Sustaining Air Power – The Influence of Logistics on Royal Air Force Doctrine

By Air Vice Marshal Peter Dye

Writing 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* 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, inter-Service rivalry, political indifference and significant technical and environmental challenges. The struggle to master the air — and the language of the time continually repeats this combative tone — 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 air power 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.

This paper explores how the question of sustainability has influenced British thinking on air power. It explores the often-troubled relationship between support activities, particularly logistics, and the delivery of military capability. It also touches on organisational and cultural issues and finally it considers how current paradigms may change with the increasing focus on effects-based operations and the arrival of network-centric warfare.

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 attain 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 logistic 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 learnt 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 air power. 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 'logistic' without the juxtaposition of 'failure', 'shortage' or 'crisis'.

These views are neatly encapsulated in Hoffman Nickerson's observation that "*Air Power 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 air power 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, it does beg the question of what came first. My personal view is that logistic processes have so dominated the delivery of air power 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 advancing German Army expected shortly, 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 logistic system that underpinned the British air effort on the Western Front. The value of the machines burnt at La Gorgue represented £5 million 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 20th 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]

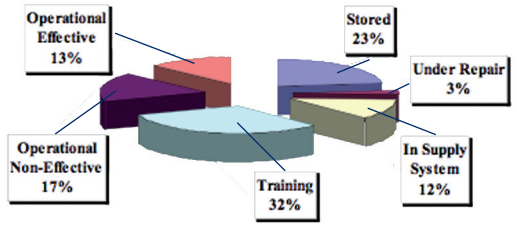
It is arguable that the most complex logistic challenge was faced by the air services as they sought to realize the potential of air power. Over recent years there has been a gradual recognition of the immense and sophisticated efforts needed to sustain the Western Front, as part of a more

balanced and dispassionate analysis of the conflict. 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 air power — 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, just 6,740 were assigned to operational duties (including the Western Front, Home Defence and Anti-Submarine activities). Out of these, only 2,896 could be regarded as effective (11% of those on charge: the remainder being in store, in transit or under repair. At any one time a further 10-15% were unserviceable, leaving approximately 2,500 aircraft to be employed on 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 *(Fig 1)*.[9] The scale of the resources needed to sustain this frontline, equivalent to some 200 squadrons in 1918, was unprecedented. The national effort was substantially larger than the total uniformed strength of 274,494 implies. When the civilian labour involved in aircraft and aero-engine production, provision of spares and repair is taken

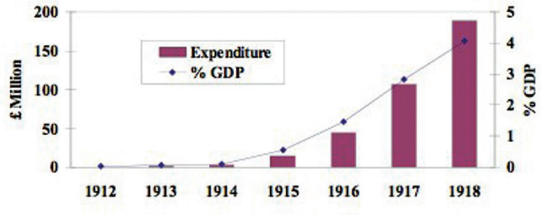
Fig 1 : RAF Aircraft Dispositions November 1918



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 £200million per year, or 4% of the UK GDP. Daily expenditure on the RAF had reached over £0.5 million, or 7% of Britain's total daily war expenditure *(Fig 2)*. This was set to rise still further with some £165 million of outstanding aviation orders, more than half the production commitments of the Ministry of Munitions, at the time of the Armistice.

Fig 2 : Aviation Expenditure 1912-1918



The result of this huge investment was the production each month of an average of 4,000 aircraft, 3,900 aero-engines (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 aero engines (written off and damaged) and some 800-900 pilot casualties would have rapidly curtailed operations.

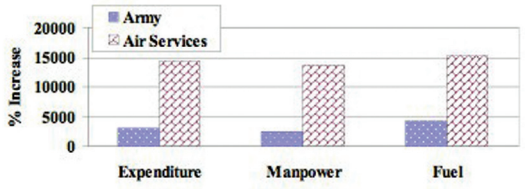
The logistic system embracing these varied activities had few if any parallels in history. By the Armistice, the RAF's technical inventory

comprised more than 50,000 separate line items. No business had 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.

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 (Fig 3). Trenchard's strategy of the "relentless and incessant offensive"[11] was only tenable because the necessary human and material resources were made available.

Fig 3 : Relative Increase in Military Resources 1914-1918



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 aero-engines, 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 on 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 logistic 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, and unlike any other arm or any previous army, non-combatants greatly outnumbered combatants. This was no subtle shift in the balance of roles but a step change in the 'teeth-to-tail' ratio. Thus, of the 51,000 RAF uniformed personnel serving in France by November 1918, only 8% were classed as combatants (pilots, observers, air gunners, etc) while the majority, some 29,000 (57%) were technicians. By comparison, 896,000 personnel (65%) of the British Army were classed as combatants *(Fig 4)*.

The other defining feature was the balance of expenditure between personnel and equipment.

Fig 4 : Relative Proportion of Combatants - France 1918

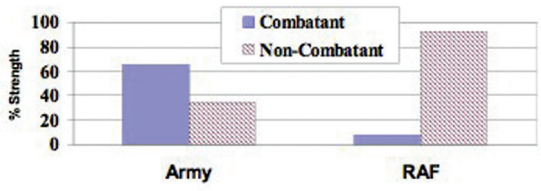
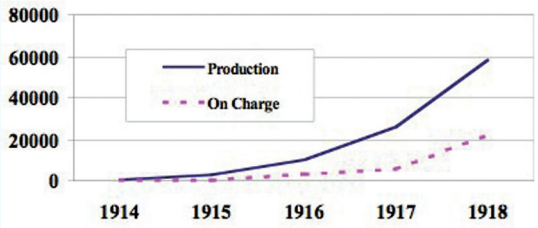
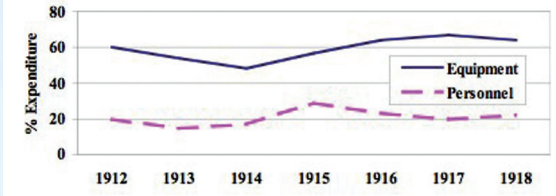


Fig 5 : Aircraft On Charge - British Air Services 1914-1918



During the course of the war more-than 50,000 aircraft were delivered to the British air services of which only 36% remained on charge by the Armistice *(Fig 5)*. In 1918, squadron frontline establishments were replaced on average every two months. Notwithstanding the importance of repair and salvage in helping to recycle aircraft, aero engines and components, huge sums had to be committed to sustain the frontline. Throughout the war, between 50% and 60% of the budget allocated to the British air services was expended on equipment *(Fig 6)*.

Fig 6 : Air Service Expenditure by Category



In summary, the RAF was created around a system of inter-linked and interdependent logistic activities, that moved high-value materiel continuously backwards and forwards at a tempo determined by daily attrition, combat operations and technological advances — JFC 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 wet nurse and, in so doing, established a dependency that has lasted for 90 years.

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 co-operation. 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. In as much 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. The expectation of a surplus in aircraft and aero-engine 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 air power 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 air power 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]

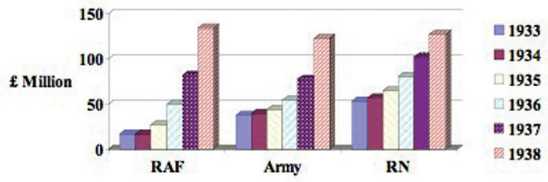
In the years that followed, Trenchard sought to construct (literally) an air force worthy of the name. The RAF Cadet College and the RAF Apprentice School were the most obvious elements in this strategy but they were part of a wider programme that enshrined a logistic-centric view of air power based 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 'GOC 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 RUSI 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 two 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 onwards, 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% of the rearmament budget in the process *(Fig 7)*.

FIG 7 : COMPARISON OF ANNUAL DEFENCE EXPENDITURE 1933-1938

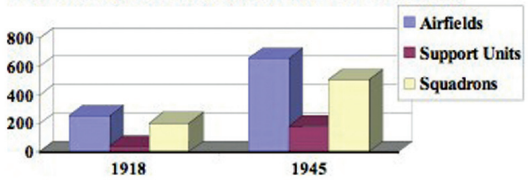


The result was a vast array of depots and maintenance units, specialising in storage, repair, salvage and armament — that had no parallel in the Luftwaffe where the doctrine of a short war negated the need for investment on a similar scale. Thus, over a period of 20 years the home-based RAF had been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

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, for example, in King's Regulations and the Air Force Act. While squadrons were the fighting arm, the majority of RAF personnel would serve 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 *(Fig 8)*. The same could certainly not be said about the number of ports and warships or the number of garrisons and regiments.

FIG 8 : UK AIRFIELDS AND SUPPORT UNITS

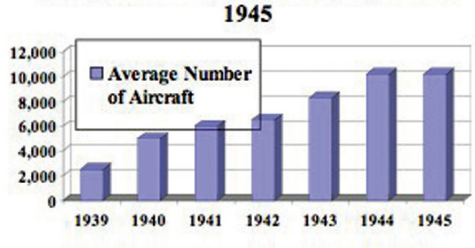


The Second World War

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

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

FIG 9 : AIRCRAFT IN STORAGE 1939-1945



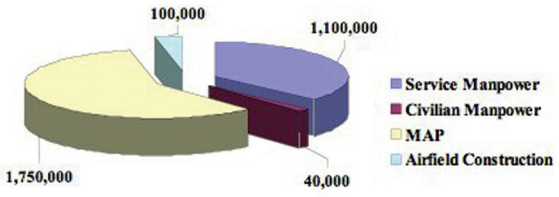
While some commentators have criticised the Allies for employing their significant economic and industrial capacity to support a military strategy built on brute force, the attritional nature of modern warfare and the pace of technological development allowed little choice.[22] It is true that both the RAF and the USAAF drew relied on high production rates, an extensive supply system and comprehensive support arrangements in order to overcome significant wastage. However, it is also true that this abundance of resources arose from careful and detailed planning that drew heavily on what had been learnt about sustainability and air power in the First World War. 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 more than 74,000 aircrew killed, wounded or prisoners of war and 12,330 aircraft to operational and non-operational 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[24] — a wastage rate of 950%.[25]

The manufacture, modification and repair of aircraft had, by 1943, become Britain's largest industrial operation.[26] From 1939-1945 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 £800 million (equivalent to £83 billion at today's prices).[27] Total wartime expenditure on aircraft and related equipment exceeded £3,750 million (£385 billion) while the capital cost expended in creating the necessary industrial capacity amounted to £350 Million (£36 billion). Overall, more than 36% of wartime defence expenditure[28], around 20% of the UK GDP, was committed to the RAF, of which some 40-50% comprised equipment costs.

At its peak, in the summer of 1944, more than three million personnel were employed in aviation-related activities — including 1.7 million in MAP and more than one million in uniform *(Fig 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.

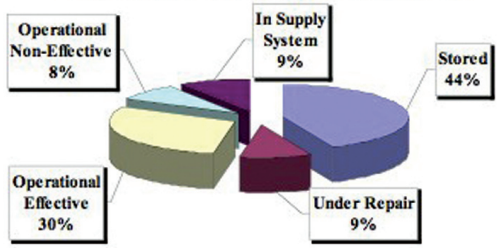
FIG 10 : BRITISH AVIATION MANPOWER - JULY 1944



Nightly attacks by hundreds of heavy bombers against targets in Germany and Occupied Europe also demanded a sound and secure infrastructure. The airfield construction programme from 1939-1945 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 from 1939-1945 at a cost of £200 million (£20 billion) and employing more than 300,000 men at its peak.[29] Roughly 1,800 airfields were constructed world-wide 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, water and waste disposal as well as extensive storage facilities and domestic accommodation. In 1942 more than £145 million (£16 billion) were spent on works for the RAF compared to just £4 million in 1935, at the start of the expansion programme.[32]

By the end of the war, the RAF frontline comprised more than 500 squadrons and 9,250 aircraft. More than 10,000 aircraft were in store and 2,200 under repair in the UK alone. New aircraft were being delivered at the rate of some 2,000 per month. The total RAF inventory was closer, therefore, to 23,000 airframes — a similar picture to that found 40 years before *(Fig 11)*.

Fig 11 : RAF Aircraft Dispositions May 1945



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'.[33] 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 trialled at RAF Tuddenham in 1946.[34] 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.[35] 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.[36]

The effort put into these studies — in addition to related work on squadron structures and 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, met considerable hostility.

Expeditionary warfare

RAF organisational 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 our Service for nearly 90 years.

Expeditionary warfare and network enabled capability may be about to shift this particular paradigm. The End-to-End Logistic Study[37], 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 air power, 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 more than 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 arrangement. 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. Not just because it is unaffordable but because it does not provide the flexibility and responsiveness that network centric warfare demands. The logistic 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.[38]

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 weapon 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.[39]

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 air power and sustainability that has held sway for nearly 90 years.

But, however much we succeed in transforming our logistic 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 logistic 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 this success 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.

Notes:

[1] Sir Frederick Sykes, From Many Angles, page 97, Harrap & Co, London, 1942.
[2] NATO AAP-6 - Logistics.
[3] Gulf War Air Power Survey, Logistics Support, Vol III, page 391, Washington, D.C., 1993.
[4] Chris Draper, The Mad Major, Letchworth, Air Review, 1962.
[5] At 2002 prices using historic GDP (a Sopwith Camel and its Clerget engine were priced at some £1,700 – War In The Air, Vol 6, Appendix XXXII, OUP, 1935).
[6] Terraine, Essays on Leadership and War, pages 27-35, Western Front Association, 1998.
[7] These figures are drawn from Appendix XXXI to The War In The Air. 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] NA/PRO AIR 2/151/290308/20.
[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] NA/PRO AIR 1/686/21/13/2252 contains a detailed breakdown of this analysis.
[11] NA/PRO AIR 1/522/16/12/5.
[12] Sefton Brancker, The Aeroplane In War, Flight, pages 632-633, 12 Jun 14.
[13] Sir Frederick Sykes, op cit, page 95.
[14] This sort of activity is now described as 'reverse logistics', to distinguish it from 'traditional logistics'!
[15] Holden-Reid, JFC Fuller : Military Thinker, pages 137-138, Macmillan, London, 1987.
[16] Brooke-Popham, The Air Force, pages 43-70, RUSI Journal, 1920.
[17] Hansard, 1944.
[18] Air Ministry, Royal Air Force War Manual, AP 1301, Part II, 1939.
[19] Williamson, Some Problems of a Technical Service, pages 780-800, RUSI Journal No 513, February 1934.
[20] 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" Terraine, The Right of the Line, page 86, Hodder and Stoughton, London, 1985.
[21] NA/PRO AVIA 46/149, The Storage and Distribution of Aircraft.
[22] Ellis, Brute Force, page 527, Andre Deutch, London, 1989.
[23] Chorley, Bomber Command Losses - 1945, page 187, Midland Counties Publications, 1998.
[24] NA/PRO AVIA 46/168, The Repair and Maintenance of Aircraft 1939-1945.
[25] Overy, Bomber Command, page 211, HarperCollins, London,

1997. 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] Barnett, The Audit of War, pages 145-146, Macmillan, London, 1986.

[27] This and subsequent comparisons are based on historic UK GDP.

[28] Terraine, op cit, page 602.

[29] Higham, Bases of Air Strategy, page 23, Airlife, 1998.

[30] Ibid, page 19.

[31] Air Ministry, Works, page 212-122, AHB, 1956.

[32] A Cat 'A' airfield cost some £2 Million to complete.

[33] Harrop, Planning for Economy, Air Clues April 1948, pages 15-20.

[34] NA/PRO AIR 20/6617 – Trials of Experimental Station Organisation.

[35] NA/PRO AIR 20/6616 – Trial of Experimental Station and Squadron Organisation.

[36] AHB IIR/60/7/13 – The Benson Experiment.

[37] 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 logistic centres of gravity.

[38] Aviation Week & Space Technology, 12 January 2004, pages 45-46.

[39] The US M-1 Abrams tank has been described as "the world's fastest strategically immobile tank" because of its huge logistics tail. Ibid.