Special Feature

However much we succeed in transforming our logistics processes, there will continue to be a tension between efficiency and effectiveness. A just-in-time philosophy built around a responsive and agile supply pipeline, a minimum deployment footprint and extensive host nation support, may not always provide the resilience needed to sustain military capability.

logistics and doctrine

Sustaining Airpower: The Influence of Logistics on RAF Doctrine

This edition's featured article was written by Air Vice-Marshal Peter J. Dye. Marshal Dye, over the years, has been a frequent contributor to the Journal. He is an accomplished military officer and logistician. In "Sustaining Airpower: Influence of Logistics on RAF Doctrine" Marshal Dye explores how the question of sustainability has influenced British thinking on airpower. He also explores the often-troubled relationship between support activities, particularly logistics, and the delivery of military capability. The article touches on organizational and cultural issues, and considers how current paradigms may change with the increasing focus on expeditionary warfare and the development of network-enabled capability. Royal Ai r Force (RAF) organizational structures and their associated processes continue to reflect the arrangements developed during the Second World War. The emphasis on infrastructure, the heavy investment in equipment and the high ratio of support to combatant personnel have been defining characteristics of the RAF for nearly 90 years.

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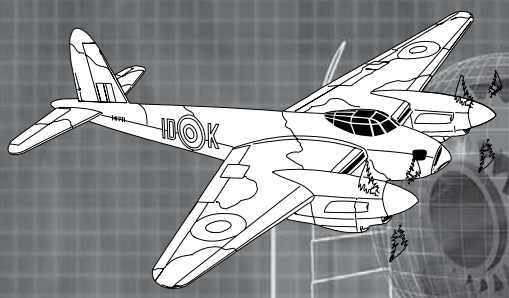
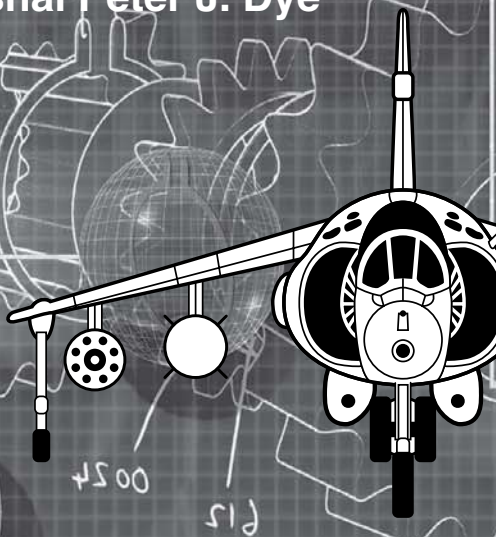
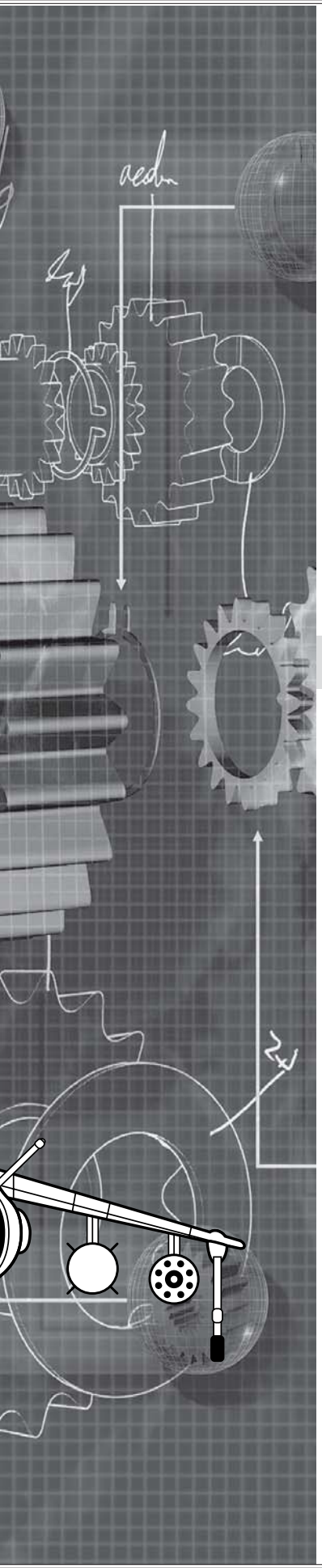


Sustaining Airpower

Influence of Logistics on RAF Doctrine

Air Vice-Marshal Peter J. Dye





Introduction

In 1942, Sir Frederick Sykes, the first commander of the Royal Flying Corps (RFC), and later chief of the Air Staff, briefly outlined how the motto, *Per Ardua ad Astra* (Through Adversity to the Stars), had been selected. Although he noted that some thought it bad Latin, he did not choose to elaborate on why it was the *best possible choice*.[1] For Sykes and his contemporaries, the reasons would have been self-evident. The RFC had emerged in the face of institutional hostility, interservice rivalry, political indifference, and significant technical and environmental challenges. The struggle to master the air had exacted a heavy price. The ethereal (the heavens) had been gained through human (mortal) effort. But, there was perhaps an even deeper message—the paradox that was the aspirational nature of airpower and the laborious, sometimes mundane and frequently complex arrangements needed to support military aviation. Thus, while the bravery and dedication of those individuals who helped to create the RFC was not in question, it was evident that the freedom of the skies (and the boundless military potential they offered) was in stark contrast to the fragility (often literal) of powered flight.

Special Feature

This article explores how the question of sustainability has influenced British thinking on airpower. It explores the often-troubled relationship between support activities, particularly logistics, and the delivery of military capability. The article also touches on organisational and cultural issues, and considers how current paradigms may change with the increasing focus on expeditionary warfare and the development of network-enabled capability.

Sustainability and Logistics

Logistics and sustainability are not the same thing, although there is sometimes an implication that they are. Strictly speaking, sustainability is the "ability of a force to maintain the necessary level of combat power for the duration required to sustain its objective."[2] Logistics, as the science of planning and carrying out the movement and maintenance of forces, clearly contributes to sustainability, but then so do training, intelligence, planning, and a wide range of other support or enabling activities that are certainly not embraced by the term *logistics*.

Sustainability is now properly regarded as a *principle of war* and, while logistics activities are hugely important in contributing to this core capability, they are subordinate to this end, together with the associated support strategies and organisational arrangements.

Enabler or Impediment?

Military aircraft spend much of their working lives parked comfortably on the ground, protected from the very elements that they supposedly conquered at the turn of the twentieth century. It is not just gravity that keeps them there. The cost, complexity, and effort needed to sustain military aviation are considerable. Air forces have learned how to manage these activities by focusing on process and organisation, but there remains a suspicion that the logistician is as much an impediment as an enabler in the delivery of airpower. For example, does the supply chain drive the machine forward or drag it back? Current sentiment seems to prefer the latter perspective. The popular press certainly seems unable to employ the word *logistics* without the juxtaposition of *failure*, *shortage,* or *crisis*.

These views are neatly encapsulated in Hoffman Nickerson's observation that "*Airpower is a thunderbolt, launched from an eggshell, invisibly tethered to a base.*"[3] Dramatic effect is balanced by a sense of fragility while still leaving one to wonder whether the tether should be viewed as an umbilical or as a brake.

Organisational Egg or Doctrinal Chicken?

To address the question of how sustainability has influenced British thinking about airpower we need first to confront the conundrum of what came first, the doctrinal chicken or the organisational egg? The widely used Doctrinal Development Model suggests that the process is best seen as a continuous loop, linking doctrine, output, feedback, and input. While this may be an entirely adequate concept,

Article Highlights

The logistics systems deployed by the RAF in both World Wars, and throughout the Cold War, were more than effective—they were winning solutions. These successes should be built on while seeking better ways to meet today's needs. Caution and a degree of humility are called for rather than a relentless dash for the new and untested.

Royal Ai r Force (RAF) organizational structures and their associated processes continue to reflect the arrangements developed during the Second World War. The emphasis on infrastructure, the heavy investment in equipment and the high ratio of support to combatant personnel have been defining characteristics of the RAF for nearly 90 years.

Air Vice Marshal Peter J. Dye postulates that expeditionary warfare and network enabled capability may be about to shift this particular paradigm. *The End-to-End Logistic Study*, now known as the Logistic Transformation Programme (LTP), and continuing work on station (base) structures offer the prospect of a significant change in the way the RAF is organized. Expenditure on logistic support and on the procurement of aviation and aviation-related equipment continues to represent a significant proportion of the UK defense budget.

According to Dye, the RAF will see fewer uniformed support staff with some functions no longer carried out at station level—and many no longer under the control of the station commander. The four lines of maintenance and repair seen in the RAF for over 50 years will disappear. The effect will be to dilute the status of the station in the overall organization with a greater emphasis on force elements as the RAF's center of gravity. Dye goes on to note that the RAF may need to *unpick* the Binbrook model. The difficulty will be to sustain ethos with the RAF logistics community while creating a more agile and adaptable organization. The basic building block in the new construct may well be the squadron, if not the flight, rather than the station.

The logistic problems faced by the RAF in Iraq are less about quantity and quality, and more about availability. The continuing concern about the inability in the RAF to track individual items, and the debate it does beg the question of what came first? My personal view is that logistics processes have so dominated the delivery of airpower that doctrine has largely followed in their wake. This is as true today as it was when the Royal Air Force (RAF) was created.

The First World War

On the morning of 7 April 1918, with the airfield at La Gorgue shrouded in heavy fog and the German army advancing, Major Chris Draper ordered the burning of all 16 Sopwith Camel fighters belonging to No 208 Squadron, RAF. Two days later, the squadron had relocated to Serny, over 20 miles to the west, and was actively engaged in the continuous air operations that sought to halt the German march offensive before it could threaten the channel ports. As the squadron commander later recalled, "It says a lot for the supply depots that we got our full complement of 20 new machines within 48 hours."[4]

This small incident, in a long and intensive war, provides some indication of the scale and effectiveness of the logistics system that underpinned the British air effort on the Western Front. The value of the machines burnt at La Gorgue represented £5M at today's prices, yet new aircraft were available almost immediately, as were the technical personnel, ground equipment, spares, fuel, ammunition, vehicles, tools, repair facilities, and hangarage needed to support a frontline squadron. [5]

The First World War and its aftermath largely shaped the twenty-first century. In scale and intensity it was quite different from any other war previously fought. It was also a conflict in which technology dominated events to an unparalleled degree. John Terraine has observed that "the Great War was from the beginning the greatest war of technical innovation ever fought," adding that modern wars had become - as a war of masses with modern weapons sustained by modern mass production - "a matter of organisation and specialist skills in all the complex areas of logistics."[6]

It is arguable that the most complex logistics challenge was faced by the air services as they sought to realize the potential of airpower. Over recent years there has been a gradual recognition of the immense and sophisticated efforts needed to sustain the Western Front, as part of a more balanced and dispassionate analysis. The air war has not attracted the same level of interest, let alone controversy, even though it presaged the great air offensives of the Second World War. In fact, there has been a remarkable lack of debate about how, in a matter of a few years, a pre-war novelty was turned into a weapon capable of influencing the course of battles and ultimately war itself.

Between 1914 and 1918 the air arms of all the major belligerents, with the exception of Turkey, underwent a revolutionary transformation, but none more so than the British Air Services. By the Armistice, the RAF possessed 22,171 aircraft and boasted a total strength of 274,494 personnel compared to the RFC and Royal Naval Air Service combined strength of 270 aircraft and 2,073 personnel on the outbreak of war.[7] The RAF also possessed, according to the author of a post-war study, the most fully developed system of aviation supply amongst the allies.[8]

There is some danger, however, in focusing just on the gross number of aircraft. It masks a fundamental characteristic of airpower—the high ratio of support to operational activities. If

the frontline squadrons were the RAF's cutting edge of the spear, the shaft represented the greater part of the weapon. Of the 22,171 total aircraft, just 6,740 were assigned to operational duties (including the Western Front, home defence and antisubmarine activities). However, only 2,896 could be regarded as effective (13 percent of those on charge)—the remainder being held in store or under repair intheatre. At any one time, a further 10 to 15 percent were unserviceable, leaving just 2,500 aircraft to be employed on active operations. While much of the difference is explained by the need to hold significant reserves against attrition, the number of operational aircraft was unquestionably modest compared to the total inventory (see Figure 1).[9] The scale of the resources needed to sustain this frontline (equivalent to some 200 squadrons in 1918) was unprecedented. Indeed, the national effort was substantially larger than the total uniformed strength of 274,494 implies. When the civilian labour involved in aircraft and aeroengine production, provision of spares and repair is taken into account, the number of personnel required rises to around 630,000 (including trainees, instructors, and support staffs).[10]

By the Armistice, the total cost to the nation, in materiel and human terms, amounted to the equivalent of £200M per year, or 4 percent of the United Kingdom's gross domestic product (GDP). Daily expenditure on the RAF had reached over £0.5M, or 7 percent of Britain's total daily war expenditure (see Figure 2). This was set to rise still further with some £165M of outstanding aviation orders, more than half the production commitments of the Ministry of Munitions, at the time of the Armistice.

The result of this huge investment was the production each month of an average of 4,000 aircraft, 3,900 aeroengines (including those repaired or rebuilt), 1,200 pilots, and 3,000 other ranks. Without this effort, average monthly losses of 2,200 aircraft and 3,000 aeroengines (written off and damaged), and some 800 to 900 pilot casualties would have rapidly curtailed operations.

The logistics system embracing these varied activities had few, if any, parallels in history. By the Armistice, the RAF's technical inventory comprised more than 50,000 separate line items. No business ever had to manage a stock holding of this size or complexity—a challenge made all the more difficult by the delicate nature of much of the equipment and spares involved, rapid obsolescence, and high modification rates.

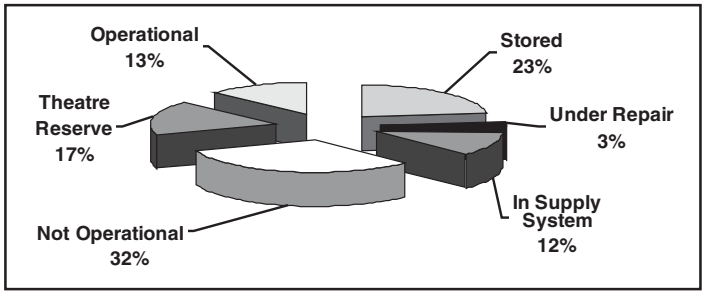


Figure 1. RAF Aircraft Dispositions November 1918

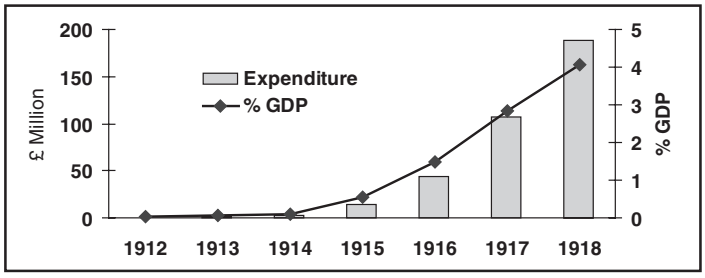


Figure 2. Aviation Expenditure 1912-1918

Article Highlights

about *precision-guided* logistics, presage fundamental changes in the way that supply chains and logistics will be managed in the future.

Dye believes it likely that the RAF will gradually see a transition from a supply chain, built around a hierarchy of organizations, to a distributed network that can respond rapidly to changes in demand.

Dye warns that we must be cautious about what can be quickly achieved. He notes the RAF has toyed with serial number item tracking for at least 30 years and has a vast inventory, support processes, and policies tied to legacy weapons systems. Much as the RAF might wish to move from supporting platforms to supporting military effect, there is a limit to what can be done with our older assets.

The distinguishing characteristics of aviation logistics, as compared to defense logistics in general, are likely to diminish with time as all military equipment becomes more complex and support systems more sophisticated and interdependent.

As warfare moves from the industrial age to the information age, there will be fundamental change in the nature of logistics. Success will be measured by the adaptability of the support organization rather than by its scale or scope. If nothing else, this threatens to transform the relationship between airpower and sustainability that has held sway for nearly 90 years. However, no matter how much logistic processes are transformed, there will continue to be a tension between efficiency and effectiveness. A just-in-time philosophy built around a responsive and agile supply pipeline, a minimum deployment footprint, and extensive host nation support, may not always provide the resilience needed to sustain military capability.

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Article Acronyms

GDP - Gross Domestic Product
LTP - Logistic Transformation Programme
MAP - Ministry of Aircraft Production
RAF - Royal Air Force
RFC - Royal Flying Corps
RUSI - Royal United Services Institute
UK - United Kingdom

Organisational Implications

The First World War demonstrated that sustaining an effective air force required significant economic and industrial power allied to a large and complex support organisation. It is not surprising, therefore, to find that the level of increase in resources committed to the air services was significantly greater than to the Army (see Figure 3). Trenchard's strategy of the *relentless and incessant offensive*[11] was only tenable because the necessary human and material resources were made available.

It was known before the war that the arrangements needed to support military aviation possessed quite distinct characteristics. Sefton Brancker described, in June 1914, how the difficulties of maintenance were sometimes lost sight of, and that the fragility of aircraft, the need for repair and large quantities of spares, together with the difficulty of supply meant that "only a small proportion of the aeroplanes in the field will be fit to take to the air at any given moment."[12] In fact, sustainability was a major consideration in the decision to standardise on the squadron as the basic organisational building block for the RFC and, ultimately, for the RAF.[13]

Wastage rates were high as a result of accidents and low reliability, as much as from enemy action. This demanded a constant stream of replacement aircraft and aircrew. The disparity between new production and supply, particularly in aeroengines, meant that salvage, repair, and maintenance made a significant contribution to sustainability. Obsolescence, design and manufacturing shortcomings, and shortages in critical equipment meant that a high level of modification and rework had to be undertaken in the field. A wide range of special equipment, tools, and a myriad of individual parts and components needed to be readily available to the frontline squadrons to support these activities, as well as routine maintenance—under the constant threat of a short-notice move. The result was an extensive ground organisation, employing large numbers of skilled and semi-skilled personnel, underpinned by a supply chain that stretched from the frontline, via the repair depots and air parks, to the factories at home.

Aircraft and their component parts largely populated the supply pipeline, together with a constant flow of technical information, spares, equipment, and personnel. Unlike traditional military logistics systems, it was not dominated by a one way flow of consumables but by scarce, high value items that moved to and from the frontline in a constant cycle of replacement, salvage, and repair.[14] As a result, noncombatants greatly outnumbered combatants. This was no subtle shift in the balance of roles, but a steep change in the *teeth-to-tail* ratio. Thus, of the 51,000 RAF uniformed personnel serving in France by November 1918, only 8 percent were classed as combatants (pilots, observers, air gunners, and so forth) while the majority, some 29,000 (57 percent) were technicians. By comparison, 896,000 personnel (65 percent) of the British Army were classed as combatants (see Figure 4).

The other defining feature was the balance of expenditure between personnel and equipment. During the course of the war over 50,000 aircraft were delivered to the British Air Services, of which only 36 percent remained on charge by the Armistice (see Figure 5). In 1918, squadron frontline establishments were replaced on average every 2 months. Notwithstanding the importance of repair and salvage in helping to recycle aircraft, aeroengines, and components, huge sums had to be committed to sustain the frontline. Throughout the war, between 50 and 60 percent of the budget allocated to the British Air Services was expended on equipment (see Figure 6).

In summary, the RAF was created around a system of interlinked and interdependent logistics activities that moved high value materiel continuously backwards and forwards at a tempo determined by daily attrition, combat operations, and technological advances—John Frederick Charles Fuller's *constant tactical factor*.[15] It was a system unprecedented in both scale and intensity. Moreover, the efficiency and effectiveness of these arrangements directly governed the degree to which air power's potential could be realised. In this sense, logistics acted as air power's *lifeline* and, in so doing, established a dependency that has lasted for 90 years.

Thus, the expansion of the RAF from 1934 onward, although overtly dominated by the need to match the Luftwaffe's frontline, also sought to provide the resilience needed to fight a modern war.

The Creation of the Royal Air Force

Concerns about sustainability also provided the catalyst for the creation of the RAF. The political imperative for an offensive air strategy and secure home defence could only be realised by the deployment of substantial national resources and closer military-industrial cooperation. The Joint War Air Committee formed early in 1916 (and the subsequent Air Board) were direct responses to the squabbling between the Services over the supply of aircraft and engines and the self-evident need to set priorities for the allocation of aeronautical material. Inasmuch as this established a favourable environment for an independent air arm, it may be claimed that the RAF was created as a structural solution to the wartime problem of maintaining an adequate supply of aircraft and aviation personnel.

Strategic Bombing

The creation of the Air Board and the more effective direction of production under the Ministry of Munitions saw significant improvements in sustainability. Indeed, the expectation of a surplus in aircraft and aeroengine production by the end of 1917 led directly to the creation of the Independent Force intended to attack military and strategic targets in Germany. In the event, the full increase in production was not achieved but by then the Independent Force had been created to employ the notional surplus of men and machines. Eventually, some 10 squadrons

out of the planned 40 were formed. Even if the numbers employed fell short of those planned, and the operational results lacklustre, the experience had a profound influence on RAF doctrine. Thus, an optimistic view of sustainability in 1917 led to the RAF's first steps in strategic bombing and, ultimately, to the Second World War's combined bomber offensive.

The First World War Legacy

I have laboured the point about the interdependence of airpower and logistics because the nascent RAF, at an organisational level, was designed around the support arrangements needed to sustain operations in war. While there was no *lessons identified* process, the central role of logistics in the delivery of airpower was widely recognised and understood. Air Commodore Robert Brooke-Popham, lecturing shortly after the end of the First World War, stated that,

> It is, therefore, of the highest importance that spare machines and spare parts of every sort shall be instantly available. This means large base depots and an efficient channel of supply between depots and squadrons and on the sound working of this supply system the efficiency of the Air Force in any theatre of war very largely depends.[16]

In the years that followed, Trenchard sought to construct (literally) an air force worthy of the name. The RAF Cadet College and the RAF Apprentice School were the most obvious elements in this strategy, but they were part of a wider programme that enshrined a logistics-centric view of airpower based on a substantial investment in support activities. Speaking in 1944, Trenchard recalled that,

> When we originally formed the Air Force in those days we were told that we were spending all our money on bricks and mortar, and on ground staff and ground personnel. In fact … it was called *the Ground Force* and I believe I was myself once described as *General Officer Commanding Ground Force*.[17]

The importance attached to organisation and process was reflected in the RAF War Manual. "Under the modern conditions in which fighting services are called upon to operate, victory inclines to the force which is most thoroughly and efficiently organized."[18] A recurrent theme in pre-war planning was the high wastage that war would bring. In a paper on *Some Problems of a Technical Service* read at the Royal United Services Institute in 1934 (with Air Marshal Sir Robert Brooke-Popham in the chair), the author stated that the average life of an aircraft in war would be 2 months—based on First World War experience—and that large reserves and high production rates were essential, underpinned by long preparation and skilled repair personnel.[19]

Thus, the expansion of the RAF from 1934 onward, although overtly dominated by the need to match the Luftwaffe's frontline, also sought to provide the resilience needed to fight a modern war. This was not a policy of quantity over quality, although there was some criticism (from even within the Service) that there were dangers in pursuing the mass-production methods employed in the First World War.[20] By and large, new technology was successfully introduced while substantially increasing the size of the frontline and the supporting reserves, consuming some 36 percent of the rearmament budget in the process (see Figure 7).

The result was a vast array of depots and maintenance units, specialising in storage, repair, salvage, and armament, that had no parallel in the Luftwaffe where the doctrine of a short war negated the need for investment on a similar scale. Thus, over a period of 20 years the home-based RAF had been transformed from what was largely a training organisation based around grass airfields and temporary accommodations to a permanent system of stations and maintenance units that would provide the fighting platform for both defensive and offensive action.

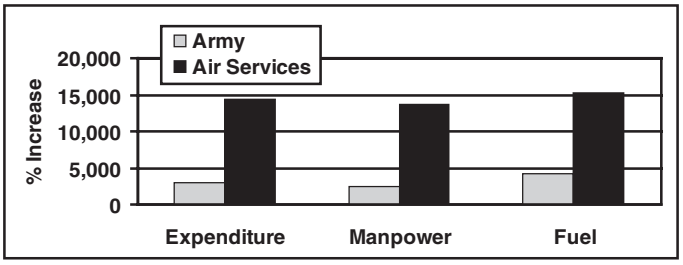

Figure 3. Relative Increase in Military Resources 1914-1918

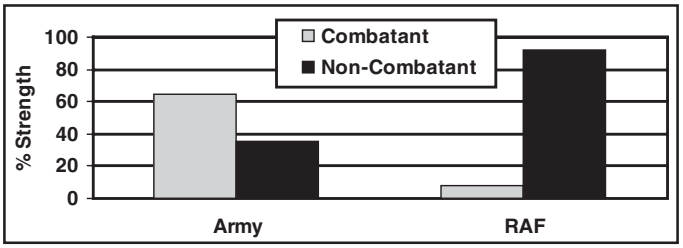

Figure 4. Relative Proportion of Combatants - France 1918

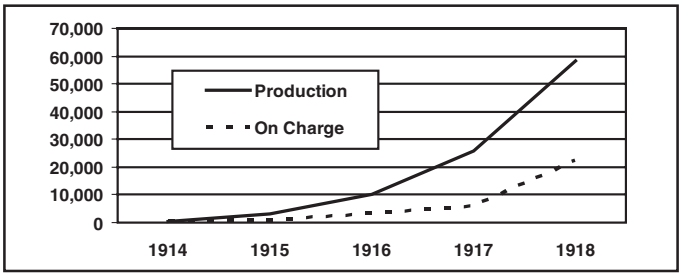

Figure 5. Aircraft on Charge - British Air Services 1914-1918

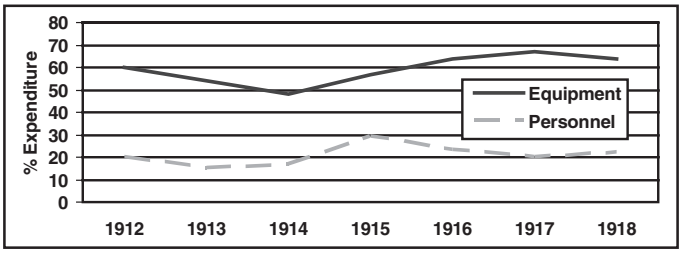

Figure 6. Air Service Expenditure by Category

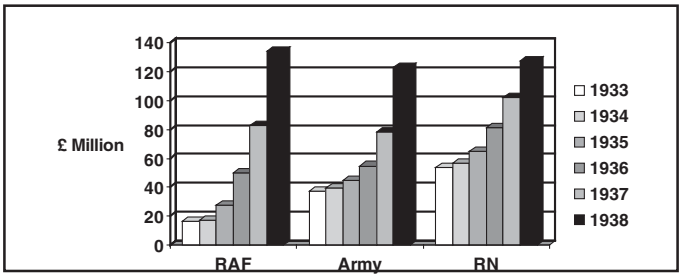

Figure 7. Comparison of Annual Defence Expenditure 1933-1938

The impact of this change was deeper than might be imagined, as it touched on that most intangible of issues—ethos and culture. The station became not only the key element in the exercise of command and control, but also a microcosm of the Service itself. In this sense, the station occupied a very different position to the garrison, shore establishment, or dockyard. This was reflected, if nothing else, in the status and authority of the station commander enshrined in King's Regulations and the Air Force Act. While squadrons were the fighting arm, the majority of RAF personnel served on the strength of a station, undertaking the wide range of support activities needed to keep aircraft flying.

To shed some light on the differences between the Services it is interesting to note that in both 1918 and 1945, the RAF possessed more airfields and support units in the UK than frontline squadrons (see Figure 8). The same could certainly not be said about the number of ports versus warships or the number of garrisons versus regiments.

The Second World War

This massive investment in sustainability came into its own during the Battle of Britain. The disparity in approach to logistics issues between the respective air forces became clearer as the campaign progressed. Fighter Command maintained (if not enhanced) its frontline numbers during the battle, while the Luftwaffe declined in strength as availability fell and aircraft and pilot wastage rose beyond the supply of replacements.

Notwithstanding heavy losses (fighter wastage reached over 50 percent per month during 1940), RAF reserves continued to grow throughout the war. The average number of aircraft in storage awaiting issue to the Metropolitan Air Force rose steadily, reaching over 10,000 by 1944, where it remained until the end of the war (see Figure 9).[21]

While some commentators have criticised the Allies for employing their significant economic and industrial capacity to support a military strategy built on brute force, the attritional nature of modern warfare and the pace of technological change allowed little choice in the matter.[22] While it is true that the RAF and the United States Army Air Force relied on high production rates, an extensive supply system, and comprehensive support arrangements to compensate for high operational wastage, it is also true that these resources were available as a result of careful and detailed planning, driven by what the First World War had demonstrated about sustainability and airpower. Both air forces had long recognised that warfare in an industrial age demanded supply on an industrial scale.

The closest parallel to Trenchard's *incessant offensive*, the combined bomber offensive was founded on a massive industrial effort and a world-wide training programme that produced sufficient heavy bombers and crews to maintain operations in the face of desperate attrition. During the course of the war, Bomber Command lost over 74,000 aircrew (either killed, wounded, or prisoners of war) and 12,330 aircraft to operational and nonoperational causes[23] against a frontline strength that reached 4,384 aircraft by May 1945. During the course of 1944, 12,295 heavy bombers were delivered to Bomber Command—3,285 repaired, and the remainder new production—a wastage rate of 950 percent.[24] [25]

The manufacture, modification, and repair of aircraft had, by 1943, become Britain's largest industrial operation.[26] From 1939 to 1945 over 131,000 aircraft were produced, compared to 55,000 in the First World War. However, the complexity and weight were a magnitude greater, as was the cost. In 1943 alone, expenditure on new production by the Ministry of Aircraft Production (MAP) totalled some £800M (equivalent to £83B at today's prices).[27] Total wartime expenditure on aircraft and related equipment exceeded £3,75M (£385B) while the capital cost expended in creating the necessary industrial capacity amounted to £350M (£36B). Overall, more than 36 percent of wartime defence expenditure (around 20 percent of the UK GDP) was committed to the RAF, of which some 40 to 50 percent comprised equipment costs.[28]

RAF organisational structures and their associated processes continue to reflect the arrangements developed during the Second World War. Indeed, the emphasis on infrastructure, the heavy investment in equipment and the high ratio of support to combatant personnel have been defining characteristics of the Service for nearly 90 years.

At its peak (in the summer of 1944), more than 3 million personnel were employed in aviation-related activities, including 1.7 million in MAP and over 1 million in uniform (see Figure 10). This compares to a total employment of 630,000 in the First World War. In fact, the remorseless consumption of labour by the RAF and the MAP soon became unsustainable and had to be scaled back in favour of the Army and other critical war industries.

Nightly attacks by hundreds of heavy bombers against targets in Germany and Occupied Europe also demanded a sound and secure infrastructure. From 1939 to 1945, the airfield construction programme was Britain's largest civil engineering project since the building of the railways in the nineteenth century. A total of 444 new airfields were constructed in the UK at a cost of £200M (£20B) and employed over 300,000 men.[29] Approximately 1,800 airfields were constructed worldwide over the same period.[30] Each airfield consumed a vast range and quantity of resources, ranging from hardcore, concrete and bitumen for the runways, taxiways, dispersals and roads, to wood, bricks, and steel for the technical

accommodation and hangars. Stations—and there were 59 distinct designs dependant on functional role[31]—also required dedicated utilities and waste disposal, as well as extensive storage facilities and domestic accommodation. In 1942 over £145M (£16B) was spent on works for the RAF compared to just £4M in 1935, at the start of the expansion programme. [32]

By the end of the war, the RAF frontline comprised some 500 squadrons and 9,250 aircraft.[33] The total inventory was in excess of 55,000 airframes with over 10,000 in store or in reserve in the UK alone, with a further 1,900 under or awaiting repair. New aircraft were being delivered at the rate of some 2,000 per month. As a result, the teeth to tail ratio was remarkably similar to that found nearly 25 years earlier—1 to 6 in 1945, and 1 to 8 in 1918 (see Figure 11).

Post-War Organisational Models

While the scale of the effort expended on the RAF during the Second World War was impressive, every brick laid and ton of concrete poured, anchored the Service's future to its infrastructure. Demobilisation and substantial reductions in manpower and estate did not alter the emphasis on the station as the RAF's centre of gravity. The Cold War, and the decreasing importance of expeditionary operations, enshrined this perspective, assisted by further infrastructure investment to accommodate heavier and faster aircraft as well as new roles, such as nuclear deterrence.

The early post-war years also saw a succession of studies and trials designed to determine optimum working patterns and organisational structures. This work had commenced during the war with research into improving manpower utilisation and aircraft availability through *planned flying* and *planned servicing*.[34] The focus was very much about treating operational output as a mechanistic process that could be improved using work study methodologies.

A similar effort was expended on determining best practice in the deployment of station manpower and appropriate station structures. An experimental station organisation was tested at RAF Tuddenham in 1946.[35] One of the aims was to relieve the station commander of a mass of administrative work. It was also hoped to weld station personnel into a single unit and thereby foster a good station loyalty and morale. A related study at RAF Binbrook also took place in 1946. It is perhaps the more famous of the two trials. From this latter study emerged the *standard* three-wing station structure (executive, technical, and flying) that has been the foundation of RAF station structures to this day.[36] The subsequent *Benson Experiment*, conducted in 1956, sought to address a number of detailed process and procedural issues largely related to personnel conditions and group cohesion.[37]

The effort put into these studies and related work on squadron structures and alternative models for the management of maintenance (centralised, autonomous and semi-autonomous), was tacit recognition that the station was central to how the RAF went about its business. They might also be seen as *legitimising* the role of sustainability in determining the organisation and management of the Service.

While the Cold War reigned, and with expeditionary warfare a remote prospect, there was little incentive to change structures and certainly no challenge to the station's primacy in the organisational hierarchy. Command of a station remained the aspiration of every ambitious officer and was widely seen as a critical test of an individual's ability and career potential. The station also loomed large in RAF culture, providing the social and domestic focus for the wider Service community. It is hardly surprising, therefore, that attempts to modify the basic station structure or to develop innovative administrative and operational arrangements, such as the Bentwaters/Woodbridge *Twin-Base Concept* in 1991, made little headway.

Expeditionary Warfare

RAF organisational structures and their associated processes continue to reflect the arrangements developed during the Second World War. Indeed, the emphasis on infrastructure, the heavy investment in equipment and the high ratio of support to combatant personnel have been defining characteristics of the Service for nearly 90 years.

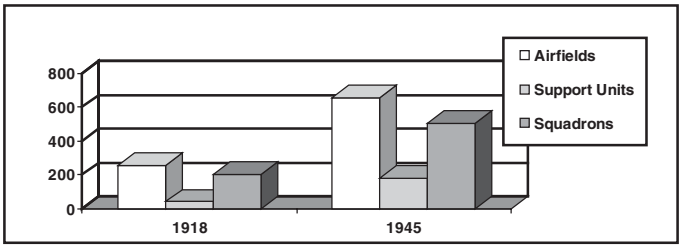

Figure 8. UK Airfields and Support Units

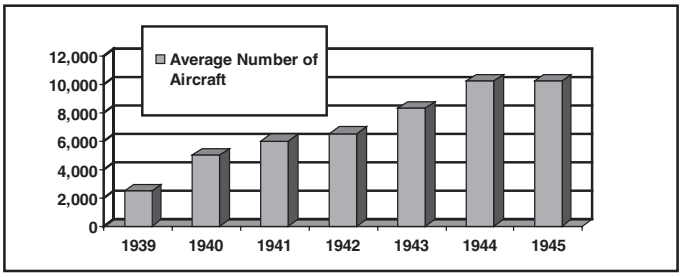

Figure 9. Aircraft In Storage 1939-1945

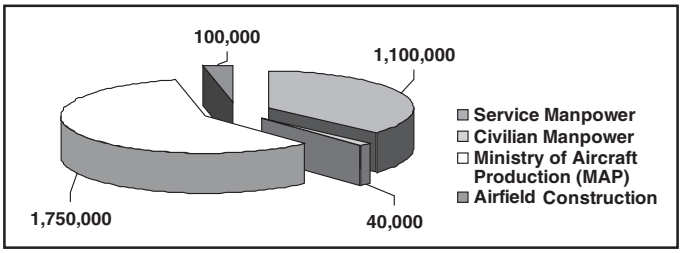

Figure 10. British Aviation Manpower July 1944

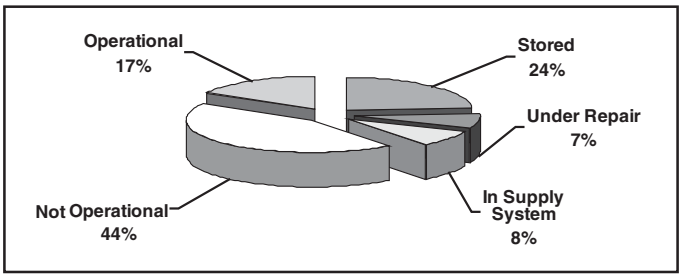

Figure 11. RAF Aircraft Dispositions May 1945

Expeditionary warfare and network enabled capability may be about to shift this particular paradigm. The *End-to-End Logistic Study*,[38] now known as the Logistic Transformation Programme (LTP), and continuing work on station structures offer the prospect of a significant change in the way the RAF is organised. Expenditure on aviation logistic support and on the procurement of aviation and aviation-related equipment continues to represent a significant proportion of the defence budget. History teaches us that this is not an unprecedented position, but, while it may prove challenging to reduce substantially the cost of sustaining airpower, the way the frontline is supported will certainly alter in the next few years.

We will see fewer uniformed support staff with some functions no longer carried out at station level—and many no longer under the control of the station commander. The four lines of maintenance and repair that have held good for over 50 years will disappear. The effect will be to dilute the status of the station in the overall organisation with a greater emphasis on force elements as the RAF's centre of gravity. We may therefore need to *unpick* the Binbrook model. The difficulty will be to sustain Service ethos while creating a more agile and adaptable organisation. The basic building block in the new construct may well be the squadron, if not the flight, rather than the station.

There is no doubt that the *brute force* approach to logistics is no longer viable. This approach is unaffordable, and does not provide the flexibility and responsiveness that network-centric warfare demands. The logistics problems faced in Iraq were less about quantity and quality, and more about availability. The continuing concern about the inability to track individual items, and the debate about *precision-guided* logistics, presage fundamental changes in the way that supply chains and logistics will be managed in the future.[39]

It is likely that we will gradually see a transition from a supply chain, built around a hierarchy of organisations, to a distributed network that can respond rapidly to changes in demand. The LTP echoes this approach although it does not (yet) offer the self-synchronisation needed to provide a *sense and respond* network.

We need to be cautious about what can be quickly achieved. After all, the RAF has toyed with serial number item tracking for at least 30 years. We also have a vast inventory, support processes and policies tied to legacy weapons systems. Much as we might wish to move from supporting platforms to supporting military effect, there is a limit to what can be done with our older assets.

Although I have stressed the distinguishing characteristics of aviation logistics, as compared to defence logistics in general, these differences are likely to diminish with time as all military equipment becomes more complex and support systems more sophisticated and interdependent.[40]

As warfare moves from the industrial age to the information age, we will inevitably see a change in the nature of logistics. Success will be measured by the adaptability of the support organisation rather than by its scale or scope. If nothing else, this threatens to transform the relationship between airpower and sustainability that has held sway for nearly 90 years.

But, however much we succeed in transforming our logistics processes, there will continue to be a tension between efficiency and effectiveness. A just-in-time philosophy built around a responsive and agile supply pipeline, a minimum deployment footprint, and extensive host nation support, may not always provide the resilience needed to sustain military capability.

A final word of warning, we must avoid the temptation of believing our predecessors to have been somehow less imaginative or more hidebound than we like to think we are. The logistics systems deployed by the RAF in both World Wars, and throughout the Cold War, were more than effective—they were winning solutions. We should build on these successes while seeking better ways to meet today's needs. To my mind, caution and a degree of humility are called for rather than a relentless dash for the new and untested. Paradigms are rarely *shifted* overnight.

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Notes

1. Sir Frederick Sykes, *From Many Angles*, London: Harrap & Co., 1942, 97.
2. NATO AAP-6, *NATO Glossary of Terms and Definitions,* 2006, 158.
3. Richard L. Olson, et al., *Gulf War Air Power Survey, Volume 3, Logistics Support*, Washington, DC, 1993, 77.
4. Chris Draper, *The Mad Major*, Letchworth: Aero Publishers, 1962.

5. At 2002 prices using historic gross domestic product.(A Sopwith Camel and its Clerget engine were priced at some £1,700 – *War In The Air*, Volume 6, Appendix XXXII, Oxford University Press, 1935).
6. John Terraine, *Essays on Leadership and War*, Western Frontier Association, Berkshire: Reading Press, 1998, 27-35.
7. H.A. Jones, *The War in the Air*, Oxford: Clarendon Press, 1935. These figures are drawn from Appendix XXXI. Although the data is undoubtedly correct and is supported by extensive and detailed tables, the purpose seems more to provide a flattering comparison with the overall strength of the German and French Air Services (20,000 and 15,342 aircraft respectively).
8. National Archives/Public Record Office, AIR 2/151/290308/20, United Kingdom.
9. A similar position was to be found on the Western Front where, at the time of the Armistice, out of a total 3,522 aircraft on charge, some 1,799 were held by the frontline squadrons with 1,576 in a serviceable condition.
10. National Archives/Public Record Office, AIR 1/686/21/13/2252, United Kingdom, contains a detailed breakdown of this analysis.
11. National Archives/Public Record Office, AIR 1/522/16/12/5, United Kingdom.
12. Sefton Brancker, "The Aeroplane In War," *Flight*, 12 Jun 1914, 632-633.
13. Sir Frederick Sykes, 95.
14. This sort of activity is now described as *reverse logistics*, to distinguish it from *traditional logistics*!
15. Brian Holden-Reid, *J.F.C. Fuller: Military Thinker*, London: Macmillan, 1987, 137-138.
16. Robert Brooke-Popham, "The Air Force," *RUSI Journal*, 1920, 43-70.
17. Hansard House of Lords Proceedings, 1944.
18. Air Publication 1301, *Royal Air Force War Manual, Part II,* Air Ministry, 1939.
19. Wg Cdr GW Williamson, "Some Problems of a Technical Service," *RUSI Journal*, No 513, February 1934, 780-800.
20. John Terraine, *The Right of the Line*, London: Hodder and Stoughton, 1985, 86. Thus Ludlow-Hewitt wrote in 1939 that "I am convinced that the idea that we will be able to fight the next war with mass-produced pilots and crews as we did in the last war is fallacious"
21. National Archives/Public Record Office, AVIA 46/149, *The Storage and Distribution of Aircraft*.
22. John Ellis, *Brute Force*, London: Andre Deutch, 1989, 527.
23. Bill Chorley, *Bomber Command Losses - 1945*, Midland Counties Publications, 1998, 187.
24. National Archives/Public Record Office, AVIA 46/168, *The Repair and Maintenance of Aircraft 1939-1945*.
25. Richard Overy, *Bomber Command*, London: HarperCollins, 1997, 211. Bomber Command's frontline in January 1944 comprised 1,298 heavy bombers. Operational losses in 1944 amounted to just over 3,000 heavy bombers.
26. Correlli Barnett, *The Audit of War*, London: Macmillan, 1986, 145-146.
27. This and subsequent comparisons are based on historic UK GDP.
28. Terraine, 602.
29. Robin Higham, "Bases of Air Strategy," *Airlife*, 1998, 23.
30. Higham, 19.
31. Air Ministry, *Works,* Air Historical Branch, 1956, 112-122.
32. A Cat 'A' airfield cost some £2M to complete.
33. Air Ministry, *Maintenance,* Air Historical Branch, 1954. Average serviceability across all commands in 1945 was approximately 80 percent.
34. Harrop, "Planning for Economy," *Air Clues*, April 1948, 15-20.
35. National Archives/Public Record Office, AIR 20/6617, *Trials of Experimental Station Organisation*.
36. National Archives/Public Record Office AIR 20/6616, *Trial of Experimental Station and Squadron Organisation.*
37. AHB IIR/60/7/13, *The Benson Experiment*.
38. The End-to-End (E2E) Study reviewed aircraft support arrangements and recommended reducing the traditional 4 lines of maintenance to 2 (Forward and Depth), concentrating support facilities at logistics centres of gravity.
39. *Aviation Week & Space Technology*, 12 Jan 2004, 45-46.
40. *Ibid.* The US M-1 Abrams tank has been described as "the world's fastest strategically immobile tank" because of its huge logistics tail.

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The Themes of US Military Logistics

From a historical perspective, ten major themes stand out in modern US military logistics.

- The tendency to neglect logistics in peacetime and expand hastily to respond to military situations or conflict.
- The increasing importance of logistics in terms of strategy and tactics. Since the turn of the century, logistical considerations increasingly have dominated both the formulation and execution of strategy and tactics.
- The growth in both complexity and scale of logistics in the 20th century. Rapid advances in technology and the speed and lethality associated with modern warfare have increased both the complexity and scale of logistics support.
- The need for cooperative logistics to support allied or coalition warfare. Virtually every war involving US forces since World War I has involved providing or, in some cases, receiving logistics support from allies or coalition partners. In peacetime, there has been an increasing reliance on host-nation support and burden sharing.
- Increasing specialization in logistics. The demands of modern warfare have increased the level of specialization among support forces.
- The growing tooth-to-tail ratio and logistics footprint issues associated with modern warfare. Modern, complex, mechanized, and technologically sophisticated military forces, capable of operating in every conceivable worldwide environment, require that a significant portion, if not the majority of it, be dedicated to providing logistics support to a relatively small operational component. At odds with this is the need to reduce the logistics footprint in order to achieve the rapid project of military power.
- The increasing number of civilians needed to provide adequate logistics support to military forces. Two subthemes dominate this area: first, unlike the first half of the 20th century, less reliance on the use of uniformed military logistics personnel and, second, the increasing importance of civilians in senior management positions.
- The centralization of logistics planning functions and a parallel effort to increase efficiency by organizing along functional rather than commodity lines.
- The application of civilian business processes and just-in-time delivery principles, coupled with the elimination of large stocks of spares.
- Competitive sourcing and privatization initiatives that replace traditional military logistics support with support from the private business sector.