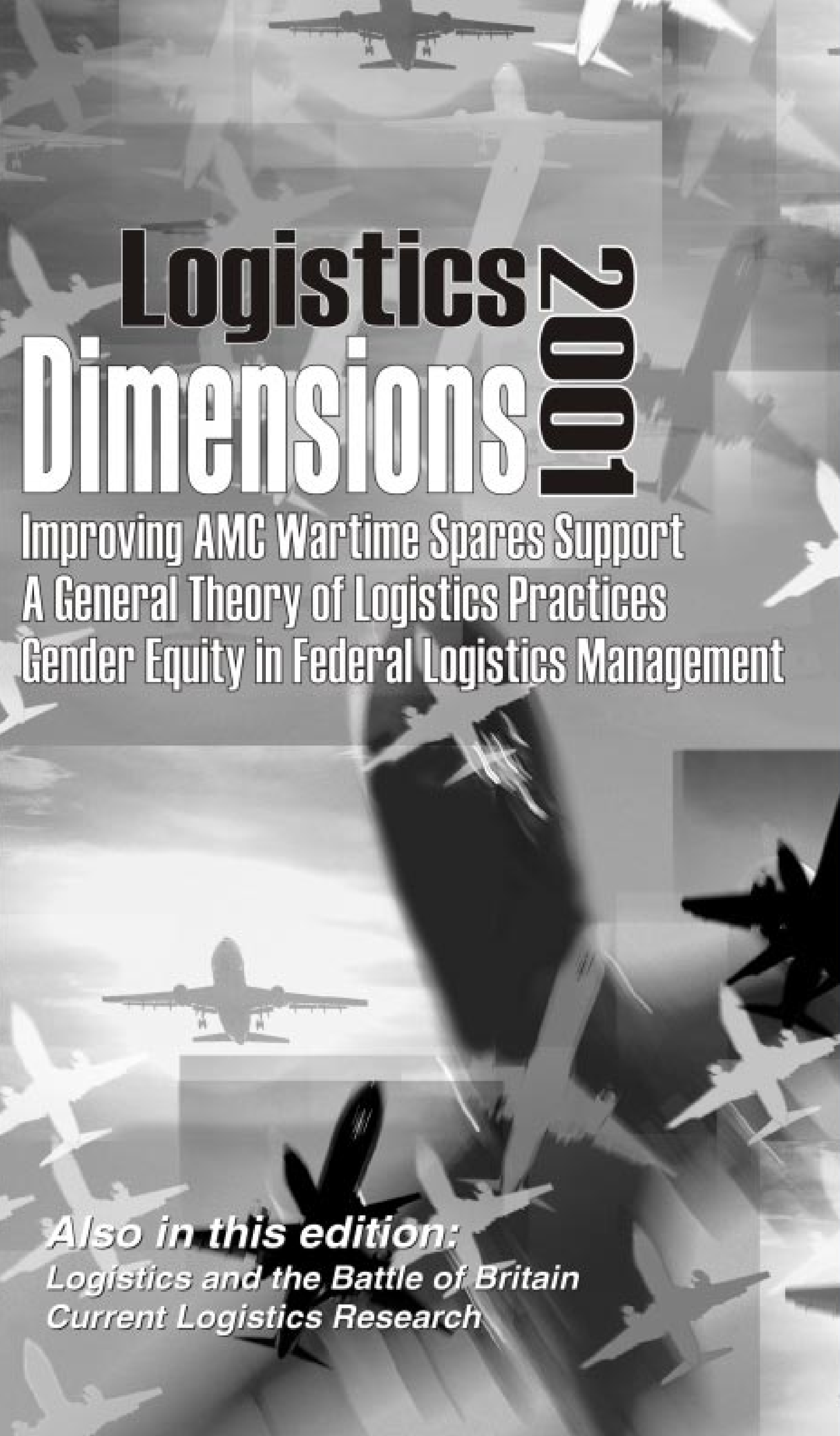

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Logistics and the Battle of Britain

Air Commodore Peter J. Dye, RAF

Introduction

It is arguable that the Battle of Britain was lost long before the Second World War started. Luftwaffe doctrine, so successful in establishing a powerful synergy between air and land operations, was deeply flawed in its understanding of the fundamentals of airpower. The causes were various, but the result was inadequate provision for the industrial investment and resources necessary to sustain operations in the face of high wastage rates that war would bring. By contrast, the Royal Air Force (RAF) was well placed to defend Great Britain, notwithstanding its perceived doctrinal emphasis on strategic bombing. As Richard Overy recently pointed out, the contest the country faced after Dunkirk had been anticipated and prepared for in the 1930s.[1] The Air Ministry, planning the rapid expansion of the front line, had clearly understood the lessons of the First World War, in particular, the high cost—in human and materiel terms—of sustaining air operations.[2] By providing the proper economic and logistics basis for realizing these plans, the air staffs had also established the foundation for increasing Allied air superiority as the war progressed. This is not to say their prewar planning was without flaws. Indeed, at a tactical and operational level, the Luftwaffe enjoyed self-evident advantages. However, by getting the fundamentals right and being prepared to learn from painful early reverses, the Royal Air Force placed itself in a significantly stronger position than the Luftwaffe to fight the Battle of Britain.

None of this is to deny the huge importance of technology, tactics, and leadership or the courage of individual pilots in determining the final outcome. No doubt these issues will continue to dominate the debate on the conduct of the Battle of Britain much as they have for the last 60 years. But the possibility of a Luftwaffe victory was effectively compromised by plans, laid down in the prewar period, that provided Fighter Command with a quantitative advantage and the means to sustain this advantage.

This article seeks to clarify the part played by logistics in the Battle of Britain and how it shaped the outcome. For brevity, the analysis focuses primarily on the single-seat fighters deployed by the respective air forces. It was in this arena that the Luftwaffe needed to prevail if it were to achieve air superiority over southern England and, in so doing, defeat the Royal Air Force.

Wastage

As the prospect of war grew ever stronger, the Royal Air Force turned to the First World War for insight. While it was recognised that technology had progressed considerably since 1918, it was expected that the problems in prosecuting a modern war would be familiar, albeit more acute. In a paper delivered to the Royal United Services Institute in 1934, the difficulties facing a technical service preparing for the next war were explored in some detail, particularly the question of how to make good wastage.[3] Chairing the meeting was Sir Robert Brooke-Popham, who had been largely responsible for the development of the highly efficient logistics system that supported the Royal Flying Corps and the Royal Air Force on the Western Front.[4] In a review of the key issues, it was stated that the average life of an aircraft in war was 2 months, a view shared by Sir Robert, who referred to the 45 percent monthly attrition rate suffered by the Royal Air Force between March and October 1918.[5] Wastage could only be made good from three sources: manufacturing, reserves, and repair. As matters stood, it was unlikely that either industry or the Service depots could satisfy the demand. Accordingly, for the Royal Air Force to prosecute the next war, it needed a greatly expanded peacetime establishment, high production rates, larger repair depots, additional skilled technical personnel, an emphasis on quantity over quality (in the sense of balancing production against continuous progress), long preparation, and careful planning.

(Continued on page 33)

Improving Support to AMC

The battle is fought and decided by the quartermasters before the shooting begins.

—Field Marshal Erwin Rommel

Operation Allied Force, sometimes called the Air War over Serbia, presented the Air Force with an operational experience that is perhaps more indicative of future air expeditionary force (AEF) operations than has been experienced in the past. This is important in that it provides a new framework for analyzing the ways in which we plan for war.

Of great interest in today's Air Force is the ability to provide logistics support to match carefully tailored force employment concepts. Rapid movement of supplies in the pipeline between factory and flight line provides a *reach-back* sustainment capability and allows for a much needed, smaller logistical footprint in theater. A focused logistics system provides the flexibility and responsiveness required of the Agile Combat Support competency.[1]

Wartime Spares

Major Jon A. Larvick, USAF

Inventory within a Logistics System

I don't know what the hell this "logistics" is that Marshall is always talking about, but I want some of it.

—Fleet Admiral E. J. King, 1942

Today, as in Fleet Admiral King's day, logistics is a concept whose need is evident, yet the concept of logistics is so broad that it is not easily definable. It is often referred to as supply chain management, integrated resource management, or other related concepts. At the same time, logistics is often referred to by its various functions, such as supply, transportation, or maintenance. However, it has been suggested the best way to understand logistics is to get back to basics.[2]

In getting back to basics, we know, from joint doctrine, that logistics is combat power's foundation.[3] And from the Air Force perspective, logistics falls within the core competency of Agile Combat Support, which requires highly responsive support as combat forces are deployed forward.[4]

As we continue to break this down to basics, responsiveness is the keystone principle of logistics.[5] One method for providing responsive force support is through the levels of inventory within a logistics system.

Inventory—Back to Basics

All businesses and institutions require materials and supplies that are either sold or used to provide inputs or supplies to the production process. These materials and supplies are called inventory.[6] Inventory serves a number of functions, such as balancing supply and demand or protecting against the uncertainty of demand. Therefore, a firm holds inventory to provide a certain level of customer service. However, this customer service has an associated cost. Hence, it is easy to see the importance of properly managing inventory.

Functions of Inventory

Inventory serves the following purposes within a firm:

- Enables the firm to achieve economies of scale
- Balances supply and demand
- Enables specialization in manufacturing
- Provides protection from uncertainties in demand and order cycle
- Acts as a buffer between critical interfaces within the distribution channel[7]

Economies of Scale. Inventory makes it possible to create economies of scale within the functions of purchasing, transportation, and manufacturing. For example, large volume purchases will often bring smaller unit costs. Also, large shipments will bring transportation economies, especially when they result in full truckload or railcar shipments. Finally, inventory creates economies of scale within manufacturing by allowing the manufacturer to schedule longer production runs with few production line changes.[8]

Balancing Supply and Demand. Different conditions exist that make it necessary to manufacture finished products in excess of current demand levels and place them into inventory. For example, manufacturers of seasonal items such as snow shovels may need to produce them in advance of the need and place them into inventory because their production rate cannot respond quickly to the demands of winter storms. Holding inventory will allow the manufacturer to avoid the costs of developing production capacity to match peak demand periods, avoid wide fluctuations between idle and production time, and provide a more stable workload for its work force.[9]

Specialization. Holding inventory in large mixing or distribution warehouses, as done by chain stores such as Wal-Mart and Target, allows the manufacturers to specialize in products. This specialization results in better manufacturing processes, longer production runs, transportation efficiencies, and other benefits.[10]

Protection from Uncertainties. The demand for a product varies greatly over time. This can be caused by seasonal influences such as holidays or simply by unanticipated demand. Holding inventory provides protection from these uncertainties by reducing the likelihood of a stockout due to unanticipated demands.[11] This inventory is often called safety stock.

Buffer. Buffer inventories are held between critical nodes of a distribution channel. These critical nodes include production, distribution, intermediary suppliers, the final consumer, and others. Since these critical nodes can be geographically separated, this buffer inventory provides time and place utility.[12]

Customer Service and Costs

Although inventory is held for various reasons, the main purpose for holding inventory is to maximize customer service. Customer service, in this sense, means having items available when the customer needs or wants them. In the commercial sector, customer service is measured in various ways: percentage of orders shipped on schedule, number of back orders, percentage of line items shipped on schedule, and order days out of stock.[13]

While customer service is an important criterion to a firm, holding large amounts of inventory to prevent a stockout is not always possible because of the costs involved; for example, item costs, carrying costs, ordering costs, stockout costs, and capacity-related costs.[14]

Item Cost. Item cost is simply the purchase price of the item, which includes transportation, custom duties, and insurance. For items that are manufactured in house, item costs include all associated direct costs, such as direct material, direct labor, and factory overhead.[15]

Carrying Cost. Carrying costs include capital, storage, and risk, which are directly correlated to the amount of inventory held. For example, capital cost is the money invested in inventory that cannot be invested elsewhere. Storage costs include cost of the storage location and the manpower required to store inventory. Finally, risk costs include those incurred due to pilferage, obsolescence, product deterioration, and damage caused during handling.[16]

Ordering Cost. As opposed to carrying costs, which correlate directly with the quantity of inventory, ordering costs are not affected by quantity. Instead, they depend on the number of orders placed in a year and include basic items such as the cost to prepare followup and receive, account for, and authorize payment for the order. Ordering costs can also include manufacturing costs as a result of setup and teardown to run numerous orders and may include the cost of lost capacity as a result of numerous setups and teardowns. Placing fewer orders for larger quantities can reduce ordering costs; however, this will increase inventory-carrying costs.[17]

Stockout Cost. When demand for an item exceeds its supply, the resulting stockout condition carries a number of costs with it. These include the cost of back orders, lost sales, and possibly lost customers.[18]

Capacity-related Cost. When output levels in a manufacturing firm must be changed, capacity-associated costs result. Examples include the costs of overtime, hiring, training, extra shifts, and layoffs. These costs can be minimized through the use of level production runs; however, level production runs will build inventory in slack periods and may result in stockouts during peak periods.

Inventory Management

When you consider these five cost categories, it is obvious that holding large amounts of inventory to ensure 100 percent customer service can be an expensive proposition. Therefore, there is a relationship between customer service and costs. This relationship drives inventory managers to ask a number of questions. For example, are you willing to accept back orders and risk lower customer service in order to save the costs of holding inventory? Or do you expend large amounts of capital because a stockout is unacceptable? These questions highlight the tradeoff between customer service and inventory costs. However, since many firms may carry a large number of items in stock, inventory managers must ask one additional question. How much effort are you willing to expend to manage your inventory in light of the costs? These questions form the basis of inventory management.

ABC Inventory Control. When forced to decide the level of effort to expend in managing inventory, managers will often divide inventory into three classes based on costs or importance. Then, the inventory management effort and methods will be matched with the different classes. For example, the most important or costly items (usually the top 5 percent of the items [class A]) will be managed more precisely than any of the less costly items. The moderate-cost items (usually the next 15 percent [class B]) deserve some type of special management, while the inexpensive items (the other 80 percent [class C]) do not require any special management effort.[19]

The relationship between customer service and costs is the main concern of inventory management. The ABC analysis shows how inventory managers concentrate management efforts on those items where their efforts will have the most benefit.

The Air Force Reparable-Item Pipeline

Within the Air Force, the management of high-cost inventory items (those that would be considered class A items under ABC inventory control) is handled in a reparable-item pipeline.

> A reparable-item inventory system is a system used for controlling items that are generally very expensive and have long acquisition lead times. Hence, it is more economical to design these items so they are repaired after they fail, rather than treating them as consumable items, which are disposed of after use. A standard, military reparable-item inventory system consists of a repair facility (depot) dedicated to support several locations (bases) dispersed over an extensive geographical region where equipment (aircraft) is assigned. Over time, equipment malfunctions occur due to the failure of a specific item internal to the equipment. A corresponding serviceable item is then obtained from an inventory location and installed on the malfunctioning equipment, thereby restoring it to full operational capability. The failed item is tracked as it is shipped to the repair facility, scheduled for repair, and subsequently shipped in a serviceable condition back to an inventory location.[20]

Functions of Inventory

By looking at the reparable-item pipeline depicted in Figure 1, in comparison with the functions of inventory discussed above, it is easy to see how inventory in the pipeline can prove beneficial to the Air Force. There are many critical, geographically separated nodes within the system. Therefore, buffer inventories can provide time and place utility. Also, since demand for an item is

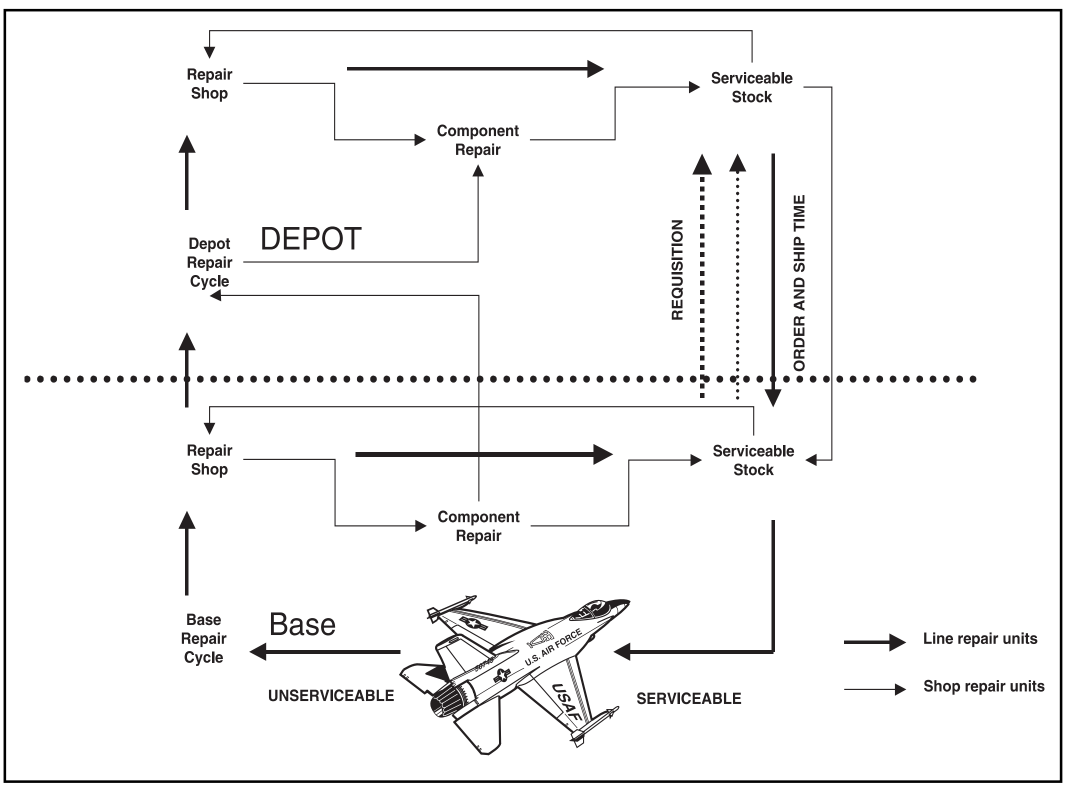


Figure 1. Air Force Reparable-Item Pipeline[21]

based on the item's failure, holding inventory can protect against the uncertainty inherent in such a system. Inventory can also allow specialization, only this time for the repair facility in place of the manufacturing facility, a unique aspect of the reparable-item pipeline due to its repair vice replace criteria.

Customer Service and Costs

Customer service is defined in terms of having items available when the customer needs them. This definition is true for the Air Force also, although it is measured differently than in the commercial sector. It is measured in terms such as the NMCS rate (percent of aircraft that are not mission capable due to supply of an item), FMC rate (percent of fully mission capable aircraft), fill rate (percent of authorized readiness spares package on hand), issue and stockage effectiveness (percent of time supply had what the customer ordered and percent of time supply had what it decided to stock), and aircraft availability (number of aircraft available to fly on a certain day).

Given the kinds of high-cost items in the Air Force reparable-item pipeline system, it is cost-prohibitive to stock inventory to avoid all possibilities of a stockout. Again, the tradeoff between cost and customer service comes into play. For the reparable-item pipeline, quantity decisions to optimize costs and customer service are made using an Air Force Materiel Command system, the Recoverable Consumption Item Requirements System (D041).

D041. D041 is a management information system used by the Air Force to compute worldwide requirements and inventory levels for reparable items. It does this by breaking the pipeline (Figure 1) into 11 segments and then computing or assigning quantities for each segment. These segments are:

- Organizational and intermediate maintenance (OIM) operating requirement
- Total OIM base stock-level requirement
- OIM depot stock-level requirement
- Management of items subject to repair non-job-routed (NJR) requirement
- Programmed depot maintenance NJR requirement
- Engine NJR requirement
- Total overhaul condemnations requirement
- Total overhaul stock-level requirement
- Prepositioned requirement
- Restocked requirement
- Additive requirement

When comparing these segments to Figure 1, segments one and two occur within the base-level block, and segments three through eight occur within the depot-level block. Segments 9 through 11 are additional requirements established to support needs such as wartime.[22] All quantities are either computed or assigned within D041 to allow inventory to provide beneficial functions, as described above, and the tradeoff between customer service and costs. These inventory calculations are based on an algorithm designed to provide *marginal analysis*. In marginal analysis, each item's contribution to the goal of aircraft availability per dollar spent is optimized and results in the best availability/cost solution for each segment of the pipeline.[23] Although not computed within D041, this same *marginal analysis* is used to compute wartime requirements separately, and these quantities are placed in segments nine and ten of the D041 system. Segment nine, the prepositioned requirement, includes items allocated as readiness spares packages (RSP). These packages are designed to deploy forward along with the fighting unit to a contingency, conflict, or war. These packages are the focus of this article.

Readiness Spares Packages

Readiness spares packages can be separated into two types: mobility readiness for units that deploy and in-place readiness for units that fight in place. In either case, management of these spares is governed by Air Force Manual 23-110, *USAF Supply Manual*, Chapter 14, which states:

> The major objective of the RSP program is to support national strategy in consonance with the guidance issued by the Office of the Secretary of Defense. Specifically, the Air Force objective is to authorize, acquire on time, preposition, prestock, and maintain in a serviceable condition ready for use all RSP needed to support the wartime activities specified in the War and Mobilization Plan (WMP).[24]

RSPs are considered supplies of vital importance whose requirements are determined based on the maintenance capabilities available at the wartime location. Again, as with all inventory decisions discussed so far, items and quantities within RSPs will be the minimum necessary to support the WMP-tasked mission—the customer service and cost tradeoff.[25] These items and quantities will be provisioned according to the quantities computed by the Aircraft Sustainability Model (ASM).[26]

The Aircraft Sustainability Model

Air Force inventory managers, in their wartime planning role, must calculate RSP items and quantities to support weapon-system readiness. To do so, they must take into account a wide range of operational situations along with the characteristics of each weapon system component. Operational situations are characterized by the weapon system's flying-hour program. Weapon system component characteristics include projected failure rates, repair times, and procurement costs. The Aircraft Sustainability Model, developed for the Air Force by the Logistics Management Institute (LMI), combines these operational situations and component characteristics into a mathematical statistical model for use by inventory managers. The ASM computes optimal spares mixes to meet the ultimate goal of the logistics system: available aircraft.[27]

Available aircraft is considered the ultimate goal of the logistics system because internal supply system performance measures such as *fill rate* have weaknesses.[28] One common example in the supply community is in reference to an A-10 RSP fill rate. If this RSP contains 99 percent of its authorized quantity of items (fill rate), it appears to be a healthy situation. However, if the 1 percent of items not available happens to be a spare needed to repair the A-10's gun (its primary weapon), a 99 percent fill rate does not provide a mission-available aircraft.

Also, fill rate does not capture information about the complexity of the aircraft being supported. The LMI report describes this best:

> All else being equal, more complex aircraft require a higher component fill rate to reach a given availability than do simpler aircraft . . . availability is defined as a product of probabilities—the probability that the aircraft is not missing its first component, times the probability that the aircraft is not missing its second component, and so on. An aircraft with more components has more factors in the product, and since each probability is less than 1.0, the product will tend to be smaller. Thus, using a fill rate criterion . . . leads to a bias in favor of the less complex aircraft types.[29]

The LMI report concludes, "In the difficult cost-effectiveness choices that military logistics planners must make, the difference between fill rate and aircraft availability is critical."[30]

To find the aircraft availability solution, the ASM computes an optimal spares mix by combining two systems, the Marginal Analysis System (MAS) and the Cross-Linker. The MAS, driven by the operational situation (sortie rates and durations), is a multi-echelon, multi-indenture model that optimizes spares support for a single day of a scenario. Multiple runs of the MAS are used to analyze multiple days of a scenario. These multiple runs are combined by the Cross-Linker to optimize spares support for the entire duration of the scenario.[31]

The output of the model provides an optimal *shopping list*. This list can show, given a specific funding level, the mix of spares that will provide the highest aircraft availability rate. Or ASM can take a given availability rate, called the direct support objective (DSO), and develop the least-cost spares mix to reach that target.[32]

To briefly recap, inventory provides function to a firm by enabling the firm to achieve economies of scale, balance supply and demand, specialize in manufacturing, protect against uncertainties in demand, and act as a buffer between critical interfaces within the channel of distribution. Because of these functions, inventory contributes to the level of customer service a firm can provide. Customer service is defined as having items available when the customer needs them. When the firm holds inventory, it often provides customer service but also incurs costs. These costs are categorized as item, carrying, ordering, stockout, and capacity-related costs. Because of customer service and cost tradeoff, inventory managers often use ABC inventory control to divide inventory into management classes. Under this system, the most expensive (Class A) items are managed more precisely than the less costly items.

In the Air Force, Class A-type inventory items are managed within the reparable-item pipeline. Within this pipeline, inventory performs the same functions as described above. These functions, again, lead the Air Force to hold inventory in order to provide customer service. Holding inventory in the Air Force incurs the same costs. The customer service and cost tradeoff for the 11 segments of the reparable-item pipeline is computed by the D041. As part of the pipeline, RSPs are included to support wartime activities specified in the War and Mobilization Plan. Deciding the composition of an RSP, again, is based on the same customer service and cost logic as with the D041. In the case of RSPs, the optimal mix of spares is calculated through a program called the aircraft sustainability model.

KC-135s in Operation Allied Force

> *Given the nature of the air campaign and the many obstacles tankers had to overcome, their accomplishments were remarkable.*
>
> **—Lieutenant General William J. Begert**

Operation Allied Force began on 24 March 1999 and ended 78 days later as the largest combat operation in the history of the North Atlantic Treaty Organization (NATO). Thirty-eight thousand combat sorties succeeded in delivering a punishing air offensive with virtually no loss to NATO forces. Because of the pressures brought to bear, Slobodan Milosevic withdrew his Serbian forces from Kosovo and acquiesced to NATO conditions.[33]

Active and Reserve component air-refueling aircraft (tankers) played a key role in Operation Allied Force. They provided multiple air bridges for aircraft transiting to the theater and refueling support for more than 24,000 combat sorties.[34] Tankers, 112 active and 63 Reserve aircraft, flew more than 5,000 sorties and delivered 250 million pounds of fuel. This operation differed from Desert Storm, as tankers were required to support reinforcement and sustainment efforts continuously until the end of hostilities. General Begert, coordinator of the operation's offensive and defensive air operations said, "Given the nature of the air campaign and the many obstacles tankers had to overcome, their accomplishments were remarkable."[35]

Based on the final results of tanker operations during Allied Force, is it safe to assume that the aircraft spares in the inventory, specifically the spares mix in readiness spares packages, were at optimal levels to support this operation?

How did authorized RSPs support operations during Allied Force? Or, based on the limitation of this project to one weapon system, the KC-135, the question should be, how did authorized RSPs support KC-135 operations during Allied Force?

Fill Rate

As a reminder, fill rate is the percentage of authorized reparables actually on hand for an RSP. Authorized RSP quantities are computed using the Aircraft Supportability Model to provide an optimal mix of spares to support the War and Mobilization Plan for 30 days and provide a sustained DSO of 83 percent. The DSO is the number of aircraft desired and available for the operation.

During Operation Allied Force, 17 of the total 40 RSPs for KC-135s were deployed. At the beginning of the operation, deployed RSPs had a fill rate of 68 percent. By the end of the operation, those fill rates had improved to 77 percent (Figure 2).[36]

Stockage/Issue Effectiveness

Stockage effectiveness is the percentage of total spares authorized to be held in inventory that are available upon customer request. While deployed, the RSP stockage effectiveness for reparable items was 98.4 percent.

Issue effectiveness is the percentage of customer requests that were filled by items in the inventory. The significant difference between stockage and issue effectiveness is that stockage

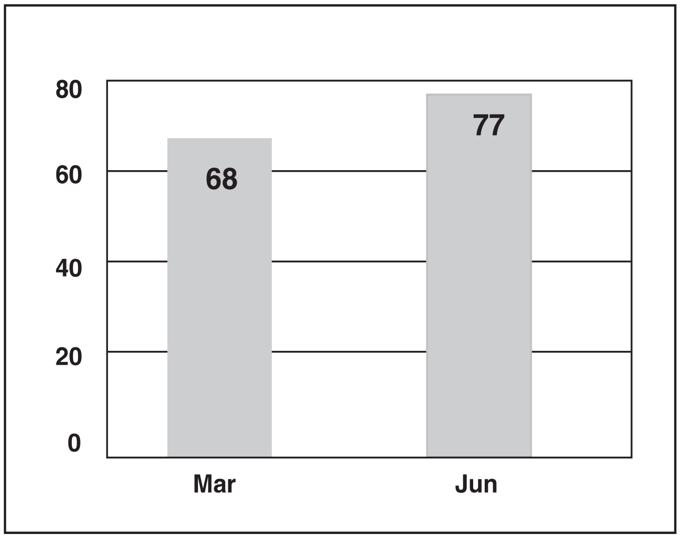


Figure 2. Deployed KC-135 Fill Rates

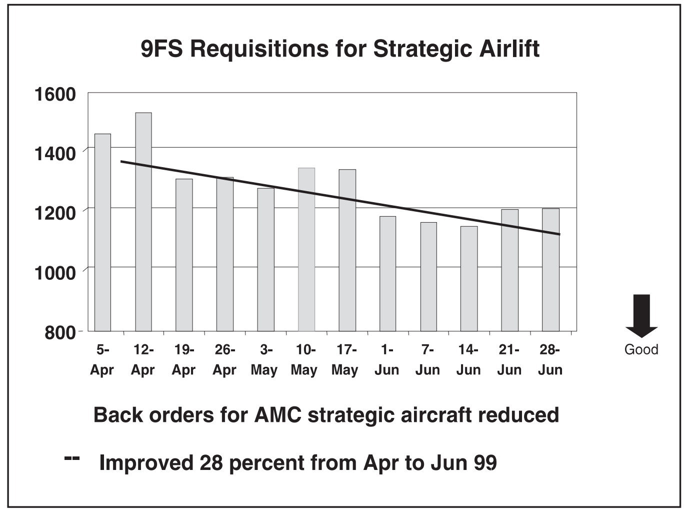


Figure 3. Allied Force Back-Order Reduction

effectiveness uses authorized inventory levels in its ratio. Issue effectiveness is based on filling *any* request, not just requests for items authorized in the inventory. Therefore, issue effectiveness will usually be lower but is more representative of the customer's view of support. For deployed operations, the issue effectiveness for reparable items was 90.6 percent.[37]

Aircraft Availability

Available aircraft is considered the ultimate goal of the logistics system. During Allied Force, the aerial refueling fleet was forced to endure extended sortie durations because tankers were based at locations extending from Budapest, Hungary, to Mont-de-Marsan, France. Also, operations required high tanker usage rates to support the combat and airlift forces. Even so, the KC-135 maintained an actual mission-capable rate of 78 percent.[38]

Analysis

Fill Rate. RSPs are often measured by their fill rate. In Allied Force, having to begin operations with RSP fill rates at 68 percent should attract immediate attention. One could quickly jump to the conclusion that inventory reductions are mandated since 68 percent of what was thought to be required produced these types of sortie numbers and positive results. The excellent stockage and issue effectiveness numbers that were achieved in theater could support this conclusion. However, this 68 percent fill rate only produced 78 percent available aircraft—the KC-135 RSP's goal is 83 percent. And RSPs were developed to support a two-major-theater-war (MTW) scenario, not another Allied Force. If we were to go to war according to the WMP, a 100-percent fill rate would be required to produce the desired DSO. Anything less has to be offset in maintenance actions (more base-level repairs, higher cannibalization rates, and so forth), a faster logistics pipeline, or fewer numbers of available aircraft.

Depot Response. One area that may be able to absorb the pressure of a low fill rate is the depots. By surging output and expediting repairs, the depots can offset a lower than desired fill rate. In Allied Force, depot response did exactly that, expediting efforts to fill back orders from units involved in Allied Force. These back orders were identified with a special project code that identified them with Allied Force and prioritized them above normal peacetime back orders. Figure 3 shows the reduction in back orders during this period.[39] Depot response not only reduced back orders but also improved deployed-RSP fill rates from 68 to 77 percent by the end of the operation. The risk in prioritizing Allied Force back orders above others is jeopardizing the readiness of other units. However, in this case, the depots not only repaired Allied Force priorities but also surged output across the board (Figure 4).[40]

Aircraft Availability. RSPs for the KC-135 are designed to provide 83 percent aircraft availability based on inputs to the Aircraft Sustainability Model. For Allied Force, RSPs, along with the rest of the logistics pipeline, fell short of the goal and provided only 78 percent mission-capable aircraft.

Operation Allied Force, from the tanker perspective, can be considered a remarkable success. However, analysis of inventory, customer service criteria show that operations did not occur exactly as planned. Fill rates were lower than desired at the beginning of the operation. In spite of that, stockage and issue-effectiveness numbers remained incredibly high. Low fill rates, combined with a flying schedule more demanding than that planned for an MTW, would not be expected to have stockage and issue-effectiveness numbers as high as those achieved. One possible explanation was that the reparable-item pipeline supplied parts at an increased rate. Depot response played a significant role in offsetting initial deficiencies in the fill rate. In addition, the depot continued to supply spares and reduce back orders to all customers. In the end, spares flowing through the reparable-item pipeline failed to meet the expected 83 percent aircraft availability rate, but the final 77 percent rate did provide enough aircraft to bring overall success.

This information describes an operation that may be indicative of the way future operations will occur. If so, an analysis of Operation Allied Force can help prepare aerospace expeditionary forces and their inventory managers in the future.

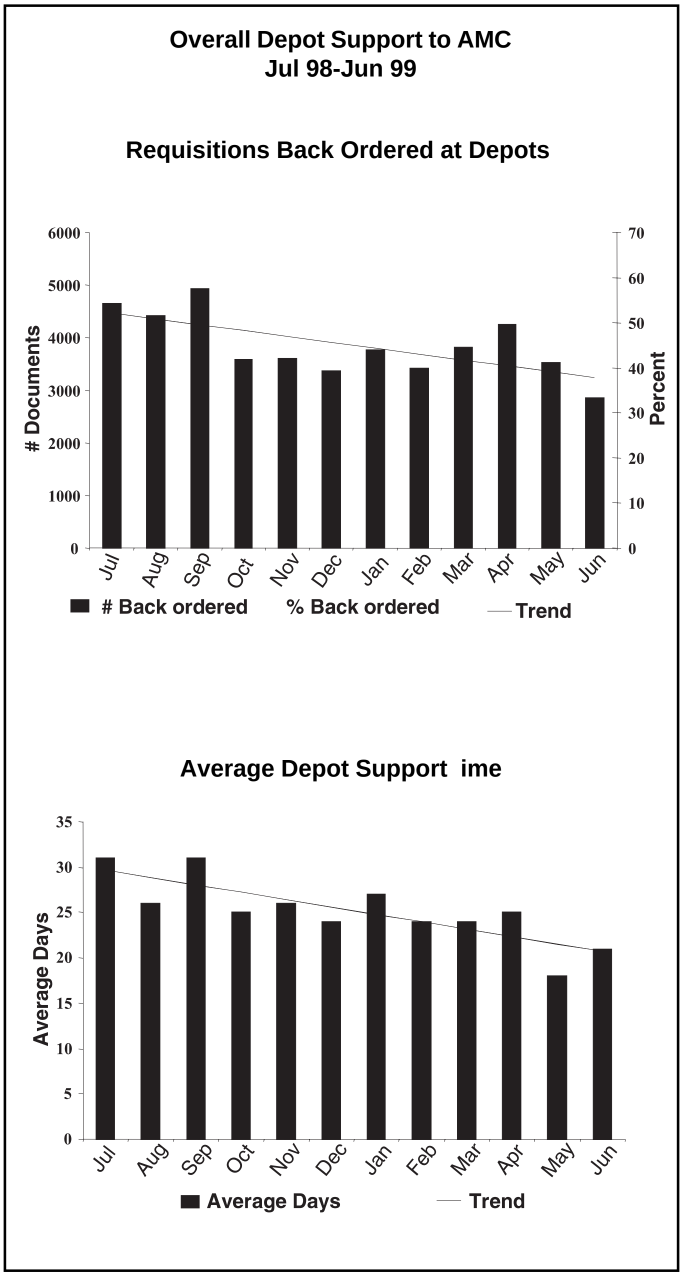


Figure 4. Depot Surge Efforts

Aerospace Expeditionary Force

The world is less stable, predictable, and harmonious than it was during the Cold War, with a whole range of new conflicts, rivalries, and challenges.

—**Richard P. Hallion, Air Force Historian**

Threats to American vital interests are much more diffuse today than ever before. The end of the Cold War did not mark the beginning of a new era of peace. Instead, American military units are deployed around the globe to places like the Persian Gulf, Somalia, Bosnia, Rwanda, Haiti, and Kosovo to confront today's largely unpredictable world.

In response to this unpredictable world, the United States Air Force introduced the expeditionary aerospace force (EAF) concept. Under this concept, rapidly deployable airpower packages can be tailored to the situation and launched—ready to operate anywhere in the world in 3 days.[41] An airpower package under the EAF concept will be called an air expeditionary force (AEF).

Today, ten AEFs have been designated from geographically separated units of the active and Reserve forces. These forces are a mixture of assets that includes fighters, bombers, and support aircraft. At all times, two AEFs are on call to respond within 72 hours. This *on-call* period lasts for 3 months every 15 months.[42]

An unpredictable world drove the need to establish AEFs, but they provide a somewhat unpredictable effect on the reparable item pipeline that is responsible for supporting them. It is important to use recent history, such as Operation Allied Force, to study the system's ability to support these types of deployments. This leads to the next question. How well do current RSP policies and computational assumptions support AEF deployments? Again, this article focuses on one weapon system, the KC-135, and uses customer service and cost tradeoff as its main criteria for analysis.

Scenario

To facilitate a *what-if* analysis, ASM inputs were based on a scenario similar to what actually occurred during Operation Allied Force. This scenario is split into three segments: sortie duration, sortie rate, and reach-back capability. The subsequent analysis will follow the same three segments and focus on the customer service and cost tradeoff.

In Operation Allied Force, tanker aircraft often operated from airfields on the periphery of the theater, and they were forced to fly missions of longer duration than those planned for an MTW.[43]

The fuel a tanker carries for air-refueling purposes includes fuel the tanker burns in its own engines. Therefore, tankers in Operation Allied Force were not able to loiter as long or provide the same level of support as that normally planned for an MTW.[44] As a result, they were forced to fly more sorties.

Finally, depot operations, along with the rest of the logistics system, provided *reach-back* capability to overcome low initial RSP fill rates. This *reach-back* capability provided good results in that fill rates at the end of the operation were better than those at the beginning.[45]

What-If Analysis

An initial baseline run was made with the ASM model, using actual KC-135 package data for a unit with ten aircraft. Some data input into the model was notional, as using actual WMP sortie rates and durations would make the analysis classified. However, even with notional data, the relationships are still clear (Table 1).

In the baseline package, ASM computed an RSP consisting of 219 different reparable types. The total number of units was 691. The cost of these 691 spares was more than $7M, and as the model is supposed to do, this mix of spares achieved an 83

	Line Items	Units	Cost	Resulting Aircraft Availability
Baseline Package	219	691	$7,091,681	83.21%

Table 1. Baseline

percent aircraft availability rate. The remaining analysis was compared against these baseline figures.

Increased Sortie Duration. In our scenario, operating from bases on the periphery of the theater increases the sortie duration. This was modeled in the ASM by using the baseline package and increasing the sortie duration by 10 and 20 percent (Table 2).

All packages still achieved the 83 percent goal; however, the number of units and overall costs to reach this goal climbed rapidly with the increase in sortie duration.

Increased Sortie Rate. The inputs to the model incorporated the next portion of the scenario. Tankers staged on the periphery must travel farther to meet the aircraft needing fuel; therefore, they have less loiter time and less fuel to dispense on each mission and require more sorties. This was modeled by using the previous model runs with an addition to the sortie rate of 10 and 20 percent (Table 3).

Again, the results were along the same lines. ASM continued to build packages that provided the correct percentage of available aircraft. However, it did this by increasing the number of units authorized. This increase in quantity increased cost.

Assuming that an increase in costs is not acceptable, the model was run with the original baseline package quantities against the various flying data. When the model is run this way, it will provide the best available aircraft percentage possible from that mix and quantity of spares (Table 4).

These results, instead of showing a change in costs, showed the change in customer service. From the baseline of 83 percent, the worst-case scenario lost almost 7 percent of the ultimate goal, available aircraft. Comparing the changes in customer service under the tests in Table 4 to the changes in price as shown in Table 3 highlights an interesting phenomenon. It seems that aircraft availability was less affected by changes in spares quantities than the costs. If aircraft availability exhibits more robustness than in costs, it may be possible, in situations, to give up a smaller percentage of aircraft availability in return for a larger cost savings. The reason behind this robustness is due to the location of the desired availability on the curve shown in Figure 5. The curve demonstrates the *law of diminishing returns*. This phenomenon shows that a desired increase in aircraft availability requires an increasingly larger cost as it gets closer to 100 percent. Also, in reverse, each dollar reduction in cost has an increasingly larger negative effect on aircraft availability as you get closer to $0. These results are significant as they demonstrate it is virtually impossible to achieve 100 percent aircraft availability. Also, aircraft availability declines in larger proportion to the number of spares available, moving left on the curve.

Reach-back Capability. The third segment of the scenario calls for increased response from the depot or other portions of the reparable-item pipeline. In the previous models, depot repair did not start until the model run ended. To depict an increased reach-back capability, the worst-case model was changed to allow depot repairs to begin on day one (Table 5).

This model run showed the capability of depot repair to offset an undesirable situation. Depot repair

	Sortie Duration	Sortie Rate	Line Items	Units	Cost	Resulting Aircraft Availability
Baseline Package	X	Y	219	691	$7,091,681	83.21%
Test #1	1.1(X)	Y	219	731	7,653,498	83.10%
Test #2	1.2(X)	Y	219	751	8,126,672	83.12%

Table 2. Sortie Duration Test

	Sortie Duration	Sortie Rate	Line Items	Units	Cost	Resulting Aircraft Availability
Test #1	1.1(X)	Y	219	731	$7,653,498	83.10%
Test #1A	1.1(X)	1.1(Y)	219	757	8,282,561	83.68%
Test #1B	1.1(X)	1.2(Y)	219	788	8,730,236	83.07%
Test #2	1.2(X)	Y	219	751	8,126,672	83.12%
Test #2A	1.2(X)	1.1(Y)	219	790	8,753,289	83.05%
Test #2B	1.2(X)	1.2(Y)	219	835	9,346,651	83.05%

Table 3. Sortie Rate Test

	Sortie Duration	Sortie Rate	Line Items	Units	Cost	Resulting Aircraft Availability
Baseline Package	X	Y	219	691	$7,091,681	83.21%
Baseline Package	1.1(X)	Y	219	691	7,091,681	82.92%
Baseline Package	1.1(X)	1.1(Y)	219	691	7,091,681	81.12%
Baseline Package	1.1(X)	1.2(Y)	219	691	7,091,681	80.86%
Baseline Package	1.2(X)	Y	219	691	7,091,681	78.86%
Baseline Package	1.2(X)	1.1(Y)	219	691	7,091,681	78.78%
Baseline Package	1.2(X)	1.2(Y)	219	691	7,091,681	76.57%

Table 4. Customer Service Measures

added nearly 3 percent aircraft availability in the first 30 days. This result is quite intuitive—response capability anywhere in the pipeline can provide increased aircraft availability. However, for depots to generate the desired DSO, they would have to improve pipeline response (for example, shorter repair times, improved transportation), in addition to starting early. Unfortunately, the costs to provide pipeline response are beyond the scope of ASM. In the end, without pipeline response improvements, the depot would have to add an additional quantity of spares to reach the desired DSO (shown on the bottom row of Table 5).

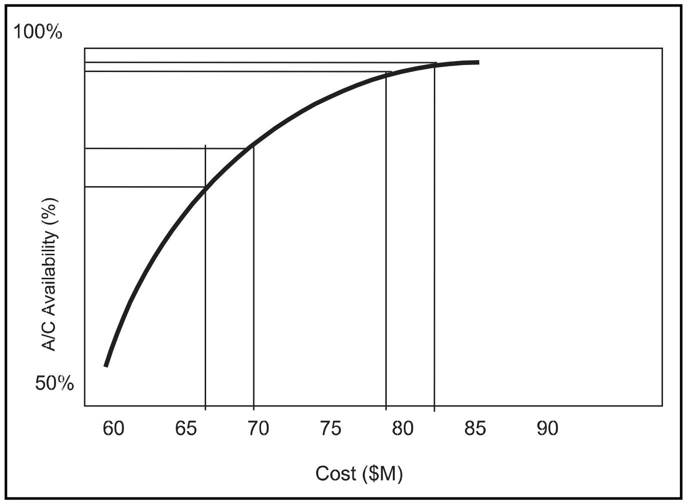


Figure 5. Law of Diminishing Returns

Conclusions and Recommendations

When it comes down to the wire and the enemy is upon you and you reach into your holster, draw your pistol and level it at your adversary, the difference between a click and a bang is logistics.

—**Editors of *Loglines***

	Sortie Duration	Sortie Rate	Line Items	Units	Cost	Resulting Aircraft Availability
Worst-case Package	1.2(X)	1.2(Y)	219	691	$7,091,681	76.57%
Reach-back Package	1.2(X)	1.2(Y)	219	691	7,091,681	79.30%
Reach-back repair + adds	1.2(X)	1.2(Y)	219	759	8,172,490	83.11%

Table 5. Reach-Back Test

AEFs were established to deal with the uncertain future. This uncertainty has implications for inventory in the logistics system. When looking to save costs within the Department of Defense, inventory is an easy target. However, it is inventory that provides available aircraft. Readiness spares packages provide inventory for a 30-day period of wartime operations. This inventory provides the ultimate customer service measure: aircraft availability. However, it is also quite expensive (a ten-aircraft unit of KC-135s can have an RSP valued in excess of $7M).

During Operation Allied Force, tanker units deployed with readiness spares kits that were at 68 percent of their authorized inventory level. For AEF operations, that may not attract a great deal of concern, as it is easy to think that an AEF will respond to small-scale contingencies. Small-scale contingencies could easily be viewed as a subset of an MTW that would not require the same amount of spares. However, Allied Force showed that basing options and mission requirements could result in sortie rates and durations higher than those planned in the WMP. In these cases, responding with an appropriate number of spares will be important for future operations.

Therefore, determining an appropriate number of spares becomes important. The Aircraft Sustainability Model is the Air Force's official tool for this purpose. As this project demonstrates, ASM easily shows the customer service and cost tradeoff of this inventory decision. This project did demonstrate a higher degree of robustness in aircraft availability than it did in costs. This effect can lead to policy changes to reduce inventory in situations where the smaller percentage of available aircraft can successfully perform the mission. In contrast, diminishing spares availability can have an increasingly negative effect on aircraft availability. Based on this, RSP fill rates should not be allowed to fall out of the area where they demonstrate the robustness around aircraft availability. For further proof, actual data from a number of individual units that participated in Allied Force should be modeled to determine if this relationship exists across the board. It is possible the relationship varies somewhat based on the scenario or weapon system. It would be beneficial to continue to analyze this relationship for future improvements.

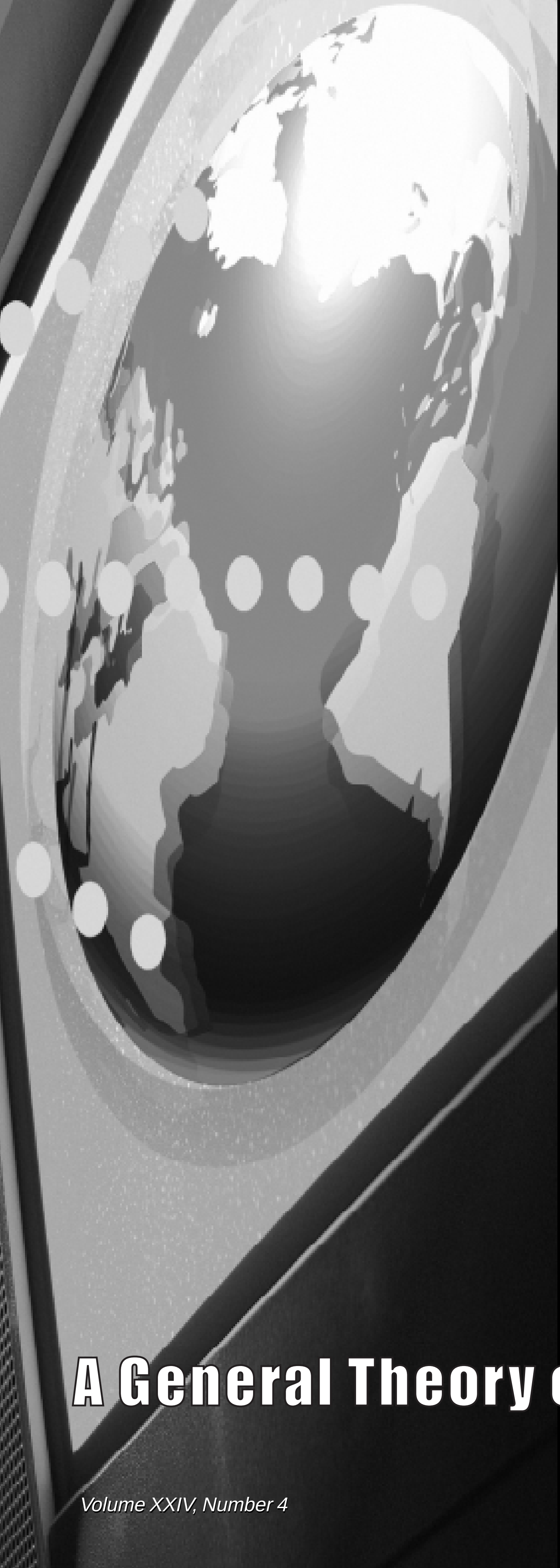
In this analysis, depot response improvements could improve the number of available aircraft. Even though this is quite intuitive, the analysis should provide yet one more reason to continue depot response and pipeline time improvements. These improvements, once quantified, must then be added to the logic of the ASM to allow reduction of RSP quantities. With pipeline response improvements, smaller RSPs will maintain or improve aircraft and allow the Air Force to reap inventory cost savings.

Another benefit of improved depot response is the ability to provide support to units in all theaters, not just units involved in AEF operations. Operation Allied Force proved the depot's capability to do so.

Finally, ASM proved to be a valuable tool. The relationships between customer service and costs are easily demonstrated through the use of ASM. Its use should be encouraged throughout the community responsible for Air Force inventory management. It brings a greater level of understanding to the tradeoffs involved in inventory decisions.

In the end, tanker operations in Operation Allied Force were extremely successful. The inventory policies concerning readiness spares packages supported this operation, even though the beginning inventory balances were lower than planned. Some robustness around the available aircraft measure, when compared with cost values, was found via *what-if* analysis. This characteristic

(Continued on page 42)



Stephen Hays Russell, PhD

Growing World of Logistics

A General Theory of Logistics Practices

Logistics is customer service, relates to developing capabilities and managing activities that focus on meeting support needs, and involves logic and calculations.

Does the term logistics have a precise meaning, or does it simply describe an umbrella concept for a variety of supply-related processes? Do root concepts exist in all contexts in which the term is employed? Is there a general theory of logistics? And what about supply chain management? Is it a new practice, or is it old-fashioned logistics?

In addressing these and related issues, this article examines the origins and applications of the term logistics, presents a new paradigm of logistics in practice, and suggests the appropriate framework of thinking for all logistics practices; that is, a general theory of logistics.

The Term Logistics

The English word logistics appears to have been derived from both the Greek word *logistikos* and the French word *logistique*. *Logistikos* is rooted in the concept of logic and means skilled in calculation. *Logistique* is probably influenced by the French *loger* meaning to quarter (or lodge) soldiers. Hence, the combination of logic, calculation, and quartering soldiers appears to have yielded the word.

The term logistics entered military terminology in 18th century Europe. The *maréchal des logis* was the administrative officer responsible for encamping and quartering troops. As warfare became more advanced with an increasing variety of weapons and ammunition, the *maréchal des logis'* duties were expanded to include the stocking of supply depots.[1]

The term was first employed in a formal sense in the American lexicon in the late 19th century when Rear Admiral Alfred T. Mahan, American naval strategist, introduced the word logistics into the US Navy.[2] The term received a written definition in 1905 as that *branch of the art of war pertaining to the movement and supply of armies.*[3] But it was not until World War II that the term began to be used pervasively to describe the support of military forces and their equipment.

Beginning in the 1960s, logistical support of weapon systems became an integral part of the planning and design stages of these systems. During this period, logistics as practiced in the military grew into engineering (or systems) logistics, with an emphasis on engineering issues, calculating initial support requirements, and programming resources to keep a system operational after introduction. Engineering logistics stresses reliability and maintainability engineering, configuration management, provisioning and continuing supply support, repair level analysis, technical manuals development, training, data and records management, and life-cycle cost management. In this sense of the word, logistics is largely a modeling and quantitative discipline.

The term logistics migrated to the business sector in the 1960s as academicians in marketing saw potential in applying the principles of military logistics to physical distribution of consumer goods.[4] Business logistics evolved into a dichotomy of inbound logistics (materials management or physical supply) to support production, where the plant is the customer, and outbound logistics (physical distribution of product) to support external customers.

Most recently, the business community began viewing logistics as a component of a larger evolving concept, supply chain management (SCM). SCM is a linking of all firms up and down the supply chain (from ultimate material sources to ultimate customers) in a collaborative and seamless network.[5]

Beginning in the 1970s, the term logistics crept into the lexicon of the common culture. The word is now being used with regard to the supply support of activities from church picnics to the Olympics. During the US famine relief efforts in Bangladesh in 1974 and in Somalia in 1992 and 1993, logistics was applied to the distribution of food.[6] In recent years, the popular press has written of the logistics of waging a Presidential campaign and the logistics challenges of providing relief to victims of the floods in Honduras in 1998 and of recent hurricanes.

Definitions of Logistics

Clearly, logistics as a concept and a practice has evolved over the years and is a discipline that is now practiced in different ways and contexts. Logistics means different things to different people. Even professionals in the field differ as to what logistics actually means.

Table 1 presents a variety of definitions of logistics. To some, logistics is managing the flow and stock of materials. To others, it is a customer support activity, a planning and engineering mechanism, or a science of calculating requirements and promoting operational capabilities. The dictionary treats logistics as purely a branch of military science. The Council of Logistics Management defines logistics purely in a product distribution context. The common culture of today views logistics as the underlying details of making something happen.

Perhaps the most fundamental definition of logistics is the classical definition: getting the right product, to the right customer, in the right quantity, in the right condition, at the right place, at the right time, and at the right cost.[7]

All these definitions, explicitly or implicitly, have in common the concept of integrating many activities toward supporting an organizational objective. Further, all have, expressed or implied, a sense of meeting the material, system, or process needs of a customer.

A New Logistics Paradigm

A consideration of the various practices that, taken together, define logistics suggests that logistics is a branch of management that is practiced in four subdisciplines:

- **Military or engineering logistics.** The design of supportability into weapon systems and other capital assets, assessment of technical requirements for training and maintenance, computation of post-sale support requirements, and integration of all aspects of support for the operational capability of military forces and their equipment.
- **Business logistics**. The planning and management of supply sources, inventories, transportation, distribution networks, and related activities and supporting information to meet customer requirements.
- **Event logistics.** The network of activities that brings together the resources required for an event to take place.[9] Event logistics is characterized by deployment of resources (forward logistics) and withdrawal of resources (reverse logistics) according to the events schedule, significant contingency planning, and the powerful presence of the logistics function in the events management team.[10] Examples of event logistics include the detailed planning and support requirements necessary to execute a circus, a rock concert, a scout encampment, news coverage of the O. J. Simpson murder trial (more than 500 reporters and their satellite-linked vans and other equipment), the Olympic Games, and a Presidential trip.
- **Process logistics.** The acquisition, scheduling, and management of human and material resources to support a service. Process logistics typically involves the coordinated employment of facilities, capital assets, and service personnel to create the framework for a process to occur. Examples

Source	Definition
Short	Management of materials in motion and at rest.
Classical	Getting the right product, to the right customer, in the right quantity, in the right condition, at the right place, at the right time, and at the right cost. (Called the Seven Rs of Logistics.)
Dictionary	The branch of military science having to do with procuring, maintaining, and transporting materiel, personnel, and facilities.
International Society of Logistics	"The art and science of management, engineering, and technical activities concerned with require-ments, design, and supplying and maintaining resources to support objectives, plans, and operations."*
Famous Nebulous	World War II Chief of US Naval Operations Admiral Ernest H. King: "I don't know what the hell this logistics is that (Army Chief of Staff General George C.) Marshall is always taking about, but I want some of it."**
Biblical	"I have heard of you . . . that light and under-standing and excellent wisdom are found in you . . . I have heard that you give interpretations and solve problems . . . you shall be clothed with purple and have a chain of gold about your neck . . . ." (Daniel 5:14;16)***
Utility	Providing time and place utility of materials and products in support of organization objectives.
Council of Logistics Management	"That part of the supply chain process that plans, implements, and controls the efficient, effective flow and storage of goods, services, and related information from point of origin to point of consumption in order to meet customers' requirements."****
Component	Supply management for the plant (inbound logistics) and distribution management for the firm's customers (outbound logistics) or material support of manufacturing and product support of marketing operations.
Functional	Materials requirements determination, purchasing, transportation, inventory management, ware-housing, materials handling, industrial packaging, facility location analysis, distribution, return goods handling, information management, customer service, and all other activities concerned with supporting the internal customer (manufacturing) with materials and the external customer (retail stores) with product.
Common Culture	Handling the details of an activity.

Table 1. Definitions of the Discipline of Logistics

include bus transportation of school children, mail delivery, drug smuggling, Red Cross relief operations, and operation of a multidimensional orthodontics office (scheduling stations, personnel, and parallel and sequential workflow for efficient and effective service).

Supply chain management is the collaborative integration of all logistics processes by all players in a chain, from original suppliers through end users. The process is a customer-driven system involving the sharing of information, risks, and assets among partners to achieve an integrated, seamless, responsive distribution system. SCM literature views business logistics as a component of supply chain management. Supply chain management is differentiated from logistics in that it involves all partners (suppliers, carriers, other distribution channel participants, and customers) up and down the supply chain and, hence, is more than the internal integration of logistics activities within a firm.[8] The key concepts of SCM are pull system, customer-driven, strategic alliances, shared data, and system (as opposed to firm) optimization. However, SCM can be viewed as fully integrated logistics, meaning not only the integration of all logistics activities in a firm but also the comprehensive backward and forward integration of all logistics processes in a channel. SCM, then, is a new term for integrated business logistics (albeit a larger view of integrated).

A General Theory of Logistics Practices

Interestingly, the dictionary gives only one definition of logistics (the military context of the term). Today, however, the various practices that are considered logistics can be classified into four types. The question arises whether future dictionaries should modernize their perspective of logistics in practice and offer multiple definitions of the term or whether there is some common platform or general theory of logistics from which all logistics practices spring.

A careful analysis of the four branches of logistical practice, as presented, suggests that logistics is customer service, relates to developing capabilities and managing activities that focus on meeting support needs, and involves logic and calculations. The proposition of this research is that there is, indeed, a general theory of logistics practice:

> Logistics is the science of developing and managing the capabilities and protocols that are responsive to customer-driven service requirements.[11]

The richness of this construct of logistics is suggested by focusing on the component words and noticing their relevance to all four types of logistics:

- **Science**: logic, mathematics, statistics, models, computers, information technology, algorithms, engineering principles, systems concept, cost analysis, optimization techniques, tradeoffs, and sensitivity analysis
- **Developing**: organizing, formulating objectives, designing, team effort, partnering, contracting, creating, evolving, augmenting, achieving
- **Managing:** planning, negotiating, programming, implementing, communicating, deploying, measuring, controlling, improving
- **Capabilities:** physical assets, programs, human capital, historical data, forecasting, experience, real-time information, software, hardware, strategic alliances, access, capacity, competence
- **Protocols:** operational plans, methods, logic networks, data systems, strategies, human decision making, techniques, outsourcing, contingency plans

Logistics	Capabilities	Protocols	Services	Customer (Example)
Military	Airlift Sealift Operational readiness Sustainability	Logistics plans Provisioning War reserve spare kits Containerization Supply support Maintenance plans Materiel and service contracts Industrial mobilization	Fuel Rations Spare parts Maintenance Ordnance Mail Medical supplies	Fighter wing
Engineering	Design for supportability Integrated logistics support Tradeoffs Life-cycle cost management	Reliability engineering Maintainability engineering Modeling Configuration management Repair-level analysis Data management Life-cycle costing Training engineering Logistic support analysis	Operational readiness Sustainability Product support	Air Combat Command
Business (Inbound)	Continuous flow World-class suppliers Shipment tracking Transportation network Inventory management Automated materials handling	Demand forecasting Material requirements planning or just-in-time system Strategic purchasing Global positioning satellite system Dedicated contract carriage Warehouse management systems Automated storage and retrieval systems Bar codes	In stock Minimal inventory Reliable deliveries Warehouse accuracy Responsive to requirements	Manufacturing Plant
(Outbound)	Customer-driven Computer systems Regional distribution centers Value-added services Shipment tracking Carrier management Information accuracy	Point-of-sale technology replenishment system E-commerce Electronic data interchange Merchandise labeling/assorting WWW site Private fleet Advanced packaging Pick-to-light system Vendor-managed inventory Collaborative planning, fore-casting, and replenishment	95% order fill rate 5-day order cycle 99% picking accuracy Damage-free delivery Liberal return policy 96% on-time delivery Customer satisfaction	Retail store
Event	Pre-event planning and staging Support Cleanup (asset withdrawal)	Logistician authority Strategic plan Tactical plans Procurement system Transportation network Requirements algorithms Command post Receiving and storage Facilities plans Service contracts Contingency plans Packing and crating Reverse Logistics	Equipment in place Supplies in place Facility operational Inventory management & issue Asset control and protection Flexible response Participant support services Spectator support services Media support services Redeployment after event	Olympic venues
Process	Bus transportation	Asset procurement Vehicle maintenance Route design Time schedules Fuel contracts Safety plans	Transportation to school	School children

Table 2. Example Elements of the General Theory of Logistics Practices

- **Responsive:** anticipate needs, meet needs, exceed needs, fulfill objectives, minimize costs, react constructively, respond to change, thwart failure, optimize performance, and differentiate performance
- **Customer-driven:** pinnacle of direction and control, source of authority, place of ultimate measure, meeting expectations, origin of pull requirements, reason for being, beneficiary of achievement
- **Service requirements:** meeting objectives, quality, excellence, operational, satisfied, value-added, efficient, responsive, available, damage-free, time-and-place utility, life-cycle management.

Table 2 portrays the general theory of logistics practices as presented in this article for all four logistics subdisciplines. Examples of the capabilities, protocols, and services are illustrated.

Consider, for example, a deployed fighter wing. The customer who drives the requirements and to whom the logistics system must respond is the wing or theater commander. The military logistics organization has in place, as examples, sustainability and airlift capabilities that are executed with specific protocols (logistics plans, supply support, materiel contracts, and industrial mobilization). Some of the services the customer-responsive logistics system provides are fuel, rations, spare parts, and ordnance.

In engineering logistics, a using command (for example, Air Combat Command) specifies readiness and support requirements for new aircraft. The logistics community, with such capabilities as design for supportability and the Integrated Logistics System, uses established protocols (reliability and maintainability engineering, logistics models, repair level analysis, and so forth) to give the customer the product-support services required.

For inbound business logistics, a firm like Proctor and Gamble will specify logistics standards for efficient and responsive support of its production operations. The firm's internal logistics operations will have established capabilities such as a network of world-class suppliers, transportation partners, and a continuous flow capability. These capabilities are realized with the employment of supporting protocols (demand forecasting, materials requirements planning, dedicated contract carriage, and so forth) to provide an inbound logistics system that ensures availability of production materials with minimal investment in inventory.

In outbound logistics, Proctor and Gamble's customer (Wal-Mart, for example) is in the driver's seat, imposing such service standards on Proctor and Gamble's logistics system as ac95-percent order fill rate, 5-day order cycle, and damage-free delivery. Proctor and Gamble will have in place customer-responsive capabilities such as regional distribution centers, information and computer technologies, and shipment tracking. These capabilities are built upon protocols such as a point-of-sale replenishment system, vendor-managed inventory, advanced packaging methods, and electronic commerce capabilities that ensure the customer's logistics standards are satisfied.

Similar relationships exist in event logistics and process logistics. Customers dictate standards of service. Logistics systems exercise protocols within their framework of response capabilities.

These illustrations reinforce the notion that there are root concepts or processes in logistics, a general theory of logistics practices that encompasses all logistics.

Summary

The new paradigm introduced in this article demonstrates that logistics is practiced in four subdisciplines: military, business, event, and process.

Logistics is logic, wisdom, calculations, models, networks, inventories, transportation, distribution, customer service, time-and-place utility, storage, flow, details, optimization, and collaborating. It is a set of support activities. It is being responsive to customer requirements for materials, goods, and services.

But the underlying general theory of logistics practices as developed here identifies the roots of logistics as being capabilities, protocols, and responsive service. Indeed, all logistics is the science of developing and managing the capabilities and protocols that are responsive to customer-driven service requirements.

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Gender Equity:

Bud Baker, PhD

Since the term was popularized in the 1980s, the *glass ceiling* has become a significant concept in the American workplace. The metaphor is an apt description of a reality in which women and minorities tend to be *overrepresented* at the lower levels of an organization yet *underrepresented* at more senior levels.

When the Civil Rights Act of 1991 established the Federal Glass Ceiling Commission, its mission was to assess the barriers hindering "the advancement of women and minorities to management and decision-making positions" and make recommendations toward bringing down such barriers.[1]

This article assesses the progress made in one area of the Federal Government since 1991—specifically, the federal government's logistics management career field—and changes in gender composition, not just for the logistics field as a whole but also the changes, by gender, in its managerial ranks.[2]

Workplace discrimination based on gender has long been a national issue and was addressed in the Equal Pay Act of 1963 and in Title VII, Civil Rights Act of 1964.[3] But by the mid-1980s, it was apparent that despite social, demographic, and legal changes, patterns of discrimination in the work force still existed, especially as related to upward mobility for women.[4] Hymowitz and Schellhardt used the term *glass ceiling* to describe this discrimination in 1986:

> Even those few women who rose steadily through the ranks eventually crashed into an invisible barrier. The executive suite seemed within their grasp, but they just couldn't break through the glass ceiling.[5]

Research on this *glass ceil*ing demonstrated that it can be subtle yet systematic.[6] Further, the precise characteristics of the barriers change from organization to organization and from level to level within a given organization (for example, *glass ceiling* barriers to entry- and midlevel management are different than the barriers to more senior leadership positions). As a result, women must adopt different strategies to gain promotion to different levels of the organization.[7]

An Analysis of the Federal Logistics Management Career Field

One particular aspect of gender discrimination is pay. Many studies cite data describing gender-based pay differentials;[8] others use statistics similar to those of the Department of Labor, in which women's hourly earnings in 1999 were only 76.5 percent of men's.[9] Some authors, though, question the validity of a gender-based differential in compensation. Some suggest little or no gap exists when pay is adjusted for years of employment, hours worked, education level, and other factors.[10] Others contend that business necessity is the most significant destroyer of *glass ceilings*; in high-tech industries, heavy competition for a limited technical talent pool tends to equalize opportunity and reduce pay inequity.[11]

Women tend to adopt a variety of techniques to counter *glass-ceiling* effects. Some of these strategies include the pursuit of difficult assignments, enhanced use of mentoring, and acceptance of the need to outperform male counterparts.[12] Faced with the need to make these adaptations, many women opt out of corporate bureaucracies in favor of entrepreneurial ventures and part-time work.[13]

Issues of gender equity affect all sectors of the economy, including the government. From 1950 to 1990, the proportional representation of women in government and not-for-profit sectors rose dramatically.[14] While high-profile female government appointees like Madeleine Albright and Janet Reno were visible icons of women's progress, *glass-ceiling* issues are no less prevalent in government than in business. The field of logistics management is similarly affected.

The Federal Work Force

The federal work force of the 1990s reflected national trends in that federal career fields typically displayed disproportionately high numbers of women in low ranks and disproportionately low numbers of women at more senior levels. For example, in 1990, the year prior to the establishment of the Federal Glass Ceiling Commission, only 6.2 percent of federally employed women were at or above the level of upper middle management (General Schedule [GS]-13 and above). However, male representation was more than four times as high, with nearly 28 percent of all federally employed males located in the GS-13 and above category.[15]

Faced with this stark imbalance, the Federal Glass Ceiling Commission recommended that government *lead by example*:

> Government at all levels must be a leader in the quest to make equal opportunity a reality for minorities and women. The commission recommends that all government agencies, as employers, increase their efforts to eliminate internal glass ceilings by examining their practices for promoting qualified minorities and women to senior management and decision-making positions.[16]

The Federal Government's Logistics Management Career Field

The vast majority of federally employed logisticians work within the Civil Service General Schedule. The General Schedule is the basic pay schedule for most white-collar jobs in the federal government, covering about 72 percent of the civilian employees. This pay schedule consists of 15 grades, designated GS-1 through GS-15, with ten rates of pay for each grade.[17] The GS system is divided into five *categories* of work, including professional, administrative, technical, clerical, and other.[18] The federal government considers logistics management (GS-0346) to be an administrative career field, along with positions like program management (GS-0340), financial management (GS-0505), and management and program analysis (GS-0343).[19]

The grades GS-7 through GS-12 are lower level management positions, roughly analogous to lieutenants and captains in the Army or Air Force. GS-13, -14, and -15 are upper level management, equivalent to majors, lieutenant colonels, and colonels. Above GS-15 are even higher level positions, the Senior Executive Service: SESs are the equivalent of generals.[20]

There were 10,694 civilian logisticians employed by the federal government in FY91. Of that number, 2,868—or 26.8 percent—were women. The average GS grade of those women (11.42) was lower than that of their male counterparts (11.92). Only a relative handful of logisticians were below the grade of GS-9.[21]

Virtually all (96.3 percent) federal civilian logistics managers work for the Department of Defense. The Air Force

Federal Logistics

- **Glass ceiling has not disappeared.**
- **Wage disparity is declining.**
- **Women are increasing proportionately in senior management.**
- **Disparity still exists at the senior executive level.**

alone employed a third (3,600) of all federal logisticians in FY91. Of those, 1,010—or 28 percent—were women.[22]

Note that these data say nothing about the gender distribution across ranks. If logistics management is like other federal career fields, one would expect to see disproportionate numbers of men in the upper ranks, with more women in the lower ranks. If the *antiglass-ceiling* movement has had any effect since 1991, one would also expect to see the proportion of senior men decline and the proportion of senior women rise during the 1990s.

A Look Back: Gender Distribution in Logistics Management in 1991

To better evaluate the progress made in cracking the glass ceiling, we need to begin by examining the state of the logistics career field in the early 1990s.

One measure of gender equity is, of course, salary. In the aggregate, male logistics professionals earned more money than women in the same field. The average salary for male logistics managers in FY91 was $45,300; for females, $39,300. Thus, in the aggregate, civilian women in the logistics field made about 86.7 percent of that made by their male counterparts.[23]

Since federal pay scales do not vary based on gender, the obvious cause of this disparity has to be rank. One would expect, then, to find that the logistics management career field was, in 1991, heavily dominated by men in the upper levels, with women clustered in the lower echelons. This is supported by the 1991 data. Note in Table 1 that women comprise nearly one-third of logisticians at or below the level of GS-12 but only about one-sixth of those at or above the GS-13 level.

The 1991 disparity grows even more pronounced at the most senior pay levels. Of 39 *senior executive* positions in the field of logistics management, the civilian equivalent of generals and admirals, only two—a little more than 5 percent— were filled by women.[24]

The Logistics Management Career Field as of 1998

The figures from 1991 show a career field with the *glass ceiling* still firmly in place. The year 1991, though, marked the passage of the Civil Rights Act and the establishment of the Federal Glass Ceiling Commission, which operated for the next 4 years. FY98 government employment data are used to assess the progress in and following those years.

From FY91 to FY98, the size of the civilian logistician work force grew slightly, from 10,694 to 11, 264. The proportion of women in the field also grew modestly, from 26.8 percent in 1991 to 29.7 percent in 1998. Also evident from the data is the fact that the gap between male and female salaries narrowed between 1991 and 1998. In 1991, women in logistics management made less than 87 percent of their male counterparts. By 1998, that had risen to nearly 90 percent.

Again, since there is no gender-based differential in federal government salary rates, the improvement in salary equity cited in Table 2 shows there has been a corresponding improvement in the number of women at higher grade levels.

The numbers in Table 3 tell an interesting story. Clearly, the logistics management field is becoming less male-dominated, with the overall percentage of women logisticians climbing from less than 27 percent to nearly 30 percent in just 7 years. And while the upper ranks of logistics managers are still overwhelmingly male, the period of time covered by this research saw women make significant inroads into upper management (GS-13 and above). From the 577 women at or above GS-13 in 1991, the number climbed 39 percent to 803 by 1998. The picture is more mixed at the most senior levels. In 1991, fewer than 6 percent of the most senior logistics management executives, those above the grade of GS-15, were women, but that changed marginally by 1998 (Table 4). Note that the total number of senior executive logisticians dropped dramatically, from 39 in 1991 to just 24 in 1998. During the same period, the proportion of females in the most senior logistics positions increased, though the number of female executives remained at just two.[27]

	≤ GS-12 Number	≤ GS-12 %	≥ GS-13 Number	≥ GS-13 %
Male	4,936	68.3	2,890	83.4
Female	2,291	31.7	577	16.6
Total	7,227	100.0	3,467	100.0

Table 1. Federal Logistics Management Employees, FY91

	FY91	FY98
Male	$45,300	$56,300
Female	$39,300	$50,700
Women's Salary as a % of Men's	86.7%	90.0%

Table 2. Mean Salary of All Federal Logistics Management Employees[25]

One potential concern is the effect of women's progress on their male counterparts. As the logistics field becomes more gender equitable, one might expect some adjustment issues affecting male members: greater opportunity for women will tend to be perceived as less opportunity for men. Indeed, a review of literature reveals the appearance of new vocabulary. Terms like *glass cellar* (hard and dirty physical labor disproportionately performed by men) and *glass escalator* (a *secret stairway* to upward mobility only available to women) seem to reveal mounting frustration on the part of men, who may not see gender changes in the workplace as affirmative action so much as they see reverse discrimination.[28]

Factors Responsible for Reducing the Impact of the *Glass Ceiling*

If the barrier of the *glass ceiling* has started to show some cracks as far as the logistics management career field is concerned, what are some of the possible reasons? A variety of sociocultural influences combined in the 1990s to improve the status of women in the federal workplace.

The years following 1991 brought a host of changes to the American political landscape and to the entire federal work force. A new President brought a new perspective regarding women in high places. Secretary of State Madeleine Albright and Attorney General Janet Reno became the first women ever to hold their cabinet positions, and other appointees—like Donna Shalala as

	≤ GS-12 Number	≤ GS-12 %	≥ GS-13 Number	≥ GS-13 %
Male	5,063	66.5	2,851	78.0
Female	2,547	33.5	803	22.0
Total	7,610	100.0	3,654	100.0

Table 3. FY98 Federal Logistics Management Employees[26]

	FY91		FY98	
Male	37	94.6%	22	91.7%
Female	2	5.4%	2	8.3%
Total	39	100.0%	24	100.0%

Table 4. Senior Logistics Management Executives (Above GS-15)

Secretary of Health and Human Services, Alice Rivlin at the Office of Management and Budget, and Sheila Widnall as Secretary of the Air Force—caused one author to note that when senior staff members meet at White House meetings half the attendees are usually women.[29]

This new level of female participation is just one part of the new environment. Other factors include the growing number of women graduating from business and graduate schools. In 1970, for example, women constituted only 3.6 percent of MBAs. By 1996, that number had soared to 37.6 percent.[30] Of the 326,000 business degrees awarded in 1996-1997 by American universities, almost 149,000—approximately 46 percent—were earned by women.[31]

Additionally, the advance of women in government was aided by a variety of early retirement programs, the effect of which fell largely on the mostly male senior levels of management. This trend affects both government and the private sector. The Hudson Institute estimates that men will make up nearly 60 percent of all work force departures nationwide in the years between 1994 and 2005.[32]

Conclusions and Thoughts on Future Research

For federally employed women in the logistics management field, the news is good. The *glass ceiling* has in no way disappeared, but it is certainly starting to show some fractures. Wage disparity is declining, and the presence of women is increasing proportionately in upper and senior management. It is true that the disparity is still greatest at the senior executive level, where women occupy only 8.3 percent of the most senior logistics management positions. But even there, the news is encouraging: that figure represents a significant increase from 1991.

While progress toward parity is a positive development, such progress can bring its own set of challenges. As more women continue to enter the lower levels of this profession, the challenge will be to continue and even improve upon the performance of the 1990s.

Notes

1. US Federal Glass Ceiling Commission, *A Solid Investment*: *Making Full Use of the Nation's Human Capital*, Washington DC, Nov 95, 4.
2. Research for this article began with an exploration of federal employment statistics. Although the titles of most documents referred to suggest the data describe the federal work force, there are interesting exceptions. For example, employees of both the federal legislative and judicial branches are not reported. Similarly, employees of certain security organizations are not reported, exempt by law for purposes of national security. Additionally, this article omits foreign employees based overseas for two reasons. First, their numbers are quite small, and second, employment of foreign workers in foreign locations might very well be driven by cultural considerations not pertinent to this analysis. The various databases analyzed in this paper are static; that is, they provide snapshots of the federal work force at particular points in time. The federal statistics contain raw data only. All interpretations and comparisons between years are the work of the author.
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11. "No Glass Ceiling in Hi Tech Fields," *Marketing to Women*, Vol 13, No 3, Mar 00, [Online] Available: OhioLINK Research Database, 8 Oct 00.
12. "A Modest Manifesto," 130. See Bell Rose Ragins, Bickley Townsend, and Mary Mattis, "Gender Gap in the Executive Suite: CEOs and Female Executives Report on Breaking the Glass Ceiling," *Academy of Management Executive*, Vol 12, No 1, Feb 98, 28.
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(Continued on page 43)

Military Readiness and Outsourcing Depot Repair

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Chaos theory attempts to explain the fact that complex and unpredictable results will occur in systems that are sensitive to their initial conditions. A common example of this is known as the Butterfly Effect. In theory, the flutter of a butterfly's wings in China could affect weather patterns in New Mexico, thousands of miles away. In other words, it is possible for a very small occurrence to produce unpredictable and sometimes drastic results by triggering a series of increasingly significant events.

When near-term fiscal expediency becomes the prime driver behind weapon system sustainment, we put long-term military readiness at great risk. The choice to outsource Air Force depot-level repair in a tightly constrained budgetary environment has neglected long-term, investment-based planning and chosen, instead, near-term executability. Leveraging the revolution in business affairs and acquisition reforms are constantly *talked-up* as a cure to the ills of the acquisition and logistics business and as sources for desperately needed modernization funding. The dialogue is unbalanced, and the proof is lacking. Thus, the question, are we declaring victory without results?

Background

A former Chairman of the Joint Chiefs of Staff told Congress several years ago, "Today's modernization is tomorrow's readiness." This is an outstanding statement! However, the statement is more instructive when restated in the following way, *Today's modernization* **[***with proper life-cycle planning and investment, to support complex, eventually decades-old, military-unique hardware that is the linchpin of national security***]** *is tomorrow's readiness.* The crux of this article is proper life-cycle planning and investment are not taking place and the primary culprit is the Source of Repair Assignment Process (SORAP).

Long-term investors understand a fundamental concept: the earliest investments reap the greatest returns over a long term. In other words, because time is so powerful, make your biggest investments as soon as possible. Another well-understood concept is nearly intuitive—scarce resources with high demand drive up prices. Finally, business practices call for providing services at the lowest cost in order to maximize profit and minimize loss. All of these are simple, instructive, and useful in many aspects of life, including long-term support of major weapon systems.

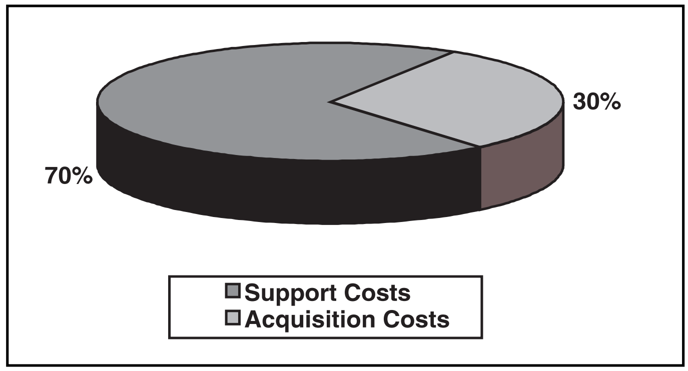

Figure 1. Percent of Life-Cycle Dollars

In this case, the investment to be made occurs (or should occur) in repair technologies, infrastructure, training, technical data, and human capital at the Air Force's air logistics centers (ALC), also referred to as depots. Second, the limited resources being considered are depot-level repair contractors. Finally, the business question is, what is the long-term best business choice for depot-level repair of our weapons systems, especially considering two primary factors:

- The Air Force cannot *divest* itself of its mission and go into a more lucrative market sector.
- The weapon systems being repaired today will be around for at least the next two generations.

So a limited contractor base is driving up repair costs (if we rely on them), and long-term support must get cheaper or face insolvency. These seem to be divergent planning factors, but they are not. We can and must plan for both because this is reality. Today, more than ever, planners, budgeters, and managers fail to recognize the macroeconomics lesson that reveals the proper perspective: *near-term investment provides long-term payback*.

I am not claiming subject matter expertise. In fact, Joint Publication 4-0, *Doctrine for Logistic Support of Joint Operations*, requires the individual Services to balance sustainability of combat capability with economy in the context of long-term objectives and capabilities.[1] It further states that this *balancing act* is the greatest challenge to the logistician. This is an unchallenged truth. With great pain, many senior leaders recognize supporting military-unique hardware for up to 4 or 5 decades (for example, B-52, KC-135, C-141, C-5, F-15, F-16, and Minuteman III) is *expensive and complex*. Also self-evident is the fact that reducing operations and support costs, particularly for an aging fleet, is the key to realizing long-term savings to be rolled into modernization efforts.

Competition Is Key

One way to achieve these cost savings is competition, according to Secretary of Defense William S. Cohen in his November 1997 Defense Reform Initiative Report.[2] "Competition between the public and private sectors works." This may be true, but competing weapon system support with a sharply decreased defense industrial base can have unintended pitfalls unless they are identified and avoided. The government's efforts to encourage defense industry consolidation were certainly prudent, but the results are today's near absence of private (that is, nongovernment) competition. In the aerospace sector, for example, some 40 different companies have consolidated into 5: Lockheed Martin, Boeing, Pratt & Whitney, General Electric, and Raytheon.

Critics of the consolidation warn that we are in danger of compromising our security as a result. Further, the present situation creates the danger of monopolistic behavior on the part of surviving companies. They also call for increased competition from defense business as the real cost-saver for future programs.

Fortunately, the government has, in the case of long-term sustainment of aerospace systems, had a *built-in competitor*. Over the last decade, air logistics centers have been able to compete effectively with the consolidated defense sector, thus keeping prices for outsourced work within reasonable limits. However, with the closing of two of the Air Force's five logistics centers and ever-increasing, aging-aircraft complications, the Air Force is relying more and more on outside repair contracts. Recently, this has been throttled by 50/50 issues that have been reached and exceeded. Nonetheless, there is a continuing pressure to move toward a Total System Performance Responsibility (TSPR) form of outsourcing.

While it is clear that TSPR can alleviate the reliance on depot infrastructure, it is not clear whether this will result in a long-term cost savings arrangement. There are several examples, both successful and not successful. In the near-term, TSPR contracts require little or no depot investment (infrastructure, training, manpower, technical data, and so forth). In the latter stages of a weapon system's life-cycle, the risk of having no competition (public or private) for repair will ultimately lead to cost growth and inflation (monopolistic behavior). Monopolies are broken up for this very reason. Finally, in spite of TSPR and best intentions, repairs and readiness cost are *eating our lunch*.

Regrettably, the Department of Defense and the Air Force, in particular, have leveraged tomorrow's readiness in an attempt to remain solvent in a budgetary drought. As a *short-term* fix, we continue to increase modification programs that extend the life of our aging aircraft, while leaders look to acquisition and logistics reforms (particularly at our depots) to do the monumental task of creating savings for future modernization investment.

Acquisition Reforms

As early as 1986, the Packard Commission suggested methods to reform the acquisition business. Clearly, their suggestions were well intended but had an obvious focus on the buying side of the acquisition equation. The Goldwater-Nichols Act codified several of the commission's suggestions, primarily by moving acquisition from military to civilian control and establishing portfolio managers for classes of weapon systems called program executive officers. Further, in the early 1990s, the Air Force established a concept called Integrated Weapon System Management (IWSM). This paradigm emerged as the first real step toward radical reform in defense acquisition and logistics for the Air Force.

A keystone of IWSM is the single-manager concept, where one individual has *cradle-to-grave* responsibility for an entire weapon system. In theory, IWSM would solve a long disliked process of one organization acquiring a weapon system and then tossing it over the wall for *loggies* to maintain.

From the long-term sustainment perspective, the problem with IWSM is that many development system managers (DSM) at Air Force product centers (Aeronautical Systems Center, Electronic Systems Center, Air Armament Center, Space and Missile Systems Center) retain single-manager responsibility decades after a system has been fielded, unlike system support managers (SSM) at air logistic centers (Oklahoma City ALC, Ogden ALC, Warner-Robins ALC). This is problematic because very few single-manager (DSM) offices are staffed with experts in depot logistics support. Further, these single managers continue to press for long-term sustainment by prime contractors via extremely limited competitions or sole-source contracts such as TSPR.

By default, single managers (DSMs) are, first and foremost, advocates for their single system, not necessarily for the Air Force enterprise. For this reason, they are primarily fielding advocates. But single managers are not just responsible for acquisition; they are *cradle-to-grave* owners, responsible for the entire life cycle. Reality is different. Putting *rubber-on-the-ramp* mentalities and political pressures did not disappear when IWSM was initiated. Therefore, ISMs are under tremendous pressure to field a system—their system. The argument is that without a *cradle* there is no reason for a *grave*. Some assert the opposing view: if you cannot support the weapon, then why birth it in the first place?

Early in the phase of an acquisition program, DSMs holding the single-manager title lack a true peer who is the proponent for long-term sustainment of individual weapon systems and the Air Force enterprise as a whole. Later in the program, long after many key decisions (investment-type) have been made, a system support manager is designated, usually at the target depot. In many cases, tension surfaces in the relationship between the SSM and single manager (still wearing the DSM hat). The SSM reports to the single manager for programmatic issues. Frequently, the single manager does not have a clear understanding of sustainment issues and maintains the rubber-on-the-ramp view that does not deal with the realities of lifetime sustainment. Unthrottled, near-term executability is absolutely paramount on this single manager's list.

This dilemma ignores the long-term commitment of sustainment and its daily changes. One reason is sustainment

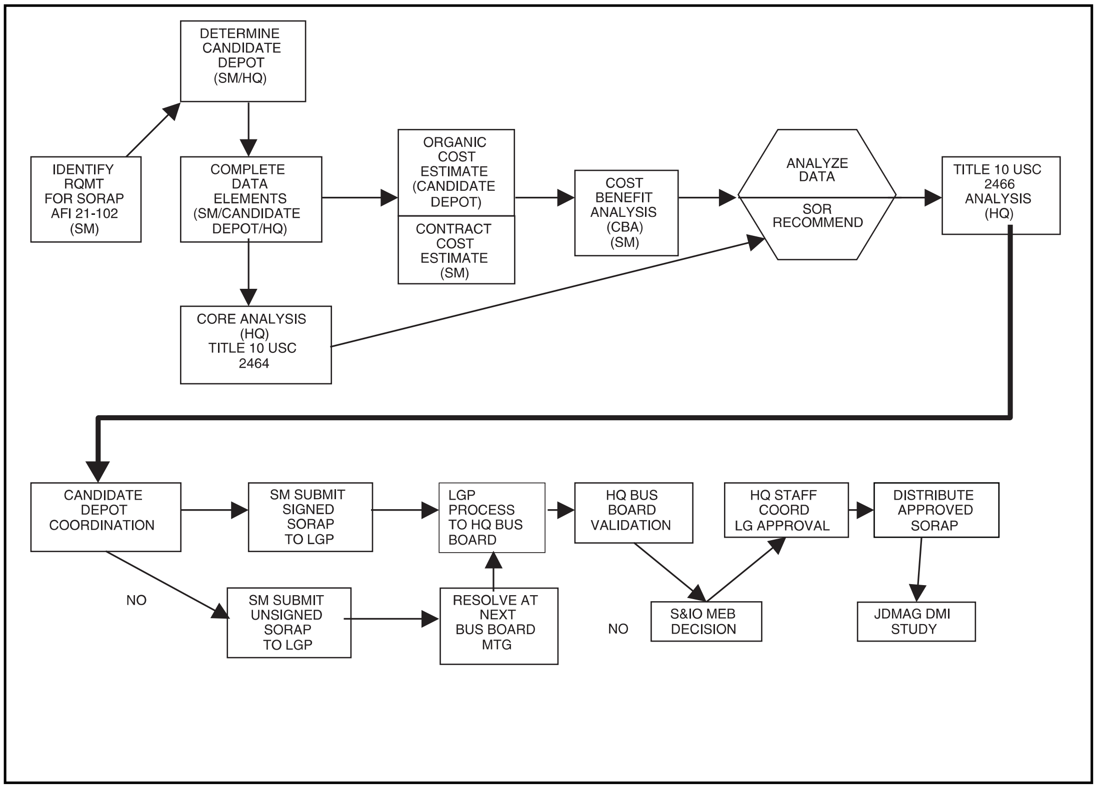

Figure 2. US Air Force Source of Repair Process

relies on the private sector, which expands and contracts to supply and demand, or the public sector (for example, depots) that base realignment and closure shut down by 40 percent. Further complicating the issue, there is no mechanism that forces disagreements between SSMs and DSMs to be resolved by program executive offices in consultation with the target ALC commanders.

In some cases, this does happen. The problem is that the SSM usually does not get a strong voice above the single manager (their boss). Logistics support considerations often take a back seat, placing great risk on ownership costs for the warfighters and long-term readiness of the force. It flies in the face of Defense Acquisition University course lessons teaching that, during the system engineering process, long-term logistics support considerations are equal to cost and performance considerations when tradeoffs are being considered. Critics contend reality differs from theory. Therefore, let us reconcile reality and theory with an example.

Case in Point

SORAP is the primary process for making depot maintenance source-of-repair (SOR) determinations and for assessing organic depot-maintenance requirements in accordance with Department of Defense Directive (DoDD) 4151.18, *Maintenance of Military Materiel*,[3] and Air Force Instruction (AFI) 21-102, *Depot Maintenance Management*.[4] SOR decisions fall under a very broad umbrella called the Acquisition Strategy Panel, which is usually chaired by a program executive office and briefed by the DSM very early in the programs life-cycle. SORAP is used to determine the best-value source of depot-level repair to support life-cycle readiness. Further, the SORAP must be completed and approved for all depot-level maintenance workloads generated by new acquisitions and modifications. The process is flawed because it is implemented with loopholes and final decisions based on near-term benefits and politically motivated rationales.

The definition of the phrase *best value* is an ambiguous loophole that lends itself to being misapplied for near-term gain and pressures to field a system or modification without delay, despite known logistics concerns. Prior to IWSM, there were two four-star commands, Air Force Systems Command and Air Force Logistics Command, that were strong advocates for acquisition and sustainment during the acquisition cycle. True, they were operating under very different fiscal constraints, but they were always equal advocates. Today, proper advocacy should come from within the IWSM framework. The integrated product team (IPT) concept is designed to alleviate gross oversight of life-cycle cost considerations. While advocacy will not always solve problems, a clear imbalance removes a safety net and has become the overarching flaw in this process. If the IPT fails, balanced risk management does not exist for the long term. Unfortunately, advocacy is not the only problem with the SORAP.

Premature SOR determinations are the second misapplication of SORAP methodology and occur when SOR determinations (either contractor or organic) are made too early in the acquisition cycle. The reason for this is, again, shortsightedness. The SORAP manual states, "It is essential that actions required to obtain a SOR decision be taken as early as possible to avoid the expense and program turbulence associated with protecting both options until a decision is made."[5] It also states, "life-cycle support decisions are made early in the design . . . rather than waiting until after the design is completed." I agree that waiting until the design is completed is overly cautious, but protecting both options until the design stabilizes is prudent. The manual goes on to state, "The single manager should initiate actions as soon as reasonable . . . but not later than the decision to proceed into engineering and manufacturing development." The design is only conceptual at this point for many of the subsystems of the end item. Detailed support planning, by all accounts, consists of bare estimates at this early stage, guesswork in many cases. If we plan to have no organic repair for an item and the design is substantially altered and/or logistics analyses prove inaccurate, the unprotected option becomes far more expensive than it would have been if we had paid the *liability insurance* to protect against this possibility.

The third miss in the SORAP process revolves around defining who bears the fiscal load. Single managers see investing in a new repair technology at an air logistics center as a burden to their program. Hypothetically, if the engine selected for the F-22 were similar to that of the joint strike fighter and others, the F-22 program might have to bear the fiscal load of the initial investment to establish the repair capability at the depot. The investment required might be large compared to other program costs (special tools, training, depot-level technical orders, facilities, and so forth.). The good news is that repair costs are controllable and not subject to the whims of market forces. The problem for the single manager is this is a *must pay bill* now. The single manager may not have sufficient insight into the design to properly budget for such a large bill in a particular year. This lapse creates a supportability issue for the program.

Then the contractor estimate arrives, and it is much lower because it can do the repairs for a slightly higher cost than the government but without any up-front investment because it already owns the capital equipment, facilities, and skilled labor (all used in production and testing). The likely result is no investment is made for organic repair. The effort goes sole-source to the original developer, and the life-cycle risk jumped another notch. This is especially, even catastrophically, true if that contractor's business base contracts as it responds to the market's supply and demand.

The investment decision would have provided the opportunity to reduce life-cycle costs for multiple weapon systems. This is the *greater-good* concept that the SORAP ignores. It is the best-value loophole in action. The decision appeared to be the best value, but it was measured only in that year, and we again declared victory before results. The lost savings in outyears would have provided needed funds for future modernization efforts. At the same time, it would keep the work force at the air logistics centers current on new technology. Instead, the decision relegates the blue-collar work force at the depots to antique fixer and dealer status (nothing new to repair, just the old stuff). As an aside, ask yourself, what youth today would want a job fixing half-century old parts at a government depot when they could work for a defense contractor making higher pay repairing new technology? The implications are astounding.

Until there is a fundamental change in policy, there is no chance this trend will reverse naturally. According to DoDD 5000.2-R, *Mandatory Procedures for Major Acquisition Programs and Major Automated Information Acquisition Programs*,[6] cost must be viewed as an independent variable. Accordingly, single managers are required to establish aggressive but realistic objectives for all programs and follow through by trading performance, supportability, cost, and schedule, beginning early in the program. This is not happening because withholding program funds for unknown support investments is nearly taboo, especially when that investment will not realize a positive return on the investment for many years. The fact remains: organic supportability requires investment in infrastructure, equipment, and training, but it usually goes unplanned and unbudgeted.

The fourth flaw in the process focuses on logistics support analyses (LSA). These analyses—including mean time between failure, failure mode effects and criticality, repair level, and other maintenance-related analyses—are completed by prime contractors. Two problems arise. First, the decisions of the SORAP are often complete before these LSAs are mature; therefore, decisions about repair requirements and their associated costs are basically guesses. Two, the entity that stands to gain the most if repairs are contracted out is the prime contractor. The cost comparison model of the SORAP considers numbers of repairs, difficulty of repairs, cost of repairs, and so on as part of the best-value calculation. All these are outputs from the LSA process. Carefully crafted analyses by profit-minded contractors, in a shrinking business base, desperate for more business will almost certainly drive SOR determinations (especially for new technology) back into their own hands.

Outsourcing Reality

Acquisition and logistics reforms and the movement toward outsourcing are reality. They are unproven in the long term, but a reality, nonetheless. According to Secretary of Defense Cohen, "We see its [outsourcing and competition] fruits every day in the better service it gives our troops and the better balance it gives our ledgers. It empowers workers, both public and private, challenging them to provide higher quality and lower cost."

I agree we can see short-term *fruits* every day. Will we see them in 20 or 30 years is the question. What is not said about the short term is equally alarming. Overhead rates for outsourced work are skyrocketing, especially for sole-source vendors. This unplanned backlash is not easily disentangled or publicly touted.

Final Thoughts

Commercial entities are loyal primarily to stockholders and profit-minded executives, not taxpayers. Therefore, when a business segment is 10, 20, or 30 years old or becomes inefficient, it is divested. What remains? Diminishing sources of repair, poor supply response, and parts shortages. Every day there are businesses going out of the business and the victims of outsourcing (warriors) frantically returning to the organic depot repair facility for emergency situations—a day late and a dollar short.

Historically, senior leaders and strategic planners mistrusted ideas that were radical, rapid, and revolutionary. They preferred calculated, complete, and correct. The SORAP and outsourcing, in general, stand as examples of getting the order wrong. The, "Fire! Ready! Aim!" syndrome has arrived. Ultimately, it is a question of who pays the highest price? Is it the warfighters in the battlespace, American who pays taxes, or a country that loses an irreplaceable treasure—a son, a daughter, or perhaps worse yet, *freedom*?

Notes

1. Joint Publication 4-0, *Doctrine for Logistic Support of Joint Operations*, 6 Apr 00.
2. Secretary of Defense William S. Cohen, Defense Reform Initiative Report, Nov 97.
3. DoDD 4151.18, *Maintenance of Military Materiel*, 12 Aug 92.
4. AFI 21-102, *Depot Maintenance Management*, 19 Jul 94.
5. SORAP Guide, *AFI 63-107, Integrated Weapon system Management Program Planning and Assessment*, 3 May 00.
6. DoDD 5000.2-R, *Mandatory Procedures for Major Acquisition* Programs and Major Automated Information System Acquisition Programs, 23 Mar 68.

The Savage War of Peace—An Uncertain Future We Can't Ignore

Lieutenant Colonel Douglas E. Anderson, USAF
Commander, 56th Medical Support Squadron

Peacekeeping is not a job for soldiers, but only a soldier can do it.

—Charles Moskos, Military Sociologist

As military professionals, we must prepare now for an uncertain future. Since the end of the Cold War, the United States has been called upon to participate in peace support. Major conflict with the Soviet Union is less relevant today, yet new concepts to respond to these emerging real-world situations and other threats have been slow to emerge. Unfortunately, other forms of conflict such as terrorism and information warfare continue to emerge also, in some cases, in our own homeland. In fact, many admit our national security establishment remains in a continuous transition phase. This phase is between the clear goals of a Cold War and an uncertain future characterized by these multiple operations. Imagine the following scenarios.

> Several countries hover in a twilight zone between conflict and peace. Until the fall of the Wall or severed relations, animosities lay dormant, controlled or repressed by the presence of the great Cold War superpowers or regional neighbors. Once the dominance was released, grievances ensued, many of which had been festering for years, and were unleashed on the landscape causing incalculable misery. Unfortunately, civil strife, starvation, atrocities, and other forms of violence erupted, generating concern from post-Cold War global partners for peace. Action was taken, yet doctrine, objectives, coordination, weapon technologies, mental preparation, and training were either underdeveloped or mismatched to mitigate the conflict. In the end, more criticism on the use of available capabilities, bloodshed, or collateral damage continues.

> Predictions about peacetime activities for post-Desert Storm fell short. Saddam Hussein escaped coups and dodged economic isolation. He backs extremist terrorist groups and continues to defy United Nations mandates on biochemical weapon production. As a result, terrorism and the use of biologicals has reared its ugly head with attacks on several US federal buildings, population centers, and embassies abroad similar to those in the movie *Siege* or the subway station in Japan. Yet, national and international law and polices remain at odds between key organizations, and new concepts of military operations on urban terrain are replete with far too many lessons learned.

> Consider the often ignored but emerging information warfare scenario. The stock market is driven into a freefall of Asian technology investments. Nobody knows why, but they were automatically closed when the Dow plunged. Something worse occurred but was unrecognized. Wall Street's computer crashed. Nevertheless, due to a lag between input and output transactions, the crash went unnoticed and trading continued. The transactions failed to be recorded, and the next day, the financial world was in chaos. Several institutions reported millions in diverted funds. Nine months later an official Korea-China joint government Internet site announces increased investment in nuclear missile testing and weapons technology development activities.

The above scenarios are fictitious; however, they are not far from real-world situations, past operations, or emerging threats. Many foreign and defense policy analysts cite the shortcomings of previous real-world operations and respective outcomes. They call for reform to the *savage war of peace*.

As military professionals and experts in our respective specialties, we have a duty to envision these future savage-wars-of-peace scenarios and plan accordingly. We must answer questions now to prepare for this uncertain future. Take the military healthcare professionals as an example. They should be asking (and acting). Are we prepared with the right doctrine and force protection measures to respond to these scenarios?

- What types of assemblages, equipment, and systems are required to optimize our human weapon system?
- As the use of nonlethal weapons emerges, what type and how many casualties do we expect?
- Should we reshape our system capabilities to respond to a *prevent-if-we-can, cure-if-we-must* mission?
- How will we help others cope with the personal traumas of collateral damage, guilt, and anguish associated with mistakes?
- How will leadership motivate troops to deal with a *fly-fight-win* versus *police-wait-see* mentality?
- What new learning and training technologies can be applied to accelerate preparation for these operations?
- Do we need to collaborate with other local, civil, or federal agencies to ensure success of future operations?
- Could we apply the principles of psychological operations to create an environment or attitude of self-care?
- How do we monitor and protect our communication-information systems from intrusions and disruption?

Although I have used the *military healthcare professional* as an example to suggest a response to this uncertain future or savage war of peace, I would challenge all military professionals to project, ponder, and integrate their collective experiences and thoughts in the above scenarios. It does not matter whether we fly jets, develop purchasing agreements with local populaces, guard airfield and housing perimeters, make policies, or design new weapon systems, our thoughts do count in this uncertain future. It is a team effort, and our military professional expertise with weapon systems capability, infrastructure, economics, environmental, and psychological issues are tied directly to national security.

These scenarios—whether peace support or other forms of conflict such as terrorism and information warfare—will continue to emerge. Like it or not, we must develop, adapt, redesign, and integrate our respective capabilities in order to respond. Again, as military professionals, we must prepare now for an uncertain future. We cannot ignore the savage war of peace and must develop capabilities and methods for responding now. Doing so will strengthen national security, shape the attainment of stated objectives, and above all, preserve precious human life and the freedoms we all cherish.

Current Logistics Research

Air Force Logistics Management Agency

Contracting

Business Solution Exchange (BSX) LC199907100—Improvement Project

1. Develops and implements a knowledge management tool (unites policy, process, and people to provide better business solutions).
2. Provides a web-based interactive system linking cross-functional teams.
3. Develops a virtual workspace that captures process and products.
4. Operates on commercial off-the-shelf software. Requires a personal computer, web browser, and access to the Internet.

Lt Col Lucy K. Yarbrough, DSN 596-4085

Competitive Sourcing and Privatization Guide LC200002800—Improvement Study

1. Updates AFLMA project LC9608100, *Outsourcing Guide for Contracting.*
2. Provides key competitive sourcing and privatization information.
3. Provides lessons learned and keys to success.

MSgt Jeffery B. Feeney, DSN 596-4085

Award Fee Guide LC200000407—Improvement Study

1. Participates in an Air Force award-fee, integrated process team to develop an *Air Force Award Fee Guide*.
2. Provides process and samples on how to conduct an award fee.
3. Introduces the award-term concept to operational contracting and provides the process and samples on how to conduct an award-term evaluation.

Lt Col Lucy K. Yarbrough, DSN 596-4085

Maintenance

Follow-On Technical Support for the Weapons Load Crew Management Program LM199812000—Consulting Study

1. Ensures the Weapons Load Crew Management Program is exploited to its fullest extent.
2. Ensures all users are knowledgeable about the program's functionalities.

SMSgt Cedric McMillon, DSN 596-4581

Aerospace Expeditionary Force Logistics (AEF) Concept of Operations (CONOPS) LM199733000—Consulting Study

1. Assists RAND in developing innovative concepts and investigating alternative ways of supporting AEF operational objectives.
2. Formulates specific data collection efforts needed to support AEF CONOPS options.

CMSgt John G. Drew, DSN 596-4581

Support Web Site for Munitions CD-ROM LM199924500—Consulting Study

Supports an Air Force Space Command tasking to install and maintain the *Senior Air Force Leaders Munitions CD-ROM* as an official-use-only Internet site.

SMSgt Cedric McMillon, DSN 596-4581

Expanded Telemaintenance Technology Survey LM200026401—Improvement Study

1. Identifies current and future telemaintenance technology capabilities and specific applications to Air Force aircraft maintenance.
2. Provides report identifying:

- Project title
- Organization and contact information
- Description of capability/effort
- Detailed information on hardware/software

SMSgt Eric J. Mazlik, DSN 596-4581

Revised Mission Capability Rates LM199906900—Improvement Study

1. Quantifies potential effect on mission capability (MC) rates should the *2-hour rule*, as stated in AFI 21-103, be deleted.
2. Quantifies potential effect on MC rates should the Air Force include *depot-possessed* time in MC.

MSgt Maura A. Barton, DSN 596-4581

Logistics Manpower Study LM200028400—Consulting Study

1. Assists RAND in its ongoing study Have We Programmed Sufficient Maintenance Manpower?
2. Looks at capabilities and limitations of the Logistics Composite Model as well as other factors related to manpower requirements.

Maj Cauley von Hoffman, DSN 596-4581

Analysis

Logistics Initiatives Database 20002100—Improvement Study

Creates or identifies a web-based database to track logistics initiatives and studies.

Capt Jeanette Reichard, DSN 596-3127

Supply

Air Force Requirements Team Consulting Efforts LS199932801—Requirements Team Consulting Study

1. Measures the requirements system performance.
2. Makes recommendations to improve policy and performance.
3. Monitors and operates readiness-based leveling.

SMSgt Michael S. Horne, DSN 596-4165

Readiness-Based Leveling (RBL) Quarterly Push Results LS200006200—Requirements Team Consulting Study

1. Extracts RBL data from the World Wide Web (WWW), uses it to generate reports, and posts the reports to the web.
2. Accesses the data, generates reports, and posts the reports on the WWW no later than 72 hours after each quarterly RBL push.

Capt David A. Spencer, DSN 596-4165

Execution and Prioritization of Repair Support System (EXPRESS) and Primary Aircraft Authorization (PAA) Study LS199801500—Improvement Study

1. Evaluates how program logic in EXPRESS treats bases with dissimilar PAAs (small versus large).
2. Compares EXPRESS prioritization sort value results for unique versus common assets.
3. Identifies depot repair policies and execution procedures, including funding aspects, that impact special operations forces (SOF) repair prioritization/distribution.
4. Compares actual asset distributions to SOF and common C-130 units since EXPRESS was implemented.

Capt Jennifer A. Manship, DSN 596-4165

National Stock Number Issue and Stockage Effectiveness (Phase Three) LS200004100—Consulting Study

Continues efforts to provide Air Force Materiel Command with issue and stockage effectiveness at the stock number level by accepting responsibility for collecting and posting the data to an AFLMA-maintained web site.

SMSgt William T. Gilreath, 596-4165

Consumable Asset Stockage Policy in a Seamless System LS199822905—Improvement Study

1. Determines and defines what the retail stockage policy for consumable items should be in the future; recommends stockage policies for both base retail and customer levels that continue to satisfy customer mission requirements but do not significantly increase current inventory investment levels.
2. Determines if the Defense Logistics Agency's Industrial Prime Vendor initiative is cost effective and a viable solution for consumable item management.

CMSgt Robert K. Ohnemus, DSN 596-4165

Measuring the Health of Supply LS199929101—Improvement Study

1. Develops health-of-supply metrics with focus on current measures that need increased visibility or new uses, data integrity and consistency, budget links, and so forth.
2. Determines what data/processes are needed to monitor/measure support.
3. Determines the office of primary responsibility for each possible metric and identifies metric shortfalls.

Capt Wesley E. Manship, DSN 596-4165

Wholesale Repair Cycle Process Metrics LS200000409—Improvement Study

1. Identifies metrics useful to major commands and air logistics centers in identifying where and why certain support problems occur in the repair process.
2. Determines what data/processes are needed to generate these metrics and how they should be provided to users.

Maj William S. Long, DSN 596-4165

NEXRAD System Reliability, Maintainability, and Supply Supportability LS199930900—Improvement Study

1. Evaluates and measures support problems experienced by the 26 Air Force-maintained NEXRAD weather radar locations.
2. Baseline support and pipeline parameters against those of the National Weather Service-maintained NEXRAD radar locations and identifies ways to improve Air Force support.

Ms Martha A. Schiller, DSN 596-4165

Analysis of F-15 Wartime Supply Support LS200004201—Improvement Study

Determines the necessary changes to F-15 kits to align with I-level repair. F-15 kits currently assume deployed I-level maintenance capability, but USAFE is now using regional repair concept. The result is inadequate kits with too few line replaceable units forward and shop replaceable units at the centralized intermediate repair facility. Air Combat Command is also interested in leaving I-level maintenance at home when deployed.

Capt Andrew W. Hunt, DSN 596-4165

Scully System Consulting
LS200022300—Consulting Study

Documents the status of Scully or equivalent systems at each active, Reserve, or Guard base:

- How many mobile refuelers are/are not equipped?
- How many fillstands are/are not equipped?
- How many bases are completely set up?
- Is there an ongoing program at any of the major commands to convert refuelers and/or fillstands?
- Actions to be taken to retrofit refuelers and facilities.
- Funding possibilities and total cost.

MSgt Robert A. McGonagle, DSN 596-4165

Analysis of Air Force Retail Retention Policy for Budget Code 9 (XB3/XF3) Items
LS200020201—Improvement Study

1. Determines if extending current retail retention periods for BC 9 consumable items would reduce cause code A and B due-outs, prevent mission capability occurrences, and/or prevent premature disposal of assets.
2. Determines common characteristics of consumable items for which longer retention periods would be most beneficial and the optimum period these items should be retained.
3. Identifies negative impacts concerning support received from the Defense Logistics Agency (DLA) as a result of extended retention periods.
4. Explores how the Air Force can improve its interface with DLA to ensure both retail and wholesale stocks are effectively and efficiently retained.

SMSgt Woodrow Parrish, DSN 596-4165

Repair Prioritization for Communications and Electronic Items
LS200012400—Improvement Study

1. Determines how Execution and Prioritization of Repair Support (EXPRESS) logic currently treats communications and electronics items. Are they already included, and if so, where do they fall out in the priority mix?
2. Evaluates characteristics of the items that impact the use of EXPRESS—low demand rates, single point failure (SPF) versus non-SPF assignment, repair shop mix of assets, geographic location versus supply accountability record, and so on.
3. Determines the process for using EXPRESS results.
4. Addresses financial issues involved with the process.

Maj William S. Long, DSN 596-4165

Fighter and Attack Aircraft Kit Performance during Operation NOBLE ANVIL
LS200008201—Improvement Study

Evaluates the effectiveness of methodologies used to determine the composition of Mobility Readiness Spares Packages and Contingency High-Priority Mission Support Kits for F-15, F-16, and A-10 weapon systems.

SMSgt Bernard N. Smith, DSN 596-4165

Analysis of Nonoptimized (NOP) Items in Support of Wartime Demands
LS200004200—Improvement Study

Validates NOP formulas and policy.

SMSgt Bernard N. Smith, DSN 596-4165

C-5 Tiger Team Support (Depot-Level)
LS200026400—Consulting Study

Provides analytical assistance and advice to C-5 tiger team as needed.

Capt Wesley E. Manship, 596-4165

Air Force Seamless Supply Integrated Process Team (IPT) Consulting
LS199926300—Consulting Study

Provides analytical assistance and advice to Seamless Supply IPT (now part of Air Force Stockage Policy Work Group) as needed.

CMSgt Robert K. Ohnemus, DSN 596-4165

The History of Supply
LS199929100—Improvement Study

Provides supply/fuels personnel with a motivational, historical perspective detailing the accomplishments of Air Force supply. Assembles a compilation of separate articles, each about a specific area of supply. Topics may include:

- US Army Air Force Quartermaster School
- The transformation of the Air Force Logistics Command to the Air Force Materiel Command
- Supply personnel achievements (medal winners and so forth)
- Major organizational changes from 1947 to 1989
- Evolution of fuels technology
- Air Force supply regionalization
- Contractor logistics support
- Two-level maintenance/Agile Logistics
- Future of space logistics
- Fuels privatization/supply-transportation merger
- Aerospace Expeditionary Force supply
- Supply's own virtual organizations
- Supply system advances (1050-SBSS-GCSS/ILS-S)

Capt Andrew W. Hunt, DSN 596-4165

Analysis of Low-Demand Items for Mature Weapon Systems
LS200009600—Improvement Study

1. Determines if items (both reparable and consumable) experience demand patterns that the Air Force forecasting system does not predict well.
2. Focuses on both reparable Materiel Stockage Division and consumable Defense Logistics Agency items.
3. Develops methods to identify these types of items.
4. Analyzes and recommends alternative forecasting methods.
5. Analyzes and recommends alternative retention and stockage policies.

Capt Wesley E. Manship, DSN 596-4165

Procedures for Turn-in of International Merchants Purchase Authorization Card Purchased Items
LS200024900—Improvement Study

1. Quantifies the base supply manpower workload for disposing of items purchased via the Government-wide Purchase Card (formerly the International Merchants Purchase Authorization Card).
2. Develops a standard set of supply procedures for disposing of items purchased via the Government-wide Purchase Card.

SMSgt Robert A. Nicholson, DSN 596-4165

Recording Demand Data for Air Force Materiel Command XD Items
LS200025300—Improvement Study

1. Determines when and how demand data should be recorded for XD/XF items in the retail and wholesale systems.

2. Determines the impact on readiness and customer support should the Air Force change the existing policy.

SMSgt Robert A. Nicholson, DSN 596-4165

Independent Assessment of the Supply Asset Tracking System
LS200015200—Improvement Study

Evaluates technological, budgeting, and fielding concerns during base manpower evaluations.

Maj William S. Long, DSN 596-4165

Transportation

Materials Handling Equipment (MHE) Capabilities Study
LT199913701—Improvement Study

1. Determines capabilities for various types of MHE for Air Mobility Command deliberate planning purposes.

2. Determines efficiency ratio for forklift to aircraft loaders for overall aerial port operations.

3. Determines the types of cargo (bulk, oversize, and outsize) that are moved in typical deployment operations.

Capt Todd A. Dyer, DSN 596-4464

Leasing Options for Wide-Body Passenger Aircraft
LT20005300—Improvement Study

Assesses the feasibility and efficiencies of implementing full-service lease options of wide-body passenger aircraft through the use of a cost-benefit analysis.

Capt Todd A. Dyer, DSN 596-4464

Commercial Bill of Lading (CBL) Processing and Payments to Carriers
LT200008200—Consulting Study

1. Identifies and determines root causes of missing CBL data reported by motor carriers participating in U.S. Bank's PowerTrack transportation payment system

2. Examines the current process, system operations flow, and integration.

Capt John W. Winkler, DSN 596-4464

Combat Readiness CD-ROM
LT199914700—Improvement Study

1. Produces a reference kit for managers involved in the deployment, sustainment, and redeployment of forces.

2. Includes critical issues such as cargo preparation, hazardous cargo, cargo movement, and various other issues.

3. Final product will be searchable, interactive, and web-enabled.

Capt John W. Winkler, DSN 596-4464

Logistics Plans

Global Engagement V
LX199932800—Consulting Study

Incorporates logistics concepts into the Global Engagement V wargame to aid in the identification of disconnects between expeditionary airpower capabilities and *Joint Vision 2010* operational concepts.

Maj John A. Bolin, DSN 596-3535

Focused Logistics Wargame
LX199902002—Consulting Study

Assesses joint logistics capabilities and the Services' abilities to support *Joint Vision 2010* tenets.

Maj John A. Bolin, DSN 596-3535

Futures Wargame
LX200027100—Consulting Study

Incorporates logistics concepts into the Futures X wargame to aid in the identification of disconnects between future expeditionary airpower capabilities and *Joint Vision 2020* operational concepts.

Maj John A. Bolin, DSN 596-3535

Afloat Prepositioning Concepts for Nonmunitions War Reserve Materiel
LX200001300—Improvement Study

1. Presents several afloat prepositioning options to complement current Air Force war reserve materiel prepositioning strategies.

2. Develops options to enhance the capability to respond across the entire spectrum of conflict. Develops alternatives that consider the number, positioning, and inventory of ships.

Capt Paul E. Boley II, DSN 596-3535

Air Force War Reserve Materiel Integrated Process Team
LX200027200—Consulting Study

Participates in the initial planning for the new Air Force war reserve materiel (WRM) integrated process team (IPT). Previous experience with the AFLMA WRM tiger team and the current bare base IPT will provide the foundation for creation of the Air Force WRM IPT.

Capt Paul E. Boley II, DSN 596-3535

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(Logistics and the Battle of Britain continued from page 3)

Field Maintenance on a Hurricane—Summer 1940

Such public pronouncements were matched by the Air Staff's own calculations in Memorandum No 50 (Secret Document 78), first issued in 1933, which provided data for the calculation of consumption and wastage in war.[6] The monthly wastage rate for single-seat fighters engaged in Home Defence was assessed to be 100 percent and that for single-seat pilots 30 percent. Thus, it was anticipated that a fighter force of 50 squadrons engaged in active operations would suffer wastage of 1,000 aircraft a month. Assuming the depots could repair 50 percent of these machines, industry would need to produce 500 new aircraft a month just to maintain front-line strength.[7] In order to cope with peaks in attrition and the inevitable delay in mobilizing industrial production, reserves equal to at least 6 weeks' wastage would also be required (some 1,500 aircraft). Finally, approximately 300 new fighter pilots would be needed each month, although it was recognised that dilution would be a major factor in determining whether operational effectiveness could be sustained.[8] Interestingly, given that prewar RAF planners were only interested in strategic bombing, it was further stated, "Home Defence was the most important commitment that the Service had to prepare for."[9]

These calculations would not prove to be grossly unrealistic (Figure 1).[10] More important, in recognising the attritional nature of any future war, the Air Staff had laid the foundations of an expansion plan, both in terms of availability and sustainability, that would provide the Royal Air Force with the resources to defeat the Luftwaffe. This is not to say that the Luftwaffe had

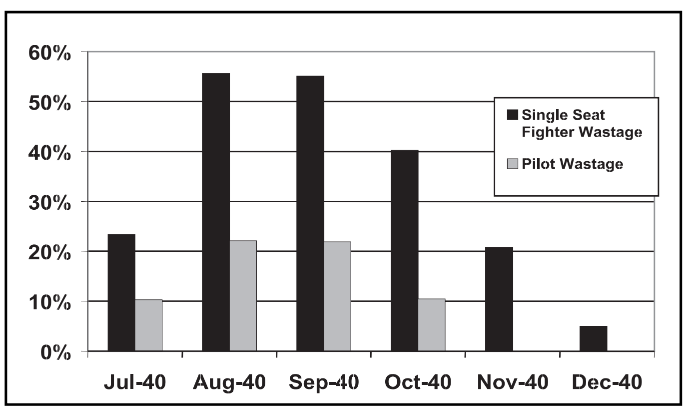

Figure 1. Fighter Command Monthly Wastage

failed to recognise the importance of wastage. Plans prepared in 1938 envisaged a monthly bomber and fighter attrition of 50 percent, but the necessary resources and organisational arrangements to make good such losses were not put in place prior to the outbreak of war.[11] Richard Overy commented that prewar air theory largely avoided the difficult question of the appropriate level of supply to sustain airpower. "This was not a question of sheer numbers alone, but also of aircraft quality, and of repair and maintenance as well."[12] It would be difficult to accuse the RAF staffs of this failing, whatever their faults in other areas of prewar planning.

Rearmament

Between 1934 and 1938, there were eight separate expansion schemes designed to close the air gap with Germany. They were, as John Terraine has observed, "All, in the strictest sense, failures," nevertheless adding that they "did provide Britain with an air force which was fit (just) to go to war in 1939 and fit (by a narrow margin) to win a decisive victory in 1940."[13] Understandably, for the purposes of deterrence, there was a strong element of show compared to substance in all of these schemes. However, they did ultimately provide for a considerably expanded and modern front line with significant reserves and the necessary industrial capacity, including shadow factories, to sustain operations. For Fighter Command, the intention had been to provide 50 squadrons of Hurricanes and Spitfires by March 1942 (the number deemed necessary to defend against a possible attack by 2,000 German bombers). This would be achieved (just) by July 1940.

Unfortunately, none of the expansion schemes addressed the question of repair and overhaul. In fact, the air staffs were divided on a large-scale buildup of a repair-and-maintenance organization in preparation for war. There was little prospect of any significant investment while Sir Edward Ellington remained Chief of the Air Staff (CAS). He had famously expressed his own views with the statement, "There will be no repair in war."[14] When Sir Cyril Newall replaced him in September 1937, the Air Member for Supply and Organisation, Air Vice Marshal Welsh, was moved to comment, "We had been building up a front-line air force, which was nothing but a facade. We had nothing by way of reserves or organisation behind the front line with which to maintain it."[15] To meet these needs, it was agreed to construct three large Service depots (Sealand, St Athan, and Henlow) and three civilian-manned depots under Service control (Stoke, Abbotsinch, and Burtonwood). The former would undertake 25 percent of the repairs, the civilian-manned depots the remainder. This presaged a huge expansion in the repair, supply, and storage organisation. While they would ultimately comprise a network of more than 300 maintenance units at home and overseas, the outbreak of war arrived before any of the large general repair depots could be completed.

Production

The expansion of the British aircraft industry in support of rearmament was an immense achievement in which there were huge obstacles. Perhaps the most significant development in prewar planning was the introduction of the War Potential programme in 1938 that sought to give Britain the capability to produce 2,000 aircraft a month by the end of 1941. As Sebastian Ritchie pointed out, this provided the basis for planning aircraft production in much greater depth and for developing a comprehensive state production organisation.[16] Although an output of 2,000 aircraft a month would not be achieved until the end of 1942, actual production soon exceeded planned targets (Table 1). By comparison, German aircraft production languished in the early part of the war. Thus, while Britain produced 4,283 Hurricanes and Spitfires in 1940 against a planned total of 3,602, Germany produced 1,870 Bf 109s against a planned total of 2,412.[17] Incredibly, Germany did not mobilize its aircraft industry at the outbreak of war and did not seek to expand the Luftwaffe's repair capability. In September 1940, when attrition was at its highest, Britain produced 467 Hurricanes and Spitfires while Germany only produced 218 Bf 109s.[18] The relative performance of the British and German aircraft industries was critical to both the size and sustainability of the front line.

	Germany	Great Britain
1939	1,541	1,324
1940	1,870	4,283
1941	2,852	7,064
1942	4,542	9,849
1943	9,626	10,727

Table 1. Single-Seat Fighter Production[19]

The Battle of France

Just how high actual operational wastage would prove was demonstrated in the Battle of France. Of the 452 Hurricanes sent to France (equivalent to some 2 month's production), only 66 returned (Figure 2). No fewer than 178 of those lost had been abandoned or destroyed through lack of repairs.[20] Only a relatively small number were lost in air combat.

These losses were ill-afforded. They were also, to some extent, avoidable. The arrangements for the maintenance of the RAF units deployed in France were unsatisfactory in many respects. In 1934, Sir Edward Ellington had decided to make deployed squadrons self-sufficient in the event of war rather than establish a supporting organisation of mobile airparks and depots (based on First World War experience) as had been originally proposed. The course of the war would demonstrate the soundness of the latter scheme. Indeed, it would form the basis of the highly

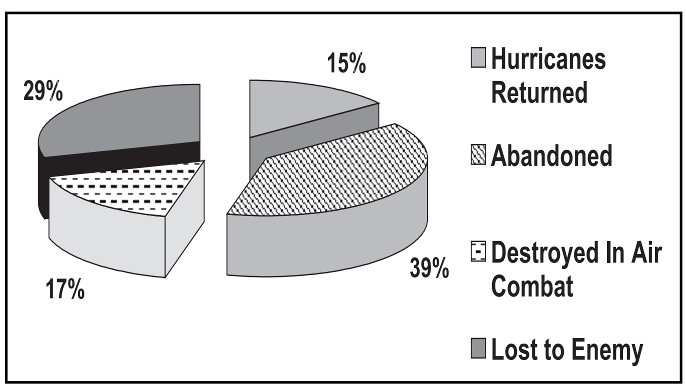

Figure 2. Hurricane Wastage During the Battle of France

effective support arrangements for the tactical air forces.[21] In the meantime, those squadrons deployed to France found themselves desperately short of reserves, vehicles, spares, and repair-and-salvage capabilities. Wastage rates were also higher than they had prepared for. As a result, in-theatre repair amounted initially to a mere two Hurricanes a week and had risen to only eight a week by June (and this after considerable effort). Almost no engine repairs had been completed, owing to a shortage of tools.[22]

Such experiences were not unique to the Royal Air Force. Anecdotal evidence indicates the Luftwaffe suffered no less seriously from high operational attrition. Feldwebel Eric Bartel, who served as a Jagdgeschwader mechanic for much of the war, recalled that after just 17 days' action his staffel of 12 Bf 109Es from JG 77 had been reduced to just 5 or 6, including spares, mainly through mechanical failures and normal wear and tear, rather than enemy action.[23]

The Royal Air Force Maintenance Organisation

With the expansion of the Royal Air Force from 1936 onward came the need to change the policy on aircraft servicing. Prior to this period, each flight within a squadron was a self-contained unit for repair and maintenance, up to write-offs. This was altered to a three-flight arrangement under which two flights undertook day-to-day maintenance and the third flight all major inspections and repair. This system remained in force during the first year of the war, but experience in the Battle of Britain exposed significant weaknesses. As the operational tempo increased, squadrons were moved at more frequent intervals. The result was that squadrons became increasingly detached from their support staff. In some cases, they found themselves distributed across three stations. In December 1940, it was decided to transfer the bulk of the squadrons' servicing personnel to station maintenance units, significantly increasing the mobility of the Fighter Command squadrons.[24] These arrangements, with some refinements, remained in place until the end of the war.

Repair was a more difficult issue. It became rapidly apparent, even before the outbreak of war, that the Royal Air Force did not have the capacity to meet anticipated requirements. As a result, in October 1939, it was agreed that a civilian repair organisation (CRO), based around the *fringe firms*,[25] would be set up under Lord Nuffield, who would also control the Service repair organisation, including the Service-manned depots. At the time, this was a difficult decision taken in the face of some understandable hostility. The CRO came into being in January 1940, and by the end of the year, it had repaired 4,955 airframes, about 33 percent of the total airframe output going to the Metropolitan Air Force. By 1941, the total was a little more than 50 percent.[26] Similar arrangements, organised around the original equipment manufacturer, were put in place for engine and propeller repair.

Prior to the expansion scheme, such reserves as existed were stored on the stations where they were to be used. The significant increase in the size of the reserve demanded dedicated storage facilities. Plans were to establish 24 aircraft storage units (ASU), equipped to store 400 aircraft each and located at existing airfields (but as far away from continental Europe as practicable). At the outbreak of war, the Royal Air Force had some 2,200 aircraft in storage at 12 ASUs. Early in 1940, it was decided the large hangars storing considerable numbers of aircraft presented too high a risk, and accordingly, aircraft were dispersed to reduce the maximum holdings in each ASU from 400 to 200 aircraft.[27] ASUs not only provided a strategic reserve of aircraft but also formed an important buffer between the factory and the front line to cope with inevitable surges in wastage and complete modification and installation work prior to final delivery. For example, in August 1940, No 19 Maintenance Unit at St Athan issued 58 Hurricanes and received 55, leaving 23 in stock, out of a total of 237 stored aircraft of 19 different types. By the last quarter of 1939, ASU holdings had risen to 3,600 aircraft and had grown to more than 5,000 by the end of 1940.

The Luftwaffe Repair Organisation

Much of June and July 1940 was used by the Luftwaffe to make good the significant losses it had suffered[28] and, in particular, to put in place the logistics arrangements needed to support operations from their new airfields across northern France. The repair organisation was less easy to improvise. Day-to-day maintenance was the responsibility of mechanics attached to each staffel.[29] In the field, major repairs and overhauls (such as routine replacement of the Bf 109 Daimler-Benz 601 engine after just 100 hours flying time) fell to the workshop section attached to the group headquarters company. Work expected to take longer than 2 days was transferred, where possible, to regional workshops based at major airfields, which were established to undertake major repairs or modifications. At this stage of the war, however, these workshops were all located in Germany. Thus, many damaged aircraft had to be transported considerable distances by road and rail just to be repaired. There was no equivalent of the CRO, although there had been a violent debate early in 1938 between Udet (head of supply and research) and Milch (Goering's deputy and state secretary for the air force) about the provision of more extensive repair capabilities to support the Luftwaffe. The latter's view—that campaigns would be short and aircraft could be repaired and salvaged at home after victory was achieved—prevailed against Udet's proposals for significant investment in spares, tools, and repair facilities.[30] It is tempting to compare this outcome with the decision reached by RAF staffs on the very same issue at much the same time.

In quality and general professionalism, it would be hard to fault the Luftwaffe maintenance organisation. It was certainly a match for the Royal Air Force. However, it was not organised for an attritional war and had made little provision for timely repair and salvage. It is also arguable that it was less flexible and had far more difficulty responding to changing circumstances. For example, as the war progressed, it became increasingly evident that maintenance personnel were finding it difficult to keep up with their parent units, much as Fighter Command would discover in 1940. Nevertheless, it would not be until late 1944 that the Luftwaffe introduced independent maintenance companies subordinate to the airfield rather than a particular flying formation to resolve this particular problem.[31]

The Battle

Over the course of June and July 1940, it became obvious that Britain was not about to sue for peace. The Germans recognised that the destruction of the Royal Air Force had now become essential to the achievement of their strategic aims. On 1 August 1940, Hitler issued his Fundamental Directive No 17 for the "Conduct of the Air and Sea War against England." The Luftwaffe was to use all means to overpower the Royal Air Force in the shortest time possible. Attacks were to be directed primarily at flying units, their ground installations, and their supply organisation as well as the aircraft industry in order to "establish the necessary conditions for the final conquest of England."[32] To achieve this aim, the Luftwaffe could muster 3,358 aircraft (Table 2).

Other sources give slightly different figures, but most agree that the Luftwaffe deployed an effective strength of slightly more than 900 Bf 109 fighters out of some 1,000 aircraft. This comprised the bulk of their single-seat fighter force. Approximately 150 aircraft remained in other theatres, including Germany, to defend against possible Bomber Command attacks.[34] By comparison, Fighter Command could field 52 squadrons of Hurricanes and Spitfires, nearly 1,100 aircraft (Table 3). Thus, in terms of single-seat fighters, the opposing air forces were fairly evenly matched, albeit Fighter Command was outnumbered more than 3:1 overall.

Of course, these figures only provide an opening balance. Not unexpectedly, the strength of the respective air forces changed over the course of the summer and autumn as attrition took its toll. However, when looking at the overall picture, Figure 3, it is evident that Fighter Command steadily fielded more single-seat fighters as the battle progressed. In fact, as the Royal Air Force grew stronger, the Luftwaffe grew weaker.[36]

What makes this all the more surprising is that Fighter Command's operational losses were significantly higher than those suffered by the Luftwaffe's fighter force (Figure 4). This was equally true for the Battle of France as it was for the Battle of Britain. Thus, for 4 months, July-October 1940, Fighter Command lost more than 900 Hurricanes and Spitfires[37] compared to 600 Bf 109s recorded by the Luftwaffe quartermaster returns.[38]

Of course, operational losses do not tell the whole picture since they exclude accidents and other wastage. Determining the actual attrition (total destroyed and damaged) in single-seat fighters during the battle is not entirely straightforward. Definitions vary between the air forces, and some interpretation is required. Figure 5 indicates the total attrition in fighters from July to December 1940.[39] At the height of the battle, Fighter Command's total wastage in Hurricanes and Spitfires was more than 180 percent of its operational losses, compared to 140 percent for the Luftwaffe's Bf 109s. Given Fighter Command's greater combat losses, it is hardly surprising to find this matched by a higher overall attrition. However, the Luftwaffe's figures seem lower than might be expected, even allowing for the fact that damaged Bf 109s were less likely to make it back to their home airfields. When comparing operational losses, as a proportion of the overall wastage recorded, this disparity becomes clearer (Figure 6). While distance and the hazards of a Channel crossing could partially explain the difference, it seems likely that the attrition suffered by the Luftwaffe was actually higher (perhaps by as much as 20-25 percent) than the quartermaster returns would indicate.

It could be argued that a better test of relative strength is serviceability. The comparative rates for Fighter Command and the Luftwaffe are shown in Figure 7. The Fighter Command data

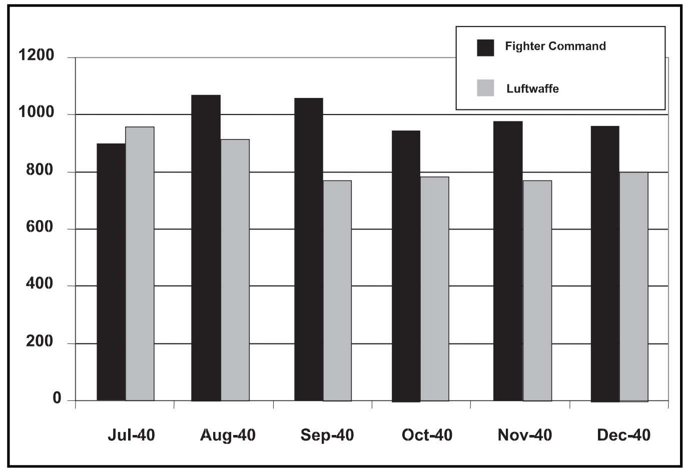

Figure 3. Single-Seat Fighter Strength

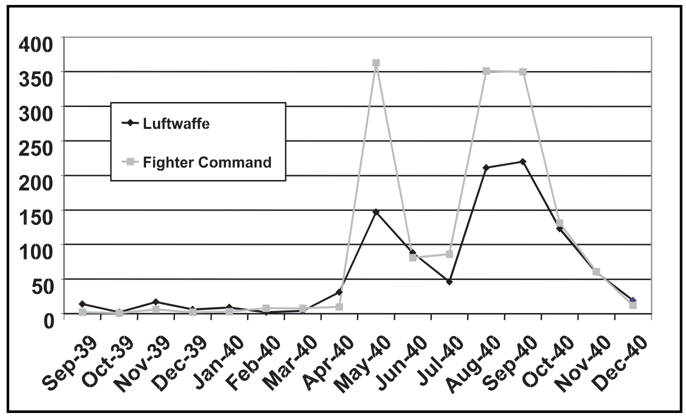

Figure 4. Single-Seat Fighter Operational Losses

	Establishment	Strength	Serviceability
Bombers	1,569	1,481	998
Dive-bombers	348	327	261
Single-engine fighters	1,011	934	805
Twin-engine fighters	301	289	224
Reconnaissance	246	195	151
Ground attack	40	39	31
Coastal	94	93	80
Total	3,609	3,358	2,550

Table 2. Luftwaffe Order of Battle—August 1940[33]

	Establishment	Strength	Serviceability
Hurricanes	723	721	656
Spitfires	366	374	334
Total	1,089	1,095	990

Table 3. Fighter Command Order of Battle—11 August 1940[35]

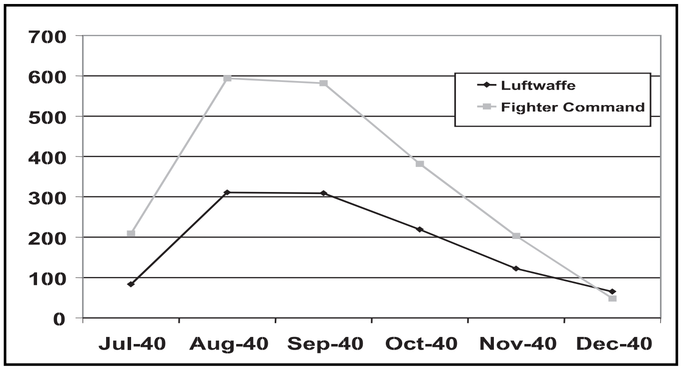

Figure 5 . Single-Seat Fighter Attrition

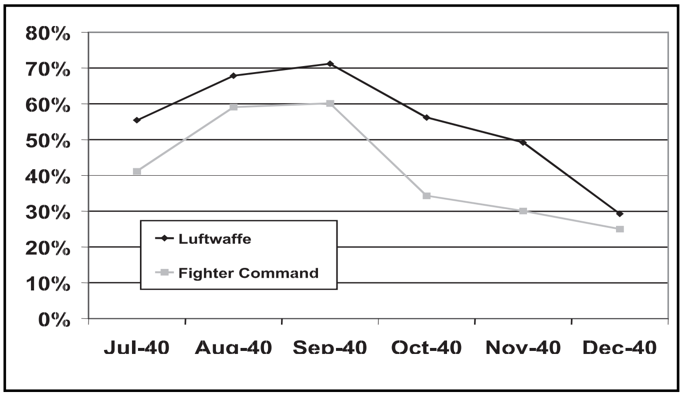

Figure 6. Single-Seat Fighter Operational Losses Against Overall Wastage

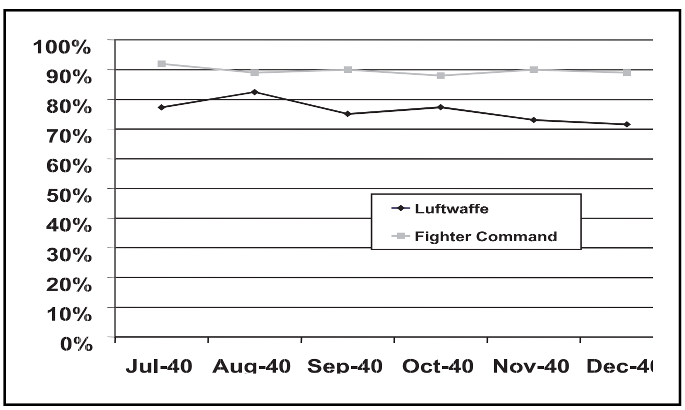

Figure 7. Serviceability Rates

have been extracted from an analysis produced in 1945 on production and wastage during the Battle of Britain.[40] The levels appear to be higher than those quoted in other sources.[41] Another source states that Fighter Command serviceability rose from 70 percent at the outbreak of war to 80 percent by November 1939 but, having fallen to 76 percent in July 1940, recovered to 80 percent by September where it stayed for the remainder of the year.[42] All in all, it seems safe to conclude that serviceability remained fairly constant in Fighter Command throughout the battle, somewhere between 80 and 90 percent.[43]

The Luftwaffe figures, drawn from quartermaster returns, indicate that the serviceability of the single-engine fighter force fell from slightly more than 80 percent at the start of the battle to close to 70 percent by autumn. These are also somewhat higher than other sources might indicate. Indeed, Richard Overy suggested that the number of serviceable Bf 109s could have fallen to as low as 40 percent of the total strength in October 1940.[44] If, as discussed previously, operational wastage was actually higher than recorded, then availability may well have fallen to these levels. What is not in doubt is that Fighter Command, unlike the Luftwaffe, was largely able to sustain the serviceability of its fighter force.

Operational Implications

The operational implication for the Luftwaffe in the steady decline in the number of serviceable Bf 109s was significant, if not crucial. Experience rapidly demonstrated that only the Bf 109 could provide adequate protection to the bomber formations. In general, attacks on mainland targets required a 2:1 fighter-bomber ratio and sometimes as high as 3:1. With only 600-700 Bf 109s available daily for offensive operations, the attacking force was limited to no more than 250-300 bombers out of a total strength of 1,800.[45] Quite simply, the number of Bf 109s available for escort duties determined the Luftwaffe's day offensive capability.

Although great emphasis has been placed on the shortage of pilots faced by Fighter Command, the Luftwaffe suffered even more from the impact of wastage. Fighter Command's pilot casualties reached slightly more than 20 percent in August and September, but with some 260 pilots (albeit inexperienced) being produced each month from the operational training units, the situation was unlikely to become desperate. In fact, as Figure 8 indicates, Fighter Command started with a distinct advantage in pilot numbers that only increased as the battle progressed.[46] Robin Higham argues that Fighter Command's effective strength was lower, between 900 and 950 operational pilots.[47] Even on this basis, in September 1940, Fighter Command was able to field 250 more single-seat pilots than the Luftwaffe. The cause was the Luftwaffe's systematic neglect of training, a chronic weakness that only worsened as the war progressed.

In operational terms, Fighter Command significantly outperformed the Luftwaffe. A comparison of day-fighter sorties between the respective air forces indicates that it was able to generate as many as four times the weekly sortie rate as the Luftwaffe (Figure 9). Even at the peak of the battle, Fighter Command's Spitfires and Hurricanes flew 1,000 more sorties per week than the Luftwaffe's Bf 109s.[48]

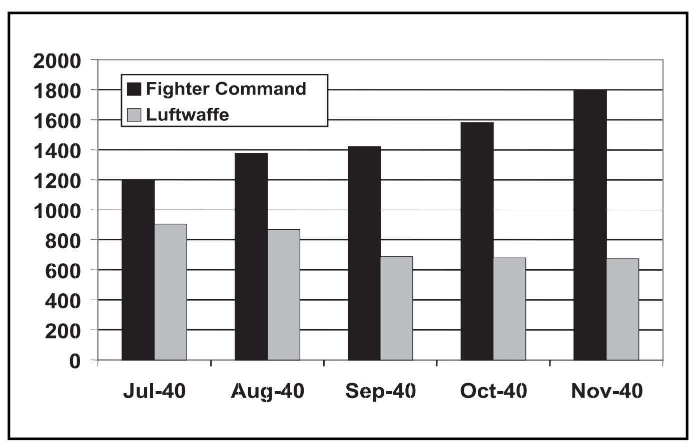

Figure 8. Single-Seat Pilot Strengths

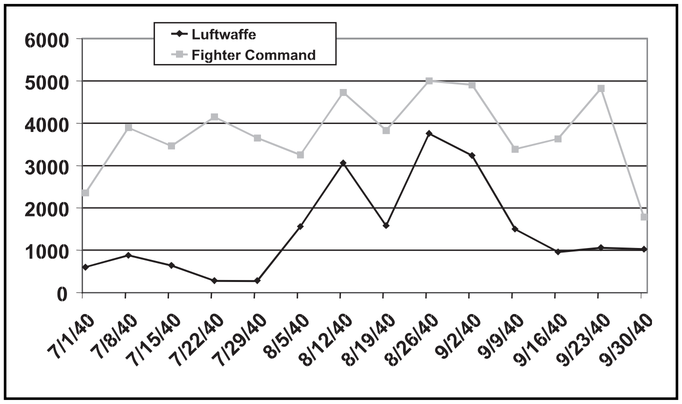

Figure 9. Comparative Weekly Fighter Sorties

Fighter Command clearly possessed an increasing advantage in single-seat fighters as the battle continued, notwithstanding higher aircraft and pilot attrition. How, then, was this achieved?

Production Balance

The simple answer is that losses were never greater than production. Deliveries to the operational squadrons actually exceeded wastage throughout the battle (Figure 10). This disguises, however, the crucial role played by the CRO.[49] While the sustained efforts of the aircraft industry were vital to maintaining the front line, repair provided 40 percent of the total output received by the operational squadrons (Figure 11). At the height of the battle, the CRO achieved Hurricane and Spitfire repair turnaround times of less than 6 weeks, employing a combination of depot, fly-in, and onsite repair. The Luftwaffe had no capability on this scale. In fact, as late as 1942, repair output was no more than 25 percent of production.[50] Germany

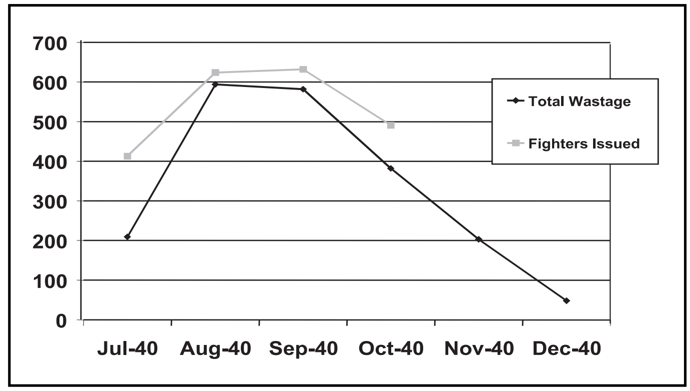

Figure 10. Fighter Command—Aircraft Issued

Engine Maintenance on a Hurricane

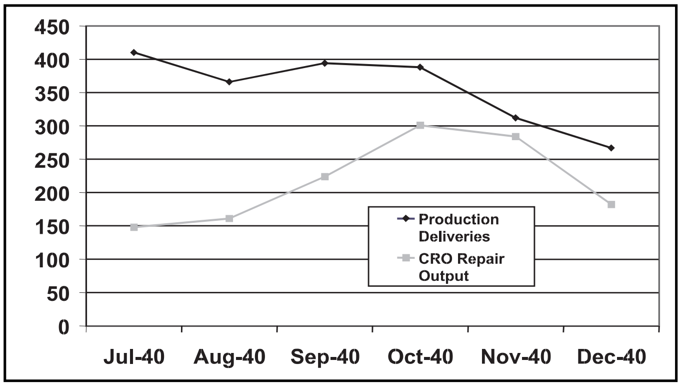

Figure 11. Hurricane and Spitfire Production Versus Repair

had entered the war with reserves of 900 aircraft, equivalent to 25 percent of front-line strength, compared to reserves of 2,200 aircraft, some 115 percent of front-line strength, held by the Royal Air Force. Accordingly, the Luftwaffe's relatively modest reserves were rapidly dissipated through operational attrition. Fighter Command's reserves did shrink after July 1940, but they never totally disappeared and by the end of the year had returned to their previous levels (Figure 12).

Perhaps the most telling comparison is the monthly balance between wastage and production (including repair). Fighter Command and the Luftwaffe both experienced a negative balance in single-seat fighters during August 1940. Against a total wastage of 594 Hurricanes and Spitfires, new production and repair could provide only 527 aircraft, the difference being made up from the immediate reserve stocks.[51] In turn, the Luftwaffe lost more than 300 Bf 109s against new production of only 173 aircraft. Repair and reserves made good some of this shortfall, but such sources were nowhere near the scale of those available to Fighter Command.[52] More important, while Fighter Command quickly recovered to a positive balance of some 50 aircraft a month by September, it took the Luftwaffe an additional 2 months to reach this position (Figure 13). In October, after 3 months of steady attrition, Fighter Command's front line stood at some 98 percent of its established strength, slightly higher than when the battle opened. By comparison, the Luftwaffe fighter force had fallen from 95 percent to 82 percent of established strength. Reserves aside, the fundamental reason for this outcome was that Britain was out-producing Germany in single-seat fighters by a ratio of 2:1; if repairs are included, the ratio is closer to 3:1 (Figure 14).

Logistics as a Target

If the RAF's logistics system was the foundation of its operational strength, it raises the question as to why the Luftwaffe did not attack such an important target more vigorously. The answer would seem to lie partly in faulty intelligence that significantly underestimated the strength of Fighter Command and partly in the flawed thinking that shaped the Luftwaffe's own logistics arrangements. It might also be added that the rapid destruction of the Polish, Norwegian, Dutch, Belgian, and French Air Forces had provided little indication that the Royal Air Force would prove any more difficult to overcome. Thus, while attacks were made on Fighter Command's airfields and some of the depot and storage units, they were never pressed home with the urgency, discrimination, and weight that their significance warranted. Continued attacks on the Supermarine's Southampton factories did eventually stop production of the Spitfire Mk 1, but this was not part of a coordinated plan and had no marked effect on the delivery of new or repaired aircraft to Fighter Command. To be fair, the dispersed nature of such facilities made success problematical. It was the view of some in the Luftwaffe that such attacks would not succeed. "We have no chance of destroying the English fighters on the ground. We must force their last reserves of Spitfires and Hurricanes into combat in the air."[53] Failure to understand the complexity and strength of the RAF's logistics system and overly optimistic combat claims led

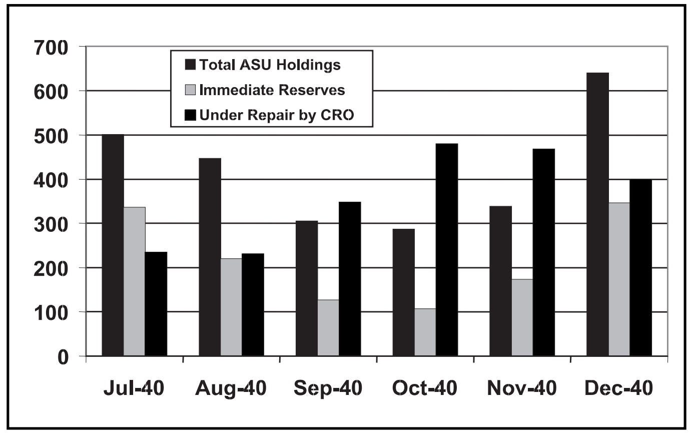

Figure 12. Fighter Command Reserves

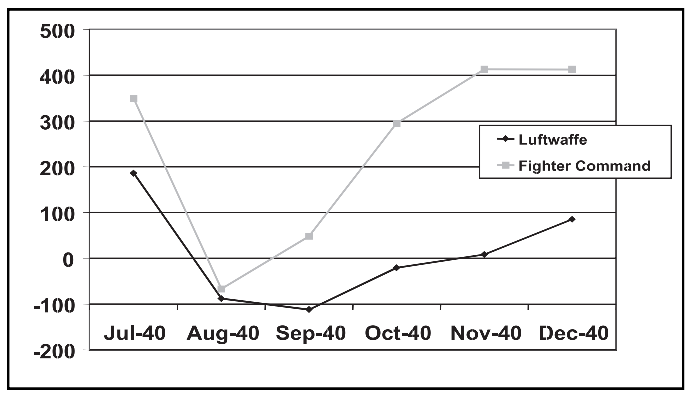

Figure 13. Single-Seat Fighter Production Balance

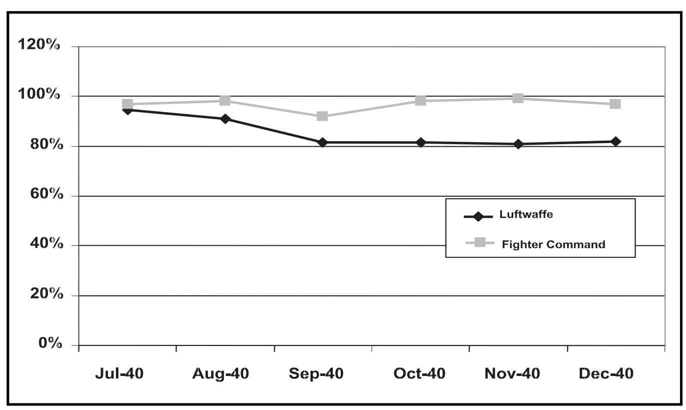

Figure 14. Comparative Fighter Strengths Against Establishment

Hurricane Being Rearmed During the Battle of Britain

directly to the fateful decision in early September 1940 to cease attacks against Fighter Command's airfields and concentrate instead on London, in the mistaken belief only a few enemy fighters were now left to prevent the Luftwaffe's final victory.

Summary

The Battle of Britain was essentially an attritional struggle that tested the logistics systems of the opposing air forces as much as it tested individual pilots, technologies, and tactics. It was a trial of strength, a relentless and grinding contest, far removed from the popular image of the *few* pitted against *the many*. Production, storage, repair, and salvage might not have been as glamorous in the public eye as the heroism shown by Fighter Command's pilots, but they were just as important.

Fighter Command's overall logistics position through 1940 is illustrated in Figure 15. Although total wastage in Hurricanes and Spitfires approached 3,000, deliveries to the squadrons were in excess of 3,500. The front-line strength of Fighter Command was able, therefore, to grow from some 500 Hurricanes and Spitfires in January 1940 to more than 1,000 by August. Even so, without a comprehensive repair-and-salvage organisation, attrition (in excess of 50 percent of front-line strength per month) would have rapidly weakened the operational squadrons. That such a decline did not occur was owed to the prewar air staffs, who not only understood the attritional nature of airpower but also put in place the necessary resources and support arrangements to enable Fighter Command to fight effectively when war came. Their achievements are all the more commendable given the Luftwaffe's failure to grasp these principles (Figure 16). Over the course of 1940, the Luftwaffe's single-seat fighter strength fell slightly, while the once considerable numerical superiority over Fighter Command was rapidly lost. With production, wastage,

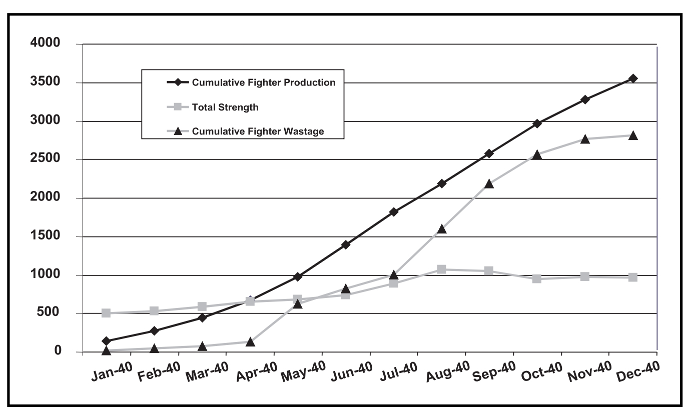

Figure 15. Fighter Command Strength, Production, and Losses

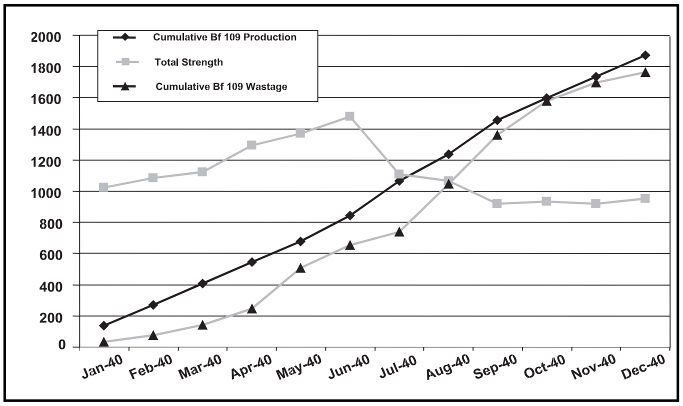

Figure 16. Luftwaffe Strength, Production, and Losses

and strength in close balance, it is clear that the Luftwaffe enjoyed few reserves and little repair capability. In turn, this left no ability to cope with surges in attrition, leading to an inevitable decline in operational capability. The Luftwaffe's halfhearted attacks against the aircraft industry, storage units, and Fighter Command airfields reflected not only a weakness in intelligence but also the shortcomings in its own approach to the logistics of an attritional war.[54]

Conclusion

The Battle of Britain was a contest that the Luftwaffe had neither prepared for nor envisaged. Created as a strategic instrument, the Luftwaffe had become a superb tactical weapon. However, the expectation of a *short war* meant there were neither the industrial resources nor the necessary logistics arrangements in place to sustain operations in the face of a determined enemy. These shortcomings were never properly addressed and, coupled with the huge resources available to the Allied air forces, would ultimately seal the Luftwaffe's fate.

Too much can perhaps be made of the Luftwaffe's doctrinal weakness and flawed decision making. It was the creation of a strategic air defence force, in the form of Fighter Command, with the necessary equipment, organisation, and resources—underpinned by a comprehensive and highly effective logistics system—that defeated the Luftwaffe. Fighter Command's victory was founded on the vision, determination, and hard work of the prewar planning staffs. As Dempster and Wood concluded in their authoritative study of the Battle of Britain, "The outcome was the combination of the preparation, good judgement, and error, made in the preceding seven years."[55]

Notes

1. Dr Richard Overy, *The Battle*, London, 2000, 9.
2. Air Cdre Brooke-Popham expanded on these issues in a lecture on the Air Force in the Great War presented to the RUSI on 3 Dec 19. One of the significant conclusions was, "It was of the highest significance 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 Royal Air Force in any theatre of war very largely depends."
3. Wg Comdr G. W. Williamson, "Some Problems of a Technical Service," lecture delivered on 21 Mar 34, *RUSI Journal*, No 516, 780-800.
4. A full description of the RAF's logistics system in France can be found in *Air Power Review*, Vol 1, No 2, 42-58.
5. Wastage grew steadily through the war. The average number of aircraft dispatched to France to maintain the front line (additional to any new squadrons) was 33 percent in 1914, 26 percent in 1915, 37 percent in 1916, 47 percent in 1917, and 52 percent in 1918 (PRO AIR1/676/21/13/1880). Interestingly, of the 6,500 aircraft struck off charge in France between March and October 1918, 6 percent were time-expired, 36 percent were due to enemy action, 24 percent arose from pilot error, and 29 percent from forced landings as a result of engine failure.
6. Air Staff Memorandum No 50, PRO AIR 10/1522.
7. This was the planning figure used in France in 1918; however, the actual achievement was probably closer to 25 percent.
8. It was recognised that such figures were only approximate in nature, being based to some extent on conjecture. When setting targets for the 1918 flying training programme, the *life* of a single-seat fighter pilot on the Western Front was estimated, for planning purposes only, to be just 10 weeks (PRO AIR 1/683/21/13/2234).
9. The traditional views on the development of Britain's air defence, prior to the establishment of Fighter Command, have been recently challenged by John Ferris, "Fighter Defence Before Fighter Command," *The Journal of Military History*, Oct 99, 845-885. He properly identifies the influence of the First World War and argues powerfully that without Bomber Command there could have been no Fighter Command. His article is highly recommended reading.
10. The aircraft wastage data are drawn from PRO AIR 20/1835 that provides gross weekly wastage in Spitfires and Hurricanes experienced by the operational squadrons. Pilot wastage has been calculated from the pilot strengths for Fighter Command provided by Overy, *The Battle*, 162, and the gross monthly casualties to be found in Appendix 34 of the AHB Narrative. If wastage is calculated on the basis of the squadrons' actual pilot strength, the rate is closer to 42 percent.
11. These wastage figures were, to some extent, drawn from British and American plans. German experience in the First World War indicated that a monthly attrition of some 30 percent might be expected. In 1938, it was calculated that a front line of 2,307 would demand a monthly production of some 1,800 aircraft. On the outbreak of war, the Luftwaffe's front-line strength was in excess of 3,600, but monthly production was less than 700 aircraft. Edward Homze, *Arming The Luftwaffe*, Nebraska, 1976, 1182-183.
12. Dr Richard Overy, *The Air War 1939-45*, London, 1980, 45.
13. John Terraine, *The Right of the Line*, London, 1985, 24-36.
14. PRO AVIA 46/168, *The Repair and Maintenance of Aircraft 1939-1945*.
15. Official History, *Maintenance*, AHB, 1954, 5.
16. Dr Sebastian Ritchie, *Industry and Air Power*, London, 1996, 5.
17. Overy, *The Battle*, 54.
18. Overy, *The Air War*, 33.
19. Data are drawn from M. M. Postan, *British War Production*, 484-485, and the BBSU Report on the German Aircraft Industry, Appendix B.
20. Norman Franks, *Fighter Command Losses 1919-1941*, Midland Publishing, 1997, 18-28.
21. Official History, 54.
22. PRO AIR 16/1023, Report on Operations of British Air Forces France.
23. Christian G. Sturm, *The Black Men*, Air Combat, 1986, 44-55.
24. Official History, 179-182.
25. The *fringe firms* were companies with some experience of the aircraft industry and a degree of familiarity with the problems of aircraft production and repair that were able to provide additional production capacity, initially for airframe modification work. By June 1939, five companies (Rollason's, Airwork, Brooklands Aviation, Scottish Aviation Prestwick, and General Aircraft) had joined the scheme.
26. PRO AVIA 46/168.
27. PRO AVIA 46/149, The Storage and Distribution of Aircraft.
28. The Luftwaffe lost 288 Bf 109s to operational causes during Apr and May 40.
29. Each fighter staffel comprised some 90 ground personnel.
30. Control Commission for Germany, *The Supply Organisation of the German Air Force*, Jun 46, 71-74. According to Milch, "*The movement of squadrons must not be hampered by administrative work. Officers will not be dependent on engineers—such a situation would prejudice the whole morale of the Luftwaffe.*" See also, Dr Horst Boog, "Luftwaffe and Logistics in the Second World War," *Aerospace Historian*, June 1988.
31. *The Supply Organisation of the German Air Force*, 229-231.

32. Dr Horst Boog, *The Luftwaffe and The Battle of Britain*, *The Battle Re-Thought*, RAFHS, 1990, and Hugh Trevor-Roper, *Hitler's War Directives*, London, 1964.
33. AAHB/VII/39, 7. This total does not include the 190 aircraft of Luftlotte 5 based in Norway.
34. Bomber Command had commenced strategic attacks on Germany from the night of 14/15 May 40.
35. PRO AIR 20/307.
36. The figures for Fighter Command are somewhat higher than those quoted in other sources but have been taken directly from PRO AIR 20/2307. Nevertheless, it is the trend that is important rather than precise strength levels.
34. Franks.
38. AHB VII/83.
39. The Luftwaffe data represent total wastage (destroyed and damaged for the entire fighter force on operational and training sorties). The Fighter Command data are from PRO AIR 20/307 and record gross wastage on the operational squadrons. The wastage rates for Nov and Dec 40 have been estimated from the known operational losses.
40. PRO AIR 20/1835.
41. Dempster and Wood, *The Narrow Margin*, London, 1961.
42. Official History, 185-186.
43. An analysis undertaken by the Fighter Command Research Branch in 1949 (PRO AIR 16/1047) indicates that the average number of serviceable aircraft per squadron across 11 and 13 groups was in excess of 15 for the period July to Oct 40.
44. Overy, 33.
45. Hooton, *Eagle in Flames*, 21.
46. Data drawn from the AHB Narrative and Overy.
47. Dr Robin Higham, *The Royal Air Force in the Battle of Britain*, Centre for Air Force History, 1994.
48. Taken from Hooton, 14-15. The Luftwaffe figures have been abated by 20 percent since Bf 110, and fighter-bomber sorties have been included in Hooton's total.
49. This is described in some detail by Dempster and Wood, 103-105, and in PRP AVIA 46/168.
50. Wg Comdr Asher Lee, *The German Air Force*, London, 1946, 234-235. Repair turnaround times are not known, but prior to the war periods, in excess of 3 months were average, Homze, 156.
51. This largely explains why ASU reserves fell so rapidly, notwithstanding the overall positive production position—an apparent anomaly identified by Higham, 135.
52. Only 400 repaired Bf 109s were accepted by the Luftwaffe in 1940, equivalent to just 21 percent of new production. Harold Faber, Ed, *Luftwaffe*, Sidgwick and Jackson, 1979, 203.
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(Wartime Spares continued from page 13)

has the potential to allow for additional cost savings and should be studied further with actual Operation Allied Force data. However, danger is evident if inventory levels fall too far, as shown in Figure 5. Finally, the Air Force's *reach-back* capability showed potential for improving customer service and reducing costs—these improvements should be institutionalized and then find their way into the ASM logic to reduce the inventory stored in an RSP.

Current RSP policies and computational assumptions will only support future AEF deployments when the operations tempo of those deployments is equal or less than the WMP scenario. In those cases where that is not the case, such as Operation Allied Force, improved reach-back capability can offset the resulting inventory shortfall.

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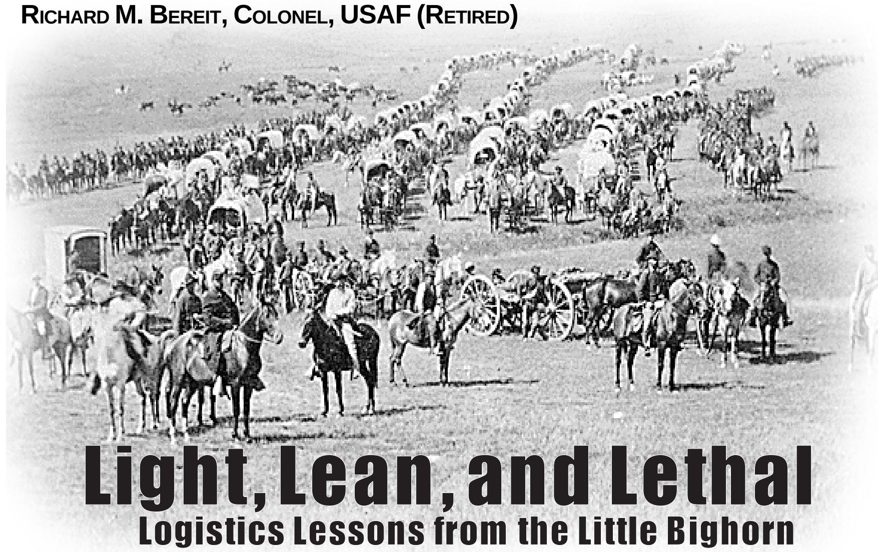

The Editorial Advisory Board selected "Light, Lean and Lethal: Logistics Lessons from the Little Bighorn"—written by Richard M. Bereit, Colonel, USAF (Retired)—as the most significant article to appear in the *Air Force Journal of Logistics*, Vol XXIV, No. 3.