemy aircraft should be a priority in order to ensure success in future operations.[78] These comments demonstrated that at the highest levels of the Army, there was an appreciation of the advantages air power could provide to an army in the field, and that they were prepared to fight to retain this advantage. Additionally the *Field Service Regulations* of 1909 provided guidance for the use of aircraft on operations. The value of an aircraft as an intelligence gathering asset was highlighted. It was stressed that the most reliable and safest place for the aircraft to gather intelligence was behind enemy lines.[79] Haig's involvement in drafting the *Field Service Regulations* is significant.[80] Haig's presence, if not influence, can be linked to both, where the air battle was perceived to take place on the battlefield and the

necessity to fight for air superiority. It seems Haig knew what he wanted from the air arm, all he needed was a man he 'trusted' to pursue his vision, and in Trenchard, he had found is man.[81] However what needs to be established now, was whether Haig and Trenchard's collaboration led to the effective development of British air power during the First World War.

Construction of the Relentless Offensive

Before it can be ascertained if Haig and Trenchard acted logically and developed the RFC efficiently, it is first necessary to briefly examine the effect they desired to achieve. When Haig took command of the British Army in France, he was explicitly informed:

> The defeat of the enemy by the combined Allied Armies must always be regarded as the primary object for which the British troops were originally sent to France.[82]

As C-in-C of the BEF, Haig believed the role of the air arm was to support the Army in its primary objective of inflicting a 'decisive victory' over the German forces in France.[83] He outlined how to best achieve this in a letter to the Army Council in November 1916. His first priority was for artillery, photographic and contact patrol aircraft and, 'sufficient fighting machines, of the best type that can be procured, to protect them.'[84] The next stated priority was for reconnaissance and disruptive bombing of tactical and strategic targets behind enemy lines. Finally, although he did not reject long range bombing out of hand, he doubted its utility to the overall campaign and rated it as a secondary requirement.[85] Haig believed the air service's primary contribution to his campaign was to be as spotters for his artillery and for the provision of accurate reconnaissance. History has shown that these were indeed the 'key roles played by air power in the Great War,' which lends legitimacy to Michael Crawshaw's assertion, that the 'greatest contribution of the RFC to the eventual victories was due to Haig's 'clearsightedness.'[86]

As General Officer Commanding (GOC) the RFC in France, it fell to Trenchard to realise Haig's aerial policies. Haig had a high regard for Trenchard who he believed 'rendered very valuable service' whilst commanding the RFC attached to Haig's First Army.[87] During the course of their working relationship Haig had come to trust Trenchard and, 'left him to his own devices' on air power matters.[88] Trenchard believed the most efficient way to provide Haig's desired effect was the offensive employment of air power. In his famous memorandum 'Future Policy in the Air' he stated:

> The aeroplane is not a defence against the aeroplane; but it is the opinion of those most competent to judge that the aeroplane, as a weapon of attack, cannot be too highly estimated.[89]

It was Trenchard's contention that air superiority could be won through a 'policy of relentless and incessant offensive' which would have allowed 'the machines detailed for artillery co-operation and photography,' which was Haig's priority, to carry out their tasks 'unmolested.'[90]

He believed that air superiority was 'essential' as it permitted 'the free employment' of the air service conducting essential ancillary tasks.[91] The critical factors which he stated contributed to the gaining of air superiority included material and supply, tactics and training.[92] It is therefore necessary to investigate Trenchard's performance in these areas, to ascertain whether his leadership contributed positively, to the gaining and maintaining of his prerequisite for success, namely air superiority.

Shortly after the Battle of the Somme Trenchard released a memorandum in which he emphasised his belief in the efficacy of an offensive aerial policy.[93] In it he highlighted the importance of procuring a 'large number of fighting machines of the best types' in order to conduct offensive operations effectively.[94] This demonstrated Trenchard's awareness that no matter how brave the pilot, in the end the quality of the machine he was flying had a significant impact on the end result.[95]

Trenchard understood that he had to fight for resources and was prepared to do so.[96] Unofficial complaints regarding the quality of aircraft were often sent to Sefton Brancker whilst he was at the War Office.[97] Brancker and Trenchard opened up this back channel in the interests of efficiency as a means to speed up the official process.[98] Nor was Brancker the only person to receive Trenchard's letters of concern. Trenchard's correspondence showed that he was extremely conscious of advances made by the German air service; he warned Robertson, then CIGS, as early as September 1916, of a German machine which was superior to most of the British aircraft.[99] He also monitored developments of German tactics and operational tempo closely. In August 1916 he notified Haig that the Germans had employed a new low flying technique which he was having difficulty countering.[100] Later that month Trenchard noted the increased German operational tempo; he pointed to evidence that the Germans were bringing in new aircraft from outside the operational area.[101] Although Trenchard believed that the RFC would maintain 'predominancy in the air' for the remainder of 1916, he was 'nervous' as to the prospects of maintaining air superiority during spring 1917.[102]

In February 1917 Trenchard felt that the situation was severe enough to voice his concerns to the General Staff through official channels. His complaint this time was the poor supply of advanced aircraft, which had deteriorated to such an extent the success of the aerial offensive had been, in his opinion, 'very seriously jeopardised.'[103] Consequently he believed there would be more casualties incurred by the RFC in pursuit of their duties than had been suffered in previous battles.[104] Although the Germans had regained air superiority by the winter 1916/17, earlier than Trenchard had anticipated, it can be seen that he predicted the possible danger and attempted to address it, in order to pre-empt the consequences.[105] Trenchard's concern to limit casualties also led him to investigate the possibility of procuring a 'bullet proof waistcoat' for his observers to wear whilst flying. Procurement of resources for the RFC was complicated by fierce competition from the Royal Naval Air Service (RNAS) which limited efficiency until the Air Ministry was formed. This could hardly be the fault of the GOC in the field. The example discussed above illustrates the methods Trenchard employed in his pursuit of valuable resources.

His correspondence demonstrated he was proactive and worked hard to ensure his men had the best equipment he could obtain, in order to effectively pursue his policies.

With regards to air power, the importance of training cannot be over emphasised, Richard Hallion believed, '*training is everything*.'[108] Hallion stated that the RFC's poor training programmes almost had disastrous consequences between 1916 and 1917.[109] Trenchard himself has been criticised for sending pilots into battle with severely limited experience, some with as little as twenty hours flying training.[110] David Jordan stated that training was a major failing of the RFC as a whole and led to many unnecessary casualties; although he cautioned, 'accusations that Trenchard and his fellow senior officers were responsible for effectively murdering new pilots are unhelpful.'[111] As commander in the field of the RFC, Trenchard's control over training in Britain was limited. That is not to say that he did not attempt to improve the situation. As early as December 1915 Trenchard wrote to protest at the inadequate training one of his pilots had received.[112] It was acknowledged that the situation was 'far from satisfactory,' and he was invited to discuss possible 'satisfactory' solutions.[113] Trenchard was not satisfied and continued to apply pressure for better training by sending pilots he deemed unfit back to England.[114]

At this stage in the development of RFC training there was little agreement regarding the best way to train pilots. Writing in March 1916 regarding the question of pilot training, Brancker stated, 'I have never yet met two people who agreed closely on this subject.'[115] Finally, due to 'several serious complaints' received from Trenchard, a new qualifying test was promulgated.[116] The new standard required graduating pilots to receive a minimum of 15 flying hours which was to be strictly observed.[117] Eventually pressure from Trenchard led to the minimum requirement being raised to 20 hours flying time, with a minimum of 2 hours on the type to which the pilot was to be posted.[118] Twenty hours was pitiful experience to be sent into battle with; however, it should be noted that the situation could have been worse without Trenchard's efforts to improve the training of the pilots of the RFC.

When Trenchard's correspondence as GOC RFC in France is examined, his reputation as an 'uncaring commander who needlessly threw away the lives of his men in a vicious battle of attrition,' is cast into doubt.[119] The only certainty for a commander in war is that there will be casualties.[120] Whilst Trenchard was not 'eager' to suffer casualties he was prepared to do so to maintain his offensives.[121] Even whilst suffering 'appalling' losses in pilots and aircraft, he wrote to Brancker and stated, 'it is worth it if the battle is won and if we hit the Bosche hard.'[122] Trenchard was aware of the exigencies of the moment and was determined to provide his commander with the service, which contributed most effectively to the overall campaign. In order that his directives could be executed successfully by the men of the RFC, Trenchard endeavoured to appropriate the best equipment and training possible in the limited circumstances. Trenchard's success operating within such narrow parameters led John Hussey to declare Trenchard as 'the second greatest British fighting commander in France, after Haig himself.'[123]

Whilst Haig had an appreciation for what air power could do for his armies, he held no illusions that he understood the technicalities of 'exactly how this would be achieved.'[124] He placed such a high regard on what air power could provide for him that on at least one occasion, he considered cancelling an operation if flying was prohibited because of bad weather.[125] For technical details he came to rely heavily on advice from Trenchard.[126] However, he did take a keen interest in the activities of the RFC as can be seen by his diary entries.[127] He was appreciative of the efforts of the RFC and in the build-up to the Battle of the Somme; he noted the 'extraordinary activity which is going on in the air.'[128] His comments on many of Trenchard's daily reports indicated that he read and was therefore well aware of the RFC's casualties and was even sympathetic to their efforts.[129] Haig, was aware from an incident earlier in the war, of a reluctance to rely on intelligence gathered by aircraft. Haig had informed his 'Gunner Generals' that 'he was going to use Air' in the war and they had better too.[130] In an effort to increase the awareness and understanding of air power amongst his various commands, he periodically insisted that Air policies be communicated down to Corps and Divisional commander level.[131] In a further effort to increase understanding and cooperation between the army and the RFC, he requested that tactics be developed for the direct cooperation between 'assaulting infantry' and RFC squadrons.[132] Haig believed in air power and did not want its efficiency limited because of ignorance of its utility by his commanders at any level.

In the battle for resources Haig supported Trenchard by 'putting his personal weight behind' Trenchard's requests for new aircraft, to ensure that the RFC had the right machines and 'enough of them.'[133] In September 1916 Trenchard wrote to inform Haig that he had requested a new type of aircraft from the War Office. Haig decided that, in the interests of expediency, the authority of the C-in-C would 'hasten' delivery, and requested Trenchard draft a letter for his signature.[134] Haig subsequently wrote to the War Office requesting the required machines as a matter of urgency, and stressed that without them air supremacy may have been lost.[135] According to Higham, the process of subordinate commanders drafting letters for their seniors for onwards transmission, was 'an old military and official habit.'[136] Haig's support for Trenchard is further highlighted by an incident in 1917. Trenchard was once again frustrated by the last minute cancellation of expected aircraft and wrote to Haig.[137] Once again Haig supported his Air commander and took the matter up with the CIGS, indicating that the late change had placed his plans at a 'grave disadvantage.[138] His appreciation of the value of air power was further illustrated when he prioritised the resource requirements of the RFC above tanks, and even guns and ammunition for the armies in France.[139]

By 1918 the RAF had a proportionately larger number of fighter aircraft than either the German or French air forces and Morrow suggests that one of the primary explanations was the RAF's policy of the 'incessant offensive.'[140] During the winter of 1917-18 the RFC had a total of 2620 active service machines on inventory, 1381 of which were of a fighter variety.[141] When Trenchard relinquished command of the RFC in France to return to England he, with Haig's backing, had 'created the fighting traditions' that Higham claimed are essential for morale, and had built a force with a distinctly offensive formation.[142] However, the most important test of generalship,

is winning.[143] Trenchard's 'essential' requirement for the successful employment of air power in support of the army was, as already stated, air superiority.[144] In modern terms, 'control of the air' is still considered the most important role of air power, as it ensures 'freedom of manoeuvre.'[145] Therefore, to briefly indicate the effectiveness of Haig and Trenchard's air force, the essential question is how successful was the RFC in maintaining air superiority? Trenchard and the RFC had secured air superiority by the start of the Battle of the Somme; however, the Germans gained the upper hand from late 1916 until the middle of 1917 when the Allies once more were in control of the skies.[146] Hallion stated that the German air service 'was never again in a position to contest seriously for control of the air,' after April 1917.[147] For long periods of time Trenchard was successful in maintaining air superiority for Haig, and so could have reasonably assumed that his offensive policies were effective. This perception may have been reinforced by reports which suggested that the Germans had been adopting British tactics.[148]

The evidence suggests that Haig and Trenchard were cognisant of the requirements of material and supply, tactics and training which Trenchard believed were critical to ensuring the achievement of air superiority.[149] They were methodical and logical in their approach to developing RFC doctrine and force structure, and their approach had met with a large measure of success. However, it is in the very awareness of these requirements that the seeds of criticism for their offensive policies can be detected. During the winter of 1916-1917 the allies had lost air superiority. Over the course of the winter the German air service had introduced a new tactical concept, the Jagdstaffeln. This was a unit of handpicked pilots whose sole duty was to intercept and destroy allied aircraft. Added to this was the introduction of newer more advanced machines that had superior performance to British aircraft. Although the defensive posture maintained by the German air service throughout the war was a strategic handicap, it did allow 'them to achieve local tactical superiority' over the Western Front during the early months of 1917.[150] The ultimate consequence of this combination of factors is remembered as 'Bloody April.'[151] The RFC lost 708 aircraft and sustained 1014 casualties, 473 of whom were killed in action (KIA) between January and the end of May 1917. In April alone 275 aircraft were lost with 421 casualties, 207 of whom were KIA.[152] This represents the worst casualty rate suffered by the RFC up to this point in the war; in fact it was not to be exceeded until the last few months of the war in 1918.[153] Haig was kept informed of casualties through Trenchard's daily reports and so both men were aware of the scale of the problem.[154] As has been demonstrated, Haig and Trenchard were aware of the inefficiencies of both the supply of aircraft and the training of aircrew. However, despite acknowledging that air superiority had been lost, it was proposed to mount 'an even more vigorous offensive,' and to send RFC units further behind enemy lines in order to regain air 'ascendancy.'[155] Within this 'overemphasis' on the offensive, the manifestation of Travers' British 'cult of the offensive' can be detected.[156] Arthur Gould Lee acknowledged the importance of 'offensive spirit' in warfare but placed a higher premium on 'technical superiority' as it 'conferred the initiative.'[157] It is clear that Trenchard, and by extension Haig, ignored the 'technical threshold' whilst promulgating their air doctrine during this period of the war. In 1939 senior RAF officials suggested that poor air tactics used during the First World War could be seen as inexperience.[158] Jordan is less

forgiving, noting that some aspects of Trenchard's approach were inflexible and displayed 'a considerable lack of vision.'[159] Although Trenchard's offensive policies may have pleased Haig, they did not provide 'the best use of the resources' that were available.[160]

However, if Trenchard and Haig are to be held responsible for shortcomings of aerial policy in 1917 then, by logical extension, they deserve some measure of 'credit' for any evidence of efficient employment of air power in 1918.[161]

Legacy of the Relentless Offensive

The only test of Generalship that matters ultimately is winning.[162] The success of Haig and Trenchard's air policies can be demonstrated during 1918 in both defensive and offensive operations. The RFC's operations in a defensive role were vital to the War effort and in defeating the German spring offensive Operation MICHAEL in March 1918. According to S.F. Wise, Operation MICHAEL was 'Germany's last great effort to win the war, and her last opportunity.'[163] The RFC's role in the event of a large German offensive had already been defined in a memorandum released in January 1918, entitled 'The Employment of the Royal Flying Corps in Defence.'[164] According to the memo, in defence, RFC operations had to be primarily offensive in order to gain and maintain 'ascendancy in the air.'[165] Morrow credits Trenchard for the document however, GHQ did invite comments before its eventual general release.[166] That the senior artillery officer noted the necessity of air superiority indicated that Haig and Trenchard had met with some success educating the army regarding RFC operations.[167] Although the 'March Retreat' is considered by some 'as one of the worst defeats in the history of the British army', Sheffield was more optimistic when he suggested the failure of the German spring offensives represented 'a British defensive victory.'[168]

The German Offensive started on 21 March, although initially the RFC were outnumbered, and casualties were heavy, the campaign was prosecuted with such characteristic aggression that by 24 March they had gained a measure of 'aerial ascendancy.'[169] According to Wise, air superiority was gained because of the 'spirit which Trenchard' had imbued within the RFC.[170] Salmond's reports to Trenchard emphasised the success of operations against the German ground forces. On 22 March he reported that 'one low flier thinks he killed at least 500!'[171] The next day he reported 'low fliers' had successfully engaged an attack 'assembling on the 3rd Army front.'[172] After concentrating one hundred aircraft over German positions with orders to 'take every risk' in order to carry out their low flying attacks, he speculated that this 'had a great effect against the enemy attack.'[173] This impression has been subsequently supported. According to Wise, the heavy casualties the RFC had inflicted, led to an over emphasis of the 'importance of British air supremacy' by the German General Staff.[174] Although he admitted that it was difficult to 'quantify precisely,' Jordan maintains RFC operations were 'arguably the most significant' contributing factor in defeating the German Spring Offensives of 1918.[175] The success of the RFC in combat during Operation MICHAEL demonstrated the air force that Haig and Trenchard had created 'had almost perfected the majority of its missions' by this stage of the war.[176]

The contribution of British air power in an offensive role is perhaps best summarised by examining its effectiveness during the Hundred Days period and its contribution to the ultimate victory in 1918. During this period a review of operations by the Tank Corps demonstrated the value of RAF operations to that arm. It stated the RAF had 'carried out their duties with great skill, pertinacity and courage,' that they had prevented the loss of tanks on 'many occasions,' and there was 'no doubt that they proved of considerable value.'[177] Although the working practices of the artillery adapted to the rapid advances of the army, the 'RAF continued to detect 80% of targets.'[178] The effect on the Germans was considerable. One report quoted a German officer 'urgently' requesting protection from 'large numbers' of British aircraft that had been operating in his area 'entirely unmolested.'[179] In another the 'indescribable panic and chaos' caused by an RAF low flying attack led to road blocks as troops fled in 'utter confusion.'[180] Captured documents revealed that the Germans acknowledged the superiority of the British air force and admitted that the German air service could not match its efficiency.[181] The evidence shows the effectiveness of the RAF was recognised by the British and the Germans. Haig and Trenchard's offensive policies had ultimately led to a force capable of winning air superiority, which enabled effective cooperation with the other arms of the army at a critical stage in the war. As an auxiliary to the Army the RAF had emerged as 'arguably the most effective air service in the world.'[182] Haig did not share the belief within the War Office that the war on the Western Front could not be won until 1919.[183] Haig believed the war could be won in 1918 and after Amiens, he was determined to win the 'War in the shortest possible time.'[184] According to Sheffield the key to victory was the 'cooperation between the various arms' of the army.[185] Without air power, Jordan concluded, winning the war would have been 'infinitely more difficult. It may even have proved impossible.'[186]

Conclusion

To understand Haig and Trenchard it is necessary to study them in the context of their 'own times.'[187] The backgrounds of the two men indicate that their attitudes were consistent with the martial culture prevalent in the Edwardian army. The years leading up to the First World War had given rise to a phenomenon that Evera has described as a 'cult of the offensive.'[188] Despite evidence to the contrary, the general perception prevalent throughout Europe was that the advantage would be held by the army on the offensive in war. This led to all of the major belligerents formulating and deploying offensive strategies at the outbreak of the First World War. The influence of the 'cult of the offensive' was also detectable in British military thinking prior to the outbreak of war. The British variant of the 'cult of the offensive' was based upon three elements. An over-emphasis on offensive action, a belief that superior morale qualities could overcome defensive firepower, and a predictable structure to war fighting. On closer examination, Haig and Trenchard's ideas on offensive action merely reflect British military thinking prevalent at that time.

With regard to air power, however, the belief in offence was an insightful starting point for the formulation of an incipient air power doctrine. The concept was validated when the Germans adopted a more offensive stance copying the successful British approach over the Somme

in 1916. Since that time, offensive operations have consistently been reiterated as the most effective use of air power. Experience, one of the pillars upon which sound doctrine is built, was in 1914 lacking, however, the army had been experimenting with aircraft prior to the First World War and by 1914 the aircraft was considered an essential weapon for war.

The objective the British Government had set Haig was the defeat of the German army in the field as part of a coalition force. He believed that the air service should support the army in that goal. His priorities were for aircraft for artillery cooperation and fighters to protect them. Secondly he required aircraft that could perform reconnaissance duties and target tactical and strategic objectives behind enemy lines. He did not pursue a long range bomber force actively as he saw the long range bombing as subordinate to his goal of defeating the German army. Haig knew what he wanted his air service to provide for his army, but was content to leave the details of how this was to be done to his air commander. Trenchard believed air power had to be offensive to be effective in support of the army. His primary objective was to win and retain air superiority, as this permitted all other duties to be carried out efficiently without interference from the enemy. According to Trenchard, the essential factors which would contribute to gaining air superiority were supply, tactics and training.[189]

Trenchard was aware that the quality of the aircraft was a critical factor when deciding the outcome of any combat and wanted the best machines available for his pilots. The RFC under Trenchard had gained and maintained air superiority during the Battle of the Somme. However, from September 1916 onwards, Trenchard became concerned that the tactical balance in the air war was shifting and aggressively pressured the authorities for more advanced aircraft types. Unfortunately, as the GOC of the RFC in France, he had little control over the procurement issues that plagued British air power at this time. The consequences as he was only too aware, was the RFC casualty rate would increase. Another area the RFC suffered was in the quality of the training. Trenchard has been criticised for sending inexperienced pilots with minimal training in to combat. What is forgotten is that Trenchard relentlessly pursued a more vigorous training programme for his aircrew. He regularly returned to England pilots he deemed unfit to fly in his theatre of operations. His efforts were instrumental in eventually raising the standard of training. Trenchard operated effectively within the narrow parameters open to him as a commander in the field. He was prepared to suffer casualties in order to win the war; but he took very real steps to limit them. His reputation as an uncaring commander does not stand up under close scrutiny.

Haig's contribution to the process was informed oversight. He remained up to date on RFC operations through Trenchard's daily reports, upon which he occasionally wrote notes. He was appreciative of RFC efforts and supported his commander with his personal authority in the battle for resources. Air power was one of Haig's highest priorities for the army in the battle for resources. Haig actively educated his army in the importance of air operations, in order to improve efficiency and to promote closer cooperation. By 1918 when Trenchard returned to England to become CAS, the force Haig and Trenchard had built was distinctive because

of the number of fighting machines it had at its disposal. Under Trenchard the RFC in France had been successful in maintaining air superiority for long periods, which suggested that the offensive policies he pursued were effective. However, during the periods that air superiority had been lost the offensive policies were applied too rigidly and resulted in heavy casualties. During the early months of 1917 especially, Trenchard and Haig can reasonably be criticised for pursuing the offensive in the air too aggressively. They were aware of the training issues, as well as the technical superiority of the German machines, yet they made no alteration to the overall prosecution of the air war during this period. This did not represent an efficient use of resources.

In 1918 the air service that Haig and Trenchard had built demonstrated its effectiveness in both defensive and offensive operations making very real contributions to ultimate victory. On 21 March, in an effort to end the war, the Germans launched Operation MICHAEL, an offensive largely directed at the British forces. Trenchard had foreseen the possibility and had carefully outlined the RFC roles for defence. Predictably emphasis was placed on the offensive deployment of the RFC. When the Germans attacked, the RFC battled aggressively and as early as 24 March had started to exert a measure of air superiority. Low flying attacks against German ground forces were particularly effective and caused panic and consternation among the German forces. Eventually the German offensives failed resulting in a British defensive victory in which the RFC's contribution was an essential part.

In offensive operations during the Hundred Days, the RAF proved to be highly effective supporting the army as a whole, and artillery and tanks particularly. The Germans recognised that the British had won air superiority and low flying attacks against ground personnel once again proved to be successful. Haig's vision of the air force was as an arm to aid the army in the field at the operational and tactical level. The RAF added a dimension to the BEF which increased its overall efficiency which in the end allowed Haig to pursue a decision in 1918. Haig and Trenchard's air policies ultimately led to an air force which was highly effective in supporting the army in the field. The model that Haig and Trenchard created was considered so effective that it was subsequently incorporated for use by the Germans in the Second World War.[190] Additionally it was consistent with Britain's 'most fervidly proclaimed' war aim; that of destroying 'Prussian militarism.'[191]

Notes

[1] This article is based on a dissertation presented for completion of MA Air Power: History, Theory and Practice at the University of Birmingham. As such the author would like to publicly acknowledge the guidance and support of Dr Peter Gray throughout the development of this project. Dr David Jordan's valuable observations and insights prior to publication are also greatly appreciated by the author.

[2] Tami Biddle. 'Learning in Real Time: The Development and Implementation of Air Power in the First World War.' In Sebastian Cox and Peter Gray, (Eds), *Air Power History: Turning Points from Kitty Hawk to Kosovo*. (Frank Cass, 2005 [2002]) p 3

[3] E. R. Hooten. *War Over The Trenches: Air Power And The Western Front Campaigns 1916-1918*. (Midland Publishing, 2010) p 6, p 11-12
[4] Gary Sheffield And David Jordan. 'Douglas Haig and Airpower.' In Peter Gray and Sebastian Cox, (Eds), *Air Power Leadership: Theory and Practice* (HMSO, 2002) p 264
[5] Quoted in, Andrew Whitmarsh. 'British Army Manoeuvres and the Development of Military Aviation, 1910–1913.' *War in History*, Vol. 13 No.3 (July 2007) p 326. It should be noted that there is some doubt as to whether Haig actually voiced this opinion. Whitmarsh goes on to note that some comments attributed to 'allegedly technophobic officers (always at second or third hand) are often contradicted by the actions of those same officers, and by their own written opinions.' Whitmarsh. 'British Army Manoeuvres and the Development of Military Aviation, 1910–1913.' p 326. Gary Sheffield and David Jordan suggest that, Haig's involvement in producing the *Field Service Regulations (FSR) 1914*, which recognised the importance of aircraft in any war, makes this sentiment 'rather surprising.' Sheffield and Jordan. 'Douglas Haig and Airpower.' p 269. Therefore this quote attributed to Haig should be treated with caution.
[6] Philip Meilinger. 'Trenchard and 'Morale Bombing': The Evolution of Royal Air Force Doctrine before World War II.' In Philip Meilinger, (Ed), *Airwar: Theory and Practice*. (London: Frank Cass, 2003) p 41
[7] Whitmarsh. 'British Army Manoeuvres and the Development of Military Aviation, 1910–1913.' p 326
[8] Gary Sheffield. *The Chief: Douglas Haig And The British Army*. (Aurum 2012) p VI Foreword by Saul David
[9] Tim Travers. *The Killing Ground*. (Pen & Sword Military, 2009 [1987]) p 97
[10] Gerard J. De Groot. 'Educated Soldier or Cavalry Officer? Contradictions in the pre-1914 Career of Douglas Haig.' *War & Society*, Vol. 4 No. 2 pp 51-69 (September 1986) p 66-67
[11] J.M. Bourne. *Britain And The Great War 1914-1918*. (Edward Arnold, 1989) p 173-174
[12] Sheffield. *The Chief*. p 380
[13] Bourne. *Britain And The Great War 1914-1918*. p 174
[14] Arthur Gould Lee. *No Parachute*. (Grub Street, 2013 [1968]) p 223
[15] Tami Biddle. 'British and American Approaches to Strategic Bombing: Their Origins and Implementation in the World War II Combined Bomber Offensive.' In John Gooch (Ed), *Airpower: Theory and Practice*. (Frank Cass, 1995) p 95
[16] Sheffield. *The Chief*. p 380
[17] Meilinger. 'Trenchard and 'Morale Bombing.' p 41
[18] Stephen Van Evera. 'The Cult of the Offensive and the Origins of the First World War.' *International Security*, Vol. 9 No. 1 (Summer 1984) p 58
[19] Ibid p 62, p 58
[20] Travers. *The Killing Ground*. p 37
[21] Richard Overy. 'Doctrine Not Dogma: Lessons From The Past.' *Royal Air Force Air Power Review*, Vol. 3 No. 1 pp 32-47 (Spring 2000) p 41
[22] Trenchard Papers, MFC 76/1/4 RAF Museum. Future Policy In The Air dated 22 September 1916
[23] Lee Kennett. *The First Air War, 1914-1918*. (Simon And Schuster, 1999 [1991]) p 220

[24] Sheffield, And Jordan. 'Douglas Haig and Airpower.' P 272
[25] Kennett. *The First Air War, 1914-1918*. p 223
[26] Air 9/8, TNA. Enclosure 4. 'Air Superiority. Extracts from a Memorandum of General Trenchard, September 29th, 1916. As the memorandum cites instances in 1917 and uses terms such as Royal Air Force and 'in the late war': the author believes the memorandum was written post 1918.
[27] Ibid
[28] David Jordan. 'The Royal Air Force and Air/Land Integration in the 100 Days, August–November 1918.' *Royal Air Force Air Power Review*, Vol. 11 No. 2 (Summer 2008) p 28
[29] Sheffield, And Jordan. 'Douglas Haig and Airpower.' P 267-268
[30] B. H. Liddell Hart. *Strategy: Second Revised Edition*. (Meridian, 1991 [1954]) p 162 On Haig, Liddell Hart argued that 'a method which requires four years to produce a decision is not to be regarded as a model for imitation. Gerard J. De Groot. 'Ambition, Duty And Doctrine: Douglas Haig's Rise To High Command.' In Brian Bond and Nigel Cave, (Eds), *Haig: A Re-Appraisal 80 Years On*. (Pen And Sword Military, 2009 [1999]) p 49, De Groot argued that Haig's 'tactical perceptions' were influenced by the then 'irrelevant cavalry myth.' Tim Travers. *How The War Was Won: Factors That Led To Victory In World War One*. (Pen & Sword Military Classics, 2005 [1992]) p 180-181. Travers believed that even the victories of 1918 were inefficient and wasteful of soldiers' lives. On Trenchard, Robin Higham. *Air Power: A Concise History*. (The Military Book Society, 1972) p 28. Higham criticised Trenchard for sending virtually untrained pilots in to combat. Biddle. 'British and American Approaches to Strategic Bombing. p 127. Biddle suggested Trenchard adapted the *offensive à l' outrance* 'and applied it to the air.'
[31] J.M. Bourne. 'Haig And The Historians.' In Brian Bond and Nigel Cave, (Eds), *Haig: A Re-Appraisal 80 Years On*. (Pen And Sword Military, 2009 [1999]) p 1
[32] Meilinger. 'Trenchard and 'Morale Bombing': The Evolution of Royal Air Force Doctrine before World War II.' p 41
[33] Peter W Gray. 'Why Study Air Power History?' *Royal Air Force Air Power Review, Vol.4 No.3* (Autumn 2001) p 10
[34] Trenchard Papers, MFC 76/1/61 RAF Museum. Andrew Boyle. *Trenchard: Man of Vision*. (Collins, 1962) p 128
[35] Sheffield And Jordan. 'Douglas Haig and Airpower.' p 271
[36] Boyle. *Trenchard*. ch 1
[37] Ibid Ch 2-5
[38] Sheffield. *The Chief*. p 9-12
[39] Ibid p 16
[40] Ibid p 16- 17
[41] Ibid p 18- 52
[42] Higham. *The Military Intellectuals in Britain: 1918-1939*. p 133. Higham stated that Trenchard was 'of his time and class.' Sheffield. *The Chief*. p 7. Sheffield stated that Haig was 'the product of an era very different from our own.'
[43] Stephen Van Evera. *Causes Of War: Power And The Roots Of Conflict*. (Cornell University Press, 1999) p194

[44] Jack S Levy. 'The Offensive/Defensive Balance of Military Technology: A Theoretical and Historical Analysis.' *International Studies Quarterly*, Vol. 28 No. 2 (June 1984) p 234
[45] Van Evera. *Causes Of War*. p193
[46] Van Evera. 'The Cult of the Offensive and the Origins of the First World War.' p 58
[47] Christopher Clark. *The Sleepwalkers: How Europe Went To War In 1914*. (Penguin Books, 2013 [2012]) p 561
[48] CAB 16/18 B, The National Archives (TNA). Note by the General Staff dated March 12, 1912.
[49] Scott D Sagan. '1914 Revisited: Allies, Offense, and Instability.' *International Security*, Vol. 11 No. 2 (Autumn 1986) p152
[50] Sagan. '1914 Revisited: Allies, Offense, and Instability.' p 154. Sagan maintains that the 'cult' was a necessary contributory factor but not sufficient cause by itself. Van Evera. 'The Cult of the Offensive and the Origins of the First World War.' p 58. Van Evera suggests that the 'cult' was 'the principle cause' of the First World War.
[51] Tim Travers. *The Killing Ground*. (Pen & Sword Military, 2009 [1987]) p 55
[52] Bourne. 'Haig And The Historians.' p 6
[53] Travers. *The Killing Ground*. p 37
[54] Sir Douglas Haig. *Cavalry Studies: Strategical And Tactical*. (General Books LLC, 2012 [1907]) p 50
[55] De Groot. 'Educated Soldier or Cavalry Officer?' p 65
[56] Sheffield. *The Chief*. p 55
[57] Gary Sheffield and John Bourne. *Douglas Haig: War Diaries And Letters 1914-1918*. (Phoenix, 2006 [2005]) p 517-518
[58] Haig. *Cavalry Studies*. p 8
[59] Sheffield and Bourne. *Douglas Haig: War Diaries And Letters*. p 522
[60] Haig. *Cavalry Studies*. p 50 Emphasis in the original
[61] Maurice Baring. *Flying Corps Headquarters 1914-1918*. (William Blackwood & Sons Ltd, 1968 [1920]) p 178. Biddle. 'Learning in Real Time. p 7. Biddle highlighted that the document was important 'and much quoted.'
[62] Trenchard Papers, MFC 76/1/4 RAF Museum. Future Policy In The Air dated 22 September 1916
[63] Ibid
[64] WO 158/17/27, TNA, enclosure 27 General Staff Note titled 'The Offensive Under Present Conditions.' Dated 15 June 1915
[65] CAB 25/120/SW70, TNA, 'Draft summary of the opinions expressed at the first session of the 3rd meeting of the Supreme War Council.' Held on January 30th 1918
[66] Biddle. *Rhetoric and Reality in Air Warfare*. p 27
[67] Maurice Baring. *Flying Corps Headquarters 1914-1918*. (William Blackwood & Sons Ltd, 1968 [1920]) p 199-200 emphasis in the original.
[68] Ibid p xvi In a letter Baring describes Trenchard as 'one of the few *big men of the world*.' Emphasis in the original.
[69] Giulio Douhet. *The Command of The Air*. Translated By Dino Ferrari. (Air Force History And Museums Program, 1998 [1942]) p 55
[70] Michael D Pixley. 'False Gospel for Airpower Strategy? A Fresh Look at Giulio Douhet's

"Command of the Air." Accessed 23 August 2013. http://www.airpower.maxwell.af.mil/airchronicles/cc/douhet.html

[71] J. C. Slessor. *Air Power And Armies*. (The University of Alabama Press, 2009 [1936]) This is stated in Meilinger's Foreword to this edition. Page is un-numbered.

[72] Ibid p 10 Emphasis in the original.

[73] *Joint Doctrine Publication 0-30 UK Air and Space Doctrine*. (The Development, Concepts and Doctrine Centre, 2013) p 4-12

[74] Richard Overy. 'Doctrine Not Dogma: Lessons From The Past.' *Royal Air Force Air Power Review, Vol. 3 No. 1* (Spring 2000) p 43

[75] Peter Simkins. *Air Fighting 1914-1918: The Struggle For Air Superiority Over The Western Front*. (Imperial War Museum, 1978) p 5

[76] WO 163/12, TNA, Minutes of the Army Council meeting held 24/25 October 1907, p 24 item 15. The council authorised further experiments with aeroplanes. Whitmarsh. 'British Army Manoeuvres and the Development of Military Aviation, 1910–1913.' p 346

[77] WO 279/47, TNA, Army Manoeuvres 1912, p 162

[78] Ibid p 170

[79] *Field Service Regulations Part 1, Operations. Reprinted with Amendments* (London: War Office, 1912 [1909]) p 118-123

[80] Travers. 'The Offensive and the Problem of Innovation in British Military Thought 1870-1915.' p 540

[81] Sheffield and Jordan. 'Douglas Haig and Airpower.' p 278

[82] WO 158/21, TNA, Enclosure 27. Letter from the War Office signed by Kitchener to Haig on taking command of the BEF dated 28 December 1915

[83] WO 158/21, TNA, Enclosure 93. Letter from Haig to the Army Council dated 01 November 1916

[84] Ibid

[85] Ibid

[86] John Buckley. *Air Power In The Age Of Total War*. (UCL Press, 1999) p 47 For the key roles of air power during the First World War. Michael Crawshaw. 'The Impact Of Technology On The BEF And Its Commander.' In Brian Bond and Nigel Cave, (Eds), *Haig: A Re-Appraisal 80 Years On*. (Pen And Sword Military, 2009 [1999]) p 167 For Haig's 'clearsighteness.'

[87] WO 256/5, TNA. Diary entry for 18 August 1915

[88] Sheffield and Jordan. 'Douglas Haig and Airpower.' p 272

[89] Trenchard Papers, MFC 76/1/4. 'Future Policy In The Air' 22 September 1916. RAF Museum

[90] Ibid

[91] Air 9/8, TNA. Enclosure 4. 'Air Superiority. Extracts from a Memorandum of General Trenchard, September 29th, 1916. As the memorandum cites instances in 1917 and uses terms such as Royal Air Force and 'in the late war': the author believes the memorandum was written post 1918.

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[94] Ibid

[95] Lee Kennett. *The First Air War, 1914-1918*. (Simon And Schuster, 1999 [1991]) p 94
[96] Eric A Ash. 'Air Power Leadership: A Study Of Sykes and Trenchard.' In Peter Gray and Sebastian Cox, (Eds), *Air Power Leadership: Theory and Practice*. (HMSO, 2002) p 172
[97] Trenchard Papers, MFC 76/1/5. Letter dated 25 March 1916 from Trenchard to Brancker. 11 April 1916 Trenchard to Brancker. MFC 76/1/6. 4th June 1916 Trenchard to Brancker. RAF Museum
[98] Trenchard Papers, MFC 76/1/5 Letter dated 23 March 1916 Brancker to Trenchard. 24 March 1916 Trenchard to Brancker. RAF Museum
[99] Trenchard Papers, MFC 76/1/8. Letter dated 30th September 1916. Trenchard to Robertson. RAF Museum
[100] WO 158/34, TNA. Letter dated 12 August 1916 From Trenchard to Adv GHQ and GS
[101] WO 158/34, TNA. Letter dated 31 August 1916 From Trenchard to Adv GHQ and GS
[102] Trenchard Papers, MFC 76/1/8. Letter dated 30th September 1916. Trenchard to Robertson. RAF Museum
[103] Air 1/522/16/12/5, TNA. Letter dated 11th February 1917. From Trenchard to CGS
[104] Ibid
[105] Buckley. *Air Power In The Age Of Total War*. p 53
[106] Trenchard Papers, MFC 76/1/8. Letter dated 2nd October 1916. Trenchard to Brancker. RAF Museum
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[108] Richard P Hallion. *Rise Of The Fighter Aircraft 1914-1918*. (The Nautical & Aviation Publishing Company Of America, 1984) p 160. Emphasis in the original
[109] Ibid
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[111] David John Jordan. *The Army Co-Operation Missions Of The Royal Flying Corps/Royal Air Force 1914-1918*. (Unpublished dissertation, 1997) p 346, p 73
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[113] Air 1/131/15/40/218, TNA. Letter dated 5th January 1916. From DDMA to Trenchard
[114] Air 1/131/15/40/218, TNA. Letters dated 3/1/16, 20th February 1916. From Trenchard to DDMA
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[120] Rupert Smith. *Utility Of Force: The Art Of War In The Modern World*. (Penguin Books, 2006 [2005]) p 67

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[124] Sheffield And Jordan. 'Douglas Haig and Airpower.' p 281
[125] Trenchard Papers, MFC 76/1/61. RAF Museum
[126] Higham. *The Military Intellectuals in Britain: 1918-1939*. p 136
[127] For examples see. WO 256/9, TNA. Haig's diary entry on 06 March 1916 he notes that a new aircraft can climb to 9000 ft in four minutes and compares this to the poor performance of aircraft in 1914. Also see diary entry 25 April 1916.
[128] WO 256/10, TNA. Haig's diary entry on 19 June 1916.
[129] For examples see, WO 158/34 Report dated 03 August 1916. Trenchard requests a rest for some of his men which Haig agreed to by writing on the report. Report dated 07 October 1916. Haig wrote on the bottom of the report, 'A highly credible performance in view of the weather conditions.' WO 158/35 Note dated 28 July 1917. Haig sends his congratulations.
[130] Trenchard Papers, MFC 76/1/61. RAF Museum
[131] Air 1/522/16/12/5, TNA. Minute Dated 6th October 1916. Minute Dated 9th April 1917.
[132] Air 1/522/16/12/5, TNA. Minute Dated 12 August 1917.
[133] Crawshaw. 'The Impact Of Technology On The BEF And Its Commander.' p 169
[134] Air 1/521/16/12/2, TNA. Letter dated 25/9/16. From Trenchard to GS and Adv GHQ
[135] Air 1/521/16/12/2, TNA. Letter dated 29/9/16. From Haig to War Office
[136] Higham. *The Military Intellectuals in Britain: 1918-1939*. p 136
[137] Air 1/522/16/12/5, TNA. Letter dated 13 July 1917 from Trenchard to CGS, Adv GHQ. In a folder marked Policy as to Type of Aeroplanes and Squadrons.
[138] Air 1/522/16/12/5, TNA. Letter dated 14 July 1917 from Haig to Chief of the Imperial General Staff. In a folder marked Policy as to Type of Aeroplanes and Squadrons.
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[146] Simkins. *Air Fighting 1914-1918*. p 77. Buckley. *Air Power In The Age Of Total War*. (UCL Press, 1999) p 52-53
[147] Hallion. *Rise Of The Fighter Aircraft 1914-1918*. p 112
[148] Air 1/522/16/12/5, TNA. Minute dated 25 April 1917 from Adv GHQ signed by Kiggell
[149] Air 9/8, TNA. Enclosure 4. 'Air Superiority. Extracts from a Memorandum of General Trenchard, September 29th, 1916.

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[151] Hallion. *Rise Of The Fighter Aircraft 1914-1918*. p 74
[152] Peter Hart. *Bloody April*. (Cassell, 2006 [2005]) p 355
[153] Ibid p 355
[154] WO 158/35, TNA. Letter dated 6/4/17 from Trenchard to GHQ. Trenchard on this occasion characterises the casualties as, 'fairly heavy.'
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[168] Sheffield. *Forgotten Victory*. p 221
[169] Morrow. *The Great War In The Air*. p 311
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[171] Air 1/475/15/312/201, TNA. Letter dated 22 March 1918 from Salmond to Trenchard. Salmond had replaced Trenchard as GOC RFC in France in January 1918
[172] Air 1/475/15/312/201, TNA. Letter dated 23/3/18 from Salmond to Trenchard
[173] Air 1/475/15/312/201, TNA. Letter dated 25 March 1918 from Salmond to Trenchard
[174] Wise. *Canadian Airmen And The First World War*. p 509
[175] Jordan. *The Army Co-Operation Missions Of The Royal Flying Corps/Royal Air Force*. p 349, p 281
[176] Ibid p 283
[177] WO 95/94, TNA. Folder marked Summary of Tank Operations August to October 1918, memorandum 'The Battle Of Amiens.'
[178] Hooten. *War Over The Trenches*:' p 264
[179] Air 1/2124/207/74/3, TNA. Summary of Air Intelligence No 216 dated 24th September 1918
[180] Air 1/2124/207/74/3, TNA. Summary of Air Intelligence No 221 dated 30th September 1918
[181] Air 1/725/97/8, TNA. 'Extracts From 17th Army Order Dated 22 August 1918,' attached to letter dated 9th October 1918 from Adv RAF HQ

[182] Jordan. *The Army Co-Operation Missions Of The Royal Flying Corps/Royal Air Force*. p 350
[183] Sheffield and Bourne. *Douglas Haig: War Diaries And Letters*. P 434
[184] John Terraine. *Douglas Haig: The Educated Soldier*. (Cassell & Co, 2000 [1963]) p 461
[185] Sheffield. *Forgotten Victory*. p 261
[186] Jordan. *The Army Co-Operation Missions Of The Royal Flying Corps/Royal Air Force*. p 350
[187] Sheffield. *The Chief*. p 379
[188] Van Evera. 'The Cult of the Offensive and the Origins of the First World War.' p 58
[189] Air 9/8, TNA. Enclosure 4. 'Air Superiority. Extracts from a Memorandum of General Trenchard, September 29th, 1916. Trenchard lists the factors which contribute to achieving air superiority as; 'material and supply, training, tactical employment of aircraft and the morale of the fighting and ground personnel.' The importance Trenchard places on these factors is highlighted when he goes on to state, the 'Combination of these factors is essential to success. The absence of any one may entail failure.'
[190] Simkins. *Air Fighting 1914-1918*. p 77. Sheffield And Jordan. 'Douglas Haig and Airpower.' p 282
[191] John Gooch. 'Soldiers, Strategy And War Aims In Britain 1914-18.' In Barry Hunt and Adrian Preston, (Eds), *War Aims And Strategic Policy In The Great War, 1914-1918*. pp 21-40 (Croom Helm, 1977) p 24

Fit For Purpose? An Analysis of Operational Training in Bomber Command 1934 - 1944

By Trevor Nash

As a new Service, the inter-war Royal Air Force had to battle for survival against the machinations of the Royal Navy and Army that wanted to disband it and retain their own air support. At the time when the Service was evolving, global financial conditions meant funds were short and political pressure to disarm was gaining traction throughout Europe. With four home squadrons in the Metropolitan Air Force, the Expansion Schemes that began in 1934 found the Service lacking in personnel, airfields and aircraft with the result that it had no firm base from which to expand. The other major factor was that instead of a doctrine to lead operational training, the policy of strategic bombing had become one of 'dogma' which meant that training objectives could not be defined or matched to operational requirements. Despite these difficulties, Bomber Command eventually developed a multi-faceted operational training process that encompassed Advanced Flying Units, Operational Training Units, Heavy Conversion Units and Lancaster Finishing Schools. As the war progressed, this organisation, combined with new and relevant syllabi, provided a training system that was 'fit for purpose' in preparing aircrew for the new four-engine heavy bombers.

Introduction

Between 1919 and 1929, Sir Hugh Trenchard fostered a totemic belief in an independent strategic approach to air power through the use of bombers to inflict physical and morale damage to the enemy's military forces, industrial infrastructure and home front.[1] The theoretical expectations of strategic bombing were encapsulated in the Western Air Plans that were developed as a targeting list for Bomber Command in 1937.[2] These plans called for attacks on a variety of targets including airfields, roads, railways, canals, battleships, industrial targets and forests but as this paper will show, expectations were not met by the provision of trained crews to undertake these operations. In essence, there was a training gap between expectation and capability. This paper will address that training gap and examine whether the operational training being undertaken by Bomber Command was fit for purpose.

Operational training may be considered as the preparation required to undertake operations and as such, has a direct bearing on operational capability and effectiveness. It differs from *ab initio* and pre-operational training that are designed to provide a platform on which operational skills can be built. The types of operation that are to be undertaken therefore dictate the scope and complexity of the training required to achieve operational effectiveness.[3]

The RAF entered the Second World War with a doctrine based upon 50 months of Army cooperation work on the Western Front in the First World War and nine years of air control operations against villagers and tribesmen in the Middle East.[4] Air power historian Neville Jones argued that these operations 'bred a complacency amongst the planners' which led to a failure to identify the key skills needed to undertake strategic bombing.[5] In short, there was a mismatch between operational doctrine and operational training. The result was that the RAF's inter-war doctrine became 'dogma' which only began to evolve into a truly workable doctrine as the Second World War progressed.[6] When Sir Arthur Harris became Air Officer Commanding-in-Chief (AOC-in-C) Bomber Command in February 1942, many lessons had already been assimilated that, when combined with the introduction of four-engine heavy bombers, meant that strategic bombing had become far more effective than hitherto.[7] As this paper will show, this was a slow process that was shaped by a number of factors.

The arrival of four-engine bombers in 1941 drove the need for improved training to cater for specialist aircrew functions and to operate more technologically capable and complex aircraft.[8] This period also saw an increase in the use of synthetic training equipment. The key questions that need to be answered when looking at the training process are what were the factors that shaped training, whether improvements to training were evolutionary or revolutionary and fundamentally, whether that training was 'fit for purpose' to meet the needs of the new and more complex bombers? These questions must be set within the context of political and economic factors; national strategies, organisation and personalities as well as Service ethos, to assess their relative impact on operational training. As we shall see, the training to accommodate complex and sophisticated, four-engine, multi-crew aircraft was initially lacking.[9]

As the training implications required to teach individual skills and multi-crew cooperation were recognised, operational training improved accordingly. In addition, the key factors of crew wastage and aircraft production have also been considered in an analysis that assesses the need to match trained manpower with available aircraft.[10] This training planning issue is made more difficult when the coordination between different agencies such as the Air Ministry, Bomber Command, Flying Training Command and the Ministry of Aircraft Production (MAP) are taken into account. These complexities are magnified still further when considering the resources required to undertake operational training for a rapidly expanding bomber force with elements such as airfields, ranges, training aircraft, trained instructors and synthetic training equipment, all being in short supply.[11] In examining operational training within Bomber Command, this paper will primarily use the experience of General Duties (GD) branch officers.

Background

Much has been written about the inter-war period and its impact on the RAF. In terms of political and economic factors, these altered markedly throughout 1919-1938 and reflected both national and international pressures. Britain's foreign policy was also changing as emphasis shifted to protecting its Empire and avoiding 'Continental Commitment' whilst disarmament, the Great Depression and antipathy towards the RAF from the other two services resulted in a general lack of support and funding.[12] The 1923 Locarno Treaty reinforced the standing of the Ten Years Rule that was originally established by the Finance Committee of the War Cabinet in 1919.[13] This predicted 'that the British Empire will not be engaged in any great war during the next ten years' and this therefore seemed appropriate and relevant to the nation's current political and foreign policy objectives.[14] This economic argument is not supported by all historians. Ferris, for example, argues that economic determinism was subordinate to more intangible considerations such as imperial policy and cultural issues.[15] A feeling for the RAF's general standing during the inter-war period was echoed by Lord Thomson in 1926 when he talked of the RAF being the 'Cinderella of the Services' and its reputation being 'blackened' by the 'jealousies' of 'the other two Services.'[16] The RAF's approach to training prior to the Second World War was retarded by 'political neglect and financial restriction' but also by other factors, notably its structure and ethos.[17]

When investment did begin to flow into the RAF in response to Expansion Scheme 'A' following approval by the Cabinet in July 1934, the Treasury remained in a strong position to dictate policy. With Germany now recognised as the potential foe and the Ten Years Rule abandoned in 1933, RAF strategic doctrine should have implied the need to bomb that country using long-range bombers.[18] Doctrine should have driven procurement policy but 22 out of its 39 bomber squadrons were designated Light Bomber Squadrons and equipped with the Hawker Hart; a purely financial decision that was considered as 'panic buying' to dress the 'shop window'.[19] In terms of the cost savings accrued by selecting the Hart over the more capable and longer-range Virginia, a squadron of 12 Harts cost £245,000 to procure and an annual figure of £83,000 to support and maintain. The figures for 12 Virginias were £375,000 and £139,000 respectively.[20]

There was also Treasury interference when it came to training and with additional aircraft being procured, the RAF's eyes were opened for the first time to the enormity of the task ahead.[21] In 1934, 300 pilots a year were being trained; by the end of 1941, the total number of pilots trained had risen to 22,000 in addition to 18,000 specialist aircrew. Air Commodore Arthur Tedder was appointed as the RAF's Director of Training in 1934 and oversaw the initial expansion. Tedder wanted pilots to be operationally trained when they reached their squadrons but this demanded extra training and the creation of new Flying Training Schools (FTS).[22] The Treasury's response was that due to cost constraints, flying training could not be longer than 12 months and that no new FTSs should be built as they felt the expansion was a short-term requirement.[23] The result was that some basic training and all operational training took place in squadrons thereby diluting operational capability and increasing the accident rates involving expensive, frontline aircraft. Where Tedder did succeed was in creating a new training system where all *ab initio* training was undertaken at civilian FTSs to be followed by advanced military training at Service Flying Training Schools (SFTS). Even so, 'training was dependent upon extraneous factors beyond its [RAF] control' that resulted in a 'training policy [that] was of necessity based on imponderables and assumptions.'[24] What was not extraneous was the culture of the RAF as well as its approach to training.

The RAF may have been formed as a separate Service but its ethos and organisation were initially, at least, drawn from the other two Services. In April 1920, the editor of the *The Royal Air Force and Civil Aviation Record* reported that:

> At present [the RAF] is not much more than a conglomeration. A conglomeration with a glorious record, truly, but still a conglomeration. Army and Navy methods are seen in it side by side, and they do not fit. The pay system is obsolete and bad...Discipline needs tightening up all round. The paper work organisation, a hybrid of naval and military origin, is appalling....[and all aspects] need reforming and standardising on the right Air Service lines.[25]

This observation indicates that the RAF had major tasks to achieve outside those of developing its operational and training capabilities. The development of its own Officer Cadet training college at Cranwell and Staff College at Andover would certainly assist this process but contrary to many authors who claim these institutions provided a firm basis for RAF expansion, in reality these formative years were precarious due to a lack of resources and trained staff officers.

The RAF's planned development post-1919 was dependent upon the Short Service Commission (SSC) whereby officers would serve between four and five years – later increased to six - before passing into the reserve.[26] Officers were initially trained at a SFTS for 12 months and then undertook basic military training before posting to their operational squadrons with between 100 and 150 flying hours. SSC officers formed the bulk of the RAF which made the service 'an essentially short service force [and] its flyers...birds of passage.'[27] The problem that

this created was that the RAF was not building a staff system for the future but relying on those that had served with the RFC and Royal Naval Air Service during the First World War. This point was made by Wing Commander Maclean, in a lecture delivered to the Royal United Services Institution in 1934 when he said that unlike the Army and Royal Navy's objective approaches, the RAF was subjective due to its lack of experience.[28] The other problem was that operational squadrons never became truly operational because the bulk of their pilots were always semi-trained and inexperienced SSC officers. This was compounded by drafts for overseas squadrons being taken from Metropolitan squadrons and the disruption caused by Hendon Air Pageants. This disruption was so acute in 1933 that Maclean said, 'not one squadron completed the syllabus of training laid down for it.'[29]

This pre-1934 expansion period also highlighted the RAF's pilot-centric approach whereby the skills of the pilot were seen as paramount. The Chairman of the Maclean lecture, Air Marshal Sir Robert Brooke-Popham summed this up by saying that, 'I should like to stress the importance of maintaining skill in piloting...everything finally depends on the ability of the pilot to handle his aeroplane.'[30] Although clearly correct in respect to purely stick and rudder skills to meet CFS criteria and entertaining the crowds at Hendon, the RAF was failing to consider flying as an operational and not entertainment task. Add to this the lack of full-time professional aircrew to support the pilot and it can be seen that the RAF was perhaps storing up problems for the future as well as failing to take heed of new technologies and operational techniques.[31] The problem was exacerbated by the RAF's need to use funds to build facilities such as airfields and training centres and this had a direct impact on training to enhance operational capability. In short, the RAF was not well placed to expand and transition to a war footing from 1934 onwards.

Training in the Build-Up and Transition to War

The pre-war expansion of the RAF took place during 1934-1939 in a theoretical eight-phase process, with each phase being referred to as an Expansion Scheme.[32] The purpose of this expansion was to match the numbers of aircraft believed to be in-service with the German *Luftwaffe* with those operated by the Metropolitan Air Force.[33] To fly the new aircraft, 4,500 pilots were 'taken into the RAF' during 1935-1938 and this meant that on average, 1,500 pilots were being trained each year compared to the 300 in 1934.[34] This expansion of manpower and aircraft had major implications for training and the creation of an effective bomber force.[35] Although the mechanics of the various expansion schemes between 1934 and 1939 fall outside the scope of this paper, it should be stated that these schemes tended to roll into one another and were exemplified by the need to 'dress the shop window' with numbers of aircraft to achieve quantity over quality whilst 'training was sacrificed on the altar of [this] expansion.'[36] According to Smith, this expansion process was 'piecemeal, erratic and disconcertingly rapid' and one where numbers took priority over efficiency.[37]

Training gaps are easily spotted in hindsight but by 1936, the RAF had recognised that the training required to fly and operate a new generation of aircraft was completely different to

the skills and knowledge needed for post-First World War biplanes.[38] The new generation of bomber aircraft were typically all-metal, were equipped with flaps, powered turrets, variable pitch propellers and had retractable landing gear.[39] Improved aerodynamic design and more powerful engines led to increased speeds, greater ceilings and better load carrying capabilities, and as far as bombers were concerned, to the creation of larger aircraft which needed additional crew. These improved technologies began to be specified in the early-1930s and the new generation aircraft first flew in the mid-1930s.[40] With more capable aircraft entering service, the need to train specialist crew members to a higher standard became a serious challenge. Sir Kingsley Wood, the Secretary of State for Air, highlighted these problems in his memorandum to Cabinet in 1938.

> I must repeat that the limiting factor in our war strength by the end of next year [1939] will no longer be the supply of aircraft but the provision of crews to man them...the great problem is that of training, and, above all, of the very complex training required for bomber crews...[41]

This challenge was not totally lost on Bomber Command although its speed in addressing training gaps was often slow. Its first major steps were taken in 1936 when the CAS, Air Chief Marshal Sir Edward Ellington, defined a new crewing policy for large aircraft. This policy stated that bombers would have a crew comprising pilot, observer, wireless operator and an air gunner.[42] The problem was that apart from the pilot, these crew members were seconded from technical ground trades; flying was a secondary duty.[43]

The emergence of the 'Big Bomber' policy in 1936 marked a transformation in the Air Staff's concept of operations with a move towards 'large and powerful heavy or heavy-medium bombers' which were designed to 'provide superiority in range and bomb-load rather than equality in numbers.'[44] In effect, this policy, combined with the specification of aircraft such as the Stirling and Wellington, helped to clarify the emergence of new operational methods, particularly long-range night operations, which would drive future training requirements.[45] These training requirements included multi-engine conversion, navigation and operating within a multi-crew environment.

The RAF's flying training syllabus from 1936 was divided into three phases: phase one comprised basic flying training at a civilian FTS; phase two was the SFTS and used Service aircraft; and phase three was bombing, gunnery and further navigation training at the SFTS.[46] Phase one was conducted in a civilian environment prior to the pilot's induction into the RAF and lasted eight weeks in summer and 10 weeks in winter. This was followed by two weeks basic military training at the RAF Depot in Uxbridge. Phase two, the intermediate stage, saw the pilot undergo instrument flying training, cross-country flights and solo night landings and lasted 13 weeks in the summer and 15 weeks in the winter. Following two weeks leave, the now breveted pilot returned to the SFTS for the advanced stage of training which lasted the same amount of time as the intermediate phase and included a four-week attachment

to an 'armament training camp'. In all, the pilot's training lasted a maximum of 44 weeks or 10 months.[47] Pilots leaving this training scheme logged around 150 hours and would have learned their skills on the Avro Tutor and variants of the Hawker Hind; aircraft types that were well behind the technology curve of the time.[48]

As pilots emerged from this new training scheme and were sent to their Service squadrons to conduct conversion to type and operational flying training, another change was made to the composition of bomber crews in 1937 when the CAS, Air Chief Marshal Sir Cyril Newall, stated that the bomber should now contain two pilots.[49] The junior pilot would be responsible for navigation.[50] Unable to expand training resources, the flying training course was subsequently reduced to six months to accommodate the need for extra pilots and it was during this period that discussions were held to provide an extra three-month course for pilots destined for bomber and maritime roles that concentrated on navigation and night flying.[51] One of the reasons for this change can be seen in the RAF's Flying Training Manual of the time which stated:

> Flying uninterruptedly for very long periods, even under good conditions, imposes considerable physical and nervous strain upon a pilot, and, without his being conscious of it, his judgement in flying is apt to become impaired.[52]

This 'physical and nervous strain' was probably due to the pilot being responsible for piloting the aircraft, its navigation and bombing, a point that was only being recognised in January 1936 with the opening of the first Air Observer School.[53] The observer school taught gunnery and bombing during an eight-week course but there was a reluctance to take navigation away from the pilot and this only became policy in May 1939 when direct-entry sergeant observers were introduced.[54] To be appointed as sergeants after qualifying as observers, the navigation training initially received by these men was confined to dead reckoning and map reading but later included a 10 week specialist navigation course on a Service Air Observers Course.[55] The AOC-in-C Bomber Command, Air Chief Marshal Sir Edgar Ludlow Hewitt, referred to these sergeants as 'counterfeit NCOs' and 'half-baked sergeant observers'.[56] In a letter to the Under Secretary of State for Air written in May 1939, the AOC-in-C pointed out that:

> The idea that is getting about from Air Ministry sources that the air observer is to be regarded as the navigator of the aircraft is already undermining the principle, which has long been fully accepted and established in the command, that efficient navigation can only be realised in (sic) the Captain of the Aircraft himself [who] is fully capable of navigating his aircraft.[57]

Although Ludlow-Hewitt showed orthodoxy towards the RAF's 'pilot-centric' approach to aircrew, the question of specialist aircrew to undertake the discrete function of navigation was gaining traction. It was becoming increasingly clear to the RAF that the ability of crews to navigate to distant targets in all weathers was extremely limited. In his annual training report

for 1938, Ludlow-Hewitt stated, with no sense of irony, that 'phenomenally slow progress' had been made in navigation training due to 'reactionary tendencies' and 'ignorance' on the part of senior RAF officers.[58] Ludlow-Hewitt believed that navigation should be undertaken by the pilot. This 'phenomenally slow progress' was reflected in the Staff Officer Notes made for Ludlow-Hewitt when he was the RAF's Inspector General.[59] The notes refer to a visit to RAF Abingdon, the home of 6 (Operational Training) Group in November 1940. The anonymous staff officer recorded that observers were the 'weakest link of the crew' being 'not fully trained and... especially weak in map reading.' This problem was exacerbated by poor navigation training and 'no practical navigation' being 'on the syllabus of the pilots at the OTU'. Although the policy of making the observer 'fully responsible for navigation' (albeit under the direction of the captain) was decided in May 1939, as can be seen in the notes from RAF Abingdon, there was still a training shortfall and the results were clear in Bomber Command's initial operations over targets such as Wilhelmshaven.[60] The first raid was mounted on the night of 3/4 September 1939 by six Hampdens of 89 Squadron, all of which failed to find the target.[61]

The operational training shortfalls within Bomber Command during the transition to war not only concerned a lack of navigation training but also instrument training, which in 1939, led to a 'rise in the number of fatal accidents'.[62] The conflict between operations and training resources is highlighted in the correspondence between Portal as the new AOC-in-C Bomber Command and the RAF Inspector General, Ludlow-Hewitt. In April 1940, Portal wrote to Ludlow-Hewitt prior to attending a CAS Conference, at which operational squadron and Operational Training Unit (OTU) resources were to be discussed.[63] In the letter, Portal recognised Ludlow-Hewitt's efforts in establishing the Group Pool Squadrons [forerunners of the OTUs] in 1939, but said that the current 55 hour flying course 'means the absorption of 1,548 heavy bombers in...the OTUs' and that 'we should find some means of reducing the amount of flying required in those units.'[64] Portal argued that OTU training could be reduced to 30 hours for pilots with twin-engine training experience or 35 hours for those just trained on single-engine aircraft if the following provisos were met: better pilot selection; that the SFTS syllabus 'must be thoroughly mastered' with added 'cloud flying;' more capable flying instructors were required; and finally, greater use of synthetic training must be achieved, 'regardless of expense.'

The use of synthetic training by the RAF began in 1937 with the procurement of 51 Link trainers and on their receipt, the order for a further 150.[65] This training device enabled pilots to practice instrument flying although Air Ministry policy was that synthetic training should be used to enhance training and not replace flying hours.[66] From 1939, Bomber Command made some major investments in synthetic training and established a Crew Training School (CTS) at RAF Finningley to act as an experimental and development centre for future synthetic training applications. As well as the individual Link trainer, the CTS also had a Link trainer coupled with an aircraft fuselage mock-up to allow full crew training and this was referred to as 'dry-swim' training.[67] The CTS concept led to the development of Airmanship Halls which later developed into Ground Training Centres that housed a variety of different simulators including

the Grope and Silloth crew training devices.[68] In an effort to coordinate the development and use of synthetic training devices, the RAF formed the 'Simulation of Air Training on the Ground Committee' in March 1940 which was later renamed, the Synthetic Training Committee.[69] By November 1942, the RAF was using 197 discrete types of synthetic trainers. The Service may have been playing catch-up in terms of conventional training but its use of synthetic training was both innovative and far-sighted.

Until 1939, Bomber Command's operational training was undertaken in front line squadrons but this presented a number of problems. To achieve the throughput of pilots, training courses had been halved to meet the 'two pilot requirement' and therefore pilots were arriving at their squadrons with even less experience than they had in 1935. Secondly, operational bomber squadrons were exactly that and were not equipped with trained instructors or the resources to make up the shortfall of SFTS syllabi.[70] Even the instructor pilots had major shortcomings. The Macdonald report of February 1941 showed that after conducting a course on the Link trainer, 95 per cent of the instructors were not noticeably better at instrument flying than the average pupil.[71] In 1939, over 70 per cent of the squadrons in Bomber Command had 'either been formed or re-armed [with new aircraft] within the last year.'[72] Ludlow-Hewitt argued that 'over expansion' had meant that 'operational training had not kept pace' with the arrival of new aircraft or changes to Bomber Command's organisation.[73] The problem here was that inexperienced aircrew were posted to squadrons and this resulted in an increase in accident rates. This point was made by Air Marshal Sir William Mitchell when he was chairman of a conference on pilot training in 1938. 'What we have to compete with is the inexperience of pilots turned out in ten months and put into squadrons where they fly these high-speed machines...I think the cause of these accidents...is purely inexperience.'[74] According to the AHB narrative, 'Squadrons became diluted, during autumn 1941, with half-trained men, and became incapable of successful or sustained operations.'[75] This period is when the numbers of Stirling and Halifax operations were slowly increasing and so clearly, at this stage of the war, Bomber Command training was not fit for purpose.

Ironically, this dilution in mid-1941 was due to aircraft output promised by the Ministry of Aircraft Production failing to meet delivery forecasts and this created a surplus of aircrew, especially pilots. For example, in terms of heavy bombers, the first quarter of 1941 saw production of seven Stirlings, six Halifaxes and 12 Manchesters.[76]

Closing Training Gaps

With the promise of increasingly capable aircraft during the later stages of the Expansion Scheme process, the RAF developed more relevant training syllabi.[77] These syllabi included greater emphasis on night flying and navigation training. In addition, there was a gradual move towards the creation of specialist aircrew trades which replaced the use of part-time ground crew trades; the Air Observer aircrew trade was the first to be created followed by that of Air Gunner and then Wireless Operator/Air Gunner.[78] In essence, the RAF began to understand the enormity of preparing aircrew to operate complex aircraft in war and in so

doing, started to create a professional aircrew cohort. As discussed above, the problem was that the operational training was undertaken in operational squadrons and this resulted in the reduction of operational efficiency and training often being delivered by untrained and sometimes unwilling instructors.[79] In addition, although poor skills in night and 'cloud flying' had been recognised and syllabi modified accordingly, skill levels still remained low.[80] For example, between 1937 and 1939, 478 aircraft made forced landings because the pilot became lost.[81] These shortcomings were recognised by Ludlow-Hewitt, in his inspection report on taking over Bomber Command in 1937 that was sent to the Secretary of State for Air, Viscount Swinton. Ludlow-Hewitt stated that Bomber Command had a 'lack of experienced personnel' and that it was 'entirely unprepared for war, [and] unable to operate except in fair weather'.[82]

With the creation of the Command structure in July 1936, each Command could provide a more focussed approach on operational training for specific roles.[83] Bomber Command created a one star position responsible for operational training known as the Air Officer Training (AOT) and Groups were staffed with a Group Captain Training post.[84] Thus, the problems specifically associated with Bomber Command: long-range navigation, instrument flying and the coordination of a large crew within a multi-engine aircraft could be addressed within a single command. The responsibility of closing the gap between the aircrew arriving from the SFTS and the operational squadron still fell upon the operational squadrons with each group providing a Group Training Syllabus.[85] AOC Groups were given, 'full responsibility for the efficiency of the Commands, and the largest measure of discretion as to the methods and routine of [the] training adopted.'[86] The task of providing this training devolved to station and squadron commanders. Although this training process sounded logical, the training burden still remained with operational squadrons and created the previously mentioned dilution to operational capability. In a letter to the Secretary of State for Air in January 1937, the AOC-in-C Bomber Command, ACM Sir John Steele stated that the delivery of operational training was 'conflicting' with three factors: the desire to lay down a long-term training policy; the combined shortage of experienced personnel and the arrival of modern equipment; and finally, the need to maintain readiness for mobilisation.[87] In a more forceful letter written in September 1937 just prior to leaving Bomber Command, Steele expressed concern:

> ...at the delay in the provision of organisation and equipment which are necessary, both on the ground and in the air, before operational training and long-distance flying by night and day conditions of bad visibility can be carried out to a satisfactory stage of development.[88]

Ludlow-Hewitt, Steele's replacement, identified the two major challenges affecting Bomber Command's readiness for war were a lack of reserves, both aircraft and crews, and poorly trained crews. He argued that the Bomber Command Groups that were so far responsible for operational training, 'shamefully neglected' elements such as blind flying.[89] According to Ludlow-Hewitt, operational training needed to be removed from operational groups to allow the latter to concentrate on operational tasks but to achieve this, aircraft had to be taken

from operational squadrons with which to train. Formed into Group Pool Squadrons, these units were initially kept within operational groups but in September 1939, were 'concentrated' into the former 6 (Auxiliary) Group.[90] The creation of Group Pool Squadrons may be considered as a seminal moment in the professionalization of Bomber Command training and their importance was highlighted by Ludlow-Hewitt in his memorandum to AOC Groups in March 1939:

> *"...you are to be quite clear that the permanent instructional personnel, both air and ground, on the establishment of the Group Pool Squadrons, is sacrosanct, and under no circumstances is it available to you for making good deficiencies in first line squadrons. The principle must be observed since on it depends the continued output of trained operational crews".*[91]

The problem was that towards the end of 1939, the Group Pool Squadrons were becoming unable to cope with the numbers of aircrew coming from the SFTS and specialist aircrew schools.[92] Ludlow-Hewitt was unwilling to reduce the six-week course length and exchange 'a reduction in efficiency in return for greater output' so therefore more Group Pool Squadrons had to be created.[93] Although the Air Ministry recognised that the Group Pool Squadrons were a 'bottle-neck', its solution was to reduce the length of the course and not increase their number.[94] The replacement of Ludlow-Hewitt by Portal as AOC-in-C Bomber Command saw the OTU (the term OTU replaced Group Pool Squadrons from April 1940[95]) course length reduced.[96] Despite the reduction, Portal wrote in May 1940 that 'our squadrons cannot possibly maintain a sustained air campaign unless there exists a powerful organisation behind them for the provision of trained crews.' He continued and talked of the 'paramount importance' of the OTU organisation with the need to 'build it up' at 'all costs'.[97] Five days later, it was agreed to form a second OTU organisation, No.7 Group.[98]

The scale of the operational training task was now clearly recognised by the staffs at the Air Ministry and Bomber Command but this task was to become magnified by the introduction of four-engine heavy bombers. OTU aircraft such as the Wellington, Whitley and Hampden, represented operational types but with the arrival of aircraft such as the Stirling, Halifax and (twin-engine) Manchester, additional training would be required.[99] On 30 October 1940, the AOC-in-C, Sir Richard Peirse, Portal's replacement, wrote to the Secretary of State for Air and stated that special conversion to type training was required for the new heavy bombers and enquired about the need to speed up the training of the 'new flight engineers'.[100] This conversion to heavy bombers added another layer of complexity to the training equation. As the Stirling and Halifax aircraft began to arrive in squadrons from August and November 1940 respectively, the first four squadron aircraft were allocated to a Heavy Conversion Flight (HCF) and this flight was used to convert the remainder of the squadron.[101] This approach marked a retrograde step as it placed training back in the remit of operational squadrons. As production of the heavy bombers began to increase and more squadrons began re-equipment, it was decided to abandon the HCFs in favour of Heavy Conversion Units (HCU), each equipped with 16 aircraft.[102]

Initially, each Group had its own HCU but in June 1942, HCUs were concentrated in 92 Group, formerly 7 Group.[103] This new nomenclature for training groups saw 6 Group become 91 Group whilst June marked the formation of 93 Group.

The final element to be added to the training structure specifically for the four-engine bomber force was peculiar to the Lancaster. When the aircraft began to enter service in early 1942, Lancasters were initially sent to HCUs.[104] Subsequently, the aircraft was considered too valuable to be allocated to an HCU.[105] Now, pilots destined for the newly formed Lancaster squadrons would complete HCU training on the Halifax or Stirling and then receive 10 hours flying at one of three Lancaster Finishing Schools (LFS) that were formed in the winter of 1943.[106] LFSs were equipped with 18 aircraft but by March 1944 it became clear to Harris that this number was inadequate and that it should be increased.[107] As Lancaster production increased throughout the war and the Stirling was withdrawn, Lancasters were again sent to HCUs and the three LFSs disbanded.[108]

Turning to the question of the professionalization of aircrew, Bomber Command had already made major changes to its training structure and it now turned its attention to crew roles and composition. Central to this discussion was the 'pilot omnipotency' issue discussed above. During the first half of 1941, Bomber Command's policy was to have two pilots, the second pilot having additional training in navigation and bomb aiming.[109] With the expansion of Bomber Command, the onus was to improve training efficiency still further by maximising training resources to get properly trained aircrew to operational squadrons in the shortest possible time. One method of increasing aircrew throughput was to halve the number of pilots within operational squadrons. In October 1941, AOC 6 Group, Air Commodore MacNeece Foster, chaired a conference with his OTU 'Chief Instructors' where it was agreed that the best bomber manning solution was 'one pilot plus "George" over 2 pilots at present (sic).'[110] Forwarded to Groups, AOC 6 Group's suggestion was largely supported. The only dissention came from 3 Group flying Stirlings as the AOC said that the aircraft could not be flown by a single pilot as the second pilot operated controls at take-off and landing, a point later disproved by MacNeece Foster when he flew the Stirling for himself.[111] During a meeting at the Air Ministry on 29 March 1942 and chaired by Portal, it was agreed that heavy bombers should be crewed by 'one pilot plus George', one WOp/AG, specialist dorsal and tail gunners, a specialist navigator, a Flight Engineer and a specialist Bomb Aimer.[112] Although the new crewing policy would result in an 'embarrassing accumulation of pilots' at the Bournemouth holding centre, Portal said that the recommendations should be sent to the Air Council, forthwith.[113]

In parallel with this process, the Air Member for Training, Air Marshal A.G.R. Garrod, submitted a paper to the Air Council in December 1941 which considered how the overall training process could be improved.[114] Part of this paper included a review of the number of aircraft written-off per 1,000 flying hours at the EFTS, SFTS and OTU phases from 1 January to 1 September 1941: these being 2.5, 5 and 10 respectively. According to Garrod, this showed that skill levels were not increasing commensurate with flying more complex types of aircraft.[115] Although much

of Garrod's improved training programme, later known as the 'New Deal', do not come under the heading of operational training, what was achieved was to raise the standard of aircrew arriving at the OTU, in particular, through an eight-week, 60 hour Advanced Flying Unit (AFU) phase after SFTS training for those pilots destined for Bomber Command. The pupils that arrived at the OTU would have five times the previous night flying experience, improved navigation and instrument flying skills and be able to conduct beam approaches.[116]

In theory at least, improvements to Bomber Command's training structure, crewing and flight training syllabi meant that 1942 could reasonably be described as 'the turning point in the operational development of Bomber Command' but problems still persisted.[117] When Air Chief Marshal Sir Arthur Harris became AOC-in-C Bomber Command at February 1942, he had 250 serviceable bombers.[118] According to Probert, this was from a total operational fleet of 594 aircraft; at the same time there were 410 aircraft in OTUs.[119] Harris was clearly frustrated with this imbalance and had previously, 'complained that the shaft of all our training organisations... was very thick and the actual spearhead of operational effort was very small.'[120] Harris' point is debatable as it was not the shortage of crews retarding expansion but the lack of bombers being produced to fit the expansion.[121] The operational training 'shaft' had a number of problems associated with it that called for such a high number of aircraft, namely serviceability and crew wastage. Stirling-equipped HCUs were causing particularly serious concerns and were adding to the OTU bottle-neck. Accidents at Stirling HCUs per 10,000 flying hours were 48.5 compared to 21 for Halifax HCUs.[122] As Harris was taking over at Bomber Command, 6 Group was complaining of a shortage of aircraft in its OTUs that was being 'aggravated by the position of spares.'[123] In August 1941 for example, the OTUs in 6 Group were 200 aircraft below establishment and its AOC complained of poor instructors, a lack of equipment and the need to lengthen the OTU course because of poor weather.[124] As far as wastage was concerned, the training pipeline had to generate more aircrew than the number of operational aircraft logically demanded. This was highlighted in February 1941 when 5 Group called for increased crew output from the OTUs because during the four months from September to December 1940, 267 pilots joined Group squadrons from its two OTUs. Of these, 237 were killed, posted missing or 'became medically unfit' to fly.[125] As a result, the Group requested the formation of another OTU.

The implementation of the 'New Deal' and Bomber Command's crewing policy certainly alleviated the training problem, but the other factor in Bomber Command's increasing efficiency was the improvement in delivery from MAP. The first month that over 100 heavy bombers were produced occurred in March 1942.[126] Annually, in the period 1941 to 1944, heavy bomber total production was 498, 1976, 4615 and 5507 respectively.[127] More importantly perhaps, Halifax and Lancaster production gradually outstripped that of the less capable and more unserviceable Manchester and Stirling aircraft.[128] This meant training could be focussed on two instead of four types and in a Darwinian process, the best heavy bombers survived thereby reducing loss rates.

As the war progressed, the training system evolved and gradually became fit for purpose in respect to preparing aircrew to operate four-engine bombers. This was not an easy or

straightforward process as of the 55,358 airmen killed in Bomber Command, 8,090 were killed on non-operational flying, significantly on training.[129] In his *Despatch on War Operations*, Harris said that training was complicated by changing tactics, new technologies and aircraft and the 'large-scale expansion'.[130] Although a challenge, Bomber Command training did become more efficient as the war progressed as measured by OTU accident rates and output. For the period 1942 to 1945, OTU accident rates per 10,000 hours flown reduced each year to: 44, 23, 15 and 8.[131] In terms of crew output from the HCUs, a spotlight on the three-month period from March to May 1944 shows that target output was 1,215, 1,787 and 2,357 crews per month; actual output was 1,305, 1,826 and 2,418 respectively.[132]

Conclusion

The RAF in the inter-war years not only had to survive in a period of economic austerity and political uncertainty, it also had to come to terms with its very existence and the development of its own structure, ethos and culture. From the first expansion scheme in 1934, operational capability and its relationship with operational training began to be taken more seriously. New training syllabi were developed, the availability of resources increased and new types of training aircraft and synthetic training equipment were developed. As new types of modern operational aircraft were ordered to replace the older biplane types, new technologies became apparent that would alter training syllabi still further. Although Tedder had managed to improve the training syllabi, the RAF still relied on a 'pilot-centric' training process, believing that the skills involved in mounting air operations lay solely with the pilot. Other aircrew were seconded from ground trades which led to a lack of professionalism in the air and also denuded groundcrew capability. When multi-crew bombers such as the Heyford and Harrow were introduced in the mid-1930s, the CAS decided to add a second pilot to act as the navigator instead of providing extra navigational training for the air observer. This decision doubled the pilot training burden and was not challenged until October 1941 when MacNeece Foster proposed a new crew structure.

This expansion brought new equipment, the deployment to new airfields and a shortage of experienced personnel. Expansion was the goal, with efficiency in training and the preparation of a force that was fit for purpose coming a very poor second. However, considering the aforementioned lack of resources, it is difficult to see how else the problem could have been addressed. The key factor that drove improved training was the formation of the RAF's Command structure in 1936 and the appointment of an AOC-in-C Bomber Command who was ultimately responsible for operational training. As well as the formation of Bomber Command, 1936 saw the release of specifications for what became the Stirling and Halifax as well as the first flights of the Hampden and Wellington. The arrival of complex, multi-crew bombers into squadron service heralded yet another change in operational training that would ultimately make the preparation of crews fit for purpose. The formation of Group Pool Squadrons was the first step in preparing aircrew to fly four-engine bombers and remove the training burden from operational squadrons. As operational aircraft became more complex and capable, additional phases were added to the training process including the addition of the AFU, HCU and LFS courses.

The massive expansion of the RAF's bomber force between 1934 to 1944 in respect to numbers, personnel and aircraft performance, often saw operational training lagging operational capability. The impetus of the Second World War, and, in particular, the clarification of Bomber Command's *modus operandi* of night, long distance bombing, made it easier to train to meet a clear operational doctrine. Training in Bomber Command was a gradual evolution rather than a revolution and as such, operational training eventually became increasingly 'fit for purpose' as the war developed. The training gap had been closed.

Notes

[1] Air Staff Memorandum No.43, The War Aim of the Royal Air Force (C.D.64) accessed at **www.airpowerstudies.co.uk/1928-AirStaffMemo_No.43Text.pdf**, on 22 March 2013.
[2] N. Frankland & C. Webster, *The Strategic Air Offensive Against Germany 1939-1945, Vol. IV* (London: HMSO, 1961), W.A Plans Annex.
[3] See JSP 822 (HMSO, 2012) for a description of the context between training and operational capability. As an example of doctrine driving training, consider that if strategic bombing requires long-range flights in bad weather at night over enemy territory, crews should be well trained in skills such as instrument flying and navigation.
[4] T. Davis Biddle, *Rhetoric and Reality in Air Warfare* (Princeton: Princeton University Press, 2002) pp.81-83.
[5] N. Jones, *The Beginnings of Strategic Air Power – A History of the British Bombing Force 1923-1939* (London: Cass, 2002) pp.xx-xxi.
[6] J. Terraine, 'Theory and Practice of the Air War' in H.Boog (ed) *The Conduct of the Air War in the Second World War* (New York: Berg, 1992) p.474.
[7] As the paper will show, by early 1942, Bomber Command's doctrine had become clearer but what was holding it back was a lack of aircraft and operationally trained crews.
[8] O. Thetford, *Aircraft of the Royal Air Force Since 1918* (London: Putnam, 1976) provides an excellent historical overview of the RAF's bomber aircraft and their capabilities.
[9] See for example Ludlow-Hewitt's 1938 report on Bomber Command training in N. Jones, *The Beginnings of Strategic*..., p.147.
[10] One element of this crew wastage and Harris' particular bête noir was posting trained crews to Coastal and Middle East Commands. Sir A. Harris, *Bomber Offensive* (London: Greenhill Books, 1990) p.99 and Harris' interview with T.Mason at the RAF Staff College Bracknell in 1977.
[11] AHB LHP, Ludlow-Hewitt's *Draft Operational Training Plan*, dated January 1939 highlights shortages of instructors, aerodromes and spares.
[12] S. Robertson, *The Development of RAF*..., p. xv.
[13] S. Robertson, *The Development of RAF*..., pp.29-30. Robertson's comments on the Ten Years Rule make the point that despite being ridiculed by some historians, future 'events...could not be foreseen.'
[14] TNA PRO, CAB/24/196. CID Minutes, *The Basis of Service Estimates*, 2 July 1928.
[15] J.Ferris, 'The Greatest Power on Earth: Great Britain in the 1920s in *The International History Review*, XIII,4, November 1991, pp. 661-880, p.726-8.
[16] Hansard, House of Lords Debate on Air Policy, 10 March 1926, Vol. 63, cc527-545.

[17] TNA PRO, AIR 10/5551, Flying Training Volume 1, Policy and Planning, AP3233, p.11.
[18] TNA PRO, AIR41/39, p.60.
[19] TNA PRO, AIR 41/39, p.80 discusses the selection of the Hart and concludes quantity and not quality of aircraft was the key factor.
[20] Ibid. pp.80-81.
[21] Ibid, provides numerous examples of the Treasury shaping equipment procurement and defence posture. The document highlighted 'comparatively slow progress' on offensive development due to economic factors.
[22] TNA PRO, AIR 41/4 *Aircrew Training 1934-1942*, pp.2-29.
[23] TNA PRO, AIR41/4, p.29 talks of the financial need to keep the course duration 12 months and use the 'bare minimum of schools'.
[24] TNA PRO, AIR 10/5551, p.1.
[25] J.W.R. Taylor, *C.F.S. Birthplace of Air Power* (London: Putnam,1958) p.93. Taylor also cites Churchill's speech in the House of Commons of March 1920 in which he said the Army and Royal Navy were supportive of the RAF's existence. Taylor says Churchill was 'deceived'.
[26] TNA PRO, AIR 41/8, p.114.
[27] Ibid.
[28] L. Maclean, 'The Royal Air Force Training Year at Home' in *The Royal United Services Institution Journal*, No. 80, February/November 1935, pp.50-68. Wing Commander Maclean was a staff officer at Air Defence of Great Britain.
[29] Ibid.
[30] ibid.
[31] S. Robertson, *The Development of RAF...*, pp.151-152.
[32] TNA PRO, AIR 41/8, p.33.
[33] See for example TNA PRO, CAB/23/90A, the Cabinet Minutes of 8 December 1937, Item 7, *Comparison of the Strength of Great Britain with that of Certain other Nations as at 1st January 1938* and 'the maintenance of parity between the Air Force of the United Kingdom and that of Germany.' The Metropolitan Air Force was the name given to the RAF forces stationed in Britain.
[34] TNA PRO, AIR 41/8, pp. 116-117.
[35] Appendix 7 'Comparison of Expansion Schemes of Aircraft Strength, 1934-39' in Webster, C and Frankland, N. *The Strategic Air Offensive...Vol. IV* gives a comprehensive view of the squadron and aircraft numbers involved.
[36] TNA PRO, AIR41/4, p.62. See also AVM M. Robinson, 'Training the Bomber Force for World War Two' in the *RAF Historical Society Journal*, No. 20, 1999. pp.8-15.
[37] M. Smith, 'Sir Edgar Ludlow-Hewitt and the Expansion of Bomber Command, 1939-40' in the *Royal United Services Institute for Defence Studies Journal*, 126:1 (March 1981) pp.52-56.
[38] AHB LHP, Ludlow-Hewitt's *Readiness for War Report* dated 10 March 1939.
[39] A.M. Sir C.L.N. Newall, 'The Expansion of the Royal Air Force' (lecture) in the *Royal United Services Institution Journal*, No.81, February/November 1936, pp.347-354.
[40] O. Thetford, *Aircraft of the Royal Air Force...*, The Whitley was first specified in July 1934 (B.3/34) and the Stirling in July 1936 (B.12/36).
[41] TNA PRO, CAB/24/279. *Relative Air Strengths and Proposals for the Improvement of this Country's*

Position, Memorandum by the Secretary of State for Air dated 25 October 1938.
[42] TNA PRO, AIR 10/5551, p. 19.
[43] TNA PRO, AIR41/4, pp.37-38. The AHB monograph says that these secondary trade aircrew, 'did not reach full efficiency in their flying duties.'
[44] TNA PRO, AIR 41/39, pp.120-125.
[45] TNA PRO, AIR41/39, pp.120-126. Doubts about the light bomber began to emerge in 1934 and the CAS memorandum of 8 November 1935 which stated that the 'short range and small load' of such aircraft made them of limited value in a war against Germany. In response O.R.2 pointed out the threat to bombers of modern fighters when engaged on daylight operations.
[46] AVM L.A. Pattinson, 'The Training of a Royal Air Force Pilot' (lecture) in the *Royal United Services Institution Journal*, No.83 February/November 1938, pp.11-21. AVM Pattinson was AOC 23 (Training) Group.
[47] Ibid. pp.11-21.
[48] AHB, *Notes on the History of Royal Air Force Training 1939-1944* (London: HMSO, 1945) p.25. In 1937, the average hours flown by a pilot joining his operational squadron was 146.
[49] TNA PRO, AIR41/8, pp.29-30.
[50] C.G. Jefford, *Observers and Navigators and Other non-Pilot Aircrew in the RFC, RNAS and RAF* (Shrewsbury: Airlife, 2001), p.131,
[51] TNA PRO, AIR41/8, pp.29-30.
[52] NAL, AP129. *RAF Flying Training Manual Part 1 – Landplanes* (Revised 1937). Chapter 4, Long-Distance Flying, para. 71.
[53] TNA PRO, AIR10/5551, p.19.
[54] TNA PRO, AIR 2/4467 Letter to RAF Commands from Principal Assistant Secretary to the Permanent Under Secretary of State for Air dated 22 May 1939.
[55] TNA PRO, AIR10/5551, p.25.
[56] TNA PRO, AIR2/2968 letter from Ludlow-Hewitt to AMP, AVM Portal dated 12 May 1939.
[57] AHB LHP, Ludlow-Hewitt letter to Under Secretary of State for Air, dated 25 May 1939.
[58] AHB LHP, *Bomber Command Annual Training Report – 1938* dated 23 January 1939.
[59] AHB LHP, *Staff Officer Notes for Visit to Abingdon, 22 November 1940*. 6 Group was home to the Group Pools and later Operational Training Units during the early years of the war.
[60] TNA PRO, AIR10/5551, p.19.
[61] P. Bishop, *Bomber Boys* (London: Harper Perennial, 2007) pp. 1-3.
[62] AHB LHP, Letter from Ludlow Hewitt, to CAS dated 3 December 1939.
[63] AHB LHP, DO letter, Portal to Ludlow-Hewitt dated 11 April 1940 concerning CAS Meeting.
[64] Ludlow-Hewitt was actually responsible for the formation of the Group Pool Squadrons that became known as OTUs from April 1940.
[65] AHB, *Notes on the History of RAF Training 1939-44* (London: HMSO, 1945) Annex W – Synthetic Training.
[66] *Ibid*.
[67] AHB LHP, *RAF Inspector General Visit Report No. 7, Finningly*, dated 26 April 1940. In the report, Ludlow-Hewitt called for the establishment of a designated officer at the Air Ministry to coordinate synthetic training.

[68] Sir A. Harris, *Despatch on War...*, p.167.
[69] AHB, *Notes on the History...*, Annex W – Synthetic Training.
[70] TNA PRO, AIR41/4, p.282.
[71] TNA PRO, AIR41/4, p.323.
[72] AHB LHP, *Readiness for War Report*, AOC-in-C to Secretary of State for Air dated 10 March 1939.
[73] Ibid.
[74] AVM L.A. Pattinson, 'The Training of a Royal...', AVM Pattinson was AOC 23 (Training) Group. Mitchell's comments are very interesting as he describes a lack of instruments hampering 'bad weather flying'.
[75] TNA PRO, AIR41/41. *The RAF in Bomber Offensive Against Germany: Vol. III Area Bombing and Makeshift Force June 1941-February 1942*, p.24.
[76] NAL, J.V. Connolly Collection, *Ministry of Aircraft Production Statistical Review 1939-1945*, published January 1946.
[77] TNA PRO, AIR41/8, pp.71-72 describes 'The winter of 1938 [as the] dividing line between the old order and the new' with the RAF in 1934 being a 'force of wooden bi-planes' and in 1939, 'a force of metal monoplanes'.
[78] TNA PRO, AIR10/5551, pp.24-25.
[79] AHB LHP, Bomber Command Annual Training Report 1938 dated 23 January 1939.
[80] TNA PRO, AIR2/4168, Paper from DWTT to ACAS dated 12 April 1940 points out the poor standard of FTS graduates with only 'a small proportion of pilots...trained on twin-engined aircraft' and pilots with 'an average of two hours (night) solo.'
[81] R. Wakelam, *The Science of Bombing* (Toronto: University of Toronto Press, 2009) p.15. Wakelam also points out that the Air Ministry did not establish an Air Navigation Office until 1938.
[82] AHB LHP, Inspection Report from AOC-in-C Bomber Command to Lord Swinton, Secretary of State for Air dated 10 November 1937. Ludlow-Hewitt also complains about the lack of W/T and navigation equipment.
[83] J. Terraine, The Right of the Line (Ware: Cumberland, 1999) p.23. Training Command was created in May 1936. Discussion on the formation of the new command structure started in 1935. TNA PRO, AIR2/8875 *Organisation of Home Commands Consequent on Expansion Scheme C*, Minute from CAS to DCAS, dated 5 June 1935.
[84] See for example, TNA PRO AIR 14/2156 and the 'Forecast on Expansion of Bomber Command to Target Force "A" By The End of 1941' paper written by Air Commodore A. Lees, AOT, Bomber Command. Group Captain Training positions are discussed by R. Wakelam in *The Science of Bombing*, p.18.
[85] TNA PRO, AIR 14/45, Bomber Command Training instructions dated 25 November 1936 from HQ Bomber Command to Air Ministry and the four Bomber Group SASOs.
[86] Ibid.
[87] TNA PRO, AIR 2/2058, letter AOC-in-C to Secretary of State for Air, dated 27 January 1937. The shortage of experienced personnel and the arrival of modern equipment were considered as one factor by Steele.
[88] TNA PRO, AIR 2/2058, letter from AOC-in-C to Secretary of State for Air dated 1 September 1937.
[89] AHB LHP, Ludlow-Hewitt War Diary, Sunday 10 December 1939.

[90] TNA PRO, AIR 2/4168, loose minute from Air Commodore R.P. Willock, D.S.D. to H.Q. Bomber Command.
[91] TNA PRO, AIR 2/4168, memorandum from AOC-in-C Bomber Command to AOC Bomber Command Groups dated 16 March 1939.
[92] TNA PRO, AIR 2/4168, letter from AOC-in-C Bomber Command to Secretary of State for Air, dated 6 October 1939.
[93] Ibid.
[94] TNA PRO, AIR 2/4168, letter from Sholto Douglas (ACAS) to AOC-in-C Bomber Command dated 3 October 1939. This reduction by two weeks would have meant crews flying 33-35 hours instead of 55-60 hours.
[95] TNA PRO, AIR 41/4, p.238.
[96] TNA PRO, AIR 2/4168, Note of Conference Held in CAS's Room, 19 April 1940. As a *quid pro quo*, Portal asked for improved pilot selection, better FTS instructors, an improved FTS syllabus and the increased use of synthetic training equipment.
[97] TNA PRO, AIR 2/4169, letter from AOC-in-C to Under Secretary of State for Air, dated 11 May 1940.
[98] TNA PRO, AIR 2/4169, memorandum from HQ Bomber Command to Operational Groups dated 16 May 1940. The new OTU organisation was referred to as 7 Group.
[99] TNA PRO, AIR 2/4169, letter from Air Commodore Capel, Director of Operational Training at the Air Ministry to the new AOC-in-C Air Marshal Sir Richard Peirse, dated 11 October 1940. Capel states that to maintain an operational squadron of 16 aircraft required 24 heavy bombers in the OTU. He asked Portal to consider how this additional heavy training should be delivered.
[100] TNA PRO, AIR 2/4169, letter AOC-in-C to Secretary of State for Air dated 30 October 1940.
[101] TNA PRO, AIR 10/5551, p.170.
[102] TNA PRO, AIR 10/5551, p.171.
[103] TNA PRO, AIR 14/1136, 'HCU and LFS Expansion', see for example, memorandum from Director of Operations to Group AOCs on the formation of additional HCUs, dated 24 March 1943.
[104] W.R. Chorley, *Bomber Command Losses* Vol.8 (Hinckley: Midland Publishing, 2003) p.176.
[105] R. Overy, *Bomber Command 1939-1945* (London: Harper Collins, 1997) p.143.
[106] K. Delve, *Bomber Command 1936-1968* (Barnsley: Pen & Sword, 2005) p.190.
[107] TNA PRO, AIR 2/7965, letter from AOC-in-C to Under Secretary of State for Air, dated 24 March 1943.
[108] W.R. Chorley, *Bomber Command Losses*, p.176.
[109] This policy even applied to the single-cockpit Hampden. See TNA PRO, AIR 14/2156, letter AOC-in-C, Air Marshal Peirse to Under Secretary of State for Air, dated 30 January 1941.
[110] TNA PRO, AIR 14/10 'Aircraft Crews – Policy', memorandum AOC 6 Group to AOC-in-C Bomber Command, dated 31 October 1941. 'George' was the name given to the aircraft's auto-pilot system.
[111] Ibid. Memorandum, AOC 3 Group to AOC-in-C dated 2 February 1942.
[112] TNA PRO, AIR 14/1020, 'Note Of A Meeting Held In The Air Council Room at 11 am. On Sunday, The 29th March, 1942', undated.
[113] Ibid.

[114] TNA PRO, AIR 10/5551, pp.161-163.
[115] Ibid.
[116] TNA PRO, AIR10/5551, pp.161-163.
[117] C. Webster & N. Frankland, *The Strategic Air Offensive*...Vol. III, p.300.
[118] D. Richards & Hilary St George, *The Royal Air Force Vol. 2*, (London: HMSO, 1953) p.121.
[119] H. Probert, *Bomber Harris* (London: Greenhill Books, 2006) p.114.
[120] TNA PRO, AIR 14/10, Harris quoted by MacNeece Foster in a memorandum, AOC 6 Group to AOC-Cin-C dated 13 January 1942.
[121] TNA PRO, AIR 41/42, *The RAF in the Bomber Offensive, Vol.IV, A Period of Expansion and Experiment March 1942-January 1943*, p.38.
[122] TNA PRO, AIR 2/7965, loose minute from Wg Comd G.N. Anison, AM O.7 (2) to AM T.01. Anison says 'that the Stirling is the most difficult of the heavy aircraft to fly.'
[123] TNA PRO AIR 14/490, letter AOC 6 Group to HQ Bomber Command dated 25 February 1942.
[124] TNA PRO AIR 14/2156, 'Minute of Training Conference Held at Headquarters Bomber Command on August 26th, 1941'.
[125] TNA PRO, AIR 14/2156, letter from SASO 5 Group to AOC-in-C Bomber Command, dated 6 February 1941.
[126] NAL, JV Connolly Collection, *MAP Statistical Review 1939-1945, Table 1*, dated January 1946.
[127] Ibid.
[128] NAL, JV Connolly Collection, *MAP Statistical Review 1939-1945, Table 3*, dated January 1946.
[129] C.Webster & N. Frankland, *The Strategic Air...Vol. III*, p.287.
[130] S. Cox (ed) Sir Arthur Harris, *Dispatch on War Operations* (London: Cass, 2001) p.163.
[131] Ibid. p.168.
[132] TNA PRO, AIR 2/7965, Monthly HCU Summaries from AOT Bomber Command to Groups and AM, various dates 1944.

Concentration and Asymmetry in Air Combat: Lessons for the Defensive Employment of Air Power

By Ian Horwood, Niall MacKay and Christopher Price

Have air power theorists learned the right lessons from history? We argue that, in the employment of air power to deny air supremacy or defend surface targets, they have not. The classic hypothesized dynamic of air combat is Lanchester's 'Square Law', under which numbers are disproportionately important. Using data from various air campaigns, we demonstrate that air combat does not obey a tactical Square Law. Rather it consistently displays a very different, hitherto-unobserved property: it is asymmetric between attack and defence. Air power theory's stress on the offensive, combined with a principle of concentration (often framed as 'mass'), obscures this asymmetry. We consider historical air campaigns to show that in air defence, especially when outnumbered, concentration does not equate with mass, instead requiring dispersal and parsimony. This resonates with the British experience: in the Battle of Britain, in the Falklands and in lessons for the future optimal employment of British fighter aircraft.

Introduction

I.

A mathematical model of war is a dangerous thing, as military analysts know. No attempt to predict the outcome of a conflict as a function of the order of battle can possibly survive the fog of war. And yet such models persist, and become ever more complex, ever higher-dimensional. The danger is that one of their principal virtues, the stimulation of careful thought about the quantifiable aspects of combat, becomes lost in the 'black box'.[1] When the UK Ministry of Defence announces that its procurement software has 'millions of variables and constraints', alarm bells should ring.[2]

The discipline of operational research (OR) has flourished for nearly a century, ample time to furnish a historical perspective.[3] The oldest and simplest mathematical models of war are the coupled differential equations of Lanchester.[4] These are very much in the spirit of their age, for they were derived independently in the USA and Russia (although not published there at the time), and their essential conclusions were also reached in France.[5]

Lanchester's aim was to understand the implications of the new conditions of warfare then developing, in which long-range weapons, both aimed and unaimed, enabled force concentration to take new forms. In particular, his 'square law' implies that, in the use of targeted long-range firepower, concentration is disproportionately effective. As we shall see, the irony is that Lanchester's work, and the subsequent formulation of the principles of war by Fuller, who precisely understood Lanchester's point, became distorted through a perspective, a distortion of Jomini and Clausewitz,[6] in which 'mass' became predominant and was conflated with concentration. Indeed, when the US Army adopted Fuller's principles of war in 1921 the term 'concentration' was replaced with 'mass,' a change which has promoted much confusion in doctrinal thinking.

Lanchester believed that the equations of his 'square law' should describe air combat,[7] and it is a striking coincidence that it was his country which, less than thirty years later in the Battle of Britain, had to fight the first great purely aerial battle of attrition. Further, the central controversy of the battle, that of 'Big Wings' whether, all else equal, it was better to concentrate fighters before engagement – was precisely a Lanchestrian question. During the inter-war period, the fighting force which had to answer this question, the Royal Air Force, was conceived, developed its principles and doctrine, and invented its traditions. Its development, and its first great task, the Battle of Britain, were the subject of recent work by two of the present authors,[8] and form a natural beginning from which to approach two questions:

(1) Does air combat obey Lanchester's 'square law' of concentration of aimed firepower?
(2) How should fighter forces, especially in defensive roles and when outnumbered, be employed?

As we shall see, the answer to the first question is 'No'. A meta-analysis, using data from the Battle of Britain, the US-Japanese Pacific air war and the Korean War, leads to a clear overall picture: air combat is not square-law. There is no tactical advantage in terms of concentration to be gained by massing aircraft. Rather the historical data, including engagement-level data from Vietnam, indicate that the opposite can be true for one force, and that attrition scaling in air combat may typically be asymmetric. Cases in which an outnumbered defence achieves its aims, as in the Battle of Britain or the Falklands War, or over Vietnam, thus indicate a nuanced situation, in which asymmetry is the most salient feature. Conversely, the defeat of a numerically inferior force defending the attacker's surface objectives, such as that of the Luftwaffe in the US daylight offensive of 1944-5, does not necessarily demonstrate a tactical advantage in battle for the larger, attacking force: the critical issue might well be the availability of resources for a sustained attritional struggle. In 1940 the outnumbered RAF enjoyed constant and growing reinforcement – in 1944-5 the Jagdwaffe did not. The resources of its enemy grew, the USAAF mounting 559,617 effective combat sorties in the European Theatre in 1944 compared to 50,163 in 1943,[10] while its own diminished at an increasing rate for reasons not exclusively connected with the battle in the air. The Lanchestrian concept of concentration, as refined by Fuller,[11] remains valid at an operational or strategic level, but requires a more subtle treatment than it has typically received.

The latter conclusion changes radically the approach needed to answer the second question. Air power theory has not been strong in conceptualizing the asymmetry between attacker and defender. Principles of air war have typically stressed offence,[12] but the tactics by which an outnumbered defending force can best frustrate an offensive have rarely been discussed, let alone elevated into theory.[13] Asymmetry was first incorporated into Lanchester's models in the 1960s,[14] but the implications for air power have been considered very little. The conditions which lead to asymmetry are those in which the defender can conceal all or part of his force from the attacker's weapons and thus shift the odds in his favour, very dramatically if the defender can still bring all his weapons to bear on the enemy. In such circumstances it is pointless to speak in terms of attrition or loss ratios as the defender has merely to frustrate rather than annihilate the enemy. It is possible, however, to discuss the Lanchestrian concept of concentration as Fuller understood it: as the economical and effective use of firepower.

This paper is structured as follows, in approximate historical order. In section II, based on the authors' previous historical work, we discuss Lanchester models and the Battle of Britain,[15] reviewing the development of ideas which culminated in the 'Big Wing' controversy. In section III we discuss the US experience during the Second World War and over Vietnam. In section IV we answer our first question, by examining attrition data from the Second World War, Korea and Vietnam,[16] and arrive at the conclusions noted above: air combat is not square-law, but it is asymmetric. In section V we explore further our second question, drawing parallels between the Battle of Britain and the use of air power in the 1982 Falklands campaign. Section VI examines the Gulf War of 1991 and lessons for the future, particularly with regard to unmanned aerial vehicles. As we note in a concluding section, the importance of this work lies in the

possibility of unhappy historical experiences being repeated in the absence of a conscious understanding of the influence of false conceptions of 'concentration' on real air warfare.

II.

To anyone steeped in the natural sciences or engineering, Lanchester's ideas are naturally framed as a question about scaling: How do two antagonists' losses scale with their own and their opponents' numbers? From the answer one can deduce for each force an *exponent*, the power of that force's number of engaged units which, when multiplied by their individual effectiveness, yields the force's fighting strength. This in turn allows us to deduce for each force the value of numbers and their concentration relative to individual prowess. Concentration adds to the fighting power of the individual to the extent by which the exponent exceeds one. When the two exponents differ – that is, when a battle is asymmetric – they have a second implication, with the ratio of the two forces' individual fighting effectiveness being multiplied by the ratio of the exponents, giving the side with the lower exponent a 'defender's advantage',[17] classically associated with guerrilla warfare.[18]

Lanchester contrasted two scenarios, in both of which the battle is symmetric, and the two forces' exponents the same. In the first, his 'linear law', the exponent is one, and there is no particular value in concentration. This occurs in 'ancient' warfare, of roughly equal numbers engaging hand-to-hand along a battle line. It also applies to long-range fire when that fire cannot be aimed accurately ('firing into the brown'). This is in stark contrast to his 'square law', where the exponent is two, and which follows from combat in which each force causes losses in simple proportion to its numbers, which Lanchester believed would result from accurate long-range aimed fire.[19]

Lanchester was a keen self-publicist, visiting the western front, corresponding with important figures such as Trenchard and Henderson, and distributing copies of his book widely to Royal Flying Corps officers.[20] His direct influence on the shaping of the RAF was great.[21] Lanchester's ideas were developed by J. F. C. Fuller, whose 1916 principles of war formed the basis of most post-war doctrine, and were taken up wholesale by the RAF via the Army's Field Service Regulations.[22] Fuller's was a subtle understanding of the square law: above all, he appreciated that 'whilst formerly the application of the principle of concentration aimed at massing numbers of men, it should now aim at accentuating weapon-power'.[23] The implications of this distinction for air defence were profound but as yet unappreciated.

When aircraft were new, operational tactics had to be developed for them *ab initio*, first in the combat conditions of the Second World War, and then at greater leisure during the inter war period. Discussion of the development of RAF fighter doctrine tends to be masked by the large literature on use of the bomber, but it is quite possible to trace its development through the inter-war period in the lectures of the RAF Staff College, and this has been done elsewhere by the present authors.[24] It is striking, indeed, how little real intellectual development and exploration there was: the College was deliberately closed to external scholarly influence and

seems rather to have functioned as a vehicle for entrenching an RAF doctrinal culture than as an open-minded and responsive developer of tactics appropriate for rapidly-changing technology.[25] The result was that ambiguity and inconsistency developed in doctrine over time in the absence of rigorous debate and the testing of concepts. Indeed, it has been argued that in most major powers before the Second World War, 'air doctrine, being drawn closely into the general battle doctrine of the army leadership, was still over-influenced by Clausewitzian thinking from which it was slowly disentangled as the war progressed'.[26]

The picture that had emerged on the eve of the Battle of Britain was confused. At squadron level, formation attacks remained paramount as they were assumed to be the best means of concentrating firepower on formations of bombers at a time when the capability of single aircraft to down raiders was not trusted. At operational level, even in 1939 there remained great uncertainty about what bomber formations should be attacked, and whether attacks should be concentrated. The main antagonists – at group level, Park and Leigh-Mallory – could both consider on the basis of their staff college education that their views represented effective concentration. Leigh-Mallory's 'Big Wings' were clearly consistent with the principle of mass.[27] But, as Fuller had emphasized, concentration of aimed weapons – in this case, the fighters themselves – in Lanchestrian terms was a matter of ensuring that all fighter sorties found targets while not becoming targets themselves in the air or on the ground at their stations. As has been pointed out, Park's tactics achieved this, often with very large numbers of planes in the air, but without necessarily achieving local numerical superiority.[28]

Nor was this necessary: Overy argues that in the Second World War, 'air activity was continuous. Air battles in the conventional sense in which armies and navies fought battles could not be fought because air forces apparently defeated could be reconstituted in days by new production, repair or re-siting.'[29] Obsession with mass was therefore inappropriate to the air battle, particularly as 'although superiority could be gained at one moment or in one place it was often to prove during the war that this was at the expense of superiority somewhere else.'[30] The concept of massing aircraft for a decisive encounter could thus be considered illusory. 11 Group units, particularly the Poles, demonstrated that slashing attacks by one or two squadrons on large bomber formations exploited a target-rich environment and degraded the enemy's cohesion while being themselves hard for escorting Luftwaffe fighters to fix and engage successfully.

Before interception there was also less reward for German fighters in bouncing a climbing squadron than a similarly disadvantaged Wing. Indeed, Wings tended to move away from the enemy initially to formate in peace before joining the battle, which limited their involvement and placed units on the ground, the bombers' targets, in danger. The large unwieldy formation was also easier for the enemy fighters to see and parry with their famously fluid tactics when it did arrive. Thus the employment of the Big Wing, which seemed quintessentially offensive to its proponents, seemed rather less aggressive to the enemy and 'suited the Luftwaffe better' than the early, constant and wearing attacks of Park's squadrons.[31]

Another way of framing the situation is as a contrast between offensive and defensive tactics.[32] While Fuller and Lanchester understood that firepower concentration was neutral on this point, the Jominian perspective adopted by the allies' inter-war doctrine emphasized offensive through mass, to which Leigh-Mallory's mind was very receptive, but which did not allow for evolution of Lanchestrian defensive tactics. Indeed, one can perhaps better frame Dowding and Park's parsimonious approach, limiting commitment of the total force and rotating units through the battle area, in very old-fashioned terms, as a reverse-slope defence in which the Luftwaffe was unable to hit the RAF accurately, and north of the Thames not at all.[33] Furthermore, destruction of German bomber formations was not entirely necessary, as disruption resulting in failure to destroy fighters on those stations they could reach achieved a Lanchestrian effect. This was a benefit opposite to the tardy Big Wings' tendency to cause losses by exposing airfields to attack. Thus Dowding and Park's employment of Fighter Command engineered for it a defender's advantage, unanticipated in the pre-war formulations of Lanchester's equations, which never incorporated asymmetry between the forces.[34]

The confusion remained in the famous Air Ministry meeting of October 1940 which led to the removal of Park and Dowding, where it reached its acme in the phrase 'it was generally agreed that ... the more we could outnumber the enemy, the more we should shoot down'.[35] This is clearly the case, but is not what was needed to win even the attritional battle, which was rather to maximize the number of enemy casualties for each of one's own casualties. Mathematically, the crux of the argument is arrived at when one recasts Lanchester's equations as a statement about the casualty exchange ratio (the ratio of the two forces' losses). If this is proportional to the force ratio, the square law follows. If it is approximately constant, the linear law follows. And only in the former case is there any value in mere massing of sorties, all other things being equal.[36]

III.

If Fighter Command in 1940 had won a great victory it did not fully understand as an institution, the same might be said of the USAAF's elimination of the Luftwaffe air defence of Germany in 1944-5. This victory is usually perceived in the context of a transformation achieved by the introduction of genuinely long range fighter aircraft in 1944-5, escorting in great strength US bombers which themselves degraded the German air defence, particularly by attacking its fuel supply. This situation is contrasted with the bloody reverses of 1942-3 when daylight bomber formations proved unable to defend themselves effectively after their escort had turned for home.

However, it is not necessarily the case that massed Mustangs swept the sky of opposition by themselves. In the first six months of 1944, for example, the Luftwaffe destroyed 2,216 enemy aircraft by day over Germany, losing 2,010 itself.[37] These numbers do not speak for the tactical extermination of the outnumbered Luftflotte Reich, especially as allied figures included only aircraft which failed to return from enemy territory and excluded those damaged aircraft which crashed closer to home. Moreover most allied aircrew who survived the loss of their aircraft would become prisoners.

The Jagdwaffe, however, was fighting more numerous enemies on many fronts and faced sharp degradation in 1944 from many causes. Not least of these was Hitler's near complete lack of interest in air defence. His concept of concentration was very much based on mass and the offensive, and he therefore 'refused to sanction the diversion of resources to a defence in depth like that practiced by the RAF in 1940'.[38] He compounded this error with a 'failure to understand how the system of air reserves operated, and insisted that reserves should be used for concentrated operations with the largest numbers that could be mobilised at any one time'.

Even without the malign influence of the Fuhrer, the Luftwaffe faced a hopeless situation in the medium term. The enduring stress caused by having to meet RAF bombing by night as well as US incursions by day, often with the same aircraft and pilots, and the attrition faced on retreating battlefields on the Eastern and Mediterranean fronts was greatly added to by the successful allied invasion of France, which the Luftwaffe was utterly unable to resist. It met 12,837 aircraft with 300 and these, 'along with the German reinforcements were shot out of the skies in ten hours'.[39]

The success of the Normandy landings and the subsequent collapse of the German position in France brought the massive tactical air power of the western allies within reach of Germany, removing a key defender's advantage which had prevailed before June 1944. It also tore a hole in the German radar screen. The Luftwaffe was thus overwhelmed on many fronts and wasted away, unable to pilot and fuel the many aircraft Speer was delivering from factories. Thus, in addition to their own efforts the vast USAAF formations which flew over Germany in 1944-5 were powerfully assisted by a concatenation of other forces. It would be a heroic assumption that massed fighter escort by itself would have turned the tide against an undiminished air defence by day.

The danger, therefore, is to confuse a massive material advantage in the context of total war with the tactical realities of air combat; and, as the Allies waged industrial war so consciously and effectively, this was a tempting mode of thought. Certainly, the victorious experience of 1944-5 reinforced the US emphasis on mass as an interpretation of concentration and enhanced confidence in the pre-war conception that offensive use of air power over the enemy homeland was the key to victory. The formation of Strategic Air Command and its leadership by LeMay embodied this interpretation of the Second World War experience which was left untouched and untested by the Korean War, in which the severe losses experienced by the escorted B-29 force were ascribed to their relative technological backwardness rather than any doctrinal failings. In the non-nuclear context, however, the next thorough test of US doctrine would come in the sustained struggle over North Vietnam, where conditions more closely resembled the Battle of Britain than the fight over Germany.

The American experience over North Vietnam gave full play to the subtleties of asymmetry and placed great strain on the US conception of concentration in air warfare.[40] The USAF and

USN faced a fully integrated air defence and one which could not be degraded by a downward spiral of material resources available to face many tasks as the Luftwaffe had been. The NVAF had only one goal, to resist US incursions on its territory, and it enjoyed secure lines of supply to a superpower through a committed neighbour.[41] Thus without escalating the war to include North Vietnam's allies, or separating the communist states diplomatically as Nixon and Kissinger attempted with temporary success late in the war, US air power faced a daunting task in achieving national goals.

Indeed, the aims of policy were unclear beyond preventing the fall of the South Vietnamese domino. In this context the offensive use of US air power would involve a bomber offensive intended to produce a collapse of the political will to continue the war in Hanoi. USAF and USN pilots thus found themselves in a position more closely resembling the Luftwaffe after 7 September 1940 in the Battle of Britain than the USAAF over Germany later in the Second World War, in that the air arm was used optimistically in pursuit of an ill-defined political effect intended to produce victory.[42]

The stage was thus set for a protracted battle of attrition in which it was revealed that mass was not synonymous with concentration. Though the US deployed its air assets continuously on a colossal scale, the failure of bombing to produce a strategic as opposed to a political result placed an enormous strain on the larger force.[43] Facing a fully integrated air defence the USAF and USN were constantly exposed to loss from ground fire of all types and a small but agile fighter force which inflicted steady losses but which did not itself suffer sufficient attrition to reduce its core strength over time.[44] American aircraft proved less suited to the struggle than obsolescent Soviet types such as the MIG 17 and MIG 19 which were nevertheless well-adapted for the air defence role, particularly against American types such as the F105, which was designed for the nuclear battlefield and was notably deficient in air-to-air combat.[45] The NVAF thus achieved concentration in that it maximised the effectiveness of its weapon power, whereas the US emphasis on fruitless bombing did not. The combat situation thus produced a political outcome opposite to that which was intended, matching that of the wider war in which the US public were not willing to countenance continued losses and expenditure without a clearly identifiable victory.

IV.

A pivotal figure in US air power theory since Vietnam is John Warden, the architect of the 1991 air war against Iraq and the last great doyen of the massed air campaign. Warden's first significant opportunity to advocate such views came when he took command of the Bitburg F15 wing in 1986, at a time when 'the established view [was] that NATO would necessarily be on the defensive in the first few days of a European war', and tactics assumed two- and four-fighter formations. Warden was an outspoken advocate of Big Wing tactics. 'He was convinced that the practice of pitting small numbers of highly capable fighters like the F15 against very large numbers of enemy [aircraft] was a recipe for disaster.' Instead he 'told his pilots that they should assume that a combat wing formation consisted of 56 aircraft'.[46]

Warden's *The Air Campaign* was published in 1988, just before he returned to the Pentagon. In it he nowhere discusses Lanchester's equations explicitly, but the work is suffused with belief in numerical superiority.[47] Warden's views are expressed very precisely, as the belief that 'Loss rates vary disproportionately with the ratio of forces involved … as the force ratios go against one side, that side will have greater loss rates than the changed ratio would suggest'.[48] This is an even stronger statement of the value of concentration than the square law which itself is still being used as a justification for views on air power policy.[49]

Since Warden claimed to have based his views on historical and statistical evidence,[50] it is worth going over this in some detail. Despite the many hundreds of papers on Lanchester theory that were written in the second half of the 20th Century, there is none that does so for air combat, nor indeed any theoretical treatment of concentration and asymmetry.[51]

Before looking at the statistical evidence, it is important to understand the effects of data aggregation. For most of the possible scaling regimes of losses with numbers, there are density effects, so that the generalized Lanchester equations only apply to individual engagements. To the extent to which the data aggregates these, it has two effects. First, it increases the apparent randomness, reducing goodness of fit, and making it harder to distinguish between linear and square laws. Secondly, it biases the results, pushing the overall scaling power of each side's loss rate towards one.[52] In a symmetric battle this bias is neutral in its effect on the single overall exponent. In an asymmetric battle, aggregation has a neutral effect on the average of the exponents, but alters the difference between them. Typically it reduces the apparent asymmetry between the two forces. Thus any observed difference between the two forces' exponents is probably underestimated: the true asymmetry will be greater than is apparent from the data.

In the Battle of Britain the best that we can do is to aggregate each day's sortie and loss numbers. When we do so, we find that the best estimates of RAF and Luftwaffe exponents are 0.8 and 1.3 respectively. Thus the RAF certainly had a defender's advantage, and (since its exponent is less than one), certainly did not benefit from mere mass. For the Luftwaffe there is modest evidence of an advantage in concentration (since 1.3>1) but little for a full square-law effect. A robust conclusion is that, while the battle overall was approximately linear- rather than square-law, it was certainly asymmetric, since the RAF defender's advantage, evident in the difference of 0.5 between the exponents, will have been reduced from its true value by the biasing effects of aggregation.[53]

Similar data for the US-Japanese Pacific Air War of 1942-45 mixes small engagements and aggregates of these. With exponents of 1.3 and 0.9 respectively for US and Japanese forces, once again we see an approximately linear-law battle with a strong (and probably understated) asymmetry between US attack and Japanese defence.[54]

The simplest way, both mathematically and intuitively, to seek evidence for a symmetric square law is to ask how the casualty exchange ratio (CER) depends on the force ratio (FR). The square

law holds if the CER is proportional to the FR, while the linear law holds if the CER is constant and independent of the FR. For the Battle of Britain, with the true data, there is almost no such dependence: the proportion of variance described by the best-fitting power of the force ratio is always less than 0.05. Results are similar for the Pacific air war.[55]

Warden bases his claim for such dependence of the CER on the FR, noted above, on a 1970 study of two data sets: monthly data from the Korean War, and a study of twelve campaigns of the Second World War.[56] The Korean data do not support any such conclusion.[57] It is only in the Second World War campaigns that there is any evidence for the square law, and this data set suffers severely from two problems: first, extreme aggregation of data, and, secondly, what Helmbold famously called 'the constant fallacy', in which the data points differ in both numbers and effectiveness of individual sorties, so that the data are not controlled for the latter and it is impossible to disentangle the two.[58] Thus the only evidence here for the square law is in the worst, most aggregated and inappropriate data.

The very best data we have is for Vietnam. Here, for the first time, we have details of numbers and losses on both sides in individual encounters, from January 1965 to July 1967.[59] Thus this is the case in which we can most clearly discriminate the effects of numbers in small engagements. Because the numbers are small (mostly single figures on each side, and including many zeros), rather than seek scaling laws and exponents we instead performed the simplest possible analysis, linear regression of the two sides' losses against their numbers. Effectively, we are limiting ourselves to the simple question 'Are losses proportional to numbers or are they not?' While the proportions of variance explained are small (because the numbers of aircraft engaged are small and thus the randomness great), the results are nevertheless stark. US losses are *not* significantly dependent on either their own or enemy numbers. However, North Vietnamese Air Force (NVAF) losses against F4s (fighters) are significantly proportional to both their own and enemy numbers, while those against F105s (fighter-bombers) are mildly proportional only to their own, NVAF numbers.[60]

From the US point of view, Warden is thus proved partly correct: F4s, at least, should sortie in large (up to squadron-size) numbers, not for their own safety but in order to shoot down enemy aircraft. But the campaign is asymmetric, and such a conclusion would be diametrically wrong for the NVAF, for whom the correct approach is to be parsimonious, sortieing in small numbers and avoiding large encounters. For the NVAF, losses are proportional to the total number of aircraft in an engagement, yet only slightly (if at all) dependent on the extent to which they are outnumbered.[61]

To summarize: if one had begun with the null hypothesis that air combat is a simple, symmetric, linear-law battle – a set of duels – one would reach the conclusion that there is no evidence to reject the linear law in favour of the square law.[62] However, in the cases for which we have the best data we observe a distinct asymmetry, between the attacker, for whom 'mass' may be an effective principle, and the defender, for whom it certainly is not. Thus the early

Lanchestrian view of attrition in air combat – that it is square law and symmetric – is precisely wrong. The answer to our first question is 'No, air combat is not square-law – but it *is* asymmetric'.

V.

So there is no principle of mass in defensive air warfare. Rather, and in answer to our second question, there is no evidence that one can do better than the pragmatic approach, as practised to good effect by British forces from the Battle of Britain to the Falklands campaign,[63] of getting the best available aircraft and honing the tactics which will utilize them, typically in small numbers, to their best possible relative advantage.

Indeed the Falklands War is possibly the most appropriate post-Second World War conflict for examination of Lanchestrian ideas.[64] Involving a discrete conflict with clear objectives for both sides and a limited number of aircraft, conditions similar to the Battle of Britain were recreated for the aerial battle. Nigel 'Sharkey' Ward's memoir of the conflict, as commander of *Invincible*'s 801 Squadron FAA, is (in every sense) combative, yet is quite unconscious in its echoes of the 1940 battle: Ward's thinking developed from his experience of air combat training and was not informed by any doctrinal influence stressing Park's tactics in 11 Group. Particularly striking is his contention that his own clear concept of the necessary role of carrier aircraft was not understood by a leadership group (on HMS *Hermes*, 'Flag,') whose conceptions now seem to owe more to the 'Big Wing' idea which emerged institutionally triumphant from the Second World War.[65]

Much commentary at the time emphasized that the British Sea Harrier force was decisively outnumbered (in the region of 10 to 1), and a number of pilots and Task Force personnel shared this fear. Ward, steeped in fighter tactics, argued that the essence of the battle he would fight could not be reduced to a 'numbers game' in this way, and that the disparity between the outnumbered British carrier aircraft and the entirety of the enemy air force was not a decisive issue. The objective was rather to impose the British agenda, frustrate the enemy's objectives completely and maintain the Sea Harrier force in being during the process. As with 11 Group's experience in 1940, Ward's training had exposed the difficulty for a large formation of attacking aircraft in dealing with a relative handful of opponents. He notes that by maintaining Combat Air Patrols (CAPs) of two aircraft he could impose his will on the enemy: 'The key to disrupting or dissuading a large number of aircraft from attacking was to get in amongst them with a small number of easily controlled fighters. One pair let loose against 10 or 15 bogeys could easily keep track of each other, whereas the opposition would have great difficulty in sorting out friend from foe. I had experienced this on several occasions in the past during exercises.'[66]

This analysis resonates with the experience of Park: to try to assemble a mass of aircraft in the hope of achieving a decisive attritional result was effectively to chase an illusion.[67] In terms of concentration the unit of mass could be as small as the individual aircraft, or pair of aircraft, and the aim was not to destroy the maximum number of enemy aircraft but to defeat their mission. The correctness of this analysis was demonstrated during the only solely air-to-air phase of the

campaign, on 1st May 1982, when the Argentinian air arm made its only attempt to gain air superiority while attacking the Royal Navy's carriers, effectively the British base. Although the number of attackers destroyed was small, their enterprise was utterly defeated and enemy groupings turned for home after the initial clash, convinced of the tactical futility of continuing their attacks against an air base and its defences which could simply move out of range and pick them off at will.[68]

After the British landing at San Carlos Water, the difficulty for the Sea Harrier force was increased, as it became necessary to defend a fixed position within range of enemy air attack which offered numerous hidden avenues of approach. Ward nevertheless believed that a low level CAP mounted by the entire Sea Harrier force, operating as the outer layer of a defence in depth, could defeat the enemy mission. A recent analysis of Argentine air operations in the conflict reveals that the mere fact of detection by a two-aircraft Harrier CAP was often enough to cause the enemy to jettison their ordnance, including scarce drop tanks, and retire without engagement.[69] Thus, while the British possessed too few aircraft to seal the beachhead, they could reduce the numbers getting through to a total insufficient to halt the landing. In this context, any kills were a bonus which enhanced the Harriers' deterrent effect. In fact Ward claims that: 'Without the jump-jets' extraordinary deterrence factor and its combat results in defence of San Carlos, the amphibious landings would probably have realised unsupportable casualties.'[70]

Ward, however, contends that these results were obtained by 'three pairs' of CAP patrols and that effectively only half the Sea Harrier Force, his own 801 Squadron FAA, performed this essential function. 800 Squadron on *Hermes* pursued what for Ward was the 'arguably misguided' policy of high level interception. It is not, therefore, surprising that Flag did not (according to Ward) understand the dynamics of the situation if the views of both mirrored conflicting interpretations of the Battle of Britain.[71] In 1940, the Big Wing took valuable time to climb and form up away from the threat and then came in to deliver a massed attack, but only after the bombing aircraft had hit their targets and were returning to base. Ward effectively contends that the decision by Flag to have *Hermes*' aircraft perform CAP at high altitude had the same effect, in that they had to descend to engage, by which time and 'critically, [they] were only able to engage enemy attack aircraft after the latter had been through their target (San Carlos) and when they, the CAP, were directed down onto the tails of the escaping Argentine aircraft'. The effective absence of 800 Squadron at key moments, Ward contends, thus resulted directly in avoidable losses of British ships as raiders infiltrated through the gaps they left. Thus: 'More CAPS at low level would have increased the deterrence factor and kept more attackers away.'[72]

However, an argument could be made that if the detection of a CAP was sufficient reason to abort a raid, then the higher, more easily detectable, CAP might have served a deterrent purpose inadvertently. Actual Argentine losses to Harriers often occurred at low level when, absorbed with their mission, raiders failed to see their attackers until missiles had been fired upon them.[73] From the British point of view a raid undramatically thwarted had a value as did

a raid destroyed. There is an echo here of the later stages of the Battle of Britain, when the sight of an approaching Big Wing had a moral effect on German aircrew, whatever its operational shortcomings.

The experience of British forces in the Falklands conflict in achieving victory in the air with dangerously limited resources is instructive. However, in the US this idiosyncratic war was rather dissonant with established doctrine, and successive Air War College theses failed to conceptualize the asymmetry of the situation. The Argentines, it seemed, failed for lack of mass, not for lack of material capability and advantage.[74]

VI.

The Falklands War was overshadowed by the far larger Gulf War of 1990-91. Many perceived this as the truly decisive modern event in the development of air warfare, the 'apotheosis of twentieth century air power'.[75] Warden, its architect, conceived the campaign as *Instant Thunder*, in conscious distinction to the perceived error of Vietnam's more gradual Operation *Rolling Thunder*.[76] The destruction of the air defence system of a 'well-endowed opponent'[77] in a matter of hours, or indeed within the first hour, was seen to have produced a decisive shift in the capability of offensive air power, and to have overcome the difficulties faced by the USAF in Vietnam. Indeed, 'the coalition's loss rate to Iraqi surface defences by the end of *Desert Storm* was only one aircraft per 1800 combat sorties, 14 times lower than the US loss rate to enemy defences in Operation *Linebacker II* against Hanoi during the Vietnam War a generation earlier.'[78] The orchestration of allied air forces delivering multiple simultaneous attacks, and thus presumably achieving concentration, was contrasted with 'the halting conduct of Operation *Rolling Thunder* against North Vietnam from 1965-8'.[79] The use of precision guided munitions delivered by stealth aircraft, and the successful application of drone-inspired SEAD techniques perfected by the Israeli Air force against Syrian air defences in the 1982 Lebanon conflict, lifted the shadow of Vietnam from the USAF as effectively as the Gulf War did from so many other areas of American consciousness, and made possible the defeat of the enemy through '*functional* effects, rather than through a more classic drawdown by way of attrition'.[80]

There are caveats, however. The extent to which Iraqi air defence was 'well-endowed' is questionable. It was certainly lavishly equipped for the size of the state it defended, Iraq possessing a population in 1990 slightly larger than the Netherlands'. However, it was devoid of allies and in terms of the forces ranged against it, consisting of a massive international coalition wrapped round NATO's Cold War core, hopelessly outmatched. Nor did it make any special attempt to prepare its air defences, choosing instead to hide and evacuate, rather than disperse, its aircraft and save the bulk of them for more manageable future conflicts while simply waiting for the blow to fall on the remainder. Even though the Coalition air campaign was carried out with notable efficiency, the outcome was never in doubt.

Iraq's position was analogous to the Luftwaffe in 1944-5, and US experience in the Gulf War was also more closely fitted to that conflict than to Vietnam. For although the Gulf War revealed

advances in offensive air power it had nothing to say about advances in defensive technique and it would be dangerous to say that Iraq's defeat proved that there had been none. The totality of historical experience in the areas of concentration, asymmetry and air defence should rather be seen as relevant to the near future. Indeed, in the conditions now faced by western powers, of financial stringency and rising new challengers, there is a far greater emphasis than previously displayed on the optimal use of resources. The age of the overwhelming coalition seems to be over.

Surprisingly, economy is seen to be embodied in the form of new technologies and in speculation about an unmanned future in which robotic aircraft will become the principal units of air combat.[81] For developing countries, who 'always find themselves at a disadvantage when it comes to bridging the gap between technology and force levels,' the Unmanned Combat Aerial Vehicle (UCAV) 'could provide lower operational costs and increase sortie rates'.[82] At the other end of the scale but with similar difficulties the British MOD is particularly interested in unmanned technology, after deep cuts have been made to air assets in recent years, including pilots in training.[83] However, while the promised environment of unmanned scientific and technical purity is closer than before, it is nearly 60 years since the Sandys Report promised the near-immediate elimination of manned interceptors in the RAF and thus caution is advisable. Nevertheless, an environment in which manned, remotely piloted and robotic aircraft are integrated is now with us; and this relationship will only become more deeply enmeshed and sophisticated as time passes and the balance shifts in favour of unmanned aircraft.[84]

It is surprising, therefore, that the possibilities of the UCAV as part of an integrated air defence have not been studied more intensively, particularly in support of an outnumbered force.[85] There are many possible reasons for this. Air power theory stresses the offensive, while recent commentary has concentrated on counterinsurgency and the use of drones for surveillance and targeted strikes on insurgents, and on the ethical and political problems raised by their use in these ways. It is also argued that unmanned aircraft are unsuited for air defence on the grounds of inferior performance relative to manned fighters, though there are no restrictions on the severity of high–*g* manoeuvres of the type encountered with manned aircraft. They also lack the sensor suite and data transfer capacity required for a remote pilot to engage in air combat, while fully autonomous robot aircraft are some distance from this capability and face difficulties in separating friend from foe.

However, unmanned aircraft of various types will only improve in these areas relative to manned aircraft over time, and the existing level of technology provides a potentially powerful air defence capability utilising aircraft with varying degrees of sophistication. The historical experience of air defence is that disruption of enemy attacks combined with sustained rather than spectacular attrition offers the best hope of victory.[86] In this context the UCAV's long endurance and low unit cost relative to manned aircraft may matter rather more than agility. A UCAV can, for example, remain on CAP for an extended period, locate an incoming enemy

force and fire missiles at it, causing sufficient disruption to defeat its mission. As importantly, UCAVs can add to the effectiveness of airborne early warning, creating a three dimensional multi- aspect coverage which would make the operation of stealth aircraft much more difficult, as well as obviating their use for precision strikes on ground based command nodes in the air defence system.[87]

There is a possible danger in attempting to replicate the performance of manned aircraft in remotely piloted or robotic vehicles, in that the complexity and thus the cost of such a vehicle may rise to a level close to that of a manned aircraft.[88] In the context of an integrated air defence based on Lanchestrian principles there is perhaps a point at which diminishing returns might be encountered in developing UCAVs such as the American X-47 or the British Taranis. Between the Battle of Britain and Vietnam, technology moved the balance of forces in the direction of the defence, in that AAA and SAM technology improved so rapidly that a genuinely integrated air defence became possible. The principle of economy achieved by Park and the Luftwaffe, before it was overwhelmed, was manifested much more effectively by the North Vietnamese in countering the most powerful air arm in history with very limited resources. The advantage apparently regained by the offensive during the Gulf War was effectively another example of the application of overwhelming force, in which the systemic mathematical advantage of the defence did not come close to offsetting the material advantage of the attacking force.

Unmanned technology, along with other advances in detection and communications, should make possible deeper and broader integration in air defence and present an attacking force with an ever greater range of difficulties to be countered at ever greater expense. There should also be growing implications for the idea that 'cheaper' nuclear deterrents are possible and a still more defined appreciation of the immutable truth that has existed since the 1950s, that ballistic missiles remain the only unstoppable form of air attack. Indeed, the recently announced development of the SR72 hypersonic strike aircraft is an acknowledgement of this fact, in recognising that aircraft can only defeat an integrated air defence if they assume some of the qualities of the ballistic missile. If it really is the case that 'Speed is the next aviation advancement to counter emerging threats in the next several decades'[89] then the inability of stealth to overcome air defence in the same time frame is tacitly admitted.

VII.

Air power in war, according to Phillip Meilinger, is both a strategic force and, primarily, an offensive weapon.[90] But, as we have seen, air power is not symmetric, and the organization of air defence to deny air power theorists' propositions may require subtly different principles, which clearly separate offensive-mindedness from conceptions of concentration. Further, the British experience in the Falklands War suggests that celebration of mass, born before the Second World War and cemented in doctrine during it, has had a remarkably long shelf-life considering the lack of evidence in its favour. In the context of defensive aerial warfare, it seems, there is no advantage in mere concentration of numbers of aircraft in single engagements.

What of the cultural lessons? As we have seen, to have acted on square-law principles of mass and offensive would have been the wrong tactics for the Battle of Britain, a conclusion reinforced by the evidence from Leigh-Mallory's 1941 fighter sweeps over France. We would argue further that neither the formalization of the principles of war nor the mathematization of the effects of firepower concentration aided RAF inter-war development of fighter tactics. They led to clarity neither of thought nor in the resulting doctrine, rather serving to reinforce the RAF's developing identity and invented tradition, so that, in the immense organizational and technical achievement that was Fighter Command in 1940, tactics were the weakest point. Of course the RAF, unlike the Luftwaffe, had not had the opportunity to learn from experience in the Spanish Civil War. But principles and models, if they are to have any worth, should give a military force a higher level of thinking, enabling it to adapt rapidly to changing technology and campaign scenarios.

The development of scholarship in the post war period has tended to repeat the confused development of the interwar period. The organisational victory of the Big Wing in the UK and a similar tendency to celebrate mass in the US might be said to spring from the same Lanchestrian root, propagated by interwar development in British and US staff colleges. In US doctrine, use of words such as 'mass' and 'focus' continues to suggest that concentration must have a spatial centre, a 'decisive place', and militates against a more subtle understanding of the role of dispersal and concealment in defensive tactics.[91] It has to be considered a failure of OR that it did not conduct the contemporary meta-analysis of the mid-20th Century wars which would have shown that air combat does not obey the square law. At the level of fine tactical detail, aerial clashes did not provide promising material for analysis until the Falklands War of 1982 pitched air arms against each other over water. Here, doctrinal problems were again evident, with clashes between different conceptions of fighter tactics echoing the 1940 experience.[92]

More recent clashes have also tended to obscure the fallacy of mass, as hopelessly outmatched air forces such as that of Iraq have been overwhelmed by combined western air forces.[93] Future operations may not be so one sided, however. It is not impossible to imagine circumstances in which a much-attenuated British air arm might have to fight alone, or even that US air power might be faced by multiple simultaneous threats and be forced to engage at a numerical disadvantage in a particular theatre. In a defensive air battle the lessons of history might have to be relearned yet again, and tactics and technology adapted.

Ultimately, the equation of concentration with mass has hindered understanding of the principles of attrition in air war. The lesson reiterated in the conflicts of 1940, 1965-7 and 1982 is that effective defensive concentration does not depend on mass, and that the effective unit of concentration can be as small as the individual aircraft if it can exert a deterrent effect on multiple opponents. More broadly, the development of tactics and strategy for a future air war requires a clear and detailed understanding of the evolution of the principles of war, from their inception to the present day, as a historical process. Such a study suggests, at the very

least, that grave difficulties have resulted from the metaphor of mass, the doctrinal emphasis on the offensive, the assumption of symmetry between forces, and the incorporation of these in air power theory.

Notes

[1] This view of mathematical modelling of war is expounded in T. W. Lucas and J. E. McGunnigle, 'When is model complexity too much? Illustrating the benefits of simple models with Hughes' salvo equations', *Naval Research Logistics* **50** (2003) 197-217.
[2] L. Hoehl and T. Scales, 'Using linear programming to support high level defence procurement decisions', proceedings of *Mathematics in Defence*, QinetiQ, Farnborough, November 2009.
[3] The standard work is M. Kirby, *Operational Research in War and Peace: The British Experience from the 1930s to 1970* (London, 2003).
[4] F. W. Lanchester, articles in *Engineering* 1913-14, reprinted in *Aircraft in Warfare: the Dawn of the Fourth Arm* (London, 1916).
[5] J. V. Chase, 'A Mathematical Investigation of the Effect of Superiority of Force in Combats Upon the Sea', unpublished secret paper, 1902 (reprinted in Appendix C of Fiske, Fighting Machine, below); B. A. Fiske, 'American Naval Policy', USNI Prize Essay, Proceedings of the United States Naval Institute **31** (1905) 1-80 and 'The Navy as a Fighting Machine' (New York, 1916 and Annapolis, 1988); Lt A. Baudry (French Navy), *The Naval Battle: studies of tactical factors* (London, 1914); M. Osipov, 'The influence of the numerical strength of engaged forces on their casualties' (1915), trans. R. Helmbold and A. S. Rahm, *Naval Research Logistics* **42** (1995) 435-490.
[6] See for example J. J. Schneider and L. L. Izzo, 'Clausewitz's elusive center of gravity', US Army War College *Parameters*, September 1987, pp. 46-57.
[7] An explicit statement of this during the Second World War is in his Letter to the Editor, *Engineering* **154** (1942) 174.
[8] I. R. Johnson and N. J. MacKay, 'Lanchester models and the Battle of Britain', *Naval Research Logistics* **58** (2011) 210-222; Niall MacKay and Christopher Price, 'Safety in Numbers: Ideas of concentration in Royal Air Force fighter defence from Lanchester to the Battle of Britain', History **96** (2011) 304-325.
[9] N. J. MacKay, 'Is air combat Lanchestrian?', *Phalanx: the Bulletin of Military Operations Research* **44** no.4 (2011) 12-14.
[10] USAAF Statistical Digest, Table 119: Airborne and Effective Combat Sorties flown in the European Theatre of Operations, August 1942-May 1945.
[11] J. F. C. Fuller, *The Foundations of the Science of War* (London, 1926).
[12] Recent examples are Phillip S. Meilinger, *Ten Propositions Regarding Air Power* (Washington, DC, 1995) and J. A. Warden III, *The Air Campaign: planning for combat* (Washington, 1989). But the criticism applies throughout the history of airpower theory: '[Trenchard's] emphasis on the importance of offensive action has remained a constant theme in the history of air power thinking.' Group Captain Peter W. Gray, 'Air Power: Strategic Lessons from an Idiosyncratic Operation', in S. Badsey, R. Havers and M. Grove (eds), *The Falklands Conflict: twenty years on* (London, 2005).
[13] US air power defensive doctrine is to 'detect, identify, intercept, and destroy' enemy air forces.

The conception is thus of attrition in the air, rather than of preventing the aerial enemy from achieving its surface objectives. *Basic Aerospace Doctrine of the United States Air Force*, Air Force Manual 1-1, vol. I (Washington, 1992), p. 6. This is later nuanced as 'defeating the enemy's defensive plan and … inflicting unacceptable losses' (p. 11), but the possibility of tension between these two goals is not explored.

[14] S. J. Deitchman, 'A Lanchester model of guerrilla warfare', *Operations Research* **10** (1962) 818-827.

[15] I. R. Johnson and N. J. MacKay, 'Lanchester models and the Battle of Britain', *Naval Research Logistics* **58** (2011) 210-222; Niall MacKay and Christopher Price, 'Safety in Numbers: Ideas of concentration in Royal Air Force fighter defence from Lanchester to the Battle of Britain', History **96** (2011) 304-325.

[16] Full details in MacKay, 'Is air combat Lanchestrian?'.

[17] See Johnson and MacKay.

[18] See Deitchman.

[19] An elementary mathematical introduction is given by one of the authors in N. MacKay, 'Lanchester combat models', *Mathematics Today* **42** (2006) 170-173. By framing the question as 'Is there a scaling law for attrition?', we are stepping back from Lanchester's association of his square law with aimed long-range fire. In air combat the natural unit is the sortie, and the question becomes whether a sortie tends to cause a kill (leading to the square law), a loss (leading to the 'logarithmic law'), or some mix of the two, summarized by the exponent.

[20] Lanchester archive 514.16-514.99, Coventry University.

[21] See for example R. Higham, *The Military Intellectuals in Britain 1918-1939* (New Brunswick, 1966), John Buckley, *Air Power in the Age of Total War* (Bloomington, 1999), J. E. ('Johnny') Johnson, *Full Circle: The Story of Air Fighting* (London, 1964).

[22] N. Parton, 'The development of early RAF doctrine', *Journal of Military History* **72** (2008) 1155-1177.

[23] Fuller, *Foundations*, p. 271.

[24] MacKay and Price.

[25] This has been commented on elsewhere regarding RAF bomber doctrine: see T. D. Biddle, *Rhetoric and Reality in Air Warfare: The Evolution of British and American Ideas About Strategic Bombing, 1914-1945* (Princeton, 2002).

[26] R. Overy, *The Air War 1939-45* (London, 1980), p. 9.

[27] Indeed Leigh Mallory's views on fighter tactics were set out at length in 1928 and changed very little thereafter. T. Leigh-Mallory, 'The maintenance of air superiority in a land campaign', *RAF Quarterly* **2** (1931) 245-252.

[28] Peter Townsend, *Duel of Eagles* (London, 1970). Park's approach would have been in flat contradiction to US air power doctrine, where the principle of concentration is that 'Aerospace power is at its most effective when it is focused in purpose and not needlessly dispersed'. Again the possibility of tension, here between unity of purpose and unity of place, is not discussed. *Basic Aerospace Doctrine of the USAF*, p. 8.

[29] Overy, *The Air War*, p. 9.

[30] Overy, *The Air War*.

[31] D. Wood and D. Dempster, *The Narrow Margin* (London, 1961), p. 272.
[32] Wood and Dempster, *Narrow Margin*, p. 273.
[33] Indeed one can find an echo of the two contrasting conceptions of concentration, mass versus firepower, in the Napoleonic column and the British line.
[34] Recall that, in the generalized Lanchester approach we described at the beginning of section II, the defender's advantage is realized in differing values of the two forces' exponents. The force with the lower exponent benefits from cover and concealment, and, bound up with this, gains less from mere concentration of numbers. See MacKay and Johnson, and the appendix to MacKay and Price. Readers steeped in the operational research literature should note that this is very different from Helmbold's 'advantage parameter,' which is not a fixed parameter of the dynamics at all but rather a variable, related to cumulative losses. See *The Advantage Parameter*, Tactical Analysis Division, US Army Concepts Analysis Agency, July 1997. CAA-MR-97-3.
[35] The minutes are reproduced in Dilip Sarkar, *Bader's Duxford Fighters: The Big Wing Controversy* (Worcester, 1997) and in Douglas Bader's 1969 notes on the controversy, RAF Museum London MF10073.
[36] Of course one of Park's central points was that all else was typically not equal: he simply did not have the time to form wings or Big Wings. Rather `It [is] better to have even one strong squadron of our fighters over the enemy than a wing of three climbing up below them' (K. Park, memo of 1st October to 11 Group, reproduced in Sarkar, *Bader's Duxford Fighters*).
[37] A. Price, *Battle Over the Reich: The Strategic Bomber Offensive Over Germany*, Vol.2, (Hersham, 2005) p. 219.
[38] Overy, *The Air War*, p. 78.
[39] Overy, *The Air War*, p. 77.
[40] Since its inception in 1947, the USAF had endorsed concentration as a fundamental principle of war. It was an article of faith within the new service that the US Army Air Forces had achieved this objective to decisive effect during their Second World War campaigns over Germany and Japan. This experience reinforced the USAF's interpretation of concentration as 'mass', and enhanced the service's confidence in the classical conception of air power as primarily an offensive weapon capable of independently achieving decisive results. Robert F. Futrell, *Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force*, Vol. II, *1961-1984*, (Maxwell AFB, Al, 1989), p. 6; James L. Cate, 'Development of United States Air Doctrine, 1917-1941', Eugene M. Emme (ed.), *The Impact of Air Power, National Security and World Politics* (Princeton, 1959), pp.187-190; David P. Handel, 'The Evolution of United States Air Force Basic Doctrine', unpublished research study (Maxwell AFB, Al, 1978), pp. 37-40 & 52-53, & Earl H. Tilford, *Setup: What the Air Force Did in Vietnam and Why* (Maxwell AFB, Al, 1991), pp. 1-40. See also: Kurt A. Chichowski, *Doctrine Matures through a Storm: An analysis of the New Air Force Manual 1-1*, thesis, School of Advanced Airpower Studies (Maxwell AFB, Al, June 1993).
The validity of the principle of concentration-as-mass remains accepted within the USAF as a generally-applicable truth. The *Warrior Knowledge Handbook* (2014), provided to USAF ROTC students still contains the 'principles' of war, including 'concentration', here entitled 'mass' and defined as 'concentrate combat power at the decisive time and place'. LLLAB6.
[41] According to a JCS report of 25 April 1968, as long as North Vietnam continued to receive

equipment from its external Communist supporters it would be able to continue to operate an effective air defence system, and it was impossible to eliminate the MiG threat while the NVAF continued to employ Chinese air bases near the North Vietnamese border that were off-limits to US air strikes. Herman S. Wolk, *USAF Plans and Policies, R & D for Southeast Asia, 1968*, (Office of Air Force History, July 1970) & Thomas C. Hone, 'Southeast Asia', in Benjamin F. Cooling, (ed.), *Case Studies in the Achievement of Air Superiority*, (Washington, D.C, 1994), p. 541.

[42] The USAF was confident that an intense bombing campaign over North Vietnam would force Hanoi to abandon its support for the insurgency in the South. At the outset, however, the shape of the US air campaign over North Vietnam was not one of the USAF's own choosing, but one thrust upon it by the civilian executive: the pressure was to be gradually increased on North Vietnam so that it would be encouraged to accept a negotiated solution that would guarantee the independence of South Vietnam. Gradual coercion, however, involved gradual escalation, and it has been argued that the final shape of the American ROLLING THUNDER campaign between 1965 and 1968 may not have been so very different from that originally envisioned by the USAF. Robert A. Pape Jr, 'Coercive Air Power in the Vietnam War', *International Security*, **15**:2 (Fall 1990), pp. 118 & 123-124.

[43] US and South Vietnamese aircraft flew about 350,000 attack sorties over North Vietnam throughout the war, delivering approximately 800,000 tons of bombs, but neither Washington nor the US military ever fully appreciated the full extent of Hanoi's commitment to the objective of national reunification. Nor, when one considers the circumstances of the war in South Vietnam between 1965 and 1968, was the interdiction of the line-of communications between North Vietnam and the South ever likely to yield a significant or permanent diminution of the NLF strength in the South. The less-constrained LINEBACKER campaigns of 1972 were more effective in impeding the North Vietnamese offensive of that year and forcing Hanoi into negotiations that would permit US withdrawal, but these were lesser objectives than those for which the USA had originally gone to war in Vietnam – indeed, by the light of those original objectives the USA had already lost the war by 1972. The point here is that 'mass', in terms of 'massive' bombing, did not constitute concentration at the decisive point, because it was not applied to a facet of North Vietnam's society or war effort that could significantly influence the outcome of the war. Wayne Thompson, *To Hanoi and Back: The United States Air Force and North Vietnam, 1966-1973* (Washington, DC, 2000), p. 301 & Pape, 'Coercive Air Power', pp. 144-146.

[44] According to US figures USAF and USN combat losses over North Vietnam during ROLLING THUNDER totalled 526 aircraft, with 54 aircraft lost to SAMs, 430 aircraft lost to anti-aircraft artillery, and 42 aircraft shot down in air-to-air combat. John Schlight, *A War too Long: The USAF in Southeast Asia, 1961-1975* (Washington, DC, 1996), p. 53. During the entire course of the air war over North Vietnam the USA lost 67 aircraft in air-to-air combat while the VNAF lost 137 aircraft to US fighters, a kill ratio of approximately two to one in the US favour. Throughout most of the war the VNAF maintained an interceptor force of 60 to 75 aircraft. Rebecca Grant, 'The Crucible of Vietnam', *Air Force Magazine* **96** no.2 (2013) 74-78.

[45] The Communist aircraft were designed from the outset as short-range interceptors. The MiG-19s and 21s outclassed the American F-105 by a considerable margin and could hold

their own against F-8s and F-4s. Although obsolete and with an inferior performance to the American aircraft in a vertical fight, the MiG-17 still proved a dangerous adversary in horizontal engagements below 500 knots. Marshall L. Michel III, *Clashes: Air Combat Over North Vietnam, 1965-1972* (Annapolis, Md, 1997), pp. 75-76, 79-84 & 86.

[46] J. A. Olsen, *John Warden and the Renaissance of American Air Power* (Dulles: Potomac, 2007), p50-96. Olsen notes that Warden's 'insistence on huge modern fighter force formations in Europe was unprecedented'. His emphasis on mass, 'for better or for worse ... bears a strong resemblance to that of Jomini', but 'they [both] ignored those cases in which military experience did not conform to the predictions based on their formulas'. Exploring the parallels further, Olsen goes so far as to say 'Warden provided an equivalent [of Jomini] for air warfare'.

[47] John A. Warden III, *The Air Campaign: planning for combat* (Washington, DC, 1989).

[48] Warden, *The Air Campaign*, p.61.

[49] E. S. Gons, *Access Challenges and Implications for Air Power in the Western Pacific*, Pardee RAND PhD thesis, May 2010, p. 99; Maj R. E. Gilbert, *Strategic implications of US fighter force reductions: air-to-air combat modelling using Lanchester equations* Air University thesis (Maxwell AFB, Al, 2011).

[50] Warden's justification for Big Wing tactics rested, according to Olsen, on precisely the dependence of the casualty ratio on the force ratio which we shall expose as being unfounded. Further, 'Warden's knowledge of the controversy over the Battle of Britain and of the actions of Dowding and Leigh-Mallory enabled him to refute most of the arguments' against Big Wings, apparently, although no evidence is given that this was refutation rather than disputation. Olsen, *John Warden*, p. 89.

[51] See, for example, S. Wrigge, A. Fransen and L. Wigg, 'The Lanchester Theory of Combat and Some Related Subjects. A Bibliography 1900-1993', FOA report D-95-00153-1 (Stockholm, 1995).

[52] See Johnson and MacKay. At its root this is due to (what is known to mathematicians as) Jensen's inequality.

[53] For details of each force's scaling of losses with own and opposing numbers, leading to this result, see Johnson and MacKay. However, if the same analysis is performed using RAF *claims* for Luftwaffe losses, rather than *actual* losses, the situation is reversed, and the RAF and Luftwaffe exponents become 1.5 and 0.8. The reason is disproportionate overclaiming on days of heavy fighting: the RAF claimed 'kills' not merely in proportion to their sorties, but nearly as their square.

[54] B. Matthews, *Fitting Generalize Lanchester Models to the Pacific Air War*, University of York BSc dissertation, May 2008. In fact the campaign splits into two clear phases, before and after the mid-1943 lull. In the earlier phase, with only 10 data points, it is the Imperial Japanese Navy which is on the defensive; in the later phase (46 points), this is clearly reversed.

[55] MacKay, 'Is air combat Lanchestrian?'

[56] *The Relationship Between Sortie Ratios and Loss Rates for Air-to-Air Battle Engagements During World War II and Korea*, Saber Measures (Charlie) (Washington, DC, 1970), document call no.M-U 42210-75.

[57] MacKay, 'Is air combat Lanchestrian?'

[58] R. L. Helmbold, 'The Constant Fallacy', Eur. J. Op. Res. **75** (1994) 647-658.

[59] J S Attinelio, *Air-to-Air Encounters in South-East Asia*, October 1967. Weapons Systems Evaluation Group report 116 / Defense Technical Information Center report R-123.
We extracted data for 157 encounters between F105s and NVAF aircraft, typically a mix of MiG-17, 19 and 21s, and for 82 F4 encounters, from the tables on Vol.I p. 17-18, Vol.II p. 17-19 and Vol.III p. 15-20.
[60] Against F4s, NVAF losses are significantly dependent on both their own (at p=0.01) and opposing (p=0.02) numbers, accounting for 0.23 of the variance. Against F105s, NVAF losses are slightly dependent on own numbers at p=0.05, although the variance explained is small. No other relationships are significant at better than p=0.3.
[61] If we make the independent variables the sum and difference of US and NVAF aircraft, we find that NVAF losses against F4s are highly significantly dependent on the sum (p=0.0004), but only mildly so on the difference (p=0.2) . Against F105s the significance of the sum declines to p=0.17, and of the difference to 0.76.
[62] For a recent perspective see Wayne P. Hughes, 'Prediction', keynote address to the Military Applications Society 2012 conference, Monterey. Hughes has long held the view that air combat is primarily a set of duels (private communication).
[63] For an account of the Falklands air campaign see Nigel 'Sharkey' Ward, *Sea Harrier over the Falklands: a maverick at war* (Annapolis, 1992), balanced by S. Woodward and P. Robinson, *One Hundred Days: the memoirs of the Falklands Battle Group Commander* (Annapolis, 1997). As we shall see, Ward's preferred tactics of forward interception can be seen as directly paralleling those of Park in both the Battle of Britain and the defence of Malta.
[64] This view is put most trenchantly by Philip Grove: 'The Falklands Conflict, which is increasingly overlooked by airpower students and writers, is … a vital paradigm in the use and misuse of air assets … in many ways it was a war of the future.' Philip D. Grove, 'Falklands Conflict 1982 – The Air War: A New Appraisal', in Badsey, Havers and Grove, *The Falklands Conflict*.
[65] In the preface to the Second edition of his memoir, Admiral Woodward notes that Ward's use of the term 'Flag' to refer to the Task Force leadership group on Hermes was, 'A very loose term' referring at different times to different people, and that he was unaware of any controversy between the aerial commanders on Invincible and Hermes. *One Hundred Days*, p. xxxv. Ward acknowledges this qualification in the second edition of his own book.
[66] Ward, *Sea Harrier over the Falklands*, p. 100.
[67] The parallel with the Battle of Britain is noted in Air Commodore R. A. Mason, '"Hay for the Hobby Horses": reflections on the air war in the South Atlantic 1982', *RUSI Journal* **127** no 4 (1982) 34-41.
[68] M. Middlebrook, *The Falklands War*, (London, 2012), Ch. 7.
[69] S. Rivas, 'Wings of the Malvinas: The Argentine Air War over the Falklands, (Manchester, 2012), pp. 181, 183, 189, 255.
[70] Ward, *Sea Harrier over the Falklands*, p. 234. This point is made in Gray, 'Air Power': 'the reliance on total superiority is misleading. [Dunkirk and the Falklands] highlight what can be done – or undone – in situations of air parity.'
[71] Similar criticisms of the command culture are made in Alastair Finlan, *The Royal Navy in the Falklands and the Gulf War: Culture and Strategy* (London, 2004). Finlan stresses the anachronism

of relying on visual searches instead of the Sea Harriers' radar (p. 167), the failure to devolve decisions on air combat tactics to lower-ranking experts, and (in a perfect echo of the Park / Leigh-Mallory dispute) the tendency to engage Argentinian aircraft 'after bomb runs on ships rather than before' (p. 90).

[72] *Ward, Sea Harrier over the Falklands*, p.234. Interestingly, Admiral Woodward acknowledges that Ward's views were 'largely correct' in that the snr command group on Hermes apparently did not trust their aircraft and particularly the efficiency of its 'Blue Fox' Radar. Woodward argues that with hindsight Ward was uniquely qualified to judge the capabilities of this new, untried and in practice devastatingly effective weapons system, and his implication seems to be that it was regrettable that Ward's views were not heeded. Woodward, *One Hundred Days*, 2nd Ed. ,p. xxxv.

[73] Rivas, *Wings of the Malvinas*, pp. 179, 255.

[74] Lt Col J. E. Marr, *War in the Falklands: Perspectives on British Strategy and Use of Air Power* Air War College thesis (Maxwell AFB, Al, 1988) notes 'the failure of the Argentines to exercise the principle of mass' and that 'the defensive air campaign was singularly successful'. Lt Col C. B. Hezsely, *Argentine air power in the Falklands war* (Air War College thesis (Maxwell AFB, Al, 1988) , writes that 'the Argentines may have underestimated the havoc that the 17 Sea Harriers caused [sic]' and concludes that 'The Argentine air campaign proved that air power alone is not enough!'. Perhaps the most incisive judgment comes much later, in Lt Cdr J. L. Huber, *The Falklands Air War: lessons revisited*, Naval War College paper (Monterey, 1995): 'Why waste airplanes and pilots attempting to shoot down Harriers one at a time when they could neutralize most or all of them by hitting a carrier?' Huber's conclusion that 'defensive air superiority schemes are only suitable when facing opponents possessing significantly weaker air power' apparently went unnoticed.

[75] Air Vice-Marshal R. A. Mason Ret. 'The Air War in the Gulf', *Survival* **33** no. 3 (1991) 225. Quoted in Benjamin S. Lambeth, 'Air Power, Space Power and Geography', *Journal of Strategic Studies* **22** nos 2-3 (1999) 64.

[76] Olsen, *John Warden*, p. 22 and Ch. 8.

[77] Lambeth, 'Air Power', p. 70.

[78] Lambeth, 'Air Power', p. 66.

[79] Lambeth, 'Air Power'

[80] Lambeth, 'Air Power', p. 70.

[81] 'The development of UAVs and UACVs thrived when the need for them was apparent, but when there was no need, they were forsaken'. Lt Col R. M. Clark, *Uninhabited Combat Aerial Vehicles*, CADRE paper no. 8 (Maxwell AFB, Al, 2000), p. 42. New technologies, especially of command and control, are likely to make this a thing of the past.

[82] G. N. Gosh, Application of Unmanned Aerial Combat vehicles in future Battles of the Subcontinent', *Strategic Analysis*, **25** no.4 (2001) 600-601.

[83] MOD Joint Doctrine Note 2/11, *The UK Approach to Unmanned Aircraft Systems*, p. 103.

[84] *Securing Britain in an age of Uncertainty: The Strategic Defence and Security Review* (London, 2010), p. 5.

[85] As with the development of inter-war doctrine, the emphasis has mostly been on offensive

rather than defensive air power. See, for example, Maj D. Larm, *Expendable Remotely Piloted Vehicles for Strategic Offensive Airpower Roles*, Air University thesis, 1996; J. M. Sullivan, 'Evolution or Revolution? Rise of UAVs', *IEEE Technology and Society* **25** no. 3, (2006) 94-101; Maj D. Berkland, 'Douhet, Trenchard, Mitchell, and the Future of Airpower', *Defense and Security Analysis* **27** no.4 (2011) 389-393; L.-M. Clouet 'Drones as Future Air Power Assets: The Dawn of Aviation 2.0?', in E. Fels *et al*. eds, *Power in the 21st Century* (Berlin: Springer, 2012).

[86] The potential revolutionary effect of UCAVs as a 'disruptive technology' is noted – albeit not in the context of air defence – in D. Hastings-Dunn, 'Drones: disembodied aerial warfare and the unarticulated threat', *International Affairs* **89** no. 5 (2013) 1237-1246.

[87] The diverse advantages of small UAV carriers for UK forces, including the possibilities for fighter UCAVs, is noted in I. Shields and J. Spencer, 'An Unmanned Future for Naval Aviation', *RUSI Journal*, **156** no. 6 (2011) 48-54.

[88] The *UK Approach to Unmanned Aircraft Systems*, p. 104.

[89] Lockheed Martin's Hypersonic Program Manager, quoted in *Combat Aircraft Monthly*, **15** no. 1 (January, 2014).

[90] Meilinger, *Ten Propositions*.

[91] The US understanding of what happened in the Battle of Britain remains ambiguous. For example, in Air Force Doctrine Document 1 (AFDD1, September 1997), we find that 'Even highly successful defensive air campaigns such as the Second World War Battle of Britain were based upon selective offensive engagements rather than fragmenting into small patrols everywhere.' Park's tactics were certainly offensive (and the Dowding system had removed the need for standing patrols), but they did not achieve this through massed numbers. AFDD1's position on 'mass' in this context remains unclear.

[92] For a wide-ranging analysis of the command culture in the Falklands, see Finlan, *The Royal Navy in the Falklands*.

[93] T. A. Keaney and E. A. Cohen, *Gulf War Air Power Survey Summary Report* (Washington, DC, 1993).

Viewpoint

How Well Do We Understand Air Command and Control?

By Air Commodore Alistair Byford

Introduction

Traditionally, the UK has exercised air command and control (C2) through a model of centralised control, decentralised execution, enabled by the concept of mission command. However, our most recent statement of environmental doctrine, *JDP 0-30 'UK Air and Space Doctrine'*,[1] mandates a change to a more flexible approach, *centralised control, adaptive execution*. In my experience, airmen and airwomen are not particularly good at understanding C2 or giving it the prominence it deserves. And this is problematic, because C2 is absolutely fundamental to the effective employment of air power. So I think it is worth considering how air C2 has evolved, why the time is ripe for change and what the implications are likely to be.

Command versus Control

We need to begin by establishing some principles and defining the terms. *British Defence Doctrine*[2] tells us that we vest *command* of a force element, organisation or operation in an individual to assign direct authority, responsibility and accountability. This differs markedly from *control*, which is merely 'the coordination of the activities necessary to achieve the commander's intent'. Put simply, command is exercised by a commander, while control is a staff-led function. This means command is inherently a human activity in a way that control is not, because we can hold a commander - as an individual person - to account for his or her actions, while control may be more about processes and procedures.

Both command and control can be facilitated by common doctrine and communication systems that allow us to share information quickly and easily. However, the peculiar nature of

air power and the specific mechanisms we use to deliver it - think, for example, of the Airspace Coordination Order (ACO) and the Air Tasking Order (ATO) - mean that in my opinion, airmen and airwomen are particularly prone to being seduced by the technicalities of control at the expense of a proper emphasis on the key principles of command. This matters, because it is the air commander's personal attributes and qualities of command (in terms of leadership, initiative, imagination, knowledge, judgement and professionalism) that will ultimately determine the success or failure of an air operation, not the sophistication of the systems and processes of control they use to achieve their intent; so ultimately, control is (or at least should be) just an enabler.

Centralised Control

This is not to say that control is unimportant. Centralised control emerged from the earliest days of military aviation as the key to the effective application of air power and this still remains the case today. It also explains why the Royal Air Force was created as the world's first independent air force nearly a century ago. In 1917, the Smuts Report recognised that decentralising control of air assets to the organic air components of the Army and Navy was inefficient and unsustainable, because it had dissipated the UK's overall air effort. Understandably, the Royal Flying Corps and Royal Naval Air Service had concentrated on direct support to the army in the field and the fleet at sea respectively. This made it impossible for them to allot sufficient resources to different and higher priorities, such as the air defence of the UK, and this became apparent in the wholly inadequate response to Zeppelin and long-range bomber raids. The solution was to centralise control of air assets and resources within a single command structure focused solely on the delivery of air power, leading to the creation of the Royal Air Force on 1 April 1918.

So centralising control is vital, because it assures unity of both purpose and effort. It means we can guarantee that inevitably scarce air resources are allocated and apportioned as efficiently and effectively as possible, meeting the commander's intent in line with the priorities he or she has set. Centralised control also embodies the principle of *strategy to task*, ensuring every sortie we fly can be tracked back to the strategic objectives set by higher authority. In contrast, decentralising control is invariably disastrous. In France in 1940, *L'Armée de l'Air* fighter squadrons were allocated to (and controlled by) individual army formations. This meant that despite overall numerical parity, 'penny-packets' of French fighters were spread along the front and simply could not match the concentrated force that the *Luftwaffe* was able to generate at the *schwerpunkts*, or points of main effort; the result was that the French air force was defeated in detail. Bizarrely, some French squadrons were held on the ground while crucial air battles were being fought nearby - sometimes in sight - because they were based on the wrong side of a divisional boundary or located in a different army formation's area of responsibility.

Execution: to centralise or not to centralise?

While centralised control is therefore a key principle - and there is no evidence to suggest this will change in the future, as air resources will, if anything, become even scarcer - the best method of executing tasks and missions has always been more open to question. At this point,

we should note that *execution* is shorthand for *execution authority* – the empowerment to take decisions, such as whether or not to release weapons, to abort or continue a sortie, or change a target – not the physical actions that can only be conducted in the cockpit or at the console, such as pulling a trigger or pressing a weapons release button. In simple terms, there are two options for execution: we can centralise it, so a remote headquarters or higher authority controls decision-making; or we can decentralise, sometimes right down to the operators of individual air assets.

Decentralised execution initially evolved not as a conscious, doctrinal preference, but rather as a pragmatic response to our limited ability to communicate with (and therefore control) aircraft in the air. During the First World War, ground-air communications were in their infancy, so centralised control was never a realistic option. But even towards the end of the Second World War, reliable, long-range, communication was difficult. So for example, Bomber Command Headquarters at RAF High Wycombe possessed neither the technological means nor the data-processing capacity to centralise the execution of raids comprising hundreds of bombers (all operating as separate speaking units) flying over Germany well beyond easy line-of-sight radio contact. Consequently, decentralising execution was the only practical method of exercising air C2 and squadrons were effectively tasked on the basis of "off you go, bomb Berlin, find your own way there and identify the target, drop your eggs, good luck, see you when you get back". However, it was clear that more control was necessary and Bomber Command soon introduced C2 measures to try to work round the constraints on communications. An Op Order was issued for every raid, detailing the targets, aiming points, bomb load, target marking technique and overall raid timings for each group, supported in turn by Group Op Orders specifying TOTs down to the minute; effectively an ATO as we would recognise it today. Also, the 'Master Bomber' concept was introduced later on in the war, where a mission commander would direct a raid in the air via R/T (radio-telephony). This was first practised by Wing Commander Guy Gibson over the Mohne Dam in 1943.

The evolution of C2 for Bomber Command indicates there will always be a desire (or requirement) to centralise aspects of execution and that the primacy of the decentralised approach to air C2 was never as cut and dry in practice as it now appears in retrospect. This is reinforced by the example of Fighter Command. The integrated air defence system used so effectively during the Battle of Britain in 1940 is often cited as a classic illustration of centralised control, decentralised execution in action. But arguably, this actually demonstrates that centralised execution (if technically viable) is actually a more effective way of exercising C2 in particular operational circumstances. It was the group and sector controllers, using the air picture provided by radio-direction finding stations (radar) and observer reports, who exercised decision-making authority from their centralised headquarters. They chose which squadrons to allocate to which raids; when to scramble them; where they should be positioned, in terms of height and geography; and if (and when) they should engage. The pilots were only responsible for the last stages of tactical execution after they had obtained visual contact with the enemy and been cleared to commit.

So what does this demonstrate about air C2? Simply that for Fighter Command in 1940, centralised execution was both possible and desirable. It was possible, because of the small number of speaking units involved[3] and easy, two-way, line-of-sight radio contact with fighters operating close to their sector control centres. And it was desirable, because the controllers were better informed than the aircrew and could therefore make better decisions; without the capability to datalink the air picture into the cockpit, only the controller on the ground could see if a raid was a feint or the main effort, assess whether an enemy formation was escorted or composed solely of fighters, and determine likely targets and the priority for their defence.

The Battle of Britain and Bomber Command's offensive against Germany therefore highlight the two key factors that shape the air C2 environment: first, our ability to communicate (including data transfer) will determine if centralised execution is feasible or not in the first place; and second, air C2 is most effective when decision-making authority is situated at the point where the best information is available. For Fighter Command, this was with the controller in the sector or group headquarters; but for Bomber Command, it had to be with the aircraft captain in the cockpit, because neither group nor command headquarters enjoyed access to any useful, real-time information once a raid was underway and the aircraft had crossed the coast.

Mission Command

Decentralised execution is closely tied to the notion of *mission command*. This concept, identified in *British Defence Doctrine* as a fundamental attribute of the 'British way of war',[4] is often misused or misunderstood. In fact, it was originally a German idea, and mission in this sense is simply a translation of *auftrag*, meaning a task directed towards fulfilling a particular purpose. Mission command deals with those aspects of leadership involved with setting and giving direction. It encapsulates the freedom for a subordinate to act (or not to act) on his or her own initiative, using allotted resources to achieve the higher commander's intent. This should be specified only in terms of what is to be achieved rather than the ways in which it is to be accomplished.

Mission command is attractive in an air power context, because it allows us to delegate the execution of certain command responsibilities, such as engagement or weapons-release authority, enabling tactical self-synchronisation and increasing tempo by shortening the decision cycle. This is particularly critical in the air environment, and it is no surprise that it was an airman, Colonel John Boyd, who articulated the concept of the Observe-Orientate-Decision-Action or 'OODA' loop following his experiences in the Korean War. So mission command provides a way of allowing operations to continue despite the Clausewitzian fog and friction of war in complex air campaigns with many assets in play, or where beyond line-of-sight communications are degraded or denied. It also – in theory – provides air commanders with the space to focus on the big issues of command without being 'fixed' by the need to control every detail of tactical execution. This explains why centralised control, decentralised execution, enabled by mission command, emerged after the Second World War as the favoured model for air C2.

The wisdom of this choice was apparently proved in the Cold War, when the freedom of action that western air forces enjoyed contrasted starkly with the Soviet predilection to centralise both control and execution. A rigid, Ground-Controlled Intercept (GCI) approach to air combat sapped Warsaw Pact pilots of initiative and was symptomatic of the inflexible, Soviet-bloc approach to air power that robbed it of much of its utility. Yet air C2 is always context-specific. In the 1967 Six-Day War, the success of the Israeli Air Force exemplified the triumph of the high-quality individual pilot in the cockpit exercising mission command over the system-based, centralised approach of his Soviet-trained and influenced Arab adversaries, who always had to wait to be told what to do. However, in the subsequent War of Attrition (1969-70), the *Heyl Ha'Avir* itself reverted to centralisation, with the Chief of the Air Force personally controlling execution from his central command bunker. This was because he had both the means to do so - the tiny size of Israel meant that all air operations took place within line-of-sight radio contact and the numbers engaged were small - and equally importantly, the motivation. Egyptian aircraft were often flown by Soviet advisors, so every tactical engagement decision implied potentially geo-strategic consequences. In these circumstances, the Israelis were simply unwilling to delegate execution when centralising it was both possible and, in this instance, desirable.

Why change?

While the Israelis could centralise execution during the War of Attrition, because of the limited range and scope of air operations, this was not a scenario that western nations could expect in an air war on NATO's central front in Europe. But since the end of the Cold War, the development of network enabled capabilities based on space-borne, beyond line-of-sight communication and data-transfer systems has created a new environment for air C2. This is a double-edged sword. On the one hand, it provides us with the ability to deepen mission command and decentralise execution if we choose to do so. We can use these capabilities to disseminate the commander's intent quickly and reliably down through the chain of command, using datalink to synthesise and project the best available information into the cockpit to support high quality decision-making at the lowest tactical level. On the other hand, this technology also makes centralised control more feasible, and the Israeli example demonstrates why this may be desirable (or even necessary) in some circumstances.

In any case, the RAF has long since departed from the simple purity of centralised control, decentralised execution, despite our stated doctrinal position. 'Operations other than war' have always attracted political scrutiny, and a generation of airmen who cut their teeth enforcing no-fly zones over Iraq in the nineties will be only too aware of the level of control exercised by the remote Combined Air Operations Centre, either directly, or through the airborne mission commander: 'Mad Dog directs'. And I would argue that we have never practised centralised control, decentralised execution and mission command in the way that we have preached; ATOs – like Bomber Command's op orders - that mandate package size and type, target and alternates, take off time, target and tanking brackets, vulnerability times, permitted weapon load-outs and flow direction do not, in reality, allow much freedom

of manoeuvre. So the publication of *JDP 0-30* in 2013 was timely, because it provided an opportunity to review air C2 from first principles and consider if there is still a single, ideal model now that technology apparently offers us the choice to centralise or decentralise as we see fit.

Towards a different Philosophy of C2

Perhaps unsurprisingly, the authors of *JDP 0-30* concluded there is no simple template that is applicable in all circumstances. As one size does not fit all, a new and more flexible approach is required instead, where centralised control is still relevant and necessary, but execution authority should be delegated to the point where the best level of understanding is available. Sometimes, this may be at the air headquarters or above, but on other occasions it will be more appropriate and effective to decentralise execution to the cockpit. This new philosophy of air C2 is characterised in *JDP 0-30* as *centralised control, adaptive execution*.

Adaptive execution acknowledges that a centralised approach may be more appropriate for small-scale missions where the stakes are particularly high or where the highest-value assets are in play; where the participation of unfamiliar or less-capable coalition partners, possibly with very different ethics and values to our own, makes it inappropriate (or unwise) to decentralise execution authority; and when a lower-level decision-maker may be unaware of the full strategic consequences of their actions. The latter may be a particular imperative when we are employing full-spectrum targeting and cross-component capabilities, as recent operational experience indicates that execution authority is unlikely to be delegated below the strategic level when we use a mix of lethal and non-lethal effects.

Any suggestion that we should centralise execution creates justifiable concern that we may sap initiative or erode agility, replicating the failed Soviet-bloc approach to air C2. But in reality, there is nothing new about centralised execution, so we should not necessarily shy away from it. Since the air attacks on the World Trade Centre on 11 September 2001, almost every western air force has developed mechanisms to centralise execution authority at the highest strategic level (usually political rather than military) if an air defence fighter is required to engage a hijacked civilian airliner, especially over densely populated urban centres. This is a good example of an air operation where the stakes are so high - in terms of loss of life and the political consequences - that centralised execution is not just desirable, but essential.

Any operations with a high political tariff are therefore likely to generate the 'long screwdriver effect' and encourage (or mandate) a centralised approach to execution. Consequently, air commanders must understand the operational implications, particularly in reducing tempo. In October 2001, the operators of a US remotely piloted air system pinpointed the supreme leader of the Taliban, Muhammad Omar, in a convoy of cars fleeing Kabul. As neither the operators nor the US Navy Fifth Fleet commander in Bahrain could authorise the strike, approval had to be sought from US Central Command in Tampa, but the ensuing delay allowed Mullah Omar to escape.

So in sum, within the framework of adaptive execution, decentralisation (enabled by mission command) remains the default ideal, because it is most likely to assure tempo and flexibility by shortening the decision cycle. However, adaptive execution also acknowledges the reality that we may have to centralise execution in some cases, even if this is not always desirable in purely operational terms.

So what?

In one sense, adaptive execution as a concept simply recognises the reality of current operational practice. In air operations over Libya in 2011, for example, authority to execute attacks was delegated up and down the chain of command on a case-by-case basis: to the combined joint task force headquarters or combined air operations centre; to joint tactical air controller teams on maritime patrol aircraft; or to the cockpits of strike aircraft. Effectively, this was centralised control, adaptive execution before the term had even been coined. However, Libya also highlights two particular challenges with adaptive C2.

First, the speed of communication is critical. When execution authority was centralised to the combined air operations centre, target locations were often passed as GPS coordinates or in verbal code, as secure communications were not available to all coalition aircraft - but this risked errors in transmission or misunderstandings because of language difficulties. So execution could be a lengthy process, especially if messages had to be relayed through third-party agencies, and this meant the ground picture could change before aircraft were ready to attack. In contrast, when execution was decentralised, we could exploit the 'eyes-on' advantage available in the cockpit to engage fleeting targets.

However, this leads on to the second challenge: determining where the best point of understanding is really located. On one occasion, the pilots of a flight of Typhoons were convinced they could positively identify pro-regime forces attacking civilians and requested engagement authority. However, the CAOC withheld execution authority, as it enjoyed access to credible, near real-time human intelligence indicating no pro-regime elements were in the area. Although the aircrew were disappointed that authority to engage was not decentralised to them, it subsequently transpired that anti-regime forces had mistakenly engaged each other in a 'green-on-green' incident, so in this case, the decision to withhold execution authority was absolutely correct.

These examples reinforce the point that no single model of air C2 is appropriate in every case and we must simply learn to live with ambiguity. This implies a cultural change, where we take the air estimate process more seriously and afford air C2 particular priority within it, so that we can select the most appropriate degree of delegation to suit the particular operational circumstances. We must also review delegations constantly, because in politically ambiguous or dynamic operations we will have to direct execution authority upwards or downwards for different phases of the campaign, particular missions, or even for different targets within the same sortie.

The bottom line

Air C2 is important. In an era of financial austerity, we cannot expect to improve our capability through a series of major platform procurements. Instead, we must fight smarter, and this includes developing a more sophisticated understanding of the processes and principles of C2. In the past, I believe airmen and airwomen have been guilty of not giving command the attention it deserves. The mantra of centralised control, decentralised execution as a 'one size fits all' approach contributed to this unfortunate state of affairs by encouraging a degree of intellectual laziness; it was easy not to think too hard about C2 when there was only one possible answer. As one of the Royal Air Force's senior leaders said after Operation ELLAMY:

> *"For the last twenty years our strategy has been to turn up and wait for the USAF to hand us the ATO. There was a tangible sense of shock when we realised this wasn't going to happen this time".*

This is not good enough in an uncertain future of potential contingent operations where we may have to think for ourselves. I believe we can use the concept of centralised control, adaptive execution as a vehicle to promote a more rigorous approach to the employment of air power that encourages air commanders (and their staff) to think harder about every air operation they undertake: what is the context, what are the operational circumstances, who is the opponent and what are the desired outcomes? Only then can the most effective model of air C2, with the most appropriate delegations, be determined to meet the objectives set by higher authority and deliver operational success. Clausewitz famously asserted:

> *"the first, the supreme, the most far-reaching judgment that the statesman and commander have to make… is to establish the kind of war on which they are embarking".*

As airmen and airwomen, we ignore this aphorism at our peril.

Notes

[1] DCDC, *Joint Doctrine Publication 0-30 'UK Air and Space Doctrine',* dated Jul 13.
[2] DCDC, *Joint Doctrine Publication 0-01 'British Defence Doctrine'* (4th Edition) dated Nov 11.
[3] Despite the numbers of aircraft engaged, in most circumstances only the formation leader spoke directly to the controller.
[4] *JDP 0-01, p 5-4.*

Book Reviews

Out of the Mountains: The Coming Age of the Urban Guerrilla

By David Kilcullen

Reviewed by Flight Sergeant Wayne Lovejoy

Introduction

Now that the lengthy campaign in Afghanistan is drawing down there is a requirement for military personnel, and those involved in international affairs, to identify and understand the environments where future conflicts are likely. This book attempts to do just that and focuses on the fact that conflict will take place where people are, which in the developing world is in urbanized, littoral areas. Conflict is taken in the widest possible sense and the whole spectrum of violence and social control is examined to give an insight into this complex web of activity that extends well beyond the counter-insurgency of the last decade.

Dr David Kilcullen is well versed in contemporary military operations and has a significant reputation within this area. During his time as an officer in the Australian Army he served on operational tours in Indonesia, Iraq and Afghanistan. He drew upon his experience in Indonesia as the basis of his PhD thesis, which examined the political consequences of military operations there. Since leaving the army he has advised key personnel in the US government and was part of General David Petraeus' team that devised the 'surge' in Iraq to quell the violence there.

His study primarily focuses on the developing world and how various nations within it will interact with four megatrends; population growth, urbanization, littoralization and networked connectivity. It is acknowledged from the outset that this is not a new area of study and it

actually began to receive much attention prior to the attacks on the US in 2001, after which interest was diverted to the more pressing matters of Afghanistan and Iraq. Over the years while attention has been elsewhere these trends have continued at a greater rate, and the data generated from this period is used to create a straight-line projection of the coming years. This projection therefore gives far greater credence to likely developments than other predications. The study does not stop at just identifying the complex terrain created by the population mass and urban sprawl, these megacities are explored as living entities with their own 'system flows' that generate 'toxic by-products'. These analogies are used to describe the interaction within such an environment, and lead onto the theory of competitive control which is used to examine social interaction and governance by non-state armed groups.

As conflict and unrest is examined at such a local level the secondary and tertiary effects of a government intervention or NGO aid program can be better understood in light of the system flows. It is explained that by intervening in one group's activities or distributing aid to another, then the balance of these flows is affected, and this can have adverse effects against those who are trying to help. It is by discussing these wider issues that the book's appeal increases as it is not just centred on a military approach. In general the logical arguments are easy to follow, while the statistically backed content that scholars require is passively written into a free-flowing tour of recent conflicts and incidents, which are informative and interesting.

These wide ranging examples really contextualise the ideas being proposed, and reinforce the fact that the overarching issues are not new. When discussing the theory of competitive control, Christopher 'Dudas' Coke's management of a garrison-district in Kingston, Jamaica, is used to demonstrate that armed non-state groups can successfully establish themselves as the local authority. It is suggested that he was successful because he applied a full range of measures from persuasive, through administrative, to coercive, which ultimately generated a normative system. This is then contrasted to Al Qaida in Iraq who only applied coercive measures, and failed to control the population, which contributed to their defeat.

Task Force Ranger's operations in Mogadishu are used to show that cities are living entities and not just a piece of complex terrain. Here the author explains how the Task Force did not understand the city, and focused purely on the tactical aspect of the mission. The population were aggrieved by US helicopters after many civilians had been killed by their fire, so when one was shot down the population, rather than an organised militia, quickly responded. This resulted in what is described as 'swarm tactics' in that there was no command and control, but simply local people responding as they saw appropriate. On the other hand, the Mumbai terrorist attacks are used to demonstrate the devastating effects that can be achieved when terrorists understand a city and its flows. The open source details that have been put together show how armed groups can disappear into congested shipping lanes before passing through smuggler routes and slums into the heart of a city completely unhindered.

The chapter entitled 'Conflict in Connected Cities' has many examples of how mobile communications and the internet can be used to generate allegiances between groups within a country, as well as to receive information and direction from outside it. This revolution in the use of communications is explored in some depth, exhibiting the almost endless amount of possibilities it creates. The Arab Spring is used to reinforce this, and as the focus remains fixed on the issues at hand, the points are clearly illustrated.

The evidence to suggest that the population expansion on the coastlines of developing countries is substantial and convincing, so too is how these megatrends converge to create network connected megacities. The diverse examples vividly illustrate how the processes and projections are prevalent, and how they will affect all future operations in these environments. The book is certainly worth buying for anyone with an interest in the type of environments that will be faced by governments and NGOs in the future, along with the trends that are affecting these. This is a very informative book on the specified subject, and it is written in a manner that makes it interesting and appealing to a wide audience.

Book Reviews

Vulcan Boys – From the Cold War to the Falklands: True Tales of the Iconic Delta V-Bomber

By Tony Blackman

Reviewed by Dr David Jordan

Introduction

The Avro Vulcan, one of the trio of 'V-bombers' which carried Britain's nuclear deterrent for just over a decade until the Polaris submarine entered service with the Royal Navy has become something of an icon of the once-considerable British aviation industry. The aircraft's distinct delta wing, impressive performance – notably its being rolled immediately after take-off by the test pilot Roly Falk at the 1955 Farnborough airshow – added to its lustre in the eyes of aviation enthusiasts and the wider public (often at the expense of the other two V-bombers, the Vickers Valiant and Handley Page Victor). If it needed further reinforcement, the Vulcan's reputation as a British aviation 'great' was secured on the cusp of its retirement with the long-range bombing and suppression of enemy air defence (SEAD) raids conducted as part of Operation Black Buck during the 1982 Falklands conflict.

As a result of this, the Vulcan is hardly ill-served in terms of aviation literature. This ranges from extensive coverage in Humphrey Wynn's excellent official history of RAF nuclear deterrent forces, books clearly aimed at enthusiasts and even dedicated magazine issues. Tony Blackman's book therefore adds to a considerable corpus of literature dealing with the Vulcan, and this might, at first sight, raise the question of whether it offers anything new to an already-impressive array of literature. The answer is that it does, and although it is clearly aimed at the general reader rather than being a more 'academic' book, it should not be dismissed simply as 'another book for spotters'. Blackman is a former Avro test pilot, thus

entirely familiar with the subject matter, and has pulled together a series of reminiscences by those who flew the aircraft with the Royal Air Force. It is this which makes the book stand out, since unlike many others covering the same subject, it serves as a useful oral history not just of the Vulcan, but of the RAF bomber force during the Cold War.

There are sixteen chapters outlining the Vulcan's career, all of them offering something of interest. The first three look at Vulcan test flying. Unlike many accounts, which would have been provided by pilots, the first chapter is from the perspective of an observer and the second an Air Electronics Officer. The first contribution from a pilot comes in chapter 3, looking at the use of the Vulcan as a test-bed for the Rolls Royce Olympus engine type which powered Concorde. The book then considers flying the Vulcan from the point of view of the pilot and co-pilot, the navigators (of which there were two – radar navigator and 'nav plotter'), and another account from an Air Electronics Officer. This latter chapter is of interest, since it covers the Vulcan's often forgotten roles in Maritime Radar Reconnaissance and the sampling of nuclear tests.

The book then moves on to address the use of the Blue Steel stand-off nuclear missile. While Chris Reid's account of his time flying Blue Steel armed Vulcans is entertaining, it must be said that the chapter does not go into much detail which is new, and it is a shame that more material on this role was not incorporated. This is followed by a consideration of the Tactical Evaluation (TACEVAL) process as seen through the eyes of Vulcan crews; again, this is an interesting insight into an often-forgotten and not fully understood area of the RAF's life in the Cold War period, and it is a shame that no more than four and a half pages could be found for the recollections about this process of two aircrew and one engineering officer. Accounts of training in North America, including at Red Flag exercises are covered next, followed by an interesting insight into the Strike Command detachment at Offut Air Force Base in the United States. Again, the reader is left wishing there were a little more detail, since this aspect of the RAF's operations during the Cold War is rarely, if ever, mentioned in any secondary source material.

All of the above Chapters provide something of interest and help to add to our understanding of how the Vulcan force operated during the Cold War period. It is, though, the next three chapters which really add value to the book, since they cover the Falklands conflict of 1982. Much has been written about Operation Black Buck, and it must be said that much of the material is deeply unhelpful. There has been a tendency amongst historians and commentators to concentrate upon the first of seven Black Buck sorties (two of which were aborted before they reached the Falklands) and to offer limited commentary about Black Buck Six, which was forced to land in Brazil after its refuelling probe broke, precluding its return to Ascension Island. This has been accompanied by a narrative deeply critical of the raids (often characterised as 'the RAF trying to get in on the act' in a selfish bid to avoid a public relations disaster of being seen to have failed to take part in the war, an accusation which the official record proves to be pernicious nonsense) for their perceived lack of success in completely

closing the runway at Port Stanley. The airmanship involved in the raids is usually given some, almost grudging, respect from the critics, but the chapters in this book help to demonstrate that there was far more to the Black Buck raids than mere service propaganda, even if they do not tell the complete story.

We are given brief but compelling insights into the challenges of establishing a forward operating base at Ascension for the Vulcan, the planning process for the Black Buck raids (including the formidable challenge presented in the provision of air-to-air refuelling) and – most interestingly – David Castle's account of Black Bucks Five and Six, with the latter ending up in Rio de Janeiro for the reason noted above. This chapter gives clear insight into the challenges of conducting SEAD operations at range, using an extremely functional ('hastily cobbled together' would be an alternative description) fit for the AGM-45 Shrike anti-radar missile and concludes with an entertainingly dramatic account of the Vulcan's unscheduled arrival in Rio - complete with a description of how the insistent and increasingly distracting demands from Rio's Air Traffic Control for flight details were ended by the claim that the flight had originated in Huddersfield, leading to puzzled silence as the Vulcan made its approach – and thoughts on the subsequent unscheduled stay in Brazil.

The book ends with an account of the Vulcan's final task in the RAF, namely as an interim refuelling tanker, a role it fulfilled until the VC10 tanker variants entered service, and a concluding piece looking at the preserved airframes. For the academic studying air power, this last chapter is not particularly useful, but for a book that is primarily intended for a general readership, it is a fitting conclusion.

Overall, any assessment of *Vulcan Boys* written for a journal such as *Air Power Review* has to note its limitations as a purely academic source. Yet to focus on this aspect is to miss the point of books such as this. Those who study air power and who do not have a service background can only benefit from reading the sort of material presented by Tony Blackman, since it provides rich (if often all-too-brief) insight into the RAF, service culture and gives a broader sense of how practitioners went about the day-to-day business of military aviation. *Vulcan Boys* is, therefore, a useful addition to the corpus of literature on air power and of interest to more than just the stereotypical 'spotter' community because of the information that it imparts.

Call for Papers

ROYAL AIR FORCE Centre for Air Power Studies

From 'Shooting the Front' to Combat ISTAR
The Evolution of Aerial Intelligence and Reconnaissance

A Conference held at the Royal Air Force Museum in conjunction with the Royal Air Force Centre for Air Power Studies

15-16 April 2015

From air observation and photographic reconnaissance in the First World War through to the emergence of Combat ISTAR, effective intelligence gathering has been at the heart of air operations since the birth of air power. Indeed, it is in the observation role that air power made its first appearance on the battlefield when a balloon was used during the Battle of Fleurus in 1794. Since then, air power has been able to provide longer, deeper and more persistent forms of information collection. Furthermore, the provisional *Training Manual* of the Royal Flying Corps stated in 1914 that, 'The most important role of aircraft in war is reconnaissance'. More recently, AP3000, the modern Royal Air Force's capstone doctrine, has codified 'Intelligence and Situational Awareness' as one of the Service's four fundamental roles. As we move through the period of the centenary of the First World War and towards the 100th Anniversary of the RAF's formation, the time is precipitate to explore the importance of aerial based reconnaissance and intelligence gathering and its effect on war in all its facets.

This two-day conference invites papers dealing with any of the topics below. In addition to established academics, the organisers are keen to receive proposals from postgraduate students, early careers scholars and those with professional experience. Panel proposals of three speakers and a chair are welcomed. Papers on other themes are also encouraged.

Intelligence | Reconnaissance | Surveillance | Target Acquisition | Operational Techniques | Development | Strategic and Operational Effect | Interpretation | Dissemination | Operational Responses | Organisation and Culture of Air Intelligence Services | Intelligence on Air Forces | National, International and Transnational Experiences

Paper proposals must be submitted to the email below by 1 December 2014 along with a 300 word abstract and curriculum vitae. Additional conference details and registration information will be available soon. It is planned to publish the conference proceedings at a future date.

Conference Organisers

ROYAL AIR FORCE museum

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Andrew Renwick (Curator of Photographs, RAF Museum)
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