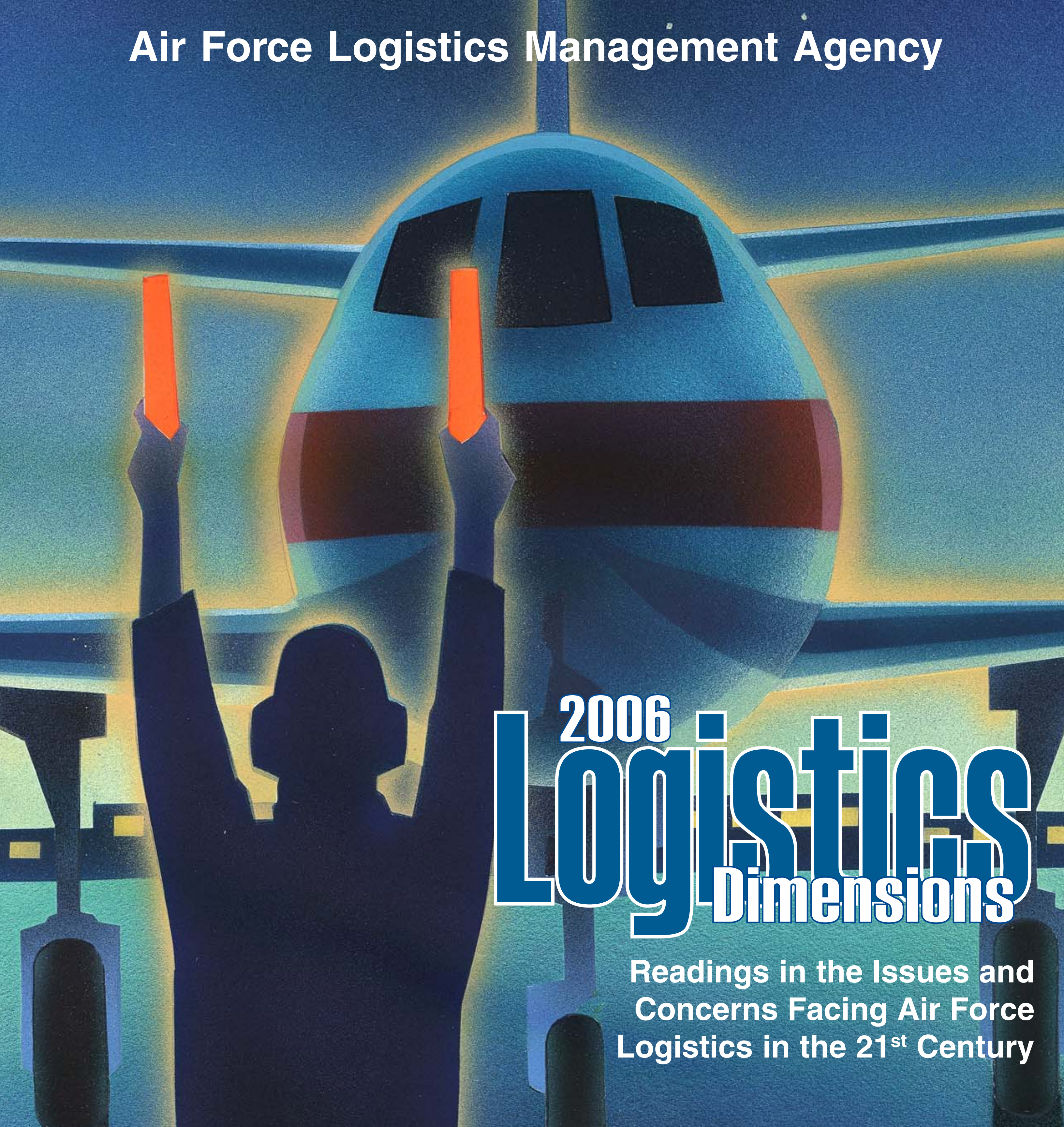
Air Force Logistics Management Agency



2006 Logistics Dimensions

Readings in the Issues and Concerns Facing Air Force Logistics in the 21st Century

2006 Logistics Dimensions

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Foreword

Logistics Dimensions 2006

Logistics Dimensions 2006 is a collection of 25 essays, articles, and vignettes that lets the reader look broadly at a variety of logistics concepts, ideas and, subjects. Included in the volume is the work of many authors with diverse interests and approaches. The content was selected for two basic reasons—to represent the diversity of the ideas and to stimulate thinking. That's what we hope you do as you read the material—think about the dimensions of logistics. Think about the lessons history offers. Think about why some things work and others do not. Think about problems. Think about organizations. Think about the nature of logistics. Think about fundamental or necessary logistics relationships.

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Introduction

Even today, the meaning of logistics can be somewhat fuzzy *in spite of its frequent usage in official publications and lengthy definition in Service and Joint regulations.*

The Dimensions of Logistics

Defining Logistics

The word logistics entered the American lexicon little more than a century ago. Since that time, professional soldiers, military historians, and military theorists have had a great deal of difficulty agreeing on its precise definition.[1] Even today, the meaning of logistics can be somewhat *fuzzy* in spite of its frequent usage in official publications and lengthy definition in Service and Joint regulations. Historian Stanley Falk describes logistics on two levels. First, at the intermediate level:

> Logistics is essentially moving, supplying, and maintaining military forces. It is basic to the ability of armies, fleets, and air forces to operate—indeed to exist. It involves men and materiel, transportation, quarters, depots, communications, evacuation and hospitalization, personnel replacement, service, and administration.

Second, at a higher level, logistics is:

> … economics of warfare, including industrial mobilization; research and development; funding procurement; recruitment and training; testing; and in effect, practically everything related to military activities besides strategy and tactics.[2]

While there are certainly other definitions of logistics, Falk's encompassing definition and approach provides an ideal backdrop from which to examine and discuss logistics. Today, the term combat support is often used interchangeably with logistics.

Logistics and Warfare

General Matthew B. Ridgway, of World War II fame, once observed, "What throws you in combat is rarely the fact that your tactical scheme was wrong … but that you failed to think through the hard cold facts of logistics." Logistics is the key element in warfare, more so in the 21st century than ever before. Success on the modern battlefield is dictated by how well the commander manages available logistical support. Victories by the United States in major wars (and several minor wars or conflicts) in the 20th century are linked more directly to the ability to mobilize and bring to bear economic and industrial power than any level of strategic or tactical design. The Gulf War and operations to liberate Iraq further illustrate this point.

Long before the Allied offensive could start, professional logisticians had to gather and transport men and materiel and provide for the sustained flow of supplies and equipment that throughout history has made possible the conduct of war. Commanders and their staffs inventoried their stocks, essayed the kind and quantities of equipment and supplies required for operations in the severe desert climate, and coordinated their movement plans with national and international logistics networks. *"The first victory in the Persian Gulf War was getting the forces there and making certain they had what they required to fight* [Emphasis added]. Then and only then, would commanders initiate offensive operations."[3] The same may be said of lightning quick victory in Iraq, although without the massive stockpile of inventory seen during the Gulf War.

In 1904, Secretary of War Elihu Root warned, "Our trouble will never be in raising soldiers. Our trouble will always be the limit of possibility in transporting, clothing, arming, feeding, and caring for our soldiers...."[4] Unfortunately, the historical tendency of both the political and military leadership to neglect logistics activities in peacetime and expand and improve them hastily once conflict has broken out may not be so possible in the future as it has been in the past. A declining industrial base, flat or declining defense budgets, force drawdowns, and base closures have all contributed to eliminating or restricting the infrastructure that made rapid expansion possible. Regardless, modern warfare demands huge quantities of fuel, ammunition, food, clothing, and equipment. All these commodities must be produced, purchased, transported, and distributed to military forces. And of course, the means to do this must be sustained.

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The End of Brute Force Logistics

The end of the Cold War and experience gained from the conflicts in Grenada, Panama, and the Persian Gulf essentially brought the era of *brute force* logistics to a close. The traditional practice of using massive quantities of troops and large stockpiles of supplies available in theater to engage sizable hostile forces is obsolete. Additionally, extensive buildup time and lengthy resupply and repair pipelines to sustain forces are unrealistic. The focus of logistics has now shifted toward rapid movement of small, independent force packages to employ precise combat power

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anywhere in the world. The rapid changes in political dynamics of the world powers, domestic fiscal constraints, and technological advances have rendered the Cold War military strategy and preparation ill-equipped to handle 21st century missions, requirements, and demands.

The US role in the post-Cold War world has changed dramatically. Military forces are no longer dedicated solely to deterring aggression but must respond to and support homeland defense and humanitarian missions. From peacekeeping to feeding starving nations, to conducting counterdrug operations, the military continues to adapt to evolving missions.

Logistics Challenges

The US role in the post-Cold War world has changed dramatically. Although currently heavily involved in Global War on Terrorism, military forces are no longer dedicated solely to deterring aggression but must respond to and support homeland defense and humanitarian missions. From peacekeeping to feeding starving nations, to conducting counterdrug operations, the military continues to adapt to evolving missions. Logistics infrastructure and processes must evolve continuously to support the new spectrum of demands. The keys to supporting both combat and peacetime operations successfully are robust, responsive, and flexible logistics systems.

Decreases in funding and the drawdown of the US military in the 1990s drove new approaches to logistics support and refinement of the military logistics systems. These fiscal constraints dictated that the military reduce infrastructure, maintain smaller numbers of both inventory and personnel, and find ways to reduce costs without degrading mission capability.

Reduced budgets impact weapons modernization programs in several ways. As dollars decrease, fewer systems can be developed, which increases the importance of decisions made in the acquisition process. The process must develop the most lethal systems while emphasizing reliability and supportability. Therefore, logistics considerations play a more important role than ever in the design, production, and fielding of new systems. Logistics capabilities for supporting future forces require systems to be *smarter* and require less maintenance.

Technology and Logistics

Technology (to include technological change and technological innovation), as a subject, covers a lot of ground and often enjoins heated debate. It has proven to be one of the major tools for dealing with problems, perhaps more so in the 21st century than at any other time in history. However, critics of technology argue that it often causes as many problems as it solves and that the new problems are often far worse than the old ones. Further, they question its validity as a major tool for solving complex problems rooted in ethical, philosophical, political, or other nontechnical areas.[5] These are, by no means, all the criticisms of technology, but they serve to frame the basic objections. The counter argument to these criticisms would answer that technology is not unique in creating new and, often, more difficult problems, while solving old ones. Very much the same criticism could be aimed at all approaches to problem solving. No problem-solving approach yields simple, final answers to the basic problems of humankind.[6] One could even argue that philosophical and other nontechnical approaches have done little when measured against the same standards; they fail just as abjectively as technology.[7] Further, the fact that technological solutions are inappropriate in certain situations does not mean that technology is always unsuited to problem resolution. Technology cannot be viewed as a separate entity within either the military or society in general. This illusion of discreteness simply does not exist. It is and will remain an integral part of both. The real issue is to recognize that technology is a tool with limitations, and these limitations should be considered in reacting to particular situations. Technology does not offer a *silver bullet* for all situations.

Organizational change should and must accompany technological change if new capabilities are to be exploited. Stephen Rosen, in *Winning the Next War,* points out that innovation does not always result from new technologies. Rather, new technology simply may be used to improve the ability to perform a particular mission.[8] The relationships among technological innovation, fundamental military operations, and changes in concepts and organizations are nonlinear. That is, changes in input may not yield proportionate changes in output or other dynamics.[9]

Significant organizational, intellectual, and technological changes are seen during periods of transition. The major change, however, must be intellectual. Without this, technological change becomes meaningless and organizational change impossible. The US military is now in a period of rapid change. Recent changes—order of magnitude changes—in technology have led to both long-range and strategic planning efforts that integrate current and future technological advances into operational concepts. In the logistics arena, these include Focused Logistics at the Joint level and Agile Combat Support (ACS) within the Air Force. The vision of both of these is the ability to fuse information, transportation, and other logistics technologies to provide rapid response, track and shift assets while en route, and deliver tailored logistics packages at all levels of operations or war (strategic, operational, and tactical).[10] This same vision includes enhanced transportation, mobility, and pinpoint delivery systems.[11] The operational forces that must be supported logistically will be smaller and more flexible—emphasizing mobility, speed, and agility. These forces will utilize technological superiority in stealth, precision weapons, surveillance, and dominant battlefield awareness.

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Military logistics, at a more fundamental level, is in a period of transition brought about by the evolving information revolution. Many challenges concerning workflow, improving data integrity, and efficient communications still exist. A variety of human and cultural factors still impede full-scale adoption of many new information technologies—complexity and difficulty in the use of some systems, loss of control, changes in fundamental power relationships, uselessness of old skills, and changes in work relationships.[12] Change and instruments of change, as apparent as they seem once implemented, often elude understanding before they enter the mainstream.[13] As an example, Chester Carlson, the inventor of the photocopy machine (often referred to as the Xerox machine) was told by business that his invention was unnecessary because libraries and carbon paper already filled the need. This was a technology that drastically altered the way people approached information, yet finding interested businesses and investors in the beginning proved elusive.

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Any discussion of technology and logistics would be lacking without citing Martin van Crevald. In *Technology and War*, he notes:

> …technology and war operate on a logic which is not only different but actually opposed, nothing is less conducive to victory in war than to wage it on technological principles—an approach which, in the name of operations research, systems analysis or cost/benefit calculation (or obtaining the greatest bang for the buck), treats war merely as an extension of technology. This is not to say … that a country that wishes to retain its military power can in any way afford to neglect technology and the methods that are most appropriate for thinking about it. It does mean, however, that the problem of making technology serve the goals of war is more complex than it is commonly thought to be. The key is that efficiency, far from being simply conducive to effectiveness, can act as the opposite. Hence—and this is a point which cannot be overemphasized—the successful use of technology in war very often means that there is a price to be paid in terms of deliberately *diminishing* efficiency.
>
> Since technology and war operate on a logic which is not only different but actually opposed, the very concept of "technological superiority" is somewhat misleading when applied in the context of war. It is not the technical sophistication of the Swiss pike that defeated the Burgundian knights, but rather the way it meshed with the weapons used by the knights at Laupen, Sempach, and Granson. It was not the intrinsic superiority of the longbow that won the battle of Crécy, but rather the way which it interacted with the equipment employed by the French on that day and at that place. Using technology to acquire greater range, firepower, greater mobility, greater protection, greater whatever is very important and may be critical. Ultimately, however, it is less critical and less important than achieving a close *fit* between one's own technology and that which is fielded by the enemy. The best tactics, it is said, are the so-called *Flaechenund Luecken* (solids and gaps) methods which, although they received their current name from the Germans, are as old as history and are based on bypassing the enemy's strengths while exploiting the weaknesses. Similarly, the best military technology is not that which is *superior* in some absolute sense. Rather it is that which *masks* or neutralizes the other side's strengths, even as it exploits his weaknesses.
>
> The common habit of referring to technology in terms of its capabilities may, when applied within the context of war, do more harm than good. This is not to deny the very great importance of the things that technology can do in war. However, when everything is said and done, those which it cannot do are probably even more important. Here we must seek victory, and here it will take place—although not necessarily in our favor—even when we do not. A good analogy is a pair of cogwheels, where achieving a perfect fit depends not merely on the shape of the teeth but also and, to an equal extent, on that of the spaces which separate them.
>
> In sum, since technology and war operate on a logic that is not only different but actually opposed, the conceptual framework that is useful, even vital, for dealing with the one should not be allowed to interfere with the other. In an age when military budgets, military attitudes, and what passes for military thought often seem centered on technological considerations and even obsessed by them, this distinction is of vital importance. In the words of a famous Hebrew proverb: "The deed accomplishes, what thought began."[14]

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Air Force Logistics in the 21st Century

The Air and Space Expeditionary Force

To meet current and anticipated challenges, the Air Force has developed an air and space expeditionary force (AEF) concept that has two primary goals.[15] The first is to improve the ability to deploy quickly from the continental United States (CONUS) in response to a crisis, commence operations immediately on arrival, and sustain those operations as needed. The second goal is to reorganize to improve readiness, better balance deployment assignments among units, and reduce uncertainty associated with meeting deployment requirements. The underlying premise is that rapid deployment from CONUS and a seamless transition to sustainment can substitute for an ongoing US presence in theater, greatly reducing or even eliminating deployments the Air Force would otherwise stage for the purpose of deterrence.

To implement the AEF concept, the Air Force created ten air and space expeditionary forces,[16] each comprised of a mixture of fighters, bombers, and tankers. These ten AEFs respond to contingencies on a rotating basis: for 120 days, two of the ten AEFs are *on call* to respond to any crisis needing airpower. The on-call period is followed by a 12-month period during which those two AEFs are not subject to short-notice deployments or rotations. In the AEF system, individual wings and squadrons no longer deploy and fight as a full or single unit as they did during the Cold War. Instead, each AEF customizes a force package for each contingency, consisting of varying numbers of aircraft from different units. This fixed schedule of steady-state rotational deployments promises to increase flexibility by enabling the Air Force to respond immediately to any crisis with little or no effect on other deployments.

To implement the AEF concept, the Air Force created ten air and space expeditionary forces, each comprised of a mixture of fighters, bombers, and tankers. These ten AEFs respond to contingencies on a rotating basis: for 120 days, two of the ten AEFs are on call *to respond to any crisis needing airpower.*

The dramatic increase in deployments from the CONUS, combined with the reduction of Air Force resource levels that spawned the AEF concept, has increased the need for effective combat support (CS).[17] Because CS resources are heavy and constitute a large portion of the deployments, they have the potential to enable or constrain operational goals, particularly in today's environment, which is so dependent on rapid deployment.[18] Consequently, the Air Force is reexamining its CS infrastructure to focus on faster deployment, smaller footprint, greater personnel stability, and increased flexibility.

The AEF rapid, global force projection goals and associated sustainment requirements create a number of support planning challenges in such areas as munitions and fuel delivery, engines and navigational equipment maintenance, and forward operating location (FOL) development. Support is a particular challenge in expeditionary operations (dealing with conflicts in an expeditionary fashion and with little warning) since the traditional assumption associated with Cold War support planning was that scenarios and associated support requirements could be fairly well developed in advance and materiel prepositioned at anticipated FOLs. Much of the existing support equipment is heavy and not easily transportable; deploying all the support for almost any sized AEF from the CONUS to an overseas location would be expensive in both time and airlift. As a result, the Air Force has focused on streamlining deploying unit CS processes, leaning deployment packages, and evaluating different technologies for making deploying units more agile and quickly deployed and employed. Decisions on where to locate intermediate maintenance facilities such as the jet engine intermediate maintenance (JEIM) shop and nonunit heavy resources—those not associated with flying units, such as munitions, shelters, and vehicles—are significant drivers of employment time lines.

Agile Combat Support—A Brief Discussion

What is Agile Combat Support

The development and refinement of expeditionary airpower (expeditionary aerospace forces) required rethinking many Air Force logistics functions and concepts—principally the combat support functions. Expeditionary airpower required making the Air Force support systems far more agile than they previously had been. Recognizing this, the Air Force began transforming its support systems into the Agile Combat Support system. ACS is the central support concept that ensures both the viability of expeditionary airpower and the ability to support Joint force requirements. It improves the responsiveness, deployability, and sustainability of forces, and it substitutes responsiveness for the massive inventories of the past.

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Time-Definite Resupply

Since the early 1990s, the Air Force has been developing and refining the practices and processes supporting Agile Combat Support and Focused Logistics. Clearly, military operations in the 21st century must have responsive and agile operational and support forces. To achieve this, Agile Combat Support employs what has been termed time-definite resupply, a fundamental shift in the way deployed forces are supported. With time-definite resupply, the mobility footprint of early arriving forces is reduced, and resupply of deployed forces begins upon their arrival, thus reducing initial lift requirements. This not only optimizes available lift and reduces costs but also makes it possible to reduce the size and, therefore, the vulnerability of forces.

Reachback

Historically, logistics systems *pushed* support to deployed forces to compensate for less-than-perfect resource information and planning systems. This often resulted in an expensive and wasteful stockpile of material in US warehouses and forward locations. This approach to prestocking large quantities of materiel globally is not viable in the 21st century—operationally or politically. Under the ACS concept, high-velocity, reliable transportation, and information systems are used to get the right parts to the right place, at the right time. When a part is required, the system will *reach back* and *pull* only those resources required. Time-definite delivery forms the basis for all resupply in the theater of operations, thereby reducing total lift requirements. This reachback approach makes it possible to deploy fewer functions and persons forward for deployment and sustainment processes. This, in turn, reduces the size and, therefore, the vulnerability of forward deployed forces.

Streamlined Depot Processes

Under ACS, streamlined depot processes will release materiel in a more timely fashion than in the past. Rapid, time-definite transportation will complete the ACS support process by delivering needed materiel directly to the user in the field. Integrated information systems will provide asset visibility throughout this process, tracking items throughout the order and delivery cycle with the capability to redirect them as the situation dictates.

There are still many issues associated with ACS that require resolution. A variety of studies have been completed or are ongoing to examine these issues. RAND and the Air Force Logistics Management Agency have played a principal role in the ACS studies and analysis process. This research[19] has resulted in what is aptly called an Agile Combat Support (ACS) network, consisting of five principal elements.

- **Forward Operating Locations (FOL)**. FOLs are sites in a theater, out of which tactical forces operate. FOLs can have differing levels of CS resources to support a variety of employment time lines. Some FOLs in critical areas under high threat should have equipment prepositioned to enable aerospace packages designed for heavy combat to deploy rapidly. These FOLs might be augmented by other, more austere FOLs that would take longer to spin up. In parts of the world, where conflict is less likely or humanitarian missions are the norm, all FOLs might be austere.
- **Forward Support Locations (FSL)**. FSLs are sites near or within the theater of operation for storage of heavy combat support resources, such as munitions or war reserve materiel, or sites for consolidated maintenance and other support activities. The configuration and specific functions of FSLs depend on their geographic location, the threat level, steady-state and potential wartime requirements, and costs and benefits associated with using these facilities.
- **CONUS Support Locations (CSL)**. CSLs are support facilities in the CONUS. CONUS depots are one type of CSL, as are contractor facilities. Other types of CSLs may be analogous to FSLs. Such support structures are needed to support CONUS forces should repair capability and other activities be removed from units. These activities may be set up at major Air Force bases, appropriate civilian transportation hubs, or Air Force or other defense repair or supply depots.
- **Theater Distribution System**. A transportation network connects the FOLs and FSLs with each other and with the CONUS, including en route tanker support. This is an essential part of an ACS system where FSLs need assured transportation links to support expeditionary forces. FSLs themselves could be transportation hubs.
- **Combat Support Command and Control (CSC2)**. CSC2 systems facilitate a variety of critical management tasks: (1) estimating support requirements, (2) configuring the specific nodes of the system selected to support a given contingency, (3) executing support activities, (4) measuring actual CS performance against planned performance, (5) developing recourse plans when

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the system is not within control limits, and (6) reacting swiftly to rapidly changing circumstances.

This infrastructure can be tailored to the demands of any contingency. The first three parts—FOLs, FSLs, and CSLs—are variable. The Air Force configures them as deployments occur to meet immediate needs. In contrast, the last two elements—a reliable transportation network and CSC2— are indispensable ingredients in any configuration. Determining how to distribute responsibility for the support activities required for any given operation among CSLs, FSLs, and FOLs is the essence of strategic support decisions. For example, in determining the number of FSLs to support a given operation and their role, the Air Force must evaluate such factors as the support capability of available FSLs and the risks and costs of prepositioning specific resources at those locations.

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12. Cassie B. Barlow and Allen Batteau, "Is Your Organization Prepared for New Technology?" *Air Force Journal of Logistics*, Vol XXI, No 3&4, 24.
13. Norma R. Klein, "Technology Trends and Logistics: An Interrelational Approach to Tomorrow," *Air Force Journal of Logistics*, Vol XIII, No 2, 36.
14. Martin van Crevald, *Technology and War*, London: The Free Press, 1989, 319.
15. In the early genesis of the concept of expeditionary operations, the Air Force used the term expeditionary aerospace force (EAF) to define this new concept of force organization. In recent years, the term air and space expeditionary force or AEF has replaced EAF.
16. Henceforth, when it is clear from the context, we will use AEF to represent both the concept and force package.
17. Air Force doctrine defines combat support to include "the actions taken to ready, sustain, and protect aerospace personnel, assets, and capabilities through all peacetime and wartime military operations."
18. Theater assets are provided by organizations outside the combat unit itself.
19. From the beginning, RAND and the Air Force Logistics Management Agency developed a close partnership in ACS research.

Generating Solutions Today, Shaping Tomorrow's Logistics

Since its inception, the Air Force Logistics Management Agency has grown to be recognized for its excellence—excellence in providing answers to the toughest logistics problems. And that's our focus today—tackling and solving the toughest logistics problems and questions facing the Air Force. It's also our focus for the future.

Many organizations have catchy mottoes. Likewise, many have catchy vision statements. We do, too. But there's a big difference—we deliver on what we promise. *Generating Solutions Today, Shaping Tomorrow's Logistics* aren't just words to us; they're our organizational culture. We use a broad range of functional, analytical, and scientific expertise to produce innovative solutions to problems and design new or improved concepts, methods, systems, or policies that improve peacetime readiness and build war-winning logistics capabilities.

Our key strength is our people. They're all professionals from logistics functions, operational analysis sections, and computer-programming shops. Virtually all of them have advanced degrees, some of which are doctorates. But more important, virtually all of them have recent field experience. *They've been there and done that*. They have the kind of experience that lets us blend innovation and new technology with real-world common sense and moxie. It's also the kind of training and experience you won't find with our competitors. Our special blend of problem-solving capabilities is available to every logistician in the Air Force.

Our track record puts us in the lead in delivering robust, tailored answers to the most difficult and complex Air Force logistics problems. This can be seen in our efforts and partnerships that are turning expeditionary airpower support concepts into real-world capability. It also can be seen in our work in making dramatic improvements to the Air Force supply system and developing high-impact logistics publications and our leadership in planning and making logistics play in wargames, simulations, and exercises truly meaningful. Likewise, it can be seen in our work with transformation and innovation. The message is also loud—we work the important projects that shape tomorrow's Air Force, and we deliver what our customers need today.

The Themes of US Military Logistics

From a historical perspective, 11 major themes stand out in modern US military logistics.

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

Colonel Walter O. Gordon, USAFR
Colonel Chuck Holland, USAF, Retired

Back to the Future: Airships and the Revolution in Strategic Airlift

The Requirement

The last major study of US airlift requirements, *Mobility Requirements Study 2005* concluded the United States requires an airlift fleet capable of transporting 54.5 million ton-miles per day (MTM/D). Recent developments indicate the requirement will be even higher, perhaps up to 60 MTM/D. According to General John Handy, commander of Air Mobility Command (AMC) and Transportation Command, even meeting the lower requirement requires a C-17 fleet of 222 aircraft, 42 more than the 180 currently under contract.[1] With the Air Force fighting the possible cancellation of the C-130J as well as a significant cutback in the number of F/A-22s, the purchase of 52 more C-17s seems unlikely, much less the number required to meet 60 MTM/D.

Is the C-17 the best way to overcome the airlift shortfall? This article proposes an alternative aircraft—a hybrid aircraft, costing about the same as a C-17, but potentially three times as productive and costing one-half to one-third as much to operate per ton-mile.

An airship obviously has significantly different operating characteristics than an aircraft. Some operating characteristics are better, some are not, and some are just different. Those characteristics will be discussed in this article, but the bottom line is that an airship is probably a viable and affordable alternative to buying additional C-17s and should be considered for filling the airlift gap.

Airship 101- A Brief History

The Flight of the *Luftschiff Zeppelin 59*

In 1917 a German aircraft departed Bulgaria on a 3,600 nautical-mile flight carrying 30,000 pounds of medical supplies and ammunition for a beleaguered army unit in Africa. When it landed 95 hours later it still had 64 hours of fuel remaining—enough

From 1923 to 1935 the US Navy operated a total of four rigid airships, Shenandoah, Los Angeles, Akron, and Macon. The loss of three of them to accidents—only Los Angeles retired without mishap—coupled with the loss of the Hindenburg several years later, sounded the death knell for large airship operations.

to have flown to San Francisco had it taken a great circle route west instead of flying south. Nonstop flights from Bulgaria to San Francisco carrying that large a payload could not have been accomplished by a B-29 thirty years later. In 1917, it was closer to the realm of science fiction.[2]

What type of aircraft was this and how was it possible in 1917? It was the German *Luftschiff* Zeppelin *59 (LZ 59)*, a rigid airship. During the flight most of the weight of the ship was held aloft by buoyant lift, the difference in weight between the air displaced by its gas envelope and the hydrogen contained within. As a result, all the engines of the Zeppelin had to do was overcome the drag of the vessel as it passed through the air. The engines on a conventional aircraft must do that as well, but must also overcome the additional drag from the wings lifting the weight of the aircraft.

Graf Zeppelin

Twelve years later, in August 1929, the German airship *Graf Zeppelin* flew around the world in four stops carrying twenty passengers and forty-one crew. The longest leg was a nonstop flight between Friedrichshafen, Germany and Tokyo, a distance of over 7,000 miles covered in 100 hours. Not only was a flight like this unthinkable by an airplane in 1929, the passengers made the flight in accommodations unavailable to the commercial air traveler even today (see Figure 1).

The spacious dining room of the *Graf Zeppelin* makes another point about airships. Because the gas envelope is necessarily many times larger than the fuselage of an airplane of comparable gross weight, they tend to have much more volume available for passengers and cargo. It is much more difficult to *bulk-out* an airship than an aircraft.

US Navy Airship Operations

From 1923 to 1935 the US Navy operated a total of four rigid airships, *Shenandoah, Los Angeles, Akron, and Macon.* The loss of three of them to accidents—only *Los Angeles* retired without mishap—coupled with the loss of the *Hindenburg* several years later, sounded the death knell for large airship operations. Looking at the losses of the individual ships, however, one sees that it was not as bad as a simple 75 percent hull loss rate might indicate.

Shenandoah flew 740 hours before being lost in a severe thunderstorm. *Los Angeles* retired with 4,181 hours. *Akron* crashed at sea in a storm due to a faulty altimeter setting with 1,695 hours, and *Macon* ditched at sea with 1,798 hours after her vertical stabilizer was ripped off by clear air turbulence.[3]

Compared to airplanes from the same period these are probably not bad numbers, and when you consider these four rigid airships were the first (and last) the US ever operated, in some ways their record is remarkable—undoubtedly, far better than the first four airplanes. But these losses, coupled with significant advances in airplane technology, enabled aircraft to surpass airships in most areas of operation. This ended operation of the large airship in the United States and the world, at least until today.

Airship Basics

In order to understand the capabilities and limitations of airships certain basic principles must be understood.

Aerostatic Versus Aerodynamic Lift

Unlike an airplane in which lift is generated aerodynamically, the lift required for an airship to leave the ground is produced aerostatically by the buoyancy of the lifting gas in the surrounding ocean of air. A very significant difference between the two is aerodynamic lift costs horsepower and fuel in the form of induced drag, which is roughly proportional to the lift required. This is in addition to parasitic drag—so-called because it does not provide anything useful, like lift—which varies with the square of the velocity of the aircraft and explains why higher speeds require significantly more thrust.

Unlike an airplane in which lift is generated aerodynamically, the lift required for an airship to leave the ground is produced aerostatically by the buoyancy of the lifting gas in the surrounding ocean of air.

Aerostatic lift, on the other hand, has no induced drag component. The vehicle is lifted by the buoyancy of the lifting gas and all the engines must do is overcome parasitic drag to move the vehicle through the air. This explains the remarkable performance of airships such as the LZ 59 and *Graf Zeppelin* given the limited performance of the internal combustion engines available at the time. The engines only had to move the airship, not lift it, and since the airships were relatively slow even the parasitic drag component was small.

The two lifting gases historically used in airships are hydrogen and helium. Hydrogen is less dense so it has slightly more lift, about 70 pounds per 1000 cubic feet of gas versus 65 for helium. It is also considerably less expensive. Because hydrogen is highly flammable all contemporary airships use helium. The reason the German airships of the twenties and thirties used hydrogen is because at the time the United States had the only useful supply of helium in the world and was unwilling to sell it to Germany because it was considered a war resource. American airships of the same period all used helium.

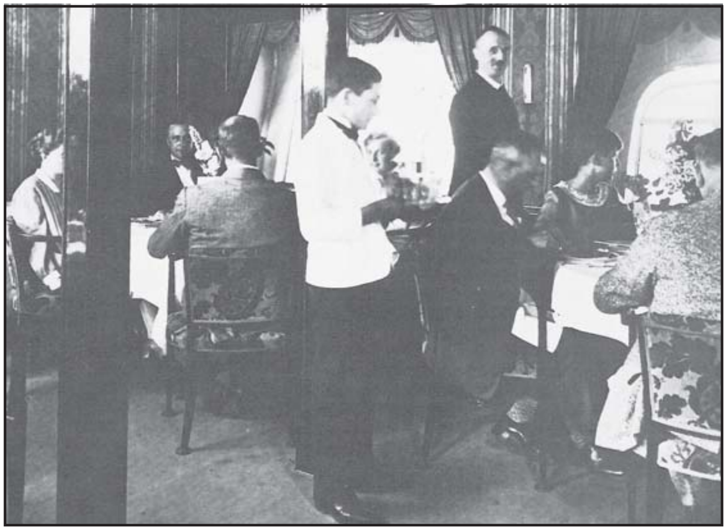

Figure 1. ***Graf Zeppelin*** **Dining Room**

Rigid versus Nonrigid Airships

From a structural viewpoint, airships may be constructed in two ways, rigid and nonrigid. In a nonrigid airship, which is the only type constructed today, the rigidity of the ship is provided by slight pressurization of the lifting gas. The Goodyear Blimp, or any other blimp for that matter, is a nonrigid airship.

Akron, *Macon*, *Hindenburg*, and all the other great airships of the twenties and thirties were rigid airships, or dirigibles, in which the rigidity of the ship is provided by a vast aluminum hull structure completely filling the outer envelope. The lifting gas was then contained within a number of individual gas cells contained sequentially front-to-back within the hull structure. The gas cells themselves had virtually no pressurization. They simply floated against the top and sides of the hull structure to keep the airship aloft.

Rigid airships are much more expensive to produce than the nonrigid variety primarily because of the complexity of the aluminum hull structure. In a nonrigid airship the hull structure consists of both the outer envelope of the ship—which serves double duty as the gas envelope—and the lifting gas itself, which is slightly pressurized to between 1/4 and 1/2 pound per square inch to give the envelope rigidity. To paraphrase a contemporary airship design engineer, "I like helium because it is a great structural material that also happens to lift itself plus more. It allows us to build these hugely large vehicles relatively inexpensively and as a bonus they don't weigh nearly as much as they would if constructed conventionally."[4]

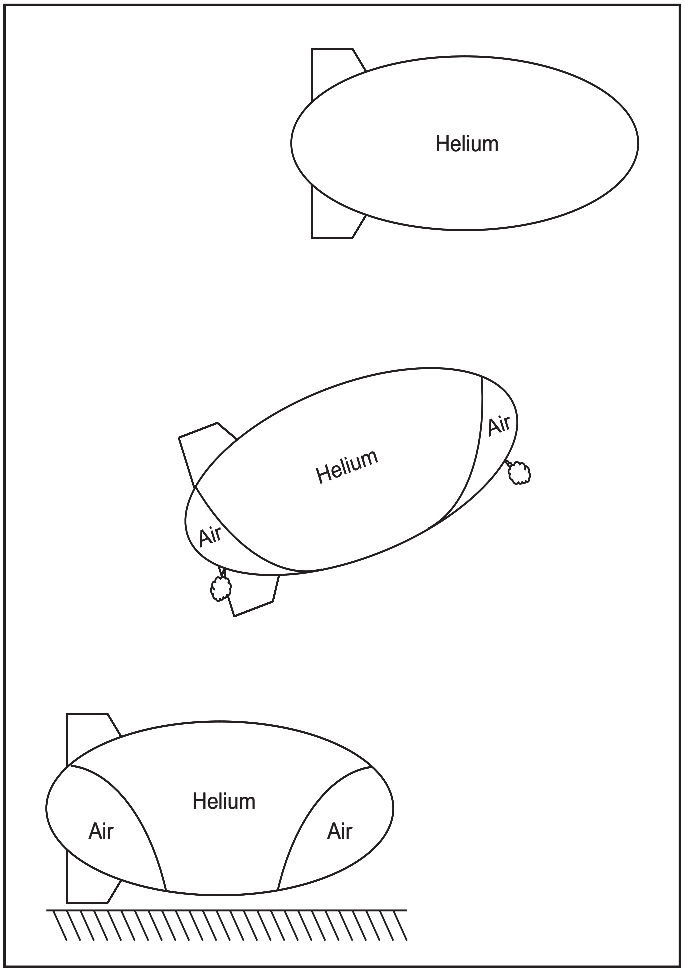

Figure 2. Ballonets at Takeoff, Climb, and Pressure Height

The biggest drawback of a nonrigid is they are limited in size by the strength of the fabric used in the envelope. Even though they are only slightly pressurized, the larger a nonrigid airship gets the greater the stress in the fabric even if the internal pressure remains constant. In the twenties and thirties the state of the art of fabric technology only allowed the construction of small blimps, hence all large airships were rigid out of necessity. Almost all airships proposed for construction today are nonrigid. The balance of this article will refer only to nonrigid airships unless specifically stated otherwise.

Pressure Height

When an airship climbs the lifting gas within it expands as atmospheric pressure decreases. As this occurs the lifting gas must be allowed to expand for two reasons. First, to try to contain it under increasing pressure puts unnecessary stress on the envelope. Though an airship may appear to be highly pressurized, the pressure inside the envelope is maintained only slightly above ambient (less than 1 pound per square inch) to maintain its structural integrity. Second, because the pressure and density of the atmosphere decreases with altitude as the airship climbs, the lifting gas must continue to provide the same amount of buoyant lift and must be allowed to expand to displace additional ambient air.

In a nonrigid airship this is accomplished by incorporating separate, smaller envelopes called ballonets within the main envelope. The ballonets are filled with ambient air and expand and contract opposite the lifting gas (see Figure 2). Before takeoff the ballonets are filled with air and the rest of the envelope with helium. As the airship rises and the helium expands within the main envelope, air in the ballonets is released into the atmosphere and the ballonets contract. The *pressure height* of the airship, which is generally the maximum operational ceiling, is the altitude at which the ballonets are completely emptied of air and helium fills the main envelope. When the airship descends and the helium contracts the ballonets are refilled with atmospheric air to compensate for the shrinking helium and maintain the same relative pressure and total volume of gas within the main envelope.

The design pressure height of an airship is important because it determines the proportion of total envelope volume allocated to air in the ballonets—more air means greater pressure height, but it also means less of the main envelope is allocated to helium at takeoff, which means less lift. An airship that is going to take off at sea level and climb to 10,000 feet en route must have approximately 30 percent of its total envelope volume taken by air in the ballonets at take off to allow room for the expansion of helium during the climb. This means the amount of helium available for lift is only 70 percent of the total envelope volume. If that same airship only had to climb to 3,000 feet, however, the ballonets need only be filled to 10 percent of the total volume so 90 percent could be filled with helium. All other things being equal, this means an airship that had to climb to 3,000 feet on a mission could take off with 28 percent more payload by weight than an identical airship that had to climb to 10,000 feet, the difference the 90 percent helium fill versus 70 percent fill.

This tradeoff must be considered during route planning for an airship, as it could be more efficient to deviate several hundred miles on a transcontinental mission to avoid an 8,000-foot mountain range instead of climbing over it. The additional payload available due to a lower pressure height would probably more than make up for the fuel required by the slightly longer route.

Almost all airships proposed for construction today are nonrigid. The balance of this article will refer only to nonrigid airships unless specifically stated otherwise.

If ballonets are placed fore and aft in the vehicle as illustrated in Figure 2, they may also be used for trimming the aircraft in lieu of aerodynamic trim. Pumping more air into a front ballonet and less out of a rear one while keeping the total volume constant is essentially a transfer of ballast (the air), which shifts the center of gravity of the airship forward. This is more efficient than using aerodynamic trim which increases induced drag that, in turn, increases fuel consumption.

Buoyancy Compensation

Another aspect of airship operations that is not technically obvious is buoyancy compensation. When an airship takes off with neutral buoyancy the aerostatic lift produced by the helium is equal to the total weight of the vehicle—the combined weight of the structure, payload, and fuel. As fuel is burned en route, however, the total weight of the airship decreases but the aerostatic lift remains the same. If nothing is done, over time the ship will gain significant positive buoyancy. As this is

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undesirable from both a control and structural viewpoint, the airship must have a mechanism for buoyancy compensation.

Hydrogen-filled airships such as the *Graf Zeppelin* and *Hindenburg* simply vented excess hydrogen into the atmosphere to compensate for the weight of fuel burned. This was an acceptable solution because hydrogen was both inexpensive and easily generated wherever the ships were scheduled to land and refuel. Not so for helium, however, which is considerably more expensive and cannot be generated locally. It must be shipped in heavy steel cylinders from where it was originally mined or subsequently stored. Helium-filled airships such as the *Akron* and *Macon* were constructed with an apparatus on the engine exhaust to condense and recover the water it contained. The water was then stored to compensate for the weight of fuel burned. While a seemingly elegant solution to the en route buoyancy compensation problem, water recovery apparatus was heavy, at least initially unreliable, and the condensers mounted on the skin of the ship added drag. While the equipment improved over time, "the water recovery problem as a whole remained the *bête noire* of the helium-inflated rigid airship."[5]

The other aspect of the buoyancy compensation problem occurs when cargo is offloaded at destination. If an airship arrives at a destination with neutral buoyancy and offloads 30 tons of cargo, it immediately has 30 tons of excess lift. For an airship in commercial operations this is addressed by onloading equivalent ballast, either outbound cargo, water, or both, as the inbound cargo is removed. It can be problematic for a military airship however, as there is often no outbound cargo during a buildup at a forward operating base, and lately many of the deployed operations of the US military have been to regions where large quantities of water are not readily available.

Hybrid Aircraft

Addressing the destination buoyancy compensation problem when ballast is not available is one of the main reasons driving examination of the hybrid aircraft (HA). A hybrid aircraft is an airship in which significant lift is provided both aerostatically and aerodynamically. While all airships generate and make use of a small amount of aerodynamic lift, it is generally only to address minor buoyancy issues en route. The cylindrical fuselage of a conventional airship is optimized for volumetric efficiency of the lifting gas and low parasitic drag, not to generate lift, and they typically take off and land with close to neutral buoyancy. A true hybrid aircraft is designed to take off and land heavier than air, but makes use of aerostatic lift to give part of the weight of the vehicle a *free ride*.

The elegance of a hybrid aircraft is that it may be designed so an apportionment of aerostatic and aerodynamic lift can completely address the buoyancy compensation problem. Assume an airship in which its gross weight consists of 50 percent structure, 25 percent payload, and 25 percent fuel. As a hybrid aircraft, it would be designed so at takeoff half the lift would be provided aerostatically, lifting the fixed structure, and half aerodynamically, lifting the fuel and payload. En route, as fuel is burned, the angle of attack of the airship (essentially the degree to which it is flying nose up) is reduced proportionally so less aerodynamic lift is generated and total lift remains the same as the gross weight of the vehicle (now reduced for fuel burned). When the HA arrives at destination with a small amount of fuel remaining and the cargo is unloaded, it will still be slightly heavy and not require ballast because the aerostatic lift is still only lifting the structure.

With this added flexibility comes several penalties. First, because it always operates heavier-than-air (think of it as an airplane with subsidized lift), it cannot take off or land vertically or hover. Second, because of the induced drag generated by aerodynamic lift, a hybrid aircraft is less efficient than a pure airship. However, it can still be considerably more efficient than an airplane.

The 21st Century Airship

Background

In January 2004, the Defense Advanced Research Projects Agency (DARPA) published a request for information in the Commerce Business Daily (CBD) for a "Heavy Lift Air Vehicle" capable of carrying "500 tons or more over intercontinental distances."[6] A draft program solicitation released in April contained additional information:

> The baseline mission for WALRUS is to transport personnel and equipment from "Origin to Destination." This mission anticipates loading at a continental US home base and flying strategic distances nonstop to deploy military units in a theater of operations in a fit-to-fight condition. Anticipating local air superiority in the area of landing operations with ground defenses suppressed, WALRUS will land vertically or short rolling at an unimproved site. It will have sufficient fuel and control to take off empty (no external ballast to offset offloaded payload will be required) and to depart the area of hostilities before refueling for return to base.[7]

Strategic distances are specified elsewhere in the document to be up to 6,000 miles.

These requirements are written for an airship. No known or planned airplane can meet the combination of cargo weight, unrefueled range, and ability to land at a short, unimproved site.

A very large conventional airship using buoyant lift could meet all three of those requirements but would require ballast at destination to offset the weight of the offloaded cargo, which is prohibited in the cited paragraph. An alternative to ballast would be to vent helium to reduce lift at an amount equal to the cargo weight. For 500 tons of cargo this would be over a million dollars worth of helium, not something that could be done for normal operations.

A hybrid aircraft would meet these requirements by using dynamic lift to carry the weight of cargo so when it is offloaded it would be neutrally buoyant or close to it, not 500 tons light.

When the HA arrives at destination with a small amount of fuel remaining and the cargo is unloaded, it will still be slightly heavy and not require ballast because the aerostatic lift is still only lifting the structure.

Back to the Future: Airships and the Revolution in Strategic Airlift

A significant advantage of the ACLS is it works equally well on land or water, making the vehicle amphibious. Missions could be flown to ships at sea, delivering or picking up cargo that cannot wait for another ship.

The Hybrid Aircraft

Several firms, including Lockheed Martin and Advanced Technologies Group (ATG), a United Kingdom-based airship manufacturer, have proposed pressurized, nonrigid hybrid aircraft in which the shape of the hull is maintained by gas pressure within the envelope. The SkyCat 1000, a 1000-ton payload version, is illustrated in Figure 3. A 500-ton class vehicle would be slightly smaller, but still very large, at approximately 850 feet long, 375 feet wide, and 250 feet high. This may seem large, but it is not much longer than the Akron which was 785 feet long, though it is considerably wider and taller. The Akron had a circular cross-section 150 feet in diameter.

The balance of this article will refer primarily to a 500-ton payload class HA with characteristics derived from several industry sources unless otherwise noted.

Physical Characteristics and Performance

Computed characteristics and performance of a notional 500-ton vehicle are presented in Table 1. The vehicle is designed with a number of unique features to meet the Walrus requirement.

Air Cushion Landing System

The proposed vehicle uses an air cushion landing system (ACLS) instead of conventional wheeled landing gear (see Figure 4). When operating in a reverse, or suction, mode, the ACLS serves to eliminate ground mooring equipment by holding the aircraft firmly against the ground.

A significant advantage of the ACLS is it works equally well on land or water, making the vehicle amphibious. Missions could be flown to ships at sea, delivering or picking up cargo that cannot wait for another ship. The vehicle may also operate like a flying boat, taking off and landing from the water and then taxiing to the shore for onload and offload. If the gradient is shallow enough it could even taxi up onto a beach, removing the vehicle completely from the water much like an air cushion landing craft. On land, the ACLS

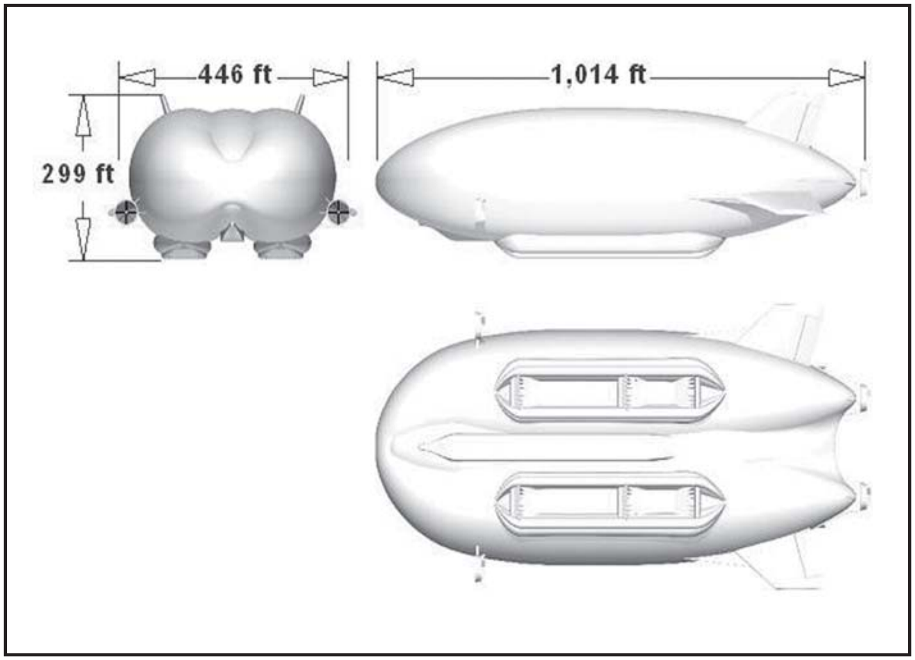

Figure 3. SkyCat 1000

will also work on unimproved surfaces such as flat fields or surfaces covered with ice or snow.[8]

A drawback of the ACLS when compared with a conventional landing gear is that it cannot be used to stop the aircraft, as is the case with wheel brakes. On nonabrasive surfaces such as ice or snow, or on other surfaces in an emergency situation, it may be possible to turn off the outflow of air to lower the skirt to the ground, bringing the vehicle to a stop faster. In normal operations, however, reverse thrust would be used to bring the vehicle to a stop.

In the ATG concept, when the aircraft is parked with little or no wind and it is heavy, the skirt is inflated (the skirt is always inflated on the ground) but outflow from within the ACLS skirt is turned off and the vehicle rests with the skirt on the ground. In higher wind conditions that might cause the vehicle to drag or if the vehicle is light, air is withdrawn from within the skirt, creating a suction to hold the vehicle down.[9] Lockheed's concept is similar, except they feel suction should be continuously on whenever the vehicle is on the ground as it is too susceptible to being moved by a sudden gust.[10]

In flight it may be possible for the ACLS skirt to be deflated and retracted against the fuselage to reduce drag.[11]

Propulsion

The HA is propelled by four gimbaled propeller units (visible in Figure 3). Two are located at the back of the vehicle and one is located on each side toward the front. ATG intends to use four external turboprop engines of the type planned for the A400M airlifter. Lockheed's propulsion system may be similar, though they are also considering using diesel or turbine power generation units centrally located in the vehicle providing DC power to electric motors in thrust pods turning propellers on the exterior. They anticipate several core power units for both redundancy and efficiency. If one fails all four thrust pods will continue to operate. Additionally, when the vehicle is lighter after some fuel has burned off en route, less power is required and one power unit may be shut down intentionally to conserve fuel. The

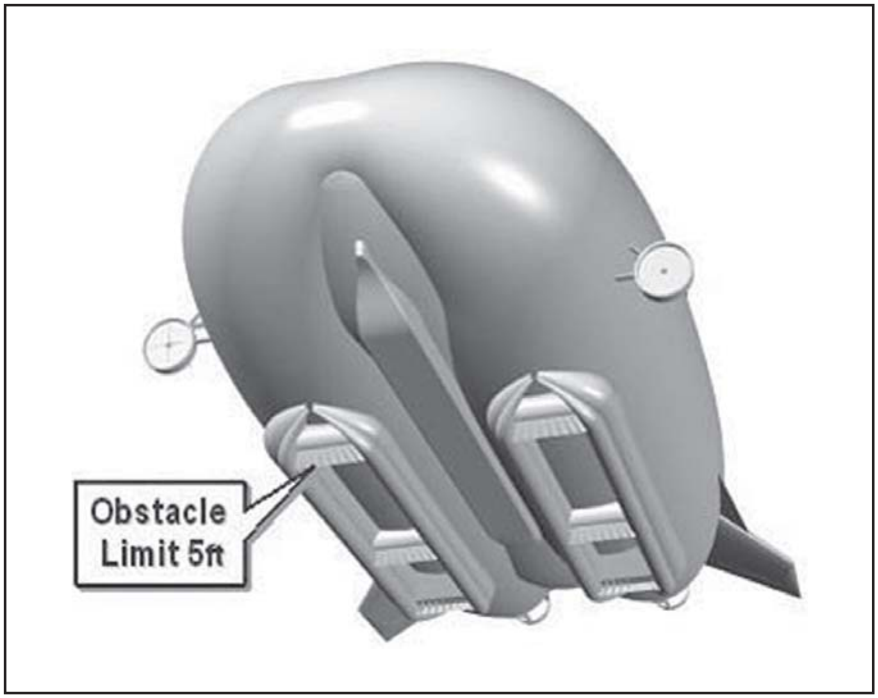

Figure 4. SkyCat Air Cushion Landing System

Characteristics	Performance
Length	850 feet*
Width	375 feet*
*Height	250 feet*
Displacement of envelope	24 million cubic feet*
Volume of helium at sea level	14 million cubic feet*
Cruising speed	80-110 knots
Range	6,000 nautical miles
Ceiling	9,000 feet
Takeoff distance, full load	8,000 feet
Landing distance at FOB	1,500 feet
Cargo weight	500 tons
Fuel weight	300 tons*
Thrust units	Two aft, two side

*** Will vary with specific design**

Table 1. Characteristics and Performance of 500-Ton Payload HA

centrally-located power generation scheme offers several other advantages. If future technology provides a more efficient means of generating electricity, such as fuel cells or nuclear power, only the power units need be replaced, the rest of the propulsion system will remain unchanged.

As the size of a nonrigid airship increases, so does the stress in the fabric. The material required to produce fabric for a 500-ton vehicle is on the borderline of what has been tested in the laboratory but has not yet been made into a flightworthy fabric.

A system to recover water from engine exhaust could be incorporated to provide buoyancy compensation for the fuel burned en route. Such a system would be simpler for centrally-located power units than separate engines mounted on the thrust pods.

Centrally locating the power also makes it easier to manage the heat generated, whether to superheat the helium for additional lift or to reduce the infrared signature of the exhaust to reduce vulnerability to man-portable air defense (MANPAD) systems. Certainly the limited heat generated by the electric motors in the thrust pods will be easier to dissipate than the exhaust of an externally-mounted engine.

Last, a power generation system that has a greater installed weight than a conventional system but uses fuel more efficiently, has the potential to ameliorate part of the buoyancy compensation problem. For example, if externally-located turboprops have an installed weight of 50 tons but burn 200 tons of fuel en route, they generate 200 tons of buoyancy that must be compensated for with ballast or aerodynamic lift. If a centrally-located turbo diesel power plant weighs 150 tons but only burns 100 tons of fuel en route, it only generates a 100-ton buoyancy compensation problem (and hence a more efficient vehicle if it is accounted for by aerodynamic lift) even though the total weight of the propulsion system plus fuel is the same as the turboprop installation.

Thrust Vector Control

In order to meet the short-field landing requirement, the HA is capable of landing and taking off at extremely low speeds on the order of 25-35 knots. At these speeds there is not enough dynamic pressure over reasonably sized aerodynamic control surfaces to adequately control the vehicle, so it is done with thrust vector control of the thrust pods. The side propeller units gimbal ±90 degrees vertically for pitch control, while the rear units gimbal 60 degrees in all directions for pitch and yaw control.

Risk Areas

While the original DARPA CBD announcement did mention the possible investigation of some fairly esoteric technologies, they are not required for the hybrid design proposed in this article. Certain technologies are, however, of medium risk.

Lockheed feels the ACLS is also a medium risk item; not because of any new technology required, but because nothing like it has been built before for this application and a significant amount of new engineering is required.

Envelope Fabric

As the size of a nonrigid airship increases, so does the stress in the fabric. The material required to produce fabric for a 500-ton vehicle is on the borderline of what has been tested in the laboratory but has not yet been made into a flightworthy fabric. This is considered to be a medium risk area. The joint technology used to join the cut pieces of fabric together to make the large envelope also must be proven at the higher stress level associated with a larger vehicle.[12]

Air Cushion Landing System

The ACLS is going to be an active structure, operating continuously while the vehicle is on the ground, either in the hover mode if the vehicle is taxiing or taking off, or the suction mode if it is stationary. Since the ACLS serves as the airship's mooring system, the worst-case consequences of it failing are quite serious. Imagine a 350-ton (or more) vehicle the size of an aircraft carrier blowing down the block.

The vulnerability of airships to surface winds is illustrated in Figure 5. A series of photographs showing the *Los Angeles* (all 75 tons and 650 feet of her) swinging over the mooring mast when a wind and temperature shift raised the tail of the ship before the crew could compensate. It is worth noting that even though the incident appears very dramatic, the damage to the ship was incidental and it could have been flown away immediately after, if necessary.[13]

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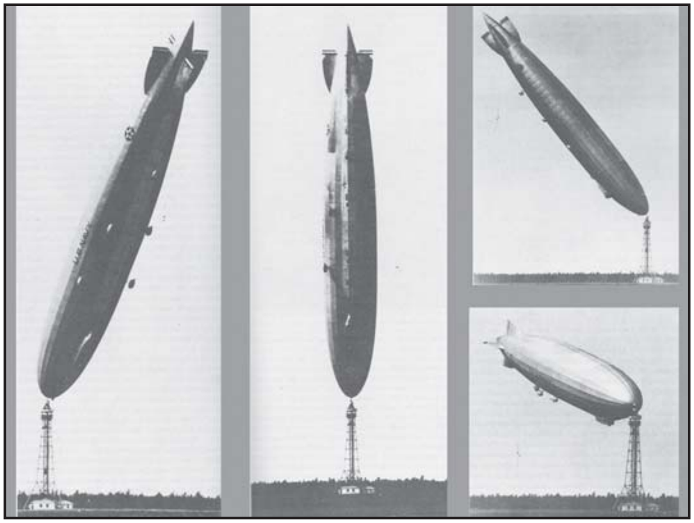

Figure 5. *Los Angeles* on End

The takeoff area required for a fully loaded HA with 500 tons of cargo and 300 tons of fuel is estimated to be 8,000 feet.

Flight Control System

The HA must have a digital flight control system both to eliminate excessively long cable runs and also to reduce the workload for the pilot of what would be a sluggish, difficult-to-control aircraft. The use of thrust vector control combined with conventional control surfaces, both in flight and for maneuver on the ground, would also increase the workload of the pilot, probably excessively so, if not managed by a computer.[15]

Operational Considerations

Runway Requirements

The HA is designed to take off and land directly into the wind, so it does not have crosswind limits. It does require rectangular or circular landing zones. The takeoff area required for a fully loaded HA with 500 tons of cargo and 300 tons of fuel is estimated to be 8,000 feet. An 8,000-foot concrete circle or rectangle may seem like a lot, but recall that because of the capabilities of the ACLS, operation from a runway is not required. The vehicles will typically operate from the water if leaving from a sea port of debarkation (SPOD) or from a drop zone if leaving from an Army base, a conventional aerial port of debarkation would normally not be used.

The landing area required at destination when most of the fuel is burned off is estimated to be 1,500 feet. Again, circular or rectangular landing areas are required so the aircraft can land and take off into the wind.

Winds Aloft

The relatively low true airspeed of a hybrid aircraft makes it especially vulnerable to increased transit time due to headwinds, so much so that significant deviation from the most direct route in pursuit of tailwinds can have a large benefit. For example, a 100-knot HA flying into an average 20-knot headwind would take 58 hours to fly 4,600 miles along the ground, the great circle distance from the West Coast of the US to Korea. If by deviating 1,000 miles around circulating weather patterns the 20-knot headwind is turned into an average 20-knot tailwind, the trip would only take 47 hours, a half day less of transit with significant fuel savings as well. In fact, because the HA is capable of such significant deviation to take advantage of tailwinds and mitigate the effect of headwinds, the presence of real-world wind on a given route would not increase transit time more than 5 percent and almost always results in lower total time for a round-trip flight.[16]

Terminal Weather

The Sky Cat 1000 report gives the ceiling and visibility requirements for the vehicle as a 200-foot ceiling and zero visibility, or "0/0 for military fields with precision approach radar capability."[17] While these figures may be correct, one needs to keep in mind that the landing zones (and water areas for SPODs) from which the vehicle is going to operate will often not have instrument approaches, so the vehicle will not always be able to operate in such poor weather. Even if self-contained Global

Positioning System/inertial navigation system approaches are constructed on the fly for a tactical landing zone they will still not have received either the level of scrutiny with respect to obstacles in the area or the flight inspection of a conventional approach.

Weather Hazards

Like any aircraft, the HA would seek to avoid thunderstorms, and equipped with an onboard weather radar and real-time weather information would be able to do so.[18] Studies anticipate the aircraft would be damaged, but not brought down should it be struck by lightning. Several means of adding conductive material to the envelope to further ameliorate the effects of a lightning strike have been discussed but would add cost and weight to the vehicle that are not included in the estimates presented in this report.[19]

In-flight icing would be addressed by a number of anti-icing and deicing measures similar to conventional aircraft. Ice accumulation while the aircraft is parked on the ground could be a significant problem as the vast area of the envelope means even a thin coating of ice would have significant weight. Conventional deicing by truck would be almost impossible because of the large size of the HA. A mechanism could be designed into the vehicle to disperse anti-icing solution over the envelope but this would have its own set of issues regarding the quantity of fluid required and whether it would have to be recovered because of environmental concerns. It would be simplest if the vehicle was flown away during prolonged icing conditions on the ground.

Snow accumulation while parked is less of a concern than ice because of its reduced weight. The HA could actually take off supporting a thin layer of snow and buildup in excess of that could be prevented by high-speed taxiing.

The amount of aerostatic lift allowed for a particular mission is limited by the requirement for the vehicle to be slightly heavy before departing the forward operating base after the cargo is offloaded.

Ballast

While one of the main reasons for employing a hybrid aircraft is to eliminate the need for buoyancy compensation ballast, the efficiency of the vehicle can be improved if ballast is available when the cargo is offloaded or even earlier in the flight after some of the fuel has been burned off. The reason is simple but probably not intuitive. The amount of aerostatic lift allowed for a particular mission is limited by the requirement for the vehicle to be slightly heavy before departing the forward operating base (FOB) after the cargo is offloaded. When the vehicle is required to operate with no ballast, this lift is equal to the empty weight of the HA plus any remaining fuel at that point. For a 300-ton empty weight HA with 25 tons of fuel remaining that would be 325 tons. As a result, before initial departure from home station the amount of air in the ballonets would have to be adjusted to 325 tons of aerostatic lift even if the total gross weight of the vehicle at the time was several times that with cargo and fuel load. The balance of the lift en route would have to be provided aerodynamically, which is not as efficient.

Compared to a C-5 or C-17, the probability of kill given a hit by anything except the largest surface-to-air ordnance is lower for an airship than an airplane. Large surface-to-air missiles, such as the SA-6 or SA-10, would probably bring down an airship as they would an airplane, but even then, because of its extreme size and lower speed, the airship might be able to land under some semblance of control where an airplane would simply come apart.

If ballast may be taken on to offset fuel burned at some point in the mission, however, initial aerostatic lift may be increased to reflect the weight of the ballast, because after the cargo is offloaded at the FOB the ballast is still present to prevent the vehicle from having positive buoyancy. If in this same example the vehicle was able to land on the ocean, prior to coasting in at the destination landmass, and onload 100 tons of ocean water ballast, the aerostatic lift at initial takeoff could be adjusted to 425 tons instead of 325, making for a more efficient flight profile, requiring less fuel overall.

Mission Effectiveness

The bottom line for acquisition of a fleet of hybrid aircraft simply comes down to mission effectiveness and cost. Will it get there soon enough, safely enough, and with enough stuff? Is it more economical to acquire and operate than the competition?

Vulnerability

The first question most people ask when told about using airships for strategic lift is, How vulnerable is it? The answer to that question is, Much less than you would think, but it depends on the situation and what you are comparing it to.

Compared to a waterborne ship, an airship is less vulnerable because over the ocean it is almost always safer to be several thousand feet in the air than on the surface of the water. Threats from mines, torpedoes from submarines or surface vessels, surface-to-surface or air-to-surface anti-ship missiles, suicide speedboats, or boarding by pirates simply do not apply to an airship. Those things that could threaten an airship, such as fighter aircraft or surface vessels armed with surface-to-air missiles or artillery (and the airship could easily detect and avoid or outrun the latter if they were perceived to be a threat), would be just as threatening to surface vessels. So even from a brief qualitative analysis it is readily apparent that only a small subset of the possible threats to surface ships could threaten an airship.

The comparison is a little more complicated when made against other aircraft. Compared to a C-5 or C-17, the probability of kill given a hit by anything except the largest surface-to-air ordnance is lower for an airship than an airplane. Large surface-to-air missiles, such as the SA-6 or SA-10, would probably bring down an airship as they would an airplane, but even then, because of its extreme size and lower speed, the airship might be able to land under some semblance of control where an airplane would simply come apart.

For simplicity the vulnerable area of an airship may be divided into three categories.

- Envelope
- Fuselage
- Propulsion units

Should the envelope be hit by antiaircraft artillery (AAA) projectiles that do not detonate but simply make holes, the effect would hardly be noticeable. Because of the extremely low pressure of the lifting gas, the rate of exchange between helium and ambient air across even hundreds of 23 mm holes would not prevent the airship from completing its mission and flying to a safe location to be repaired, if not even back to its home base. Even if a MANPAD were to detonate against the envelope instead of punching a hole in it, the resulting hole would be much more significant, but it would still take hours, not minutes, to bring the airship down. And it would land, not crash.[20]

If the fuselage were struck by AAA it would certainly detonate, but industry designers believe they could allocate sufficient weight to incorporate Kevlar armor under the entire fuselage designed to protect it up to direct hits from 23 mm AAA.

If a MANPAD were to strike one of the four propulsion units it would probably destroy it. As with a four-engine airplane, however, the HA is capable of maintaining flight with only three propulsion units. In fact, only two are necessary in most circumstances as long as they are on opposite sides. The likelihood of a MANPAD striking the propulsion unit is open to question, however, if the HA has a central power generation system in which power is generated in the center of the fuselage and routed to electric motors in each propulsion unit. The electric motors would have a much lower infrared signature than a turbine engine, and the heat from the central generation unit would either be vented out the top of the airship or used to heat the lifting gas several degrees for extra lift. The HA would also be able to be fitted with large aircraft infrared countermeasures that would further reduce its vulnerability to MANPADs.

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The above discussion applies to the probability of a kill given a hit. However, the vulnerability of an airship to a hit is unquestionably higher than an airplane. While a C-5 or C-17 cruises above all except the largest surface-to-air threats and is only exposed to smaller ones in the terminal environment, an airship cruising at 9,000 feet over land is exposed to everything, except small arms. This is the long pole in military airship vulnerability and except for the protective measures outlined above there is no getting around it. If there is a threat along the route of flight, efforts would have to be taken to ameliorate it as much as possible by flying at night and avoiding threats to the greatest extent possible. This effort would be aided by the fact that unlike a large airplane, which has to head for a runway near which threats could be placed, the airship can land anywhere there is a 1,500 foot diameter circle of unobstructed ground, significantly complicating the enemy's targeting problem.

Notional Scenario

The results of an industry study of the deployment of a Stryker brigade combat team (SBCT) from Fort Lewis, Washington, to Kimhae Airbase (AB), Korea, are shown in

Critics dismiss airships out of hand because they are not capable of flying over medium altitude threats as airplanes can. The utility of airships is more readily apparent, however, if one considers them not as a replacement for the C-17 but as a vehicle with the payload of a small ship that flies several thousand feet over the ocean at 100 knots, and can then proceed inland as far as the threat will permit, and land in a large field. They would constitute a valuable third mode of strategic transportation for USTRANSCOM with speed much better than a ship and economics much better than an airplane.

Table 2. The study compares 30 HAs against 63 C-5s. The much slower HAs have a slight edge in total deployment time, 96 hours against 102 hours for the C-5s, because the 500-ton payload HAs need only make one trip versus three for the 130-ton payload C-5.

From a cost standpoint, though a detailed cost comparison is outside the scope of this article, the HAs have a 3:1 advantage in fuel burned to accomplish the mission. Even in acquisition cost, the price to purchase 30 HAs, about $6B, is only 50 percent more than the $4B cost to the Reliability Enhancement and Reengineering Program for the 63 C-5s that are already in the inventory. If the comparison was made between buying 30 HAs and buying the 90 C-17s needed to accomplish this mission in the same length of time, the difference in cost is quite significant as it is estimated a 500-ton payload class HA would cost about the same as a C-17.

The ability of the HAs to operate from completely unimproved surfaces such as open fields also gives the Army more flexibility in the deployment than the C-5s. In this scenario the HAs could be operated from the drop zone at Fort Lewis, which is potentially more convenient than transporting the SBCT the 15 miles to McChord Air Force Base to be loaded on the C-5s. Similarly, when the HAs arrive in Korea they would not have to land at Kimhae AB should it be occupied to capacity by other aircraft. With full payload, but only destination fuel (fuel to fly 500 more miles) the HA is capable of operating out of a 1,500-foot circle, so if the Army wants the SBCT inserted closer to their eventual destination the HA should be able to do it.

Conclusion

Over the next several years the US Department of Defense has some very hard decisions to make regarding strategic airlift. If funding is not available to meet 54.5 MTM/D or more with conventional airlift, either sacrifices in capability must be made or an alternative will have to be found. This article presents a potentially viable alternative in the form of a hybrid aircraft.

When the author spoke to a United States Transportation Command (USTRANSCOM) officer to gauge their interest in airships he was told, “We looked at that a few years ago but dismissed it because none of the players were real companies.” Today, a key player in airships is Lockheed Martin, one of the largest aerospace companies in the world. On the other hand, AMC, and therefore to a certain

	HA	C-5
Number of aircraft	30	63
Number of flights	30	188
Cruise (knots)	100	490
Total time (hours)	96	102
Fuel (million pounds)	30	89

Table 2. Operational Comparison of HA versus C-5

extent USTRANSCOM, is currently working very hard to purchase a C-17 fleet of at least 222 aircraft and may not be interested in alternatives.

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Lessons from the First Deployment of Expeditionary Airpower

The lens of history speaks to many of the issues that are significant in today's expeditionary airpower environment. Particularly relevant are the lessons learned during first deployment of expeditionary airpower by the Royal Flying Corps during WWI. These include:

- The use of airpower is an expensive proposition.
- Maintaining aircraft away from home station demands considerable resources.
- Attrition from active operations is often very high.
- Effective support demands the ready availability of spares.
- Transport and protecting the transportation system is critical.
- Preserving mobility (the ability to redeploy quickly) is a constant battle.
- The supply system must be adequate in scope with a margin in capacity to meet unplanned events.
- The essential *lubricant* is skilled manpower.

Group Captain Peter J. Dye, RAF

Captain Kevin P. Dawson, USAF
Captain Jeremy A. Howe, USAF

Analyzing Air Force Flying-Hour Costs

Introduction

We've all, at one time or another, walked into a room and flipped on the light switch, only to hear the *pop* of a light bulb going out. In terms of wear and tear, is leaving a light turned on day and night a quicker route to failure than turning the switch on and off excessively? The light bulb is a good example of certain components that are more likely to fail when being turned on and off than operating continuously. This phenomenon is known as *failure on demand*. When Headquarters Pacific Air Forces (PACAF) asked the Air Force Logistics Management Agency (AFLMA) to evaluate the idea of flying more F-15C/D sorties at reduced average sortie duration (ASD), *failure on demand* was just one of a variety of component failure modes considered. In less than 1 month's time, the AFLMA team illustrated not only the proposed sortie duration change's impact to the cost per flying hour (CPFH), but also how varied modes of failure influence the nature of aircraft breaks.

In the end, the study team would identify five ways in which aircraft and parts fail, as well as the effect varying sortie durations have on each failure mode. The analysis indicated that CPFH will increase as ASD decreases, irrespective of the amount of sorties or hours flown. The research and findings contributed to PACAF's design of the Kadena AB F-15C/D flying-hour program. The results proved to be both rapid and beneficial, including most notably an 18 percent improvement in the mission capable rate after just 2 months time.

Background

When the study team was first approached, Kadena AB was experiencing a higher number of F-15 C/D maintenance issues than other F-15 C/D bases. For some time, mission capable (MC) rates had been approximately 20 percent lower than other F-15 C/D units, and Kadena AB had failed to meet any (all ten) Air Force F-15 C/D

Aircraft part costs for each fiscal year are broken down into consumable and repairable parts; however, this research aggregated these categories to simply aircraft parts. Aviation fuel represents the cost of fuel used throughout the fiscal year. Modifications and sustainment costs represent planned depot modifications and weapon system upgrades. CPFH is calculated by adding the three major cost variables and dividing by the number of hours flown throughout the fiscal year.

maintenance standards from May through June 2005.[1] With the intent of reducing an already heavy maintenance burden, Headquarters PACAF was considering the idea of reducing Kadena's F-15 C/D average sortie duration to reduce the overall number of flying hours accrued by each aircraft. However, PACAF maintenance leadership believed that reducing ASD would have a negative effect (increase) on the CPFH for Kadena's F-15 C/D fleet. In the absence of any measurable data that directly addressed this claim, the study team would need to address the following items:

- Define the CPFH model and the data used to compute hourly costs
- Identify Air Force maintenance metrics used to represent component failures
- Evaluate the factors contributing to component failure and reduced aircraft reliability
- Through statistical analysis, establish a lack of correlation between ASD and component failures

While the first three items could be accomplished through a review of existing literature and Air Force regulations, the last would require more extensive analysis. This analysis was necessary since illustrating a lack of correlation between ASD and component failures would validate the following sequence of logic:

- If component failures are not correlated to ASD, then an airframe can be expected to experience the same number of component failures per sortie, regardless of sortie duration.
- If an airframe experiences the same number of component failures per sortie, the same number of repair parts (consumable and repairable) will be required.
- If the same number of repair parts is required, the cost of parts will remain unchanged.

Once these assumptions were validated, changes in CPFH could be calculated, factoring in the following general assumptions:

- Modification costs will remain unchanged across all ASDs.
- The cost of aviation fuel will change linearly with changes in ASD. This assumption suggests that if ASD decreases by 10 percent, fuel consumption will

$$\frac{\text{Parts + Fuel + Modifications}}{\text{Hours Flown}} = \text{CPFH}$$

Equation 1. CPFH Calculation

also decrease by 10 percent and the resulting fuel costs will decrease by 10 percent. This assumption accounts for a worst-case scenario as fuel consumption will most likely not be linearly related to ASD because of the fact that excessive fuel burn is encountered during the takeoff phase of flight.

- For the purposes of valid cost comparison, paired scenarios must hold constant either the number of sorties or the number of hours flown. This is to ensure a fair comparison in the spirit of *apples to apples*. For example, it would not be valid to compare a 1.65 ASD, 500-sortie scenario (825 flying hours) with a scenario of 1.5 ASD, 600 sorties (900 flying hours).

Analysis and Research

Kimbrough identified the three major cost variables of the aircraft CPFH calculation model to be:

- Aircraft parts
- Aviation fuel
- Modifications and sustainment costs.[2]

Aircraft part costs for each fiscal year are broken down into consumable and repairable parts; however, this research aggregated these categories to simply *aircraft parts*. Aviation fuel represents the cost of fuel used throughout the fiscal year. Modifications and sustainment costs represent planned depot modifications and weapon system upgrades. CPFH is calculated by adding the three major cost variables and dividing by the number of hours flown throughout the fiscal year. Equation 1 illustrates this calculation.

Manuel discovered that 70 percent of total aircraft flying program costs were attributed to repair parts, 19 percent were attributed to aviation fuel, and 11 percent were attributed to modifications and sustainment.[3] Assuming these ratios can be applied to strategic CPFH models across any weapon system, we are able to estimate CPFH changes based on ASD and the number of sorties flown.

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Ebeling identified five different methods of inducing a failure:

- Hourly operation time
- Operating cycles
- Clock time
- Failures on demand
- Maintenance-induced failures[4]

Component failures attributed to *hourly operation time* should experience fewer failures per sortie as ASD (and the resulting total operating time) is reduced. However, if the number of *low ASD* sorties is increased to achieve the same number of flying hours as the baseline ASD, the number of *hourly operation time* failures will remain

The number of failures will remain unchanged for components failing on an operating hour distribution; therefore, these failures will not increase total aircraft operating costs for comparable flying hours.

unchanged. Components failing based on an *operating cycle* failure distribution, fail based on the number of uses. Therefore, flying the same number of sorties with a lower ASD will result in approximately the same number of operating cycle failures. However, increasing the number of sorties will result in increased failures based on operating cycles. Components failing on a clock time failure distribution should experience the same number of failures regardless of ASD or the number of sorties flown.

Failures on demand may occur when a system is turned on. Sometimes referred to as the *light bulb theory*, this failure mode pertains to light bulbs and many other electrical components that have a higher probability of failure when activated as opposed to normal operational loads.[5] In terms of applying this failure logic to aircraft sorties, if the number of sorties remains unchanged, the number of failures on demand—in this case, electrical failures as well as physical failures incurred during the event demands of aircraft takeoffs and landings—should remain unchanged as well. It follows then, that increasing the number of sorties will yield an increased number of failures on demand. Likewise, the number of maintenance-induced failures should increase, because more maintenance is required to repair an increased number of component failures and perform additional through-flight actions. A maintenance-induced failure is defined as a maintainer damaging a component during repair. The number of maintenance-induced failures increases as the amount of either scheduled or unscheduled maintenance increases. With more sorties, maintenance will increase.

Table 1 summarizes the effect of reducing ASD with respect to the number of component failures based on the different methods of inducing failures described above.

It can be seen from Table 1 that reducing ASD only results in a lower number of component failures when the number of sorties flown remains unchanged. Increasing the number of *low ASD sorties* to achieve the baseline flying-hour program will result in an increased number of component failures for three of the five different failure induction methods.

The number of failures will remain unchanged for components failing on an operating hour distribution; therefore, these failures will not increase total aircraft operating costs for comparable flying hours. Next, it is important to identify metrics capable of providing measurable data that would allow for the examination of failures based on operating cycles, failures on demand, and maintenance-induced failures.

Failure Rate Distribution	Lower ASD, Same Sorties (Reduced Flying Hrs)	Lower ASD, More Sorties (Constant Flying Hrs)
Operating Hours	Less	Same
Operating Cycles	Same	Increased
Clock Time	Same	Same
Failures on Demand	Same	Increased
Maintenance Induced	Same	Increased

Table 1. Impact of ASD, Sorties Flown, and Flying Hours on Component Failures

Of the numerous maintenance metrics tracked by the Air Force, three are of primary interest:

- Break rate
- Pilot-reported discrepancies (PRD)
- Ground abort rate

A secondary maintenance metric of interest is total not mission capable maintenance (TNMCM) time.

Aircraft break rate represents the number of Code 3 breaks divided by the total number of sorties flown.[6] A Code 3 break indicates that an aircraft has a major discrepancy in mission-essential equipment that may require repair or replacement prior to further mission tasking. The break rate is "an indicator of aircraft system reliability ... and is an excellent predictor of parts demand."[7] A sortie is considered to be one operational cycle for an aircraft at the strategic level, and break rates capture the number of grounding breaks per sortie. Break rates convey an expected number of *breaks* per operational cycle, and can supply data for components failing on an operating cycle failure distribution. PRDs can also be used as an indicator of breaks, and account for most Code 2 breaks and delayed discrepancies. A Code 2 break is one in which an aircraft has a minor discrepancy, but the aircraft is capable of further mission assignments.

The break rate is "an indicator of aircraft system reliability ... and is an excellent predictor of parts demand."

When an aircrew accepts an aircraft and then encounters a grounding maintenance condition, a ground abort occurs. Basically, this scenario indicates that an aircraft subsystem did not fail until it was placed under an operational load by the aircrew. Preflights and through-flights will test most systems for operability, however many systems will be powered down until crew arrival. Therefore, ground abort rates are the most suitable data source for identifying failures on demand.

Based on the reliability theory depicted in Table 1, the number of component failures should increase as the number of sorties flown increases. The study team hypothesized that the number of failures would increase at an amount proportional to the break rate. For example, a unit flying 100 sorties with a 15 percent break rate can expect to experience 15 failures. Likewise, flying 200 sorties should then result in approximately 30 failures. As the number of sorties increases, PRDs should also increase. TNMCM time should increase as well due to the added repair actions resulting from an increased number of component failures.

A critical piece of this analysis pertained to establishing that ASD has little to no impact on the break rate and number of PRDs reported. If ASD is correlated to break rate and PRDs, we cannot safely assume that aircraft, strategically speaking, fail on a cyclical basis (per sortie), as extended sorties may induce additional wear and tear on components. However, a lack of correlation between ASD and both break rate and PRDs would validate the aforementioned assumption.

Analyzing Air Force Flying-Hour Costs

Figure 1 shows the correlation matrices for PACAF F-15 C/D maintenance data delineated by command and base. These matrices show no direct relationship between ASD and break rate, nor do they show a direct relationship between ASD and the number of PRDs. Regression analysis confirmed a lack of correlation with an R^2 value of .1851 for ASD to break rate, and an R^2 of .0079 for ASD to PRDs. Therefore, it can be said that changes to ASD are unlikely to bear witness to significant changes in break rate or the number of PRDs. In other words, while the number of breaks will increase as the number of sorties increases, the rate at which the aircraft break remains unchanged.

With the statistical analysis complete, we are able to examine and discuss the specific impact of failures to CPFH under two distinct scenarios. The first is one in which the total number of flying hours is held constant; the second is one in which the total number of sorties is held constant.

ELMENDORF & KADENA COMBINED

	ASD	*Sorties*	*Hours*	*NMCM*	*PRDs*	*Break Rate*	*Fix Rate*	*GA Rate*
ASD	1							
Sorties	-0.423329	1						
Hours	0.459953	0.576527	1					
NMCM	-0.045099	0.100756	0.056012	1				
PRDs	-0.089061	0.432281	0.33525	0.825703	1			
Break Rate	0.430272	-0.51202	-0.131974	0.438816	0.244312	1		
Fix Rate	0.084292	0.039852	0.059803	-0.876954	-0.726926	-0.394789	1	
GA Rate	0.209038	-0.383863	-0.1771	0.467582	0.293111	0.455907	-0.536551	1

ELMENDORF

	ASD	*Sorties*	*Hours*	*NMCM*	*PRDs*	*Break Rate*	*Fix Rate*	*GA Rate*
ASD	1							
Sorties	-0.437363	1						
Hours	0.383377	0.639519	1					
NMCM	-0.048088	0.184529	0.144108	1				
PRDs	-0.048227	0.457789	0.423036	0.471886	1			
Break Rate	0.545413	-0.507781	-0.107503	0.047028	0.142843	1		
Fix Rate	0.086518	0.016116	0.095437	-0.533626	-0.261427	-0.083821	1	
GA Rate	0.228785	-0.3941	-0.202464	0.267789	0.131635	0.240222	-0.500488	1

KADENA

	ASD	*Sorties*	*Hours*	*NMCM*	*PRDs*	*Break Rate*	*Fix Rate*	*GA Rate*
ASD	1							
Sorties	-0.419614	1						
Hours	0.516478	0.52428	1					
NMCM	-0.118738	-0.089334	-0.150463	1				
PRDs	-0.2127	0.655179	0.436042	0.422141	1			
Break Rate	0.36924	-0.654058	-0.231923	0.543617	-0.079104	1		
Fix Rate	0.202313	0.185897	0.377599	-0.655427	-0.161726	-0.430747	1	
GA Rate	0.230726	-0.581919	-0.291922	0.49828	-0.071508	0.633967	-0.447102	1

KEY

Green Values Approaching 1
Positive Correlation

Red Values Approaching -1
Negative Correlation

Values near zero
No Correlation

Note: correlation does not indicate causality, merely that a linear trend may exist between two variables

Historical data does not indicate strong correlation between ASD and any performance measures

Figure 1. Correlation Matrices for PACAF F-15 C/D Maintenance Data

Flying Hours Held Constant

If ASD is reduced but the number of sorties is increased to maintain a desired flying-hour program, the number of *breaks* (Codes 2 and 3) will increase and the parts required to repair these breaks will also increase. The presumed increase would be linear and proportional to the increased number of breaks. Having established that the break rate remains relatively unaffected by ASD, it is valid to assume it will remain unchanged and produce additional breaks proportional to the increase in sorties flown. For this model, the assumption is that the cost of parts will increase proportionally to sorties flown. Depot modifications and equipment upgrades are planned and scheduled on a fiscal year basis, independent of sorties and flying hours. Therefore, the assumption can be safely made that the cost of modifications will also remain more or less the same over time regardless of ASD or number of sorties flown. Because the number of flying hours remains constant, we will assume the cost for fuel remains unchanged; however, we believe that, realistically, this cost should increase given the greater amount of fuel being expended during the increased number of takeoffs. Referring to equation 1, the increased cost for repair parts will raise the numerator value while all other variables (including the denominator) remain unchanged. With the numerator increasing, and the denominator held constant, we see an increase in CPFH. This model is represented in Figure 2, and although the data used in this research was notional ($6,000 original CPFH for a 1.5 ASD), the same trends are experienced regardless of the cost data used: CPFH increased as ASD was reduced.

Regression analysis confirmed a lack of correlation with an R^2 value of .1851 for ASD to break rate, and an R^2 of .0079 for ASD to PRDs. Therefore, it can be said that changes to ASD are unlikely to bear witness to significant changes in break rate or the number of PRDs. In other words, while the number of breaks will increase as the number of sorties increases, the rate at which the aircraft break remains unchanged.

Sorties Held Constant

If the same number of sorties is flown over different ASDs, the number of *breaks* (Codes 2 and 3) will remain unchanged and the parts required to repair these *breaks* will also remain unchanged. Furthermore, if the repair parts required remain

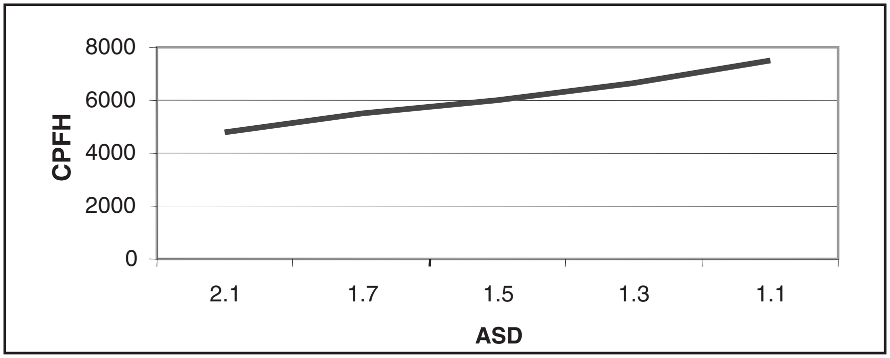

Figure 2. CPFH Estimates: Variable ASD, Variable Number of Sorties, Same Flying Hours

Analyzing Air Force Flying-Hour Costs

The findings of this research show that CPFH will increase as ASD decreases irrespective of the number of sorties or hours flown. The analysis indicates that reducing ASD cannot decrease the cost of aircraft repair parts, which accounts for approximately 70 percent of the total flying-hour program costs. Reducing ASD and pursuing the same flying-hour program increases the cost of repair parts and significantly contributes to an increased CPFH.

unaffected by changes in ASD, the cost of parts should remain relatively the same. Depot modifications and equipment upgrades are planned and scheduled on a fiscal year basis independent of sorties and flying hours. Therefore, we can safely make the assumption that the cost of modifications will also remain more or less the same over time regardless of ASD or number of sorties flown. As such, when measuring the effect of ASD changes on CPFH, we can hold constant the cost of parts and cost of modifications. With reduced ASDs, it follows that we will observe reductions in quantity of fuel consumed and total hours flown. Under a worst-case scenario, we could assume a perfectly linear relationship between fuel used (and consequently, cost of fuel) and hours flown. For this model, the cost of fuel was assumed to decrease proportionally to the reduction in flying hours (for example, 10 percent fewer flying hours would result in 10 percent lower fuel costs). Realistically, more fuel is likely expended at takeoff versus level flight, but for the purposes of this analysis, we assumed a linear relationship. Since the number of flying hours is simply a manipulation of ASD (that is, the product of ASD and the number of sorties), the same logic can be applied to ASD reduction. Referring to Equation 1 under this scenario, the numerator is decreasing while the denominator is also decreasing. CPFH will increase in this scenario as the numerator is not decreasing at the same rate as the denominator. Therefore, a direct comparison can be made between CPFH calculations for different ASDs. Due to the lack of operational data, notional cost data was used to populate the model represented in Figure 3. The numerical values of the CPFH change; however, the trend established in Figure 2 remains constant—CPFH increased as ASD was reduced.

Conclusions and Recommendations

The findings of this research show that CPFH will increase as ASD decreases irrespective of the number of sorties or hours flown. The analysis indicates that reducing ASD cannot decrease the cost of aircraft repair parts, which accounts for

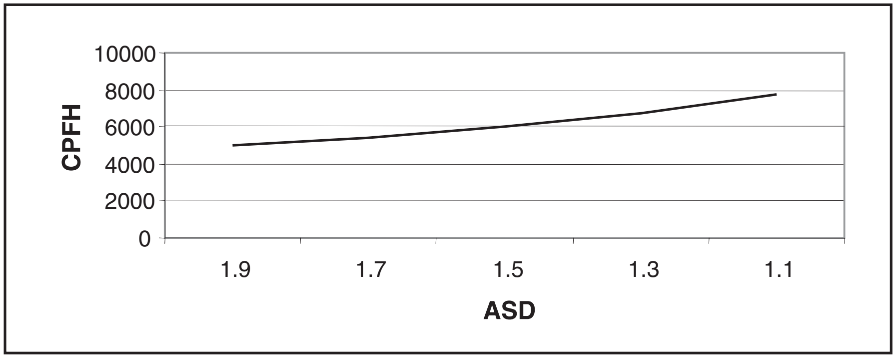

Figure 3. CPFH Estimates: Variable ASD, Same Number of Sorties, Variable Flying Hours

approximately 70 percent of the total flying-hour program costs. Reducing ASD and pursuing the same flying-hour program increases the cost of repair parts and significantly contributes to an increased CPFH. This scenario will require more maintenance effort to generate additional sorties and will require more maintenance effort to repair the additional aircraft breaks.

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7. *Ibid*.

Napoleon and Logistics Capacity

It should be recognized, however, that the worst shortages were experienced during the first 2 weeks of the advance (that is, precisely the period for which Napoleon had made his most careful and extensive preparations) and that the situation gradually improved afterwards. Also, the *Grande Armee's* problems were at all times, including the retreat from Moscow, largely due to bad discipline. This, of course, was itself partly due to logistics shortages. However, the fact remains that those units with commanders who were strict disciplinarians (for example, Davout's) consistently did better than the rest, while the Guard even managed to keep such good order that, far from running away, the inhabitants enthusiastically welcomed it. Nor is it true, as is so often maintained, that the country as a whole was too poor to support an army. Writing from Drissa early in July, Murat—operating as he was in an area which Pfuel had selected for the erection of his fortified camp precisely because it was supposed to be without resources—informed Napoleon that while the region around was tolerably well provided it would be possible to exploit it only after a proper administration was set up and an end put to the troop's marauding.

That the *Grande Armee* suffered enormous losses during its march to Moscow is true, as is the fact that hunger and its consequences—desertion and disease—played a large part in causing these losses. It would, however, be unwise to attribute this solely to the problems of supply. The need to protect enormously long lines of communication and to leave garrisons behind and the effect of distance *per se* were also factors of major importance. As regards the army's materiel losses, there is reason to believe much, if not most, of the equipment abandoned on the way to Moscow was later retrieved. In 1812, Napoleon's main force marched 600 miles, fought two major battles (at Smolensk and at Borodino) on the way, and still had a third of its number left when entering Moscow. In 1870, as in 1914, the Germans, operating over incomparably smaller distances, in very rich country and supported by a supply organization that became the model for all subsequent conquerors, reached Paris and the Marne respectively with only about half of their effectiveness. Compared with these performances, excellent as they were, the French Army of 1812, for all its supposedly worthless service of supply, did not do too badly.

Martin van Crevald, *Supplying War*

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Combat Support: Overseas Basing Options

Introduction

The global geopolitical divide that once defined US military policy faded away as communist governments in Eastern Europe collapsed and the Soviet Union disintegrated in the late 1980s and early 1990s. It was replaced by a security environment characterized both by a range of regional security threats and by a persistent global insurgency and counterinsurgency. The ability of US forces to provide swift and tailored responses to a multitude of threats across the globe is a crucial component of security in today's complex political environment. The Air Force, as with the other services, has responded by transforming itself into a more expeditionary force. To realize its goals of global strike and persistent dominance, it is vital that the Air Force support the warfighter seamlessly and efficiently in all phases of deployment, employment, and redeployment. One of the major pillars for achieving these objectives is a global combat support basing architecture.

This article focuses on an analytic framework for evaluating options for overseas combat support basing or forward support locations (FSL). The presentation of this framework is important because it addresses how to assess these options in terms of the relevant programming costs while considering a novel approach to scenario planning. This formulation minimizes the costs of facility operation, construction, and transportation associated with meeting the training and deterrent exercises needed to demonstrate US global power projection capability to deter aggression, while maintaining the necessary storage capacity and system throughput to engage in major combat operations.

This framework is based on the notion that US interests are not only global but dynamic as well, particularly when the United States is confronted with emerging anti-access and area denial threats. Consequently, the Air Force must be ready to deploy forces quickly across a wide range of potential scenarios.

RAND has developed a new framework that integrates the traditional threat-based assessments concept with capability-based planning. This framework relies on a sequenced, potentially simultaneous set of deployment scenarios, which was given the term multiperiod-multiscenario concept.

Development of a Multiperiod, Multiscenario Combat Support Planning Methodology

In recent years, the focus of contingency planners was on individual, deliberate, threat-based deployments. This led to supporting the warfighter by developing *optimal* combat support networks which were designed to counter known threats. An unfortunate characteristic of this type of designed network is that it often performs poorly if the set of demands, such as locations and quantities, differs from the plan. The new planning environment, with its broad and unclear set of potential adversaries, calls for robust and efficient combat support networks that meet operational requirements at reasonable costs over a wide range of contingencies.

The Air Force's new role in this environment will inevitably include a commitment to multiple, overlapping engagements in diverse geographical areas with varying degrees of operational intensity. Some of these engagements, such as drug interdictions, will occur multiple times over a short time horizon. To capture the nuances of the multifaceted, continuous deterrent environment, temporal and spatial elements with other parameters, such as combat support capability and costs must be integrated. These parameters are captured in a new planning methodology in which several likely deployment scenarios, from small-scale humanitarian operations to major regional conflicts, are considered. For any given scenario, decisions should be made regarding its likelihood of occurrence over time, its interrelationship with other scenarios, and its finality.

RAND has developed a new framework that integrates the traditional threat-based assessments concept with capability-based planning. This framework relies on a sequenced, potentially simultaneous set of deployment scenarios, which was given the term *multiperiod-multiscenario (MPMS)* concept. This methodology is a major departure from the current war planning mindset. Previously, whether planning for nuclear warfare against the Soviet Union or for large-scale conventional war in the Near East, US analysts were planning for one large conflict that would occur only once and that would change the defense environment so greatly that plans for outyears following this conflict would no longer be valid.

The Geopolitical Environment

One of the United States' major defense policy goals is to deter threats and coercion against US interests anywhere in the world. This multifaceted approach requires forces and capabilities that discourage aggression or any form of coercion by placing emphasis on peacetime forward deterrence in critical areas of the world. In addition, US forces must maintain the capability to support multiple conflicts if deterrence fails. [1] Air Force core competencies, such as agile combat support, global attack, and rapid global mobility, reflect these changes in the global threat environment. *Global attack capability* is defined as "the ability to engage adversary targets anywhere, [and] anytime." *Rapid global mobility* is defined as "the ability to rapidly position forces anywhere in the world." [2]

The Air Force can rapidly airlift forces anywhere in the world if those forces are sufficiently small, and if the airlift capacity is not consumed by other requirements elsewhere. However, the United States' strategic policy goals and the reality of today's security environment require a capability that can project a continuum of power both swiftly and globally. Doing so requires a combat support system that has both the agility and the adaptability to support a broad range of potential engagements anywhere in the world.

US Operations and Exercises Since 1990

It has been more than a decade since the end of the Cold War, and in that period US forces have been involved in numerous operations and conflicts. Although the United States does not respond to every crisis in the world, the regions of the world in which it has conducted operations reflect the strategic interests of the United States and its allies. Many of the deployments have occurred in regions where the United States has either a permanent support infrastructure, such as Europe, or a long-standing presence, such as the Near East. However, a large number of recent deployments have required US forces to enter new locations that had neither existing US infrastructure nor a historical US presence. Factoring in the relative paucity of these locations' organic logistics infrastructure, these operations and exercises have frequently required deployments to bare bases, with the associated heavy use of combat support assets. The remainder of this section outlines several potential military and nonmilitary operations in the Near East, the Asia-Pacific, Central Asia, South America, Europe, and Northern and Sub-Saharan Africa. The type and the location of potential operations were selected to reflect both historical US involvement and potential locations where future conflicts might intersect with US interests. We were also mindful of selecting a set of operations that would place varying stresses on the combat support system so we could evaluate a wide range of demands on the combat support requirements.

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Near East

Despite the demise of the Baathist regime in Iraq, the US military will continue to be involved in Iraq for the foreseeable future. Moreover, most nations in that region have authoritarian governments.[3] There is a potential for instability in many of these governments, which may not be able to cope with growth in popular unrest. The potential growth of fundamentalism in many Islamic countries may also contribute to further volatility in this region. Although Iran may eventually become friendlier with the United States, its current system of government, with a powerful nonelected head of state, has severely hampered any movement toward normalization of relationships. Crises such as a regime change in Saudi Arabia would further change the security environment in the Persian Gulf and may consequently increase the importance of Iran's role in the region.[4] A destabilized Saudi Arabia and a potentially prolonged interruption of the flow of oil would have severe consequences for the United States and the global economy.[5] Currently, the most immediate threats may be the proliferation of weapons of mass destruction and the increase in insurgency movements.

In our analysis we use different types of Southwest Asia (SWA) scenarios to simulate different-sized regional conflicts and to measure the combat support capabilities of alternative FSLs. We also give attention to Eastern Africa, with the Horn of Africa playing an important strategic role.

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Asia-Pacific

Over the past 50 years in the Asia-Pacific region, the United States has focused on the security of South Korea and has established support plans for containing North Korea. Although the United States may not be challenged by a *near-peer* for the near future, the potential exists for regional powers to develop capabilities to threaten US interests. Asia is also a region where there could be large-scale challenges to the US military. China, in particular, may emerge as a more powerful maritime force in the future, challenging the US Navy and Air Force dominance in the Pacific. Although China may not match the advanced military power of the United States, it could play an *asymmetric game* in the region by taking advantage of its vast coastline, as well as the large geographic extent of its rear base that reaches all the way to Central Asia.[6] China, in essence, could occupy the same role in the Pacific in this century that the Soviet Union played in Europe in the latter half of the twentieth century. Therefore, *near-peer* scenarios, such as Taiwan-China or China-Russia, can be used to assess the effect of potential FSLs in these very stressing scenarios.

The sea-lanes of the South China Sea and the waters surrounding Indonesia are transited by nearly half of the world's merchant marine capacity. These areas are also critical to the movement of US forces from the Pacific to the Indian Ocean and beyond. Although the end of the Cold War has reduced the clear and immediate global military threat, the potential for both conventional and nonconventional threats still exists. One of the growing concerns is the threat of piracy and its connection to terrorism. Another issue is the overlapping claims to the South China Sea by China, Taiwan, and several Southeast Asian countries all laying claims to some or all of the Spratly Islands.[7] The distances in this region are vast, and US basing and enroute support infrastructure are not as rich as in other important regions. Other potential scenarios in this region include counterterrorism activities in Indonesia or the Philippines and counterinsurgency operations in the Philippines.

Central Asia

The support of some Central Asian countries in Operation Enduring Freedom (OEF), the ongoing US military presence in Afghanistan, and the rich oil reserves of the Caspian Sea region—combined with potential conflicts in the Caucasus and Central Asia—have brought this region to the attention of many policymakers. However, the poor infrastructure of the Central Asian region provides a test to any combat support capability. Moreover, the trepidation of some North Atlantic Treaty

Organization (NATO) allies to project force into the region because of its proximity to Russia could put most of the burden on the United States.[8]

Some Central Asian countries may be able to play a role in supporting the Air Force's continued efforts in Afghanistan or potentially in an Indian-Pakistani conflict. Furthermore, we are interested in measuring the effectiveness of our global storage and maintenance system in supporting the US response to a potential conflict in this region. For example, the tension between the ethnic Kazakh and Russian populations of Kazakhstan could hypothetically trigger a civil war that would lead to the secession of the northern provinces of Kazakhstan or even Russian occupation of part or all of the country.

South America and Caribbean

The United States' continued efforts in antidrug activities in South America is likely to be the main focus for the military in this region.[9] Nevertheless, economic and political upheavals could require differing military roles for US forces in the future. In this region of the world, planning concentrates on small-scale operations that would mostly involve special operations force.

Europe

The United States has strong historical ties with Europe, with dozens of US bases located across the continent. In the near term, it is hard to imagine any major conflicts in Europe such as the ones in the former Yugoslavian states that culminated with Operation Allied Force. Nevertheless, we will include a variation of a Balkan scenario to test United States Air Forces in Europe combat support capabilities. In addition, we assume a continued European role as a support command, as in OEF and Operation Iraqi Freedom.

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Africa

Northern and Sub-Saharan Africa continue to be plagued with civil wars, ethnic or clan-based conflict, and severe economic disasters. The 2003 civil war in Liberia led to the deployment of Nigerian peacekeepers with a small US force in the country.[10] In 2002, with the help of Britain and a large United Nations peacekeeping mission, the West African state of Sierra Leone emerged from a decade of civil war. More than 17,000 foreign troops disarmed tens of thousands of rebels and militia fighters.[11] The Gulf of Guinea in West Africa, particularly Nigeria, has become a strategic interest of the United States because of an increased oil export to the world market.

Recent developments in Northern Africa have been encouraging, with Libya pledging to abandon its pursuit of nuclear weapons. However, the continued threat of insurgencies in Algeria and the Western Sahara may require future US involvement in Northern Africa. The countries of this region continue to be sources of Islamic fundamentalist groups, providing pools of recruits and staging areas for terrorist acts, most notably the Casablanca bombing of May 2003, and possibly the subway attack in Spain on March 11, 2004. Across Africa, political instability and high levels of violence may continue to persist. The potential for extraction of large volumes of oil from African nations may add to their geopolitical importance. In this region of the world, we concentrate our scenarios on humanitarian support requiring a small-scale aerospace force presentation.

The Tenets of Deployment Scenarios

The primary approach attempts to minimize the overall system cost while meeting operational requirements. The other approach focuses on maximizing the support capability (for example, reducing the time to initial operating capability).

In keeping with the new security paradigm and the concept of MPMS, we constructed a deployment framework using the following tenets.

- Although it is impossible to select combat support bases without specific operational deployments, the selection process should not be slaved to a particular deployment. For that reason, we do not seek to optimize the system for a handful of deployments alone.
- Combat support requirements should be dynamic and deployment scenarios should cast a wide geographical net in order to stress the combat support and transportation requirements.
- Deployments should be sequenced in time and space in order to evaluate physical reach and test long-term effects of location and allocation of assets.
- To hedge against the uncertainty of the future security environment, multiple series of possible scenarios should be developed to test the robustness of the overseas combat support bases.

Analysis Approach

To evaluate and select alternative forward-basing options, we developed an analytic framework that uses an optimization model to assess the cost and capability of various portfolios of overseas combat support basing or FSLs for meeting a wide variety of global force projections.

We have taken two complementary approaches in developing the optimization model. The primary approach attempts to minimize the overall system cost while meeting operational requirements. The other approach focuses on maximizing the support capability (for example, reducing the time to initial operating capability [IOC]). Examining the costs of alternative support basing options, for a constant level of performance against a variety of deployments, is an important process in the development of suitable programming and budgeting plans. In this approach, we are careful to ensure that adequate capacity is maintained to meet requirements as specified in the defense planning scenarios.

Our analyses show the costs and deployment timelines for various FSL options under different degrees of stress on combat support while taking into account infrastructure richness, basing characteristics, deployment distances, strategic warning, transportation constraints, dynamic requirements, and reconstitution conditions. We developed several sets of deployment scenarios using the MPMS concept, with each including training exercises, deterrent missions, and major combat operations (MCO). These so-called *streams of reality* allow our model to measure the effect of timing, location, and intensity of operational requirements on combat support—and vice versa. We develop several of these streams (or *timelines*) to account for the inherent uncertainties in future planning associated with each timeline.

After we determined the desired requirements in terms of combat support resources, our optimization model, the *RAND Overseas Basing Optimization Tool*, selects a set of locations that would minimize the costs of supporting these various deterrence and training exercises while maintaining the capability to support major regional conflicts should deterrence fail. This tool essentially allows for the analysis of various *what-if* questions and assesses the solution set in terms of resource costs for differing levels of combat support capability.

Our analytic approach has several steps, (Figure 1) as seen below.

- We first select a diverse set of deployment scenarios that would stress the combat support system. These deployments include small-scale humanitarian operations, continuous force presentation to deter aggression, and major combat operations.
- The deployments and the force options drive the requirements for combat support, such as base operating support equipment, vehicles, and munitions.
- These requirements, the set of potential FSLs and forward operating locations (FOL), and the transportation options, such as allowing sealift or not, serve as the inputs to the optimization model.
- The optimization model selects the FSL locations that minimize the FSL facility operating and transportation costs associated with planned operations, training missions, and deterrent exercises that are scheduled to take place over an extended time horizon, satisfying time-phased demands for combat support commodities at FOLs. Major combat operations are included in this analysis to

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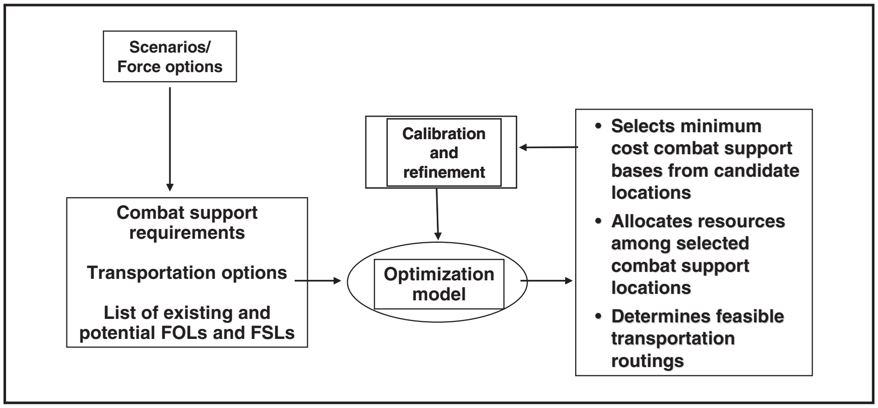

Figure 1. Overview of the Analytic Process for the Optimization Model

The end result of this analysis is a portfolio containing alternative sets of FSL postures, including allocations of war reserve materiel to the FSLs, which can then be presented to decisionmakers. This portfolio will allow policymakers to assess the merits of various options from a global perspective.

ensure that the resulting network has sufficient capability to allow for such operations should deterrence fail. The transportation costs associated with these operations are not considered in the model because of the different funding mechanisms for the execution of combat operations. The model also optimally allocates the programmed resources and commodities to those FSLs. It computes the type and the number of transportation vehicles required to move the materiel to the FOLs. The result is the creation of a robust transportation and allocation network that connects a set of disjointed FSL and FOL nodes.

- The final step in our approach is to refine and recalibrate the solution set by applying political, geographical, and vulnerability constraints based on current expert judgments concerning the global environment. Since this step is applied post optimally and may make additional iterations necessary, it may require reevalution and reassessment of the parameters and options chosen.

The end result of this analysis is a portfolio containing alternative sets of FSL postures, including allocations of war reserve materiel (WRM) to the FSLs, which can then be presented to decisionmakers. This portfolio will allow policymakers to assess the merits of various options from a global perspective.

Combat Support Factors

Several major constraining and contributing factors affect the capability of FSLs to support the warfighter. Our analytic framework takes each of these parameters into account in its process of selecting an optimal set of combat support locations.

- **Base Access.** This important issue deserves careful consideration and must be addressed before each conflict or operation. However, rather than eliminating some sites a priori because of potential political access problems, we allowed the model to select the most desirable sites based on other factors first. We then *forced* specific sites out of the solution set if we had reason to believe that these sites presented access issues—thereby providing the economic cost of restricting the solution to politically acceptable sites.
- **Forward Support Location Capability and Capacity.** The parking space, the runway length and width, the fueling capability, and the capacity to load and offload equipment are all important factors in selecting an airfield to support an expeditionary operation.[12] Runway length and width are key planning factors and are commonly used as first criteria in assessing whether an airfield can be selected.
- **Airlift and Airfield Throughput Capacity.** Timely delivery of combat support materiel is essential in an expeditionary operation. However, a mere increase in the aircraft fleet size may not improve the deployment timelines. The fleet size must always be determined with respect to the throughput capacity of an airfield.

The maximum-on-ground (MOG) capability, for example, directly contributes to the diminishing return of deployment time as a function of available airlift.

- **Forward Operating Location Distance**. Distance from FSLs to FOLs can impede expeditionary operations. As the number of airlift aircraft increases, the difference in deployment time caused by distance becomes less pronounced. Adding more airlifters to the system will reduce the deployment time, albeit at a diminishing rate, until the deployment time levels off as a result of MOG constraints.
- **Modes of Transportation.** There are several advantages to using sealift or ground transportation in place of, or in addition to, airlift. Allowing for alternative modes of transportation might bring some FSLs into the solution set that otherwise may have been deemed infeasible or too costly. Ships have a higher hauling capacity than do aircraft and can easily carry outsized or super-heavy equipment. In addition, ships do not require overflight rights from any foreign government.
- **Afloat Prepositioning.** We examined the potential for storing combat support resources (munitions and nonmunitions) aboard an Afloat Preposition Fleet (APF). Although afloat prepositioning does offer additional flexibility and reduced vulnerability versus land-based storage, the APF is much more expensive than land-based storage and presents a serious risk with regard to deployment time. Even if a generous advance warning is assumed to allow for steaming toward a scenario's geographic region, it can be difficult to find a port that is capable of handling these large cargo ships. The requirements placed on the port, including preemption of other cargo movement, also restrict the available ports that can be used by an APF.
- **Cost.** The main objective of the model is to reduce the total cost of exercises and deterrent missions while meeting the time-phased operational demand for combat support resources—for those missions as well as for major combat operations. These costs include construction and expansion of facilities and operations and maintenance and transportation for peacetime and training missions. Incorporated in each of these costs is the effect of differences in regional cost-of-living or country cost factors.

Results and Recommendations

We focused on three of the most important combat support resources—basic expeditionary airfield resources (BEAR),[13] munitions, and rolling stock such as trucks. These resources comprise the bulk of many of the consumable and repairable items in the combat support package. In the case of munitions, they pose storage and transport complexities.

We focused on three of the most important combat support resources—basic expeditionary airfield resources, munitions, and rolling stock such as trucks. These resources comprise the bulk of many of the consumable and repairable items in the combat support package. In the case of munitions, they pose storage and transport complexities.

From the outset of the study, we attempted to answer two basic questions. First, how capable are the Air Force's current overseas combat support bases of managing the future environment? Second, what are the costs and benefits of using additional or alternative overseas combat support bases for storing heavy combat support materiel?

Combat Support: Overseas Basing Options

We devised five different streams of reality—or deployment timelines—to represent a wide range of possible future Air Force deployments across the globe.

To answer these questions, we devised five different *streams of reality*—or deployment timelines—to represent a wide range of possible future Air Force deployments across the globe. (Table 1)

The baseline scenario, or the *most likely global deterrent scenario*, places the focus on supporting a number of deployments in the Persian Gulf region, Asian littoral, and North Africa over a time horizon of 6 years, in keeping with the future years defense program (FYDP) convention. Figure 2 represents the size in terms of combat support requirements, and the timing of each deployment for the base scenario. The sizes of recent deployments are given on the y-axis as a reference. Notice that we have *scheduled* the major combat operations in each scenario for execution at the end of the FYDP period. This approach focuses attention on providing resources to support deterrent deployments. It ensures their funding while also placing major combat operations requirements in the planning, programming, budgeting, and execution process.

Selection of Existing Combat Support Bases

We solved the problem of finding the least-cost bases that would satisfy operational requirements using existing forward support locations. For this example it was Ramstein Air Base. The model selected 11 FSLs (Table 2). These locations represent the optimal locations to support the baseline scenario. Although the model was allowed to select from the four existing munitions preposition ships, none was chosen unless infrastructure expansion at the existing land-based FSLs was excluded from the solution. In that case, a single APF ship assigned to the Arabian Sea was used to compensate for the lack of storage space at the land-based FSLs.

	Base Scenario	Stream 1	Stream 2	Stream 3	Stream 4
Year 1	SWA 1	SWA 3	SWA 1	South America 2	Spratleys
	Singapore	South Africa	Horn Africa	Cameroon	Chad
		East Timor		Singapore	
Year 2	Central Asia	Thailand	Central Asia	SWA 3	South America 1
	Thailand	Sierra Leone	Liberia	Thailand	Horn of Africa
				Haiti	
Year 3	Horn of Africa	Spratleys	Balkans	Taiwan	SWA 2
	SWA 2	Haiti	Rwanda	South Africa	Singapore
		Chad			
Year 4	Thailand	Balkans	Singapore	Spratleys	Taiwan
	India	Egypt	Cameroon	Egypt	Haiti
			India		
Year 5	SWA 2	SWA 1	SWA 2	SWA 1	SWA 2
	North Africa	North Africa	Taiwan	Rwanda	East Timor
		Liberia	Sierra Leone	East Timor	
Year 6	Egypt	Central Asia	Spratleys	Central Asia	SWA 1
	Taiwan	India	Chad	North Africa	Rwanda
		Cameroon	Thailand	Singapore	
Year 7+	MCO1	MCO1	MCO1	MCO1	MCO1
	MCO2	MCO2	MCO2	MCO2	MCO2

Table 1. Sequencing of Scenarios by Timeline

Ramstein AB, Germany	Seeb, Oman
Sigonella AB and Camp Darby, Italy	Thumrait, Oman
RAF Mildenhall and Welford, UK	Kadena, Japan
Al Udeid AB, Qatar	Andersen AB, Guam
Sheik Isa, Bahrain	Diego Garcia, UK
Masirah Island, Oman	

Table 2. Optimal Existing FSLs to Support the Baseline Scenario

Ramstein, Germany	Sheik Isa, Bahrain
Sigonella and Camp Darby, Italy	Thumrait, Oman
Mildenhall and Welford, UK	Incirlik, Turkey
Al Udeid AB, Qatar	Clark Field, Philippines
Masirah Island, Oman	Paya Lebar, Singapore
Andersen AB, Guam	U-Tapao, Thailand
Diego Garcia	Balad, Iraq
Kadena, Japan	Seeb, Oman

Table 3. Optimal FSLs from an Expanded Set to Support the Baseline Scenario

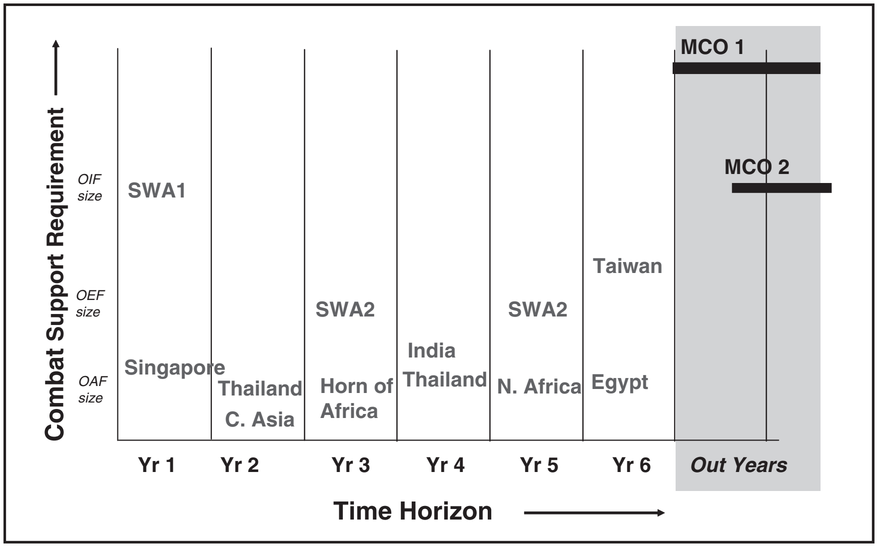

Figure 2. *Most Likely* or Baseline Scenario

The baseline scenario, or the most likely global deterrent scenario, places the focus on supporting a number of deployments in the Persian Gulf region, Asian littoral, and North Africa over a time horizon of 6 years, in keeping with the future years defense program convention.

We assessed the capabilities of the selected FSLs (Table 2) against the remaining four timelines. These FSLs, along with an additional site at Eielson Air Force Base, were able to meet the demand for three of the four additional streams, although with

Combat Support: Overseas Basing Options

We generated a list of potential FSL locations around the globe that could support a wide range of deployments. As before, the model selected an optimal list for the baseline scenario—the most likely scenario.

increased transportation requirements and costs. However, for Stream 4, the 10-day IOC requirement had to be relaxed to 12 days for the South American deployment, and a single munitions ship, with Guam as its home base, appeared in the solution.

Selection of Additional Combat Support Bases

The next step was to evaluate existing and potential FSLs against the baseline scenario and the four alternative streams of reality. We generated a list of potential FSL locations around the globe that could support a wide range of deployments. As before, the model selected an optimal list for the baseline scenario—the *most likely* scenario. The earlier 11 existing sites presented in Table 2 remained in the solution (the model selected them again), along with five new sites in Europe and Asia: Incirlik, Turkey; Clark Field, Philippines; Paya Lebar, Singapore; U-Tapao, Thailand; and Balad, Iraq (Table 3). It should be noted that the list in Table 3 is by no means sacrosanct, and alternative sites may provide the same capability at a similar or marginally greater cost. In particular, Souda Bay, Greece; Akrotiri, Cyprus; Constanta, Romania; or Burgas, Bulgaria may be suitable alternatives to Incirlik, Turkey. In addition, some realignment of existing sites may be more efficient and effective than current sites. For example, the port of Salalla in Oman could be used to meet some requirements met by Seeb or Thumreit with lower cost and less time than the current sites. The new combination of existing and potential FSLs offers about 30 percent savings in total costs by reducing the overall transportation cost to the system.

Figure 3 illustrates the final results from the combination of the baseline scenario and the four other streams of reality. This figure also shows the locations of the

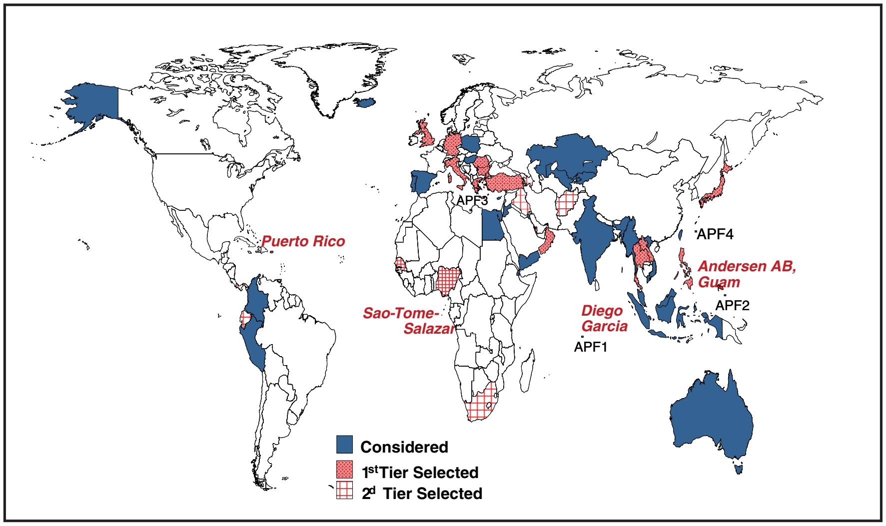

Figure 3. Supporting Global Deterrence Using a Global Set of Overseas Bases

Tier 1	Tier 2
Al Udeid AB, Qatar	Louis Botha, South Africa
Andersen AB, Guam	Bagram, Afghanistan
Diego Garcia	Baku, Azerbaijan
Kadena, Japan	Roosevelt Roads, Puerto Rico
Masirah Island, Oman	Tocumen, Panama
Mildenhall and Welford, UK	Cotipazxi, Ecuador
Ramstein, Germany	Sao Tome/Salazar, Sao Tome
Seeb, Oman	Kaduna, Nigeria[b]
Sheik Isa, Bahrain	Balad, Iraq
Sigonella and Camp Darby, Italy	
Thumrait, Oman	
Clark Field, Philippines	
Incirlik, Turkey	
Paya Lebar, Singapore	
U-Tapao, Thailand	
Souda Bay, Greece[a]	

[a] Alternatives to Souda Bay, Greece, are Akrotiri, Cyprus; Burgas, Bulgaria; or Constanta, Romania.
[b] An alternative to Kaduna, Nigeria, may be Dakar, Senegal.

Table 4. Global Set of Overseas Bases

For each stream the expanded set of FSLs offer the same capability at a reduced overall cost to the Air Force.

other candidate sites that were not selected by the model. It and the accompanying Table 4 divide these locations into Tier 1 and Tier 2 categories. We use the label *Tier 2 FSLs* for a set of FSLs that require a more detailed consideration as potential sites. They may also have appeared in the solution as a result of one or two individual deployments, and therefore their role is closely fixed to the nature of those particular deployments. Additionally, all the Tier 2 FSLs, with the exception of Puerto Rico, have uncertain political futures or limited internal capabilities. Iraq, for example, falls in this category, but its location for support of many operations makes it invaluable. However, we emphasize that the focus should not be on a particular latitude and longitude but rather on a particular region. Balad, Iraq, would be suitable if all the issues of security and long-term political amenities were resolved. If the uncertainties continue, then an alternative location in the region with similar capabilities should be considered.

Figure 4 presents the costs for the base scenario and all four streams. For each stream the expanded set of FSLs offer the same capability at a reduced overall cost to the Air Force. Note especially that the set of existing land-based FSLs could not support Stream 4 requirements and required that the IOC deadline be extended from 10 to 12 days and also required the use of an APF munitions ship. However, when we selected from the expanded set of land-based FSLs, the need for the afloat option disappeared. The advantage of the global basing option is not limited to cost and

Combat Support: Overseas Basing Options

For each stream, the model was able to make better use of trucks and high-speed sealift for the expanded pool of bases, yielding about 50 percent less airlift usage without compromising operational requirements.

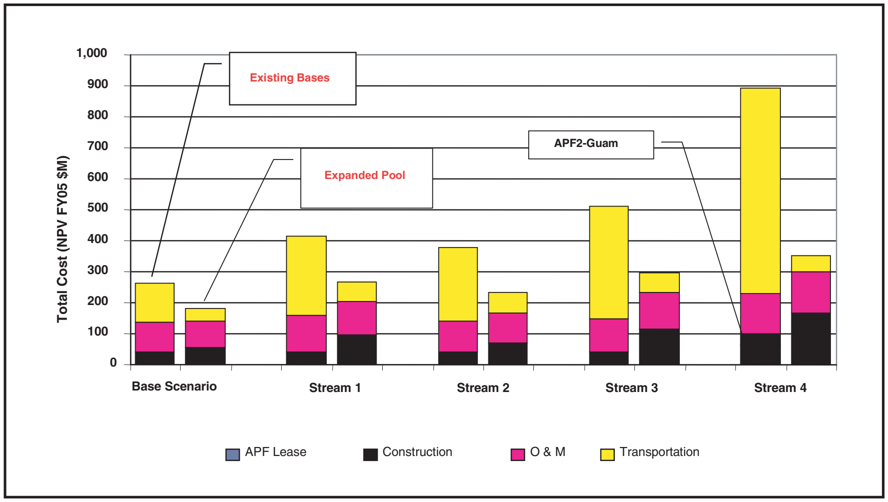

Figure 4. Total Cost of Supporting All Scenarios Using Existing and Expanded Set of FSLs

encompasses a more efficient use of multimodal transportation. For each stream, the model was able to make better use of trucks and high-speed sealift for the expanded pool of bases, yielding about 50 percent less airlift usage without compromising operational requirements.

Recommendations

We make the following recommendations based on our analysis of overseas combat support basing options.

- **Using a global approach to select combat support basing locations is more effective and efficient than allocating resources on a regional basis.** One of the strengths of the analytic framework chosen is the lack of regional command boundaries. We are able to look at all regions of the world simultaneously with operations occurring in various locations at the same time, thereby extracting the most efficient solution without adversely compromising the capability needs of a particular region.
- **Political concerns need to be addressed in any decision about potential overseas basing locations.** For instance, while an APF is much more expensive than alternative land-based storage options and may suffer from increased risk in deployment time, it may be necessary to consider the APF option because it offers more flexibility if access is denied. Additionally, countries like Iraq are continually selected by the model because cost and time are its major driving criteria. However, the uncertainty surrounding the future of Iraq (and similar

countries) should force us to pause and consider alternative sites that may be less desirable mathematically but offer a higher probability of access and stability.

- **Closer attention should be paid to Africa both as a source of instability and as a possible location for combat support bases.** Africa, with its potential as a source of future oil combined with the uncertain future of many of its nation states, requires a great deal of attention from policymakers. Northern and Sub-Saharan Africa continue to be plagued by civil wars, ethnic, or clan-based conflicts, and severe economic disasters. There is an increased likelihood that terrorists may seek haven in the remote areas of Africa because of the continued US military presence in the Middle East and Southwest Asia. Also, the geopolitical importance of the region, with its high levels of oil production, makes it an area of interest to the United States. If deployments to the region increased in the future, the current set of bases would not support those operations. Possible FSL locations in Africa could support operations across the entire southern half of the globe. Although the initial construction costs for these bases would be high, the costs would be quickly offset by the reductions in transportation costs. As an initial phase, we recommend closely evaluating western regions of Africa, with particular attention to Nigeria, Sao Tome/Salazar, and Senegal, along with South Africa.
- **Some Eastern European nations should be considered as serious candidates for future overseas bases.** The potential for continued conflicts in central Asia and the Near East has made many of the countries in the eastern part of Europe very attractive as potential storage locations for WRM. The appeal of this region has been further heightened by the inclusion of some of these countries in the European Union and NATO, combined with the lower cost of living and the relatively large professional labor market. Romania and Bulgaria in Eastern Europe, along with Mediterranean locations such as Greece and Cyprus, form an appealing region that would allow easy access to both the United States Central Command and the United States European Command areas of responsibility. These locations are especially attractive because they allow for multimodal transport options, using Black Sea ports for Romania and Bulgaria, assuming passage through the Bosporus Strait in Turkey to the Mediterranean. Poland and the Czech Republic, although very accommodating to US efforts in the current operations, are located relatively far from the potential deployments that were considered in this report. Also, the Czech Republic is a landlocked state, and while Poland has significant coastline on the Baltic Sea, these ports do not allow for rapid transport to the regions of Air Force interest. In terms of transportation time and cost, Germany can provide a better capability than either Poland or the Czech Republic, because of existing US installations.
- **Southeast Asia offers several robust options for allocation of combat support resources.** The remoteness of Guam and Diego Garcia from most potential

conflicts in the region requires the consideration of other locations in the Pacific. The geographical characteristics of the United States Pacific Command put a heavy reliance on airlift and possibly fast sealift. Most of the current US bases are located in Japan and the Korean Peninsula with the main purpose of supporting the Korean deliberate plan. To support other possible contingencies, we propose a closer examination of three locations—Thailand, Singapore, and the Philippines. Each of these locations offers a host of options for the Air Force, including storage space, adequate runway facilities, proximity to ports, and strategic location. Darwin, Australia, has many of the desired attributes for an overseas combat support base, but its remoteness to most potential conflicts makes it a comparatively poor choice.

- **Potential future operations in South America may be greatly constrained unless additional infrastructure in the region is obtained.** In our analysis, a large South American scenario obtained from the defense planning scenarios overstressed the system of existing facility locations, preventing the satisfaction of a 10-day IOC deadline, even with the use of APF ships. While the states of South America are relatively stable, the recent difficulties in Ecuador, Bolivia, and Venezuela demonstrate the potential volatility of the region. As with Africa, future US intervention cannot be discounted owing to significant US interests in the region's oil supply. Although the current combat support infrastructure is sufficient for small-scale operations such as drug interdiction, an expanded combat support presence would facilitate larger-scale operations in the region.
- **Multimodal transportation option is the key to rapid logistics response.** RAND has shown in several earlier reports that overreliance on airlift may in fact reduce response capability because of throughput constraints and lack of airlift.[14] A comprehensive mobility plan should include a combination of air, land, and sealift. Judicious use of trucks and high-speed sealift in fact may offer a faster and less expensive way to meet the Air Force's mobility needs.

Notes

1. United States Department of Defense, "Military Transformation: A Strategic Approach," fall 2003.
2. United States Air Force, "Air Force Strategic Plan, Long-Range Planning Guidance, Volume 3," May 2000.
3. The main exception is Israel, which is democratic. It is certainly too early to assess the outcome of Iraq's recent elections.
4. For more information on Iran and its security strategies see the following publications:
   Daniel Byman, Shahram Chubin, Anoushiravan Ehteshami, and Jerrold Green, *Iran's Security Policy in the Post-Revolution Era*, Santa Monica, California: RAND Corporation, MR-1320-OSD, 2001.
   Shahram Chubin, "Whither Iran? Reform, Domestic Politics and National Security," Adelphi Paper, Issue 342, The International Institute for Strategic Studies, 2002.
5. Sokolsky, Richard, Stuart E. Johnson, and F. Stephen Larrabee, *Persian Gulf Security: Improving Allied Military Contributions*, Santa Monica, CA: RAND Corporation, MR-1245-AF, 2000.

6. As a simple illustration of the size of the US and Chinese navies, consider the following: The U.S. Navy's warships have a total "full-load displacement" of about 2.9 million tons, whereas China's have less than 300,000 tons. The United States deploys 24 aircraft carriers (out of world's 34); China deploys none.
7. Khalilzad, Zalmay, and Ian Lesser, *Sources of Conflict in the 21st Century*, Santa Monica, CA: RAND Corporation, MR-897-AF, 1999.
8. Sokolsky, Richard, Stuart E. Johnson, and F. Stephen Larrabee, *Persian Gulf Security: Improving Allied Military Contributions*, Santa Monica, CA: RAND Corporation, MR-1245-AF, 2000.
9. At the urging of Peru and Colombia, President Bush may authorize the resumption of antidrug surveillance flights over Colombia. (*The New York Times*, August 6, 2003)
10. The role of American troops was confined to assisting with logistics, reflecting the general uneasiness of the Pentagon over making a long-term commitment while US troops were heavily committed in Afghanistan and Iraq (*The New York Times*, August 5, 2003)
11. A short description of this action may be found on the BBC News Web site, [Online] Available: http://news.bbc.co.uk/1/hi/world/africa/country_profiles/1061561.stm (last accessed October 7, 2005).
12. In our analysis, some of these factors are computed parametrically in order to assess a minimum requirement of a potential field for meeting a certain capability.
13. BEAR provides the required airfield operational capability (such as housekeeping or industrial operations) to open an austere or semi-austere airbase.
14. Amouzegar, Mahyar A., Robert S. Tripp, Ronald G. McGarvey, Edward W. Chan, and C. Robert Roll, Jr., *Supporting Air and Space Expeditionary Forces: Analysis of Combat Support Basing Options*, Santa Monica, CA: RAND Corporation, MG-261-AF, 2004. Vick, Alan, David T. Orletsky, Bruce Pirnie, and Seth G. Jones, *The Stryker Brigade Combat Team, Rethinking Strategic Responsiveness and Assessing Deployment Options*, Santa Monica, CA: RAND Corporation, MR-1606-AF, 2002.

For Want of a Spanner

A curious minor logistical mystery of Royal Air Force History in World War II was the shortage of hand tools. This lasted well into 1943, four years after the war began and nine years after rearmament started in 1934.

Before wartime expansion, fitters and riggers did their initial course at No. 1 Technical Training School at Habton. They specialized either as engine fitters or as airframe riggers. Upon completion of the course, they were sent to squadrons where in seven years their education was completed.

At the squadron they reported to A, B, or C Flight where they were issued a toolkit. If they were transferred from one flight to another, they had to turn in their toolbox and have the contents accounted for before proceeding across the street to draw another set from their new flight. In biplane days, a fitter or a rigger assigned to a two seater not only acted as the gunner, but in colonial theaters lashed his toolbox to the wing next to the fuselage in case of a forced landing.

What makes the case of the missing hand tools so intriguing is that the historical documentation concerning the ordering of such necessary items has disappeared (meaning it has either been destroyed or it has been filed with the papers of a successor organization of unlikely title).

The first clue to the problem came from the Operational Record Book (ORB) of a repair and salvage unit (RSU) in the Middle East in 1940 which opened by noting that of the RSU’s 62 personnel, only 25 had tools. So they were happy to pass on salvaged aircraft to whoever claimed them.

What this meant was that in a theater then desperate for serviceable aircraft, many were standing idle because the necessary repairs could not be made *for want of a spanner*, let alone the necessary spares.

But the matter is important because in 1943 in Burma (South-East Asia Command or SEAC), the Beaufighters of No. 26 Squadron only sortied once every 18 days due to lack of tools and spares.

The fact that the RAF had insisted on standardized nuts, bolts and other fittings meant that special tools were not needed. Unserviceability was due to the unavailability of regular tools.

Robin Higham, PhD

Don Snyder, PhD, RAND
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Air Force Deployments: Estimating the Requirement

Introduction

Flying combat aircraft out of deployed locations frequently requires deploying thousands of people and thousands of tons of equipment. Determining how much and what kind of each is not easy. Nevertheless, deploying the right amount and types of equipment and people is very important, both during the execution of contingency operations and for planning purposes. During operations, not having enough resources causes risk of not being able to perform the mission. Taking too much risk delays operations, because of unnecessarily tying up lift, or impairs operations elsewhere by unnecessarily tying up resources. During planning, misestimating the resources needed for deployments may lead to a force structure of the wrong size or balance to meet future national security needs.

Whether done for executing a contingency operation or for planning purposes, deployment resource requirements are principally expressed in the form of unit type codes (UTCs). UTCs are sets of equipment and manpower resources needed to perform a specified capability. They vary considerably in size, and the requirements for a deployment to a single base can involve over a hundred UTCs. Various approaches have been used to estimate which UTCs are needed for deployments.

Force Deployment Requirements

The direct way is to assemble an ad hoc group of subject matter experts for all relevant functional areas and have them assess their resource needs given relevant operational details of the contingency. We call this the ad hoc approach to deployment planning. This approach generally begins with a site survey and input information from operational planners giving details of aircraft to be bedded down, *Both of the approaches for estimating deployment requirements have benefits and shortcomings.*

sortie rates, and other relevant factors. Requirements for each functional area are estimated by experts in that area. For example, given the size and numbers of aircraft expected at a base, civil engineers can estimate the water flow needed to meet fire-fighting needs. From this estimate, they determine how many and what types of trucks to deploy. Given the trucks, they in turn estimate the manning and managerial staffing. Other functional areas go through similar, often more complicated, procedures to estimate their resources. For many functional areas, however, the work does not stop at this point because the resource requirements in one area may impact another. For example, civil engineers planning for base support needs—such as number of billets and water and power requirements—need to know how many personnel are expected at the site. This number is determined by the sum of all the other functional areas' requirements. This interdependency forces some communication among the functional area experts, or iteration of estimates, or both. The process necessarily engages numerous personnel and consumes considerable time.

A second way is to determine, in advance of deployments, what is expected to be needed for a nominal deployment location. Such an effort has been recently pursued in the form of force modules. Force modules are sets of UTCs for supporting operations at a nominal location. Within the Air Force, the current implementation of force modules has been developed to estimate the resources needed to operate out of an austere deployed location. Five force modules have been developed.

- Open the base
- Establish the base
- Operate the base
- Provide command and control
- Generate the mission.

These modules represent an integrated capability that crosses many functional areas. The modules not only list UTCs, but also specify the order in which they need to arrive. The task of creating these force modules and testing their deployment at the Eagle Flag exercise has caused UTC contents and sizes to be adjusted for modularity.

Force modules can be viewed as a special case of the ad hoc approach to planning. Groups of subject matter experts have gone through the same process of building a UTC list as in the case for real deployments, except in the case of force modules, the target location is a generic, nominal bare base. Some of the assumptions made in the development of force modules are as follows.

- The base has a water source that can be made potable within 10 days.
- The base has limited fuel storage capability, but fuel is available from the host nation.

- General purpose vehicles can be obtained from the host nation.
- The base has a low to medium threat exposure.[1]

Having studied in advance the needs of a nominal deployed location and made a list of the required UTCs clearly saves time and effort when executing contingencies.

Both of these approaches to estimating deployment requirements have benefits and shortcomings. To see these more clearly, consider the Air Force expeditionary activities of the past few years. To support these contingencies, the Air Force has deployed to dozens of locations, nearly all of them unique in their support requirements. Total numbers of Air Force aircraft at these sites ranged from fewer than ten to more than a hundred. Different airframes have been collocated more often than not. In over half of the locations, aircraft from other services or coalition partners have shared the base with the Air Force. Additionally, the existing infrastructure at these locations varied widely. A few are truly bare bases, whereas more commonly, the airfield has some kind of usable infrastructure that reduces the resources the Air Force needs to deploy, such as an international airport or coalition partner military airbase. Locations with usable infrastructure also vary considerably, both in the nature of the infrastructure and in how much is made available to deploying forces. Locations of recent deployments indicate that not only is there no typical base in the sense of infrastructure and numbers and types of aircraft, there are scarcely two that are alike.

Without tailoring, force modules fail to accurately capture the nuances of deployment requirements involving a range of base types and mixes of aircraft. These differences will reduce the economies of effort that the force modules would provide had they been able to account for the enormous range in types of Air Force deployed operations.

How well do the ad hoc and force-module approaches handle the vicissitudes of these demands on expeditionary planning? Suppose, for the purpose of sizing the future force, the Air Force needed to estimate the deployment requirements for activities resembling recent contingencies. The ad hoc approach is capable of making good estimates of the UTCs needed to support operations at each of the locations. This accuracy, however, comes at a high cost in time, money, and manpower. Assembling these UTC lists can take teams of experts weeks or months. The costs can be prohibitive, especially if the number of sites to be investigated is numerous, or the number of scenarios to be examined are many.

Force modules economize on the time, money, and manpower of assessing requirements by having standardized these in advance. This economy was indeed one of the main motivations for their creation. Their weakness is that they do so for a generic base, yet no characteristic generic deployed location has emerged from recent deployments. The bases of interest in planning may depart significantly from the one envisioned in the development of the force modules, including such sites as international airports. Without tailoring, force modules fail to accurately capture the nuances of deployment requirements involving a range of base types and mixes of aircraft. These differences will reduce the economies of effort that the force modules would provide had they been able to account for the enormous range in types of Air Force deployed operations. Further, when used to size and shape

The proposed method combines the speed at which planning can be done using force modules, with the accuracy of the ad hoc approach. This method extends the concept of force modules from a list of UTCs that support nominal operations out of a generic base to an algorithm that generates a list of UTCs needed at a base that has specified infrastructure and supports specified aircraft and mission.

the future force, they may not generate the best mix of capabilities to meet national security objectives given a constrained budget.

Here, we introduce a third way to estimate deployment requirements. The proposed method combines the speed at which planning can be done using force modules, with the accuracy of the ad hoc approach. This method extends the concept of force modules from a list of UTCs that support nominal operations out of a generic base to an algorithm that generates a list of UTCs needed at a base that has specified infrastructure and supports specified aircraft and mission. The emphasis is on assembling the *rules* for selecting UTCs rather than assembling *lists* of UTCs. We call this methodology a *parameterized rules-based* approach to calculating deployment requirements. A prototype algorithm using a parameterized rules-based approach for estimating deployment requirements was recently developed by RAND, and is called the Strategic Tool for the Analysis of Required Transportation (START)[2].

A Prototype: The RAND START Algorithm

A parameterized rules-based approach for estimating deployment requirements rests on the principle that expeditionary needs can be calculated accurately enough for planning purposes given a small set of driving factors. Consultations with subject matter experts in a range of support areas confirm this supposition[3]. Many functional areas exercise such rules implicitly during planning, such as the fire-fighting example given above. Most support needs can be estimated from the following.

- The number, type, and sortie rates of the aircraft at the location, and whether they are bedded down at the site, or use it as an enroute base
- The level of risk that the site has from both conventional and nonconventional attack
- A limited number of attributes of the existing infrastructure at the base, such as whether the base has a hydrant fueling system available to the deploying forces, if any billeting is available, and so forth

With these few driving factors and a set of rules, UTC lists can be estimated for most functional areas[4].

We assembled rules for UTC deployment by consulting a number of senior noncommissioned officers and logistics readiness officers. For purposes of demonstrating the concept, the following functional areas were covered: deployed communications, bare-base support, civil engineering (engineering craftsmen, fire protection, explosive ordnance disposal, and readiness), medical, force protection, fuels support, aviation and maintenance, and aerial port operations. The rules were vetted by calculating the needs for a variety of deployments and having these examined by subject matter experts not involved in the consultations used to establish the rules. Generally this meant conferring with experts from one major command to derive the rules, and consulting experts from another major command to vet the results. The method is similar to what is done in assembling UTC lists by the ad hoc method, or making the UTC lists that constitute force modules, except that what is being assembled is rules rather than UTCs.

The resulting rules were incorporated into Visual BASIC for Applications code hosted in an Excel spreadsheet. The Excel spreadsheet contains a list of available UTCs directly imported from the manpower and force packaging (MEFPAK) database. The user specifies operational details at approximately the level of an air order of battle. Inputs are in the form of checklists that specify the following parameters: which aircraft are bedded down at the location (or use it as an enroute location), how many of each type, their sortie rate, and mission. Some high-level aspects of the available base infrastructure can be selected, such as whether a fuels hydrant system is available, or how much billeting may be available. The user also indicates whether the threat to the base is high, medium, or low for both conventional and nonconventional attack. Finally, a working maximum on ground (MOG) can be specified in order to estimate aerial port equipment and manpower. From these inputs, planning factors are used to calculate base population[5]. The algorithm then takes these parameterized inputs and uses the rules to determine which UTCs are needed and how many. The algorithm searches the MEFPAK for these UTCs and collects the movement data that is compiled in the MEFPAK. The final output is a list of UTCs and their associated movement characteristics[6].

A parameterized rules-based approach for estimating deployment requirements rests on the principle that expeditionary needs can be calculated accurately enough for planning purposes given a small set of driving factors.

Illustrative Applications

The most straightforward illustration is calculating the requirements for a single base hosting a mix of aircraft. Figure 1 shows the requirements for a deployed location with 18 F-16CGs flying 1.5 sorties per day, and 8 C-130s, each flying one sortie per day out of a bare base with a MOG of 2. The threat levels for both conventional and nonconventional attack are taken to be low. This calculation takes a few seconds using the START program. The figure summarizes the requirement in terms of weight; for all functional areas calculated, the sum is 4,775 short tons. These results not only give a planner an excellent starting point for assembling an executable UTC list, but also provide a first-order estimate of the movement requirements. A user can adjust parameters such as the numbers of aircraft, their sortie rates, and so forth in order to examine the impact on the required UTC list. The power of the method is that the UTC list is not static, but can be derived from variations in these input parameters.

Now consider the issue of force lay down as an implicit parameter. For example, what is the difference in the support requirements of the following alternative for the lay down of 3 squadrons of F-16CJs flying 1.5 sorties per day: (1) all three collocated at one bare base; (2) two placed in one bare base and one in a second bare base; or (3) each squadron deployed to its own bare base. Figure 2 shows the results, aggregating all equipment resources in terms of weight. To emphasize the

Air Force Deployments: Estimating the Requirement

Caution should be exercised in extracting rules from historical deployments. We did not use historical data in assembling the rules in the prototype START program. Aside from the limitations of knowing what was not requested during a contingency (because it was already available), and the general reality that operational needs change nearly continuously with time, it is difficult to separate needs from wants.

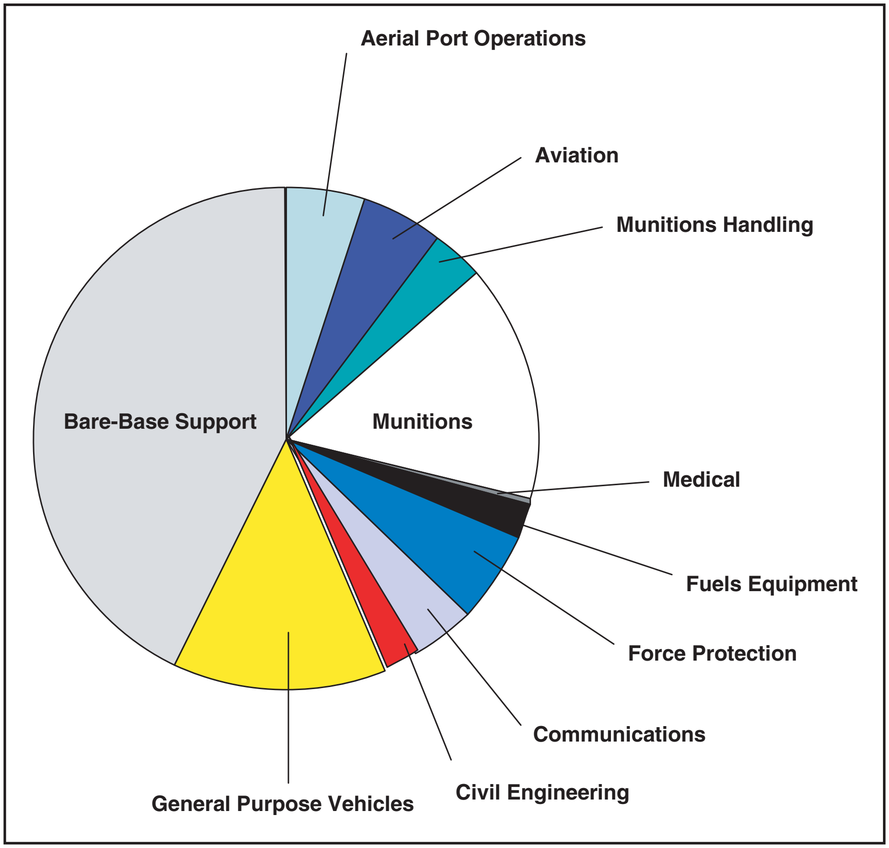

Figure 1. Summary of Support Requirements for a Deployment of a Squadron of F-16CJs and a Squadron of C-130s at One Location

resources that are likely to be deployed, the figure excludes general purpose vehicles. Placing the same numbers of aircraft flying the same mission at three bases rather than one increases the total support materiel by nearly 70 percent. This figure may be an underestimate of the increase, as it does not take into account the likely reduction in personnel needs that the economies of scale of a single base provides. The ability to perform tailored calculations like these can be a useful guide during both deliberate and crisis-action planning.

Finally, note that the algorithm can be used in two directions. A scenario can be created, and the deployment requirements calculated to meet those operational needs. The above calculations are examples of this direction, and this is useful in obvious ways for crisis-action planning, and planning for force sizing. Alternatively, a capability could be specified, such as the ability to deploy a set of aircraft to a number of sites of certain types. The required resources could then be compared with those currently authorized or available. This direction provides a nuanced way to express Air Force expeditionary capabilities, such as how many bases of a certain type can be supplied by an aerospace expeditionary force (AEF).

Implementing a Parameterized Rules-Based Approach to Deployment Planning

The program we have described is a prototype, concept demonstrator. Additional work will need to be done to make this approach operational. Much of the knowledge needed to implement a parameterized rules-based approach to estimating deployment requirements already exists. A knowledge base of rules for deployments has been developed by most functional areas, and if not yet formalized, exists *virtually* in the subject matter experts.[7]

Areas that have already developed algorithms to assist in estimating deployment, such as fuels support, can furnish such rules without further effort. For most areas, the rules need to be assembled. These could be assembled by a similar effort as was made in creating the force modules.

Caution should be exercised in extracting rules from historical deployments. We did not use historical data in assembling the rules in the prototype START program. Aside from the limitations of knowing what was not requested during a contingency (because it was already available), and the general reality that operational needs change nearly continuously with time, it is difficult to separate needs from wants. Materiel and manpower may be requested during an operation not just to cover the operational needs of the time, but also to mitigate risk in case of an unplanned surge in operations. These needs can be difficult to separate.

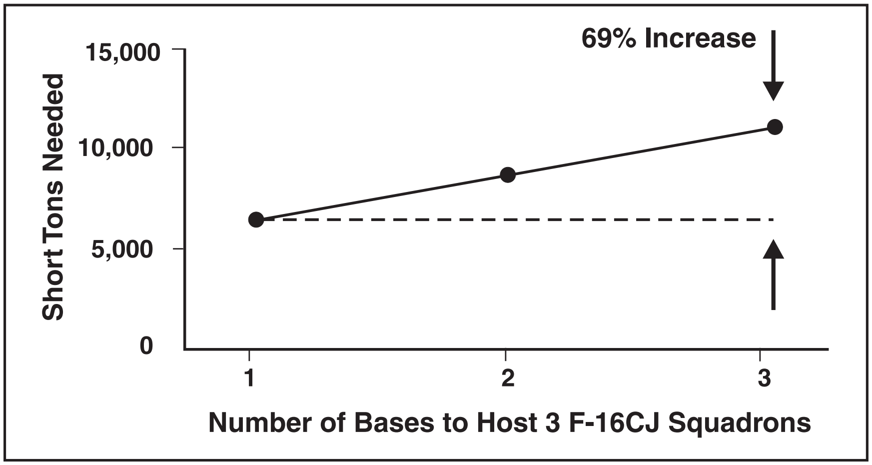

Figure 2. Plot Showing the Increase in Support Needs if 54 F-16CJs are Based at One, Two, or Three Bare Bases

A parameterized rules-based approach may reveal aspects in which the sizing and constitution of UTCs might be improved to meet expeditionary needs. For example, in some areas, parameterization and rules collection might reveal value in establishing separate UTCs to supply a given capability to a bare base versus an international airport.

Once compiled, rules need only be maintained during the routine management of UTCs. As part of the introduction of new UTCs, the pilot unit could be responsible for developing rules for their deployment, just as they now are responsible for estimating movement characteristics. A secondary benefit of this process may be that it impacts the development of UTCs in the same constructive way that force modules have. A parameterized rules-based approach may reveal aspects in which the sizing and constitution of UTCs might be improved to meet expeditionary needs. For example, in some areas, parameterization and rules collection might reveal value in establishing separate UTCs to supply a given capability to a bare base versus an international airport.

We hope this prototype effort will lead to the next step in the evolution of the force module concept, one that moves from UTC lists to sets of rules for deployment. Doing so should further advance the expeditionary mission of the Air Force.

Notes

1. Lt Col Raymone Mijares, Presenting the AEF-AETF Force Modules, 2005.
2. Don Snyder and Patrick Mills, *A Methodology for Determining Air Force Deployment Requirements*, RAND MG-176-AF, 2004. The emphasis on transportation in the name START is because the algorithm was initially written as a component in an analysis of minimizing lift costs for deployments.
3. Don Snyder and Patrick Mills.
4. Other factors can play a role. For example, base layout and topography may influence the needs for vehicles and place greater demands on security forces. If topography impedes line-of-sight communications at the base, additional communications equipment may also be needed. These are secondary factors, and results can be tailored to accommodate these factors when they play a significant role.
5. In the START program, these planning factors for base population are used directly. Further refinement would use these estimates as *seeds* to calculate all manpower needs, then use the sum of the manpower needs as a second estimate of base population. The calculation would then be iterated until convergence.
6. No time-phasing or sourcing of the UTCs is currently done. Time-phasing could be introduced as a further refinement, and the outputs could easily be used as the inputs to an algorithm that does sourcing.
7. Lionel A. Galway, Mahyar A. Amouzegar, Richard J. Hillestad, and Don Snyder, *Reconfiguring Footprint to Speed Expeditionary Aerospace Forces Deployment*, RAND MR-1625-AF, 2002; Lionel A. Galway, Mahyar A. Amouzegar, Don Snyder, Richard J. Hillestad (2002) "Footprint Configuration: An Essential Element for Agile Combat Support in the EAF," *Air Force Journal of Logistics*, Vol XXVI, No 4, 20-26, 43; Don Snyder and Patrick Mills, *A Methodology for Determining Air Force Deployment Requirements*, RAND MG-176-AF, 2004.

Shaping Logistics—Wargames

As you can well imagine, this is nor an easy task or one that creates universal consensus in the Air Force logistics community. However, the utility of exploring new logistical concepts in wargames versus real life quickly becomes obvious when you look at the funds, personnel, and equipment impacts associated with live exercises. In exercises such as Foal Eagle or Cope Thunder or older exercises like Reforger or Bright Star, you discover the manpower, financial, and equipment costs are extremely high. In these exercises, we deploy up to 10,000 people and their equipment for a month or more to distant parts of the earth. With preparation, the actual exercise, and reconstitution, these personnel and their units are often unavailable to respond to other taskings for 3 to 4 months. In terms of financial cost, live exercise costs often run into millions of dollars and contribute to increased wear and tear on critical weapon systems and our airlift fleet.

Wargames cannot completely reflect the real world; however, you can draw close parallels with sufficient fidelity to allow functional experts to determine if concepts are feasible and workable and if other advanced testing methods, such as live exercises, are appropriate. Or you may determine a concept is simply unworkable and unrealistic and should be sent back for rework or totally scrapped. Further, in a wargame, you don't require massive numbers of troops, you don't wear out weapon systems, and you require only a fraction of the dollar outlay that live testing requires.

In wargames a broad range of logistical concepts are explored that will allow us to better support the warfighter and the expeditionary air force. Concepts such as forward operating locations, forward support locations, various types of prepositioning (including prepositioning ships), redesigned maintenance and support kits, ways to increase the velocity of the resupply pipeline, and intermediate depot-repair sites are typical of what's being examined and evaluated.

Wargames have the added advantage and flexibility of being able to explore today's concepts or those 25 years in the future. With today's concepts, we can validate the outcome with an increased level of fidelity because the reliability of the data is high. Even with concepts set many years in the future, we can determine if the concept is feasible with envisioned technology.

Wargaming is a valuable force multiplier for the Air Force. We can explore concepts and determine outcomes for a fraction of the cost of live exercises and not lose or damage a single aircraft or put the first airman in harm's way. It's a valuable tool in the logisticians' toolbox, and its use will grow in importance.

Colonel Kenneth P. Knapp, USAF, Retired

Historical Perspective

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

—Field Marshal Erwin Rommel

No matter their nationality or specific service, military logisticians throughout history have understood the absolute truth represented in the above quote. Whether they were charged with supplying food for soldiers, fodder for horses or the sinews of modern war—petroleum, oil, and lubricants (POL), they have understood that victory is impossible without them—even if, sometimes, it seemed their vital contributions were forgotten or ignored. None of the great military captains of history were ignorant of logistics. From Frederick the Great to Napoleon to Patton, they all understood the link between their operations and logistics. The great captains also have all understood that history had much to teach them about the nature of the military profession. Yet, military logisticians do not often spend time studying the history of military logistics.

There are at least three general lessons from history that might prove of some use in understanding how best to prepare for the future. The first of these is the best case operationally is often the worst case logistically. The second is promises to eliminate friction and uncertainty have never come to fruition. And the third is technological change must be accompanied by organizational and intellectual change to take full advantage of new capabilities. While these lessons are not exclusive to logistics, when applied to the understanding and practice of military logistics, they provide a framework for understanding the past and planning for the future.

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Strategic Brigade Airdrop: Effects of Army Transformation and Modularity

Introduction

On March 26, 2003, more than 1,000 soldiers of the 173d Airborne Brigade parachuted from 12 Boeing C-17 Globemaster III aircraft into northern Iraq, 8 days after the initiation of Operation Iraqi Freedom. Assigned to the US Army Southern European Task Force, the *Sky Soldiers* parachuted into Iraq to secure the strategically situated Bashur Airfield and to assist special operations forces in deterring the following.

- Iraqi operations against the Kurdish-held region
- Factional fighting among regional Kurdish tribes
- Intervention into Iraq by Turkey[1, 2]

During the next 96 hours, C-17s airlifted the second echelon of the brigade's forces into Bashur, consisting of over 400 vehicles, 2,000 soldiers, and 3,000 tons of equipment.[3]

The airdrop of the 173d Brigade into Iraq was the largest American airborne operation since Operation Just Cause, the invasion of Panama in 1989.[4] A complete success in terms of execution and objectives achieved, this large-scale combat airborne operation constitutes what is known within Joint doctrine as a strategic brigade airdrop (SBA). SBA has long been a part of US military capability but known by different names. SBA has in recent years received significant attention within the Army and Air Mobility Command (AMC). The focus of this attention is AMC's inability to execute SBA within specified Army timing parameters and the measures it has taken to meet those requirements. Army transformation and its concept of modularity presents new dimensions that may affect the nature and execution of SBA as well as AMC's multifaceted program to satisfy Army requirements for SBA.

Strategic Brigade Airdrop: Effects of Army Transformation and Modularity

Modularity is the Army's concept of reorganizing its division-based combat force structure into one that is brigade-based. The goal of modularity is to "obtain a more relevant and ready campaign-quality Army" that better serves Joint requirements.

Transformation permeates today's Army. The post-Cold War environment prompted the Service to examine its roles, mission, and structure during the 1990s, which the September 11th attacks and Operations Enduring Freedom and Iraqi Freedom accelerated. The Army recognized that its heavy force orientation constrained its ability to meet current and future probable threats and initiated a Service-wide agenda to transform itself into a more capable and responsive force. Service structure, unit organization, equipment, and personnel now fall under various transformation initiatives and programs—a number of which may directly affect SBA operations.

Modularity is the Army's concept of reorganizing its division-based combat force structure into one that is brigade-based. The goal of modularity is to "obtain a more relevant and ready campaign-quality Army" that better serves Joint requirements.[5] Change within the Army will be far-reaching and among the many possible consequences of modularization are modifications to the composition and execution of SBA. While the Army wrestles with this process, Air Mobility Command has the responsibility of determining how to execute whatever changes are implemented to SBA operations.

SBA – Doctrine and Practice

SBA in Joint Doctrine

Airborne operations have been integral to American military strategy and force structure for 7 decades. Although the strategy, doctrine, and capabilities for airborne forces have varied over the years, there has always been a requirement for the capability to execute large airborne combat operations. Referencing current guidance, SBA falls within the domain of early-entry capabilities in the *2004 National Military Strategy* and *forcible entry operations* in Joint guidance.[6] Joint Publication 3-18, *Forcible Entry Operations*, defines forcible entry as "seizing and holding a military lodgment in the face of armed opposition."[7] Joint Publication 3-17, *Tactics, Techniques, and Procedures for Air Mobility Operations*, categorizes SBA as a specific forcible entry capability.[8] Numerous other documents detail aspects of forcible- entry. For instance, United States Joint Forces Command produced the *Joint Forcible-Entry Operations, Joint Enabling Concept* in 2004 to provide Joint commanders a set of principles and capabilities to consider for forcible-entry operations through at least 2015.

As the enabler of SBA, the Air Force imparts its doctrinal say in Air Force Doctrine Documents 2-6, *Air Mobility Operations,* 2-6.1, *Airlift Operations*, and 2-6.2, *Air Refueling Operations*. Ultimately, it is AMC's responsibility to execute SBA and it resources that responsibility in its *Air Mobility Master Plan* (AMMP). According to AMMP, mobility air forces must be able to "airdrop a brigade-size force over strategic distances and sustain combat forces by aerial delivery or airland operations."[9] Rather than redundantly discuss how various Army publications cover forcible entry and SBA, it is now possible to examine what the Army actually plans for and requires of the Air Force to execute SBA operations.

SBA Defined

In 1980, the requirement for strategic brigade airdrop was levied by a Joint Chiefs of Staff memorandum.[10] In 1997, the Army and Air Force formed a Joint integrated process team (IPT) to examine SBA in light of several dynamics facing both Services. First, the composition and capability of the AMC strategic air fleet was changing—C-17s were entering the inventory in greater numbers and C-141s were being retired. Second, the Army began its introspective path towards transformation and was scrutinizing its roles and missions. Third, the changing international environment and threats to the United States merited a joint look at SBA.[11]

Two future Chiefs of Staff (Lieutenant General Jumper-Air Force, Lieutenant General Shinseki-Army) chaired the IPT, which made a number of determinations. Among the most significant determinations were the following.

- Intercontinental distances, assumed compressed mission timeline, and force protection issues precluded the general use of staging bases. SBA can be conducted within a theater, as was the case of the airdrop and deployment of the 173d Airborne Brigade into Iraq, however the baseline scenario is one conducted from an intercontinental distance.
- Intercontinental distances precluded the use of C-130 aircraft. The use of alternative aircraft, such as the C-130 for SBA, is not addressed within this article.[12]
- SBA is planned for use at or near a short, austere airfield. Such an airfield is loosely defined as a hard or semiprepared airfield, which is too short to accommodate C-141, C-5, or other heavy lift aircraft. As a result,
- SBA will be accomplished by C-17 aircraft only. Since this 1997 IPT decision, the Air Force has contracted for 180 C-17s and is likely to increase the current total. Headquarters AMC also ceased discussions of using other aircraft to execute or assist in executing SBA. Based on these factors, the use of any other aircraft to augment the C-17 in executing SBA will not be discussed.
- The maximum on ground at the airfield is four C-17s. This item, along with the previous and last item, raise an aspect of SBA not mentioned yet. SBA, in fact, comprises two echelons of combat forces insertion—an initial echelon of airdrop and a follow-on echelon of troops and equipment airlanded to a target airfield.
- The airdrop portion of the SBA must be completed within 30 minutes of the time over target (TOT).[13] Hereafter, this period of time will be referred to as *pass time*.
- The airland portion of the SBA commences no later than 4 hours after the airdrop TOT and concludes no later than 24 hours after the TOT.

Airborne operations have been integral to American military strategy and force structure for 7 decades. Although the strategy, doctrine, and capabilities for airborne forces have varied over the years, there has always been a requirement for the capability to execute large airborne combat operations.

SBA – The Army's Perspective

Strategic brigade airdrop is a method of employing Army forces into combat. This mission belongs to the 82d Airborne Division of the 18th Airborne Corps. As the lead

SBA is an airdrop and airland delivery of a DRB. The airdrop package is referred to as alpha echelon and the airland package is referred to as bravo echelon. Although the DRB is tailorable, there is a planning standard.

agent for SBA, the 82d has had the responsibility of devising the composition of SBA since the late 1980s. In conjunction with the higher-level doctrine discussed previously, the 82d approaches SBA using this statement of work: "Within 18 hours of notification, the 82d strategically deploys and conducts forcible-entry parachute assaults to secure key objectives for follow-on military operations in support of US national interests."[14]

The division ready brigade (DRB) is the means by which the 82d executes SBA. The DRB concept is based upon the division's three-brigade organization and comprises a three-cycle rotation of each brigade. Each cycle is 6 weeks in duration. One brigade, known as mission DRB1, is fully trained, mission-ready, and on the hook for deployment within 18 hours. A second brigade, known as training DRB2, is in a training phase during which it trains and prepares for its operational mission. This training includes events accomplished at home station and away from home station. Examples of off-station training are participation in Louisiana's Joint Readiness Training Center, California's National Training Center, and Joint task force exercises. The third brigade is the Support DRB3 and is in a stand-down mode in which personnel are on leave, attending school, or assisting with post support activities.[15] Each of the three brigades and battalions within those brigades, abide by specific recall windows. Using baseball vernacular, DRB1 is at bat, DRB2 is on deck, and DRB3 is in the hole.

SBA is an airdrop and airland delivery of a DRB. The airdrop package is referred to as alpha echelon and the airland package is referred to as bravo echelon. Although the DRB is tailorable, there is a planning standard, which is described in Tables 1 and 2. The number of C-17s required to deliver both echelons is listed in Table 3.

As shown in Tables 1, 2, and 3, executing a strategic brigade airdrop is a mammoth undertaking. Although this discussion does not include force structure or planning considerations it is worth mentioning how massive such an operation would actually be. The total aircraft requirement of 99 C-17s represents nearly five-sixths of the entire fleet as of September 2004. Given the assumption that SBA is conducted from an intercontinental distance, few, if any, of the aircraft and crews will be able to conduct multiple sorties. The scope of the operation is magnified when taking air refueling into account. Depending on where the SBA is conducted and how many air refuelings are needed for each C-17 it is possible for the tanker requirement to reach approximately 200 airframes.[19] Even when all 180 C-17 aircraft have been procured, this force comprises a significant portion of AMC's airlift and air refueling capability.

Resolving SBA Issues

Pass Time

Notional theory and good intentions aside, executing an SBA within the 1997 SBA Joint IPT requirements has been a difficult, expensive, and somewhat elusive proposition. The central reason for the difficulty in translating paper-based

Alpha Echelon – Airdrop Package		
1 Brigade HQ	Troops	2,460
	105mm Howitzers	18
1 Division Command Post	Wheeled Vehicles	102
	TOW Systems	60
3 Infantry Battalions	Javelin Systems	58
1 Artillery Battalion	81mm Mortars	12
	60mm Mortars	18
1 Engineer Company	Stinger MANPADS	21
1 Air Defense Battery	Engineer Repair Packages	12
	CDS Bundles	54
1 Combat Support Element	Supply Platforms	9

Table 1. Division Ready Brigade Alpha Echelon Composition[16]

Bravo Echelon – Airland Package		
Aviation Task Force	Troops	680
- Cavalry Troop	Wheeled Vehicles	227
- Attack Company	UH-60 Blackhawk Helicopters	12
- Assault Company	OH-58D Kiowa Helicopters	16
Armor/Mechanized Team	M1A1 Abrams Tanks	4
- Tank Platoon	M2 Bradley Fighting Vehicles	4
- Mechanized Infantry	M113 Armored Personnel Carriers	2
Platoon	Avenger Air Defense Systems	12
Tailored Support Package	Engineer Repair Packages	12
Remainder of SBA Units	Supply Platforms	41

Table 2. Division Ready Brigade Bravo Echelon Composition[17]

Type of Delivery	Number of C-17s
Equipment Airdrop (Alpha Echelon)	
Dual Row Airdrop	21
Standard Airdrop	7
Personnel Airdrop (Alpha Echelon)	
Personnel	24
CDS Platforms	1
Airland (Bravo Echelon)	46
Total Aircraft	99

Table 3. C-17 Aircraft Required for SBA[18]

requirements into actual capability has been the C-17's inability to meet the 30-minute drop zone pass-time requirement. There are several different reasons why the alpha echelon of C-17s has exceeded the 30-minute pass time.

Strategic Brigade Airdrop: Effects of Army Transformation and Modularity

The consequence of the exceedingly large spacing between elements, magnified over the entire length of a C-17 SBA airdrop formation, resulted in a pass time of 51 minutes. As a result, AMC, the C-17 SPO, and the Army initiated a comprehensive three-program effort to reduce the pass time.

C-17 Personnel Airdrop Geometry

During the mid-1990s, personnel airdrop testing of the C-17 at Edwards Air Force Base revealed an occasional tendency for the parachutes of jumpers (exiting both the left and right paratroop doors) to come into contact as the chutes deployed downstream of the aircraft. Rare as it was, AMC, the C-17 System Program Office (SPO), and the Army decided that such interactions were not safe and initiated a program to eliminate the problem. In 1996 engineers developed a solution that consisted of modifying the paratroop doors, raising the deck angle of the aircraft during airdrop, and using 20-foot static lines to initiate parachute deployment (as opposed to standard 15-foot static lines). Testing then commenced for formation personnel airdrop.

Remedying the chute collision problem resulted in another problem. During evaluations of formation personnel airdrop, parachutists from following aircraft were observed being jostled about excessively after exiting the aircraft. Analysis revealed that the jostling was caused by excessive wake turbulence from the proceeding aircraft. High-wing, high-drag, powered-lift design characteristics that enabled the C-17 to perform its tactical airland and airdrop missions at large gross weights caused the C-17 to generate a significant amount of wake turbulence and wingtip vortices. When the deck angle was raised during personnel airdrop to alleviate chute interactions, it exacerbated the extent of wake turbulence and vortices.

To rectify this new problem, the program office and AMC initiated an extensive modeling and aircraft-testing program. After months of testing, a workable solution was achieved by altering the geometry of personnel airdrop formations. Standard C-17 formation airdrop of personnel and equipment had been similar to that of the C-141 and C-130—aircraft flew in three-ship elements with 12,000 feet of separation between the lead aircraft of each element. The number two and three aircraft flew to the right and left respectively of the element leader at a spacing of either wingtip-to-wingtip separation (visual conditions) or 500 feet (instrument conditions). The new personnel geometry required 40,000 feet between elements and both wingmen flew on the same side of the element lead (which side depended on wind drift) at a spacing of 650 feet and 1,500 feet respectively.

The consequence of the exceedingly large spacing between elements, magnified over the entire length of a C-17 SBA airdrop formation, resulted in a pass time of 51 minutes. As a result, AMC, the C-17 SPO, and the Army initiated a comprehensive three-program effort to reduce the pass time. The first program involved more modeling and formation geometry testing that resulted in a new procedure of 32,000 feet spacing between elements. This reduced the pass time by 5 minutes to 46 minutes. The program office then analyzed reducing the element spacing to 27,000 feet, but the interaction rate exceeded an acceptable margin and the effort was terminated.[20] The other two programs are Dual-Row Airdrop System (DRAS) and station-keeping equipment (SKE) upgrades.

DRAS

The DRAS is a process by which C-17 cargo compartment logistics rails are used to airdrop equipment platforms. A C-17 cargo floor has two types of rail systems built into it—Aerial Delivery System (ADS) rails and logistics rails. The ADS rails are a pair of centerline rails designed exclusively to airdrop heavy equipment platforms along the aircraft centerline. Logistics rails are two pairs of rails used to load standard 463–L pallets side-by-side along the length of the cargo compartment.

In 1997, based upon a company loadmaster's idea, Boeing made a proposal to use the logistics rails for airdropping heavy equipment platforms.[21] By using both sets of logistics rails to airdrop platforms this would enable the jets to airdrop more platforms per plane, decrease the total number of aircraft required for SBA, and reduce the airdrop pass time. The SPO and AMC agreed and authorized testing in 1997.

Testing proved successful; however, DRAS raised several difficult and expensive deficiencies. One issue was the logistics rail locks were not designed for the load forces the ADS locks experience during airdrop, which necessitated alternate drop procedures. Platforms that are dropped via standard procedures exit the aircraft when the extraction chutes exert enough force to overcome predetermined values on each of the variable lock settings on the ADS rails. The logistics rails do not have locks with variable resistance settings. As a result, the drop procedures were altered for DRAS by retracting the locks prior to a DRAS airdrop. Sometimes DRAS platforms shifted slightly during flight due to turbulence, deck angle changes, or pilot maneuvering and the platforms applied pressure to the logistics locks and caused one or more locks to bind when the time came to retract them. Such binding occasionally damaged the locks. A second deficiency was the mechanisms for releasing the parachutes and extracting the loads using the ADS rails could not completely support the extraction of two rows of platforms. Instead of extracting DRAS loads through a drogue chute process, as is the case with standard equipment loads, they exited the plane using a gravity-release process flown at a different deck angle. The deck angle change induced a third set of problems involving center of gravity issues that affected how the platforms exiting the aircraft caused interactions during deployment, and complicated the rigging process of DRAS platforms.[22] A fourth problem was that 463-L pallets were not designed for airdrop. They are smaller than standard airdrop pallets and not as durable.

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Faced with a *must do* situation, the Air Force and Army set about resolving the DRAS issues as best they could. New DRAS air review procedures were developed and new contracts let to procure new platforms. Modifying the logistics rail locks, however, proved to be too expensive and AMC has not been able to acquire the funds to modify the fleet. Using procedures for the current aircraft capabilities, DRAS reduces SBA pass time by 6 minutes, lowering the total pass time to 40 minutes.[23]

During the late 1990s, the Army embarked upon a long-term plan to reorganize and equip its forces to more capably meet the nation's security needs of today, for the next 20 years, and beyond.

SKE Follow-On

C-17s utilize SKE to maintain formation position and execute airdrops during instrument meteorological conditions. Formation aircraft do not have to see each other—aircraft positions are displayed electronically on screens in the cockpit. One aircraft serves as the *master* and the other aircraft electronically synchronizes their internal clocks off of it, providing accurate presentations on all aircraft. A limitation of SKE is that aircraft must be within 10 miles of the master in order to receive acceptable signals. Another limitation is there can only be one master per formation. Aircraft greater than 10 miles from the master must operate on a different SKE frequency (of which there are four) and the SKE presentations are only capable of displaying aircraft using the same frequency. A large formation can tactically work around the frequency limitation by flying separate, smaller formations but the formations require separation for safety sake that greatly lengthens the overall formation. A final limitation is that formations using the same SKE frequency must be at least 80 nautical miles from each other.

Remembering SBA consists of 53 aircraft, which equates to a formation length of roughly 90 miles, C-17 SKE hindered executing SBA. Air Mobility Command initiated an acquisition program to procure a new, more capable SKE system which it named SKE Follow-On (SKE-FO). Completely digital in nature and capable of managing and displaying up to 100 aircraft, SKE-FO eliminated SKE's shortcomings. Most importantly, SKE-FO closed the formation and reduced pass time by 14 minutes, bringing the overall pass time down to an acceptable 26 minutes.[24]

SKE-FO was scheduled for a completion date of mid-2005 but the contractor encountered technical difficulties that forced AMC to cancel the contract in late 2003. AMC and the SPO responded with a short- and long-term solution. The short-term solution is a software modification to current equipment, known as Traffic Alert and Collision Avoidance System (TCAS) overlay. TCAS overlay solves certain all-weather issues associated with traditional SKE, but it does not provide any capability to condense formations and therefore does not shorten the pass time. The long-term solution is called Formation Flight System (FFS) and is tentatively planned for a production cut-in of aircraft number P-153 in July 2006. Full fleet modification will occur in 2013.[25] FFS will solve all SKE limitations and reduce pass time by 14 minutes.

Army Transformation and Modularity

Transformation – The Concept

During the late 1990s, the Army embarked upon a long-term plan to reorganize and equip its forces to more capably meet the nation's security needs of today, for the next 20 years, and beyond. The Army Chief of Staff at the time, General Eric K. Shinseki, launched this sweeping program in October 1999 with the following words.

> To adjust the condition of the Army to better meet the requirements of the next century, we articulate this vision: Soldiers on point for the nation transforming this, the most respected army in the world, into a strategically responsible force that is dominant across the full spectrum of operations. With that overarching goal to frame us, the Army will undergo a major transformation….[26]

Every aspect of the Army—personnel, organization, equipment, strategy, and operations—is enveloped within the transformation construct. Seven goals are enumerated to guide the efforts of organizations and individuals alike. Transformation is to make the Army more *responsive, deployable, agile, versatile, lethal, survivable, and sustainable.*[27] Transformation comprises three capabilities-based phases. *Legacy forces* are the heavy armored and mechanized forces that constitute the Army's current primary combat power and will do so for the near future. The *interim forces* are units modified in structure and enhanced with new, available technologies to make them more deployable than heavy units and better armed and protected than the lighter airborne and air assault units. Not all forces would necessarily transition to this stage. Some interim forces will function as technology and feasibility demonstrators for forces that will comprise the third phase of forces. The third phase was initially entitled the *Objective Force* and constituted "the art of the possible: what can be done to equip, organize, and train units to assimilate the best aspects of the heavy, light, and interim forces."[28] In late 2003, the new Chief of Staff, General Peter J. Schoomaker, renamed this phase *Future Force* to reflect a programmatic change in emphasis that is more process-oriented and aimed at "fielding future capabilities as soon as they are available."[29]

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A core element of transformation is the institutionalization of brigades in place of divisions as the fundamental combat unit of the Army. Given the immense size of a division (typically around 15,000 personnel) and the dynamic nature of the strategic environment America now faces, divisions are not readily transportable and employable in contingency operations. The primary drawbacks of divisions are as follows.

- They are optimized for major land campaigns against similarly organized forces.
- They are large, fixed organizations with interconnected parts.
- They require extensive reorganization to create force packages.
- They limit the combatant commander's ability to mix and match packaged capabilities for multiple missions.
- They possess limited Joint capabilities.[30]

Brigades are more inherently capable of attaining what General Schoomaker envisions for the Army, a "more relevant and ready campaign-quality Army with a Joint and expeditionary mindset."[31] Brigades are strategically flexible, adaptive, sustainable, lethal, and can be the antithesis of the division shortcomings identified. The brigades of today are not optimally structured or equipped to maximize these attributes so the Army is focusing on transforming the various brigade types. The overarching concept that governs the transformation of brigades is modularity.

The Modular Army

At present, brigades employ via unit structures known as brigade combat teams (BCT). A BCT is formed by augmenting a brigade with functional elements from the division such as artillery. Commanders form BCTs to accomplish a specific mission. To do that, they employ force tailoring to build the BCT. Force tailoring is the process of selecting units of particular capabilities to accomplish a specific mission. This requirement to reorganize and force tailor reflects the conditions that brigades are not self-contained units nor are they capability-based, which limits their flexibility and immediate deployability. To provide combatant commanders with better capable units for rapid employment, standing combined-arms brigades are required. The Army is moving in this direction by creating units of employment (UE) and modular BCTs (also known as units of action).

The Army's primary tactical unit will be the combined arms maneuver BCT. There are three types of maneuver BCTs: heavy, infantry, and Stryker.

A UE is a force of indeterminate, but large, size brought about to confront a contingency and is composed of modular BCTs. There are actually two UE organizations—UEx and UEy. The UEx is "the principle war fighting headquarters of the Army, exercising operational control over brigades employed in tactical engagements," and the UEy, which focuses "primarily on the Army Component responsibilities, supporting the entire theater and the operational forces … as required by the combatant commander."[32] The new building block of the Army, a modular BCT, is composed of modular battalions and companies that are "self-contained organizations that can plug into and unplug from unit formations with minimal augmentation or reorganization."[33] Force tailored for mission purposes, modular BCTs are self-contained organizations that are more flexible, responsive, and deployable than traditional BCTs.

The Army's primary tactical unit will be the combined arms maneuver BCT. There are three types of maneuver BCTs: heavy, infantry, and Stryker. Other modular brigades will support the maneuver BCTs and serve UEx functions. By 2012, the Army plans to field a fourth type of BCT composed of future combat systems units.[34]

Of crucial importance to the concept of a modular Army is deployability. Units are reorganizing and equipment is being designed that will be capable of "operational maneuver from strategic distances," which is defined as the rapid projection of scalable, modular, and force tailored combined arms that are capable of operations immediately upon arrival.[35] Pursuant to this philosophy, the Army requires that brigades be capable of deploying worldwide in 96 hours and UEs in 120 hours. These ambitious requirements have reverberated throughout the Army as units at all levels investigate, plan, and structure themselves to meet them.

Modularity and Systems Development

Unit deployability in the modular Army encompasses not just the structure or size of units but also unit equipment composition. Central to transformation and modularity are robust new weapon systems optimally designed for functionality and deployability. Several of these programs will likely affect SBA operations. One program is currently being fielded and the other two are under development.

Stryker IAV. The Stryker Interim Armored Vehicle (IAV) is a family of vehicles the Army is procuring from General Dynamics Land Systems under the interim forces construct of transformation. Departing from the Army's tracked-vehicle tradition, the Stryker is an eight-wheeled, 19-ton armored vehicle that is both strategically (C-5/C-17) and operationally deployable (C-130). There are two Stryker variants, the infantry carrier vehicle, of which there are eight configurations, and the Mobile Gun System. The vehicle is capable of speeds in excess of 60 miles per hour and its range exceeds 300 miles.[36] A C-17 aircraft can airlift four Strykers (airland mission) or carry and airdrop two vehicles.

The Army is on contract for 2,112 Strykers that are being fielded to six Stryker brigade combat teams (SBCT).[37] Strykers present combatant commanders a vehicle that is very mobile, armored, combat ready, and more easily deployed than Abrams tanks or Bradley fighting vehicles. On August 13, 2004, a Stryker was successfully airdropped by a C-17 at Edwards Air Force Base. It was the first of several test airdrops planned to evaluate its suitability for use with airborne forces. Although programmed for long-term use by Army units, the Stryker is an interim program that leverages current technology to satisfy current needs.

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FCS Vehicle. The Future Combat System (FCS) vehicle will be the primary weapon and infantry-carrying vehicle of the Future Forces. The vehicle and its eight variants encompass a portion of 18 hardware systems collectively known as the Future Combat System. Still largely on the drawing board, FCS will incorporate many advanced technologies in multiple configurations that make use of a common vehicle platform. Variants of the FCS vehicle roles include mounted combat, command and control, infantry carrier, reconnaissance and surveillance, cannon, mortar, maintenance and recovery, and medical treatment. The vehicle will also incorporate network-centric capabilities for reception and dispersal of information.

Deployability is critical to the FCS vehicle design. The vehicle must meet the following requirements.

- Total weight is limited to 20 tons.
- Be capable of airlift by a C-130.
- Be 70 percent lighter and 50 percent smaller than an Abrams tank. (An Abrams tank weighs 70 tons.)[38]

An airdrop requirement has not been set for the FCS, however since it is approximately the same size as a Stryker, that capability is assumed for this discussion. The Army is striving to design, build, test, and field the FCS by 2008 and equip a majority of intended units by 2013.

PEGASYS and JPADS. The Army and Air Force are keenly interested in developing precision airdrop capability, particularly from high altitude. Currently, *The effects of Army transformation and modularization on SBA are still largely unknown.*

equipment airdrop is accomplished by C-17s and C-130s using unguided *dumb* chutes normally at an altitude of 1,000 feet above the ground or less, at airspeeds close to landing speed. These factors make the aircraft extremely vulnerable to ground fire and surface-to-air missiles. Dropping at higher altitudes to avoid threats decreases the accuracy of the airdrops. It is not uncommon for airdrops conducted at altitudes greater than 20,000 feet mean sea level (MSL) to result in touch downs a mile or more from the planned point of impact.

The Army initiated a program to field a *smart* airdrop system known as the Precision Extended Glide Airdrop System (PEGASYS) to negate the disadvantages of standard airdrop capabilities. PEGASYS is a family of four Global Positioning System-guided, autonomous, precision high-altitude airdrop systems. The system capabilities are as follows.

- PEGASYS-XL. Cargo from 200 to 2,200 pounds
- PEGASYS-L. Cargo from 2,201 to 10,000 pounds
- PEGASYS-M. Cargo from 10,001 to 30,000 pounds
- PEGASYS-H. Cargo up to 42,000 pounds

The systems are releasable at altitudes up to 25,000 feet MSL with a drop accuracy of 25 to 300 meters, depending on the drop altitude. Each of the PEGASYS systems will be linked to the Combat Track II satellite system, which will allow for in-flight changes of the release point.[39]

In 2003, the Army's PEGASYS-L program teamed with AMC to form a program titled the Joint Precision Airdrop System (JPADS). The Joint Requirements Oversight Council recognized the importance of the program by ranking JPADS as its second highest priority for fiscal year 2004 technology demonstrations. JPADS will be *payload independent*, meaning it will use a platform that can accommodate anything that can fit on the platform. A PEGASYS-M variant will be capable of handling the Army's Heavy Expanded Mobility Tactical Truck Load Handling System and Future Tactical Truck System vehicles.[40]

Transformation, Modularity, and Their Effect on SBA: Determining a Reasonable Approach

The effects of Army transformation and modularization on SBA are still largely unknown. Planners on the 18th Airborne Corps and the 82d Airborne Division staffs have worked various elements of both programs. Members of the corps G-3 (operations and plans) staff indicate that progress has been steady but many issues remain to be worked.[41] Planning to this point can be characterized in three ways. First, both units have been subject to a high wartime operations tempo—personnel deployments have constrained planning efforts. Second, many aspects of the two programs remain in flux. Decisions on organizational issues are further along than weapon system considerations. The 82d is already programmed to transition from a three-brigade to a four-brigade structure. The FCS vehicle and JPADS/PEGASYS programs, on the other hand, are not close to production and this impedes decision making. Third, since the programs are so new, nearly all planning remains at the classified level.

This article suggests two approaches for analyzing how transformation and modularity may affect SBA. The first examines the issue from an Army perspective—*What are general actions the Army could take that affect SBA?* Since there are many potential permutations and combinations of hardware and organizational structure, the Army could implement general courses of action. Qualitative considerations are discussed as opposed to quantitative guesses with too many unknown variables. The second presents a proactive Air Force perspective—*What can Air Mobility Command do to optimize SBA for the Army?* This method assumes that forewarned is forearmed. That is, participating in the decision-making process that involves a significant portion of AMC assets is better than reacting to Army decisions after they have been made.

Army Actions Affecting SBA

There are four principal ways transformation and modularity can affect SBA—Improve unit restructuring; field the Stryker, FCS vehicle, and JPADS/PEGASYS. None of these are mutually exclusive of each other. In fact, it is not a question of whether any of them will be incorporated into SBA, but when they will and to what extent. In the following discussion only the predominant positive or negative factors are examined.

There are four principal ways transformation and modularity can affect SBA—Improve unit restructuring; field the Stryker, FCS vehicle, and JPADS/PEGASYS. None of these are mutually exclusive of each other.

Unit Restructuring. Deployability, flexibility, and independence are key characteristics that govern the reorganization and restructuring of Army units. Although the Army is due to increase in overall size during the next few years by 30,000 or more personnel, Army planning is for more efficient and effective *smalle*r units.[42] The four-brigade structure that the 82[d] is in the process of transitioning to maintains the division's current overall manning strength.[43] However, reducing the brigade size may decrease the number of aircraft required for either or both echelons.

It should be noted, however, some individuals caution that modularizing units may actually increase the size of the subunits or the parent unit because of the economies lost by having certain support functions pooled at the parent-unit level.[44] Spreading a function across battalions within a brigade or across brigades within a division may result in more total personnel performing that function than originally was the case. Similarly, modifying units by fielding smaller or lighter weapon systems may entice commanders to want more of the new system. All weapon systems have a logistical tail associated with them, so placing more of them within a unit may enlarge the unit's logistical footprint. Because a C-17 can carry three or four Strykers at a time as opposed to just one Abrams tank does not mean commanders will need to or should do so.

Stryker. There are five major options for incorporating the Stryker into the SBA. These options are not mutually exclusive.

Option 1 – Replace Alpha Echelon Vehicles. Replacing vehicles to be airdropped on a one-to-one basis with any Stryker variant will increase the number of C-17s required. Strykers are twice the length and wider than the average vehicle that is airdropped. Most alpha echelon vehicles are capable of airdrop via DRAS procedures, however, Strykers are not. Thus C-17 requirements would increase. If each Stryker added replaced more than one vehicle because of its greater utility, then it would be possible to maintain or reduce the number of C-17s required.

Option 2 – Add to Alpha Echelon. Adding Strykers to the standard airdrop package without decreasing the number of other vehicles airdropped will increase the number of C-17s required at up to a one-for-two rate. A C-17 is capable of dropping two Strykers on a single pass, but doing so requires the aircraft's maximum airdrop capability. No other platforms can be dropped from the aircraft.

Option 3 – Replace Wheeled Bravo Echelon Vehicles. This option is similar to Option 1 but with less negative impact. Airlanding any type of cargo permits more efficient use of the cargo compartment because fewer rigging and restraining devices are required than for airdropping equipment. The ratio of wheeled vehicles removed per Stryker is greater than it is for Option 1.

Option 4 – Add to Bravo Echelon. C-17s are capable of carrying four Strykers per aircraft. The number of C-17s required is therefore a one-to-three Strykers carried ratio.

Option 5 – Replace Tracked Bravo Echelon Vehicles. A C-17 is capable of carrying four Strykers, two Bradley infantry fighting vehicles, or one Abrams tank. Depending on which and how many vehicles are replaced, it is possible to reduce the number of bravo echelon C-17s, especially with a one-to-one replacement. Conversely, if the Army desires to retain the same number of C-17s, more Strykers can be carried. However, logistical and personnel support would have to be taken into account.

FCS Vehicle. The FCS affords the Army opportunities similar to those of the Stryker since the two vehicles will be approximately the same size and weight. Changes to the airland and airdrop components of SBA will depend on which vehicles or pieces of equipment the FCS replaces. There is the potential to reduce the number of C-17s if the Army replaces equipment at roughly a one-to-one ratio. If the FCS proves to be a quantitative leap forward in capability over the current wheeled, tracked, or towed equipment, there is the possibility for a greater ratio of legacy equipment replaced, which would also serve to reduce the number of aircraft required.

JPADS/PEGASYS. These two systems may have more of a qualitative than quantitative impact on SBA depending on how they are actually fielded. Their precision nature will facilitate the post-drop assembly of airborne forces on the ground—soldiers will not have to spend as much time searching for their designated equipment. The payload-independent functionality of JPADS and PEGASYS-M may influence the number of C-17s required if they allow for higher density airdrops. Higher density airdrop means the platform or container used can hold more equipment or cargo. If the systems can airdrop more equipment, fewer C-17s may be required unless the Army decides to make use of the additional volume by adding more equipment to the drop package.

What Can AMC Do to Optimize SBA for the Army?

Air Mobility Command is a major stakeholder in transformation and modularity initiatives. Although\ AMC does not always have a vote in Army decision making, it does have opportunities to facilitate and optimize planned initiatives. There are four ways in which AMC can specifically optimize SBA for the Army.

- **FFS.** The unfortunate cancellation of the C-17 SKE-FO program imposes a 3-year delay in AMC's ability to meet the 30-minute pass time requirement for SBA. The 3-year slip should obligate AMC to advocate Formation Flight System (FFS) as a priority program and be willing to fund it accordingly. Both the C-17 SPO and AMC must carefully monitor the program to prevent setbacks and any further delays.
- **JPADS.** Precision airdrop capability benefits AMC and all its airdrop customers, not just the Army, during SBA operations. Properly designed and functional JPADS platforms will not only facilitate ground recovery, they will reduce equipment losses due to errant and off-drop zone drops. The *2004 Air Mobility Master Plan* combat delivery and C-17 roadmap both identify precision airdrop systems as a highly desired capability.[45] AMC should fully support the design and testing of JPADS, which is being carried out by the Army Natick Soldier Center (NSC) in Natick, Massachusetts. AMC should also consider providing additional funding to NSC for JPADS. Such action would accelerate the program and serve as a good-faith gesture in light of the pass time delay caused by the cancellation of SKE-FO.
- **Stryker Airdrop.** Now that a C-17 has successfully airdropped a Stryker, the Air Force and Army need to coordinate, fund, and initiate a full developmental testing program followed by full operational testing. Since the first drop was made using estimated ballistic data, actual ballistic data for a drop of 10 G-11C parachutes must be developed and incorporated into AFI 11-231, *Computed Air Release Point Procedures*, and the C-17 mission computer database.[46]
- **SBA-Related Training.** Conducting a complete SBA or even a portion of a brigade airdrop (known as a *brigade slice*) in a training or combat environment is a daunting operation for all involved, from crews to maintenance personnel to ground support personnel. C-17 formation flights and airdrops of more than nine aircraft are only occasionally practiced due to limitations of available crews, aircraft, ground support, and real world operations tempo. As difficult as it may be to schedule, AMC should ensure that the operational C-17 wings perform periodic large formation airdrop flights of 12 or more aircraft. The 18th Airborne Corps and AMC conducted such exercises on nearly a quarterly basis at Pope Air

Modularizing the 82d presents the best opportunity to reduce the size of SBA operations for the Army and AMC.

Force Base during *Large Package Weeks* and annual *Big Drop* exercises; however, high wartime operational tempos for Airborne and C-17 units forced the cancellation of some of these events over the past several years.

Ideally, large formation exercises should be conducted in concert with the 82d, dropping personnel and actual SBA cargo and equipment. In particular, AMC should coordinate to drop Stryker and FCS vehicles as they enter the inventory. Outsized, 20-ton vehicles such as these are a challenge for ground personnel to rig and aircrew to load and drop, and are seldom actually airdropped. Providing as many individuals as possible with first-hand experience airdropping Strykers and FCS vehicles will improve the execution of actual SBA operations.

Conclusion

Predicting with precision the effects transformation and modularity will have on strategic brigade airdrop is a difficult proposition. The four primary elements of potential influence discussed in this article—unit reorganization, the Stryker, the FCS vehicle, and JPADS/PEGASUS—are independent programs with separate timelines spread out over a number of years. It is possible to make some general assertions using the framework of how Army actions may affect SBA and how the AMC can optimize SBA for the Army. It is also possible, and wise, to compare the two sets of options, and determine what actions can be considered *deal makers* or *deal breakers*.

Modularizing the 82d presents the best opportunity to reduce the size of SBA operations for the Army and AMC. Implementing a four-brigade structure with the existing division decreases the size of each brigade, which should reduce the amount of airlift required to airdrop and airland it. Adopting either or both the Stryker and FCS vehicles for SBA could increase or decrease the size of a notional SBA depending on how it occurs. Replacing alpha or bravo echelon wheeled vehicles with either system could reduce the airlift required depending on the ratio of vehicles replaced. Adding Strykers or FCS vehicles to either echelon will increase echelon size by a handful of C-17s if the swaps are done on a one-for-one basis. Swapping at a different ratio could still result in a net airframe reduction depending on the ratio used. It is too early to judge the influence JPADS or PEGASYS will have on SBA, since the systems are still under development. If the system variants employ some sort of container or platform that will allow a greater density of material to be airdropped, some airframe reductions are possible.

Air Mobility Command has several opportunities to positively influence SBA for the Army. First and foremost AMC, in concert with the C-17 program office, must vigilantly manage the FFS program so as to expeditiously field an effective system. The Air Force is on contract with the Army to meet a 30-minute drop zone pass time. The 3-year slip due to the failure of SKE-FO accentuates AMC's obligation to achieve this capability. AMC's active support of a successful JPADS program will improve post-drop ground operations and could result in decreasing the size of a notional SBA. The successful test drop of a Stryker appears to prove the viability of doing so in an SBA. If AMC accelerates the test program it can verify that possibility sooner and facilitate ongoing transformation planning. Finally, AMC should maintain an active large formation training program for its C-17 crews. The demands of real-world operations do constrain training opportunities but AMC can provide temporary relief for periodic exercises.

Deal Makers and Deal Breakers.

The Army and AMC have a number of courses of action by which they can influence SBA. Since these options are different in terms of viability, cost, timing, and impact, certain courses of action can be considered *deal makers* or *deal breakers*—the bottom line actions that will most positively and negatively affect SBA. There are two deal makers, unit restructuring and FFS, and two deal breakers, FFS and FCS.

Unit restructuring presents an opportunity to condense SBA and save air mobility resources if 82[d] brigades are reduced in size. Since AMC is the supporting command, it is not in a position to actively pursue or advocate brigade downsizing. The Army does not have to reduce the size of its brigades but there are significant advantages in doing so. The FFS, on the other hand, is a *must do* for AMC which qualifies it as a deal maker and deal breaker. AMC cannot make the 30-minute pass time requirement without replacing the C-17's current SKE system. A sufficiently functional FFS must permit at least a 10-minute reduction in pass time. FFS will be a deal maker if it functions as advertised; it will be a deal breaker if it doesn't function as advertised, or is fielded later than planned because of technological or funding issues.

Air Mobility Command has several opportunities to positively influence SBA for the Army. First and foremost AMC, in concert with the C-17 program office, must vigilantly manage the FFS program so as to expeditiously field an effective system.

The FCS poses the potential to be a deal breaker if it is not fielded within or close to the design weight criteria. If technological limitations preclude a 20-ton vehicle, a heavier vehicle could significantly affect SBA. A heavier FCS vehicle may not be capable of being airdropped. The FCS should prove a benefit to SBA if its weight is kept under control and the Army replaces SBA vehicles (wheeled or tracked) vice adding FCS vehicles to the echelons.

The airdrop and airland movement of the 173[d] Airborne Brigade into Bashur, Iraq in March 2003 proved the Army and the Joint Chiefs of Staff are willing to conduct a strategic brigade airdrop in combat. The comprehensive impact of the Army's transformation and modularity programs on all aspects of Army combat capability does not diminish this desire. In fact, the central thrusts towards improved deployability, mobility, and lethality, leveraged by technology, increased the possibility of future SBA operations. As the Army reinvents itself through transformation and modularity with the support of AMC, both institutions will affect the composition and execution of SBA. With proper coordination and realistic planning the Army and AMC can significantly enhance a vital element of our national military combat capability.

Notes

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Shaping Logistics—Just-in-Time Logistics

Geostrategic, economic, and technological changes will make support of air operations, both at home and overseas, increasingly dependent on the flexibility and responsiveness of the military logistic organization. This requires the creation of a highly integrated and agile support chain with global reach. The most promising strategy to achieve these aims is based on a joint management approach, teaming the public and private sectors, under long-term partnering arrangements. While it is probable that organic military maintenance capabilities will be retained, particularly to address life-extension and fleet-upgrade requirements, the alliance partners will largely determine the size and shape of the military logistic organization as part of their wider responsibilities for shaping the overall support chain. Success will be measured by a reduction in inventories, faster turn-round times, more rapid modification embodiment, swifter deployment of new technologies, a smaller expeditionary footprint, lower support costs, and greater operational output.

This strategy requires more, however, than the application of just-in-time principles. It embraces commercial express transportation; innovative contracting arrangements including spares-inclusive packages; the application of commercial information technology solutions to support materiel planning and inventory management; collective decisionmaking involving all stake-holders; an overriding emphasis on operational output; and most important, a high level of trust between all the parties. These changes may well result in smaller organic military repair facilities and the greater use of contractors at all maintenance levels, including overseas. Most important, it will require the military aviation maintenance organization to move away from an internal focus on efficiency and utilization to a holistic approach that puts customer needs, in the form of operational output, first and foremost.

As with any new strategy, there are risks. The fundamental building block in determining a successful partnership with industry is *trust*. As one commentator has observed, "Trust is the currency that makes the supply chain work. If it's not there, the supply chain falls apart."[1] As support chains are more closely integrated and maintenance strategies are better aligned, the more vulnerable is the logistic organization to the impact of inappropriate behavior. In the past, the risk might have been minimized and resilience enhanced by providing duplicate or alternative in-house capabilities backed up by large inventories. This is neither affordable nor compatible with today's operational needs. In the future, therefore, the main safeguard will be the creation of an environment in which government and industry, both primes and subcontractors, can function coherently, effectively, and harmoniously.

Notes

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Group Captain Peter J. Dye, RAF

Pipeline Purdah and the Barbed Wire Strand

In Moslem countries purdah is seclusion from the public of female *assets*. *Pipeline purdah* is when assets such as new aircraft and spares or personnel are unavailable because they are in-transit.

For the British in the Second World War, this became a critical condition with the fall of France in June 1940. Until the Italians entered the war in that month and the Middle East became a theater of war, transit delays were only a matter of days between Britain and forces in France. But once the Italians closed the Mediterranean, the 6000 miles from the United Kingdom or the US to Egypt became a 3 to 6 month matter.

This was especially critical in the early years of the war before production and purchase of provisions had reached such wartime equilibrium levels that the pipeline was full and supplies flowed out the far end at about the same speed as they were pumped in.

Wartime equilibrium refers to that short period at the peak between rearmamental instability and demobilizational instability when the war economy has been fully developed and crisis has been accepted as the norm. The other equilibrium is peacetime when money rather than time dominates.

In the case here, pipeline purdah was critical since the Middle East had not been envisioned in prewar days as a theater of war. Thus, it was essentially garrisoned to a peacetime colonial level and was short of everything from men and supplies to the invisible infrastructure of air stores parks, workshops and airfields, not to mention repair and salvage facilities, fuel storage, etc.

Thus, at the time the Royal Air Force (RAF) was dispatched to Greece in November 1940, there was a critical shortage of aircraft. This became a highly acrimonious matter between headquarters in Cairo and the Cabinet in London, resulting in the end in the recall of the long-suffering Air Officer Commanding-in-Charge, Middle East. It was only at that critical juncture when Greece and Crete had fallen in April and May 1941 that someone in London saw fit to comment that, of the 1782 aircraft which had by that time been allotted to the Middle East, only 330 had actually arrived. This observer failed to note that even those in the theater, such as the 28 Wellington's of Nos. 37 and 38 Squadrons, had only flown 12 operational sorties in support of operations in Greece in 6 months in the Middle East. Moreover, all the Hurricanes dispatched across the desert route to Cairo from West Africa via Khartoum had to be stripped and inspected before they could be issued to operational squadrons. Without the necessary invisible infrastructure that existed in Britain, this was a time consuming process not really eliminated until after the establishment of a full-scale base in Egypt. Meanwhile, operations, as well as ferrying, caused wastage to exceed replacements, thus making the Royal Air Force Middle East at times almost impotent.

Moreover, pipeline purdah was and is related to the barbed-wire strand. In this conception, all of the information, decisional analysis and the decisions themselves can be viewed as points along a strand of barbed wire; the segments between the barbs as periods of time; and the barbs themselves as events (both good and bad). Continuing with this conception, in the time between facts becoming evidence, management or command becoming aware of them and making a decision, the facts may have all changed. This is why it is critical that command be able to think and see the strand between the two ends and not just between two barbs, or only a single barb.

In the Middle East case it was also critical that London recognize that the Germans had interior lines and could switch assets from France to Sicily and the Balkans much faster than the British could. So for the British in Greece and the Middle East there was a need to equip the RAF with first-line machines and not with those cast off or not wanted at home. In other words, it would take prescience of mind to see that what mattered took account of both pipeline purdah and of the barbed-wire strand effects.

Robin Higham, PhD

Colonel Dennis M. Crimiel, USAF

Logistics Executive Agents: Enhancing Support to the Joint Warfighter

Introduction

The science of logistics concerns integration of strategic, operational, and tactical sustainment efforts while scheduling the mobilization and deployment of units, personnel, equipment, and supplies in support of the employment concept of the geographic combatant commander. The relative combat power that military forces can bring to bear against an enemy is enabled by a nation's capability to plan for, gain access to, and deliver forces and material to the required points of application across the range of military operations.[1]

—Joint Publication 4.0, Doctrine of Logistics Support of Joint Operations, 6 April 2000

The excerpt above was taken from Joint Publication 4.0. It underscores the very nature of the changing face of logistics support across the Department of Defense (DoD). The point emphasized in Joint Publication 4.0 is that logistics enables our military to bring combat power against our enemy across a full range of military operations. Our military is transforming to meet a very different threat than those that emerged during the Cold War. These emerging threats require our forces to be more flexible, agile, responsible, and lethal. Secretary of Defense Donald Rumsfeld made the point during a Pentagon town hall meeting in March 2003 when he stated:

> We entered the century really arranged to fight big armies, big navies, and big air forces, and not to fight the shadowy terrorists and terrorist networks that operate with the support and assistance of terrorist states. And that's why we are so focused on transforming the department and the armed services. To win the global war on terror, the armed forces simply have to be more flexible, more agile, so that our forces can respond more quickly.[2]

As part of the overall transformation process, the military is jointly moving ahead in transforming its logistics processes as well.

Logistics Executive Agents: Enhancing Support to the Joint Warfighter

In a memorandum dated March 2003, the Deputy Under Secretary of Defense for Logistics and Readiness, Diane K. Morales wrote, "Transforming logistics to meet the Future Logistics Enterprise objectives requires that we realign key roles and responsibilities to ensure end-to-end warfighter support, from requirements planning to acquisition through distribution and on to the ultimate customer."

In 2004, the Joint Staff updated its *Focused Logistics Campaign Plan,* which articulates a comprehensive, integrated approach for achieving full spectrum logistics support for the future Joint warfighter.[3] The plan is intended to be used at all levels of the Joint Staff, military Services and Agencies as the cornerstone for logistics transformation. The Office of Force Transformation within the Office of the Secretary of Defense (OSD) produced a Joint concept for logistics entitled the *Operational Sense and Respond Logistics Concept Plan* (S&RL) which "is a transformational, network-centric, knowledge-driven concept plan that enables Joint effects-based operations and provides precise, agile support."[4] The two initiatives complement one another and provide the overarching guidance and approach DoD will use to transform logistics.

Logistics is a complex business, and while great improvements have been made since the first Gulf War to streamline processes and better respond to warfighter needs, much work remains. Several reports including recent General Accounting Office (GAO) and OSD-sanctioned after-action reports, as well as others on Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF) have highlighted the need for the type of transformational changes in logistics noted in the *Focused Logistics Campaign Plan* and the S&RL Initiative. Recurring themes in all of these documents focused upon the continuous need for improvements in areas such as end-to-end distribution, logistics enterprise and integration, and supply-chain management. The *Focused Logistics Campaign Plan* addresses the challenges noted in the reports through transformation in the areas of Joint deployment/rapid distribution and agile sustainment. Under agile sustainment, one of the measures now underway to address future warfighter support is to reengineer the executive agent (EA) process. According to the plan, the use of EAs is one means to improve efficiency in the end-to-end distribution process, prevent duplication of effort, reduce waste of scarce resources, and provide a common means for warfighter support for certain commodities.[5]

In a memorandum dated March 2003, the Deputy Under Secretary of Defense for Logistics and Readiness, Diane K. Morales wrote, "Transforming logistics to meet the Future Logistics Enterprise objectives requires that we realign key roles and responsibilities to ensure end-to-end warfighter support, from requirements planning to acquisition through distribution and on to the ultimate customer."[6] She went on to say, "The DoD Component sources of supply whether they are weapon system program managers, commodity executive agents, or traditional Defense Logistics Agency (DLA) or military Service material commands, must assume full responsibility for satisfying warfighter support, regardless of what entities are executing the supply chain."[7] DoD Directive 5101.1, *DoD Executive Agent*, defines a DoD Executive Agent as, "The head of a DoD Component to whom the Secretary of Defense or the Deputy Secretary has assigned specific responsibilities, functions, and authorities to provide defined levels of support for operational missions, administrative, or other designated activities that involve two or more of the DoD components."[8] The use of executive agents presents a real opportunity for DoD to capitalize on improvements in end-to-end distribution, supply-chain management, logistics integration and interoperability for commodities such as fuel, food, medical, and construction barrier materials.

How Did We Get Here

For nearly 30 days after D-Day, the requisition flow out of [3^d Infantry Division] dwindled to a trickle. During 3 weeks of intense combat operations, the logistics requirements for this superb division were nearly invisible to the sustaining base because their division's logisticians could not pass their requirements off the battlefield. An expeditionary Army will not succeed if unit requirements are not visible in real time.[9]

—Lieutenant General C. V. Christianson Deputy Chief of Staff, USA/G4

Numerous articles and books have been published over the past several years on how to improve logistics support to the warfighter. DoD has made tremendous strides in logistics support during the past 20 years. General Christianson's remarks above highlight some of the difficulties our military faced during OIF and underscores the need for transforming logistics as our military looks to the future. An Air Force Logistics Management Agency (AFLMA) article noted, "The end of the Cold War and the experiences gained from conflicts in Grenada, Panama, and the Persian Gulf essentially brought the era of brute force logistics to a close." [10] Interestingly enough, however, that article was written in March of 1999. In an era where America's military remains the preeminent force in the world, one could ask why transformation is necessary. The *National Security Strategy* published in 2002 greatly clarifies why our military must transform. It states:

> The unparalleled strength of the United States armed forces and their forward presence has maintained the peace in some of the world's most strategically vital regions. However, the threats and enemies we must confront have changed, and so must our forces. A military structured to deter massive Cold War-era armies must be transformed to focus more on how an adversary might fight rather than where and when a fight might occur. We will channel our energies to overcome a host of operational challenges.[11]

The OSD report revealed numerous challenges in providing logistics support to the warfighter and noted that in one of the Army's after-action reports logistics was characterized as brute force logistics.

OSD and GAO Findings

The OSD-sponsored after-action report (*Objective Assessment of Logistics Operations in Iraqi Freedom*) published in March 2004 used the same term, brute force logistics, in its introduction when describing logistics support in OIF. The OSD report revealed numerous challenges in providing logistics support to the warfighter and noted that in one of the Army's after-action reports logistics was characterized as *brute force logistics*.[12] In both cases the authors were referring to the old practice of using large or massive stockpiles of supplies and equipment to

The OSD report specifically states, "each step in the chain is fully capable of executing its functional objective, but end-to-end warfighter support is not the primary objective."

support combat operations. This concept is analogous to a phrase coined by Lieutenant General Gus Pagonis after the Gulf War in which he described logistics support in terms of "moving mountains." [13]

Retired Rear Admiral Andrew A. Giordano wrote,

> The military supply chain's only reason for existence is to deliver support to the warfighter in such a way that combat readiness is both achieved and sustained … how to accomplish that objective is the question, and the answer lies in the reengineering of the military's supply chain's last and weakest line—delivery of support to the warfighter, in the way it is needed. [14]

Another logistician also argues that today's logistics and concepts of support are remnants of the old Cold War structure that was designed with an extensive infrastructure with somewhat predictable requirements.[15] He argues further that this concept of support ultimately resulted in logistics tails characterized by stockpiles of materials at various echelons of support.[16]

After reviewing these thoughts, one could draw the conclusion that not much has changed over the past 20 years. However, that is not the case. The research for this article indicates that all of the Services now recognize the need to change legacy systems and push toward more jointness and interoperability in logistics. This article draws upon the reviews of our most recent military operations as a means to identify the weaknesses in Service logistics operations that must be rectified in order to improve support to the Joint warfighter.

The OSD report highlighted specific problems with end-to-end distribution and supply-chain management. Figure 1, taken from the OSD report, highlights the various nodes in the DoD distribution process. The chart provides a good illustration of the complexity of the distribution process. It also characterizes how loosely the actual supply chain is integrated should one try to trace the actual path a part would have to travel to move from the source provider to the intended recipient. Why is this important? This complex process is part of what generates the many problems for the Services as noted in their after-action reports in terms of in-transit visibility (ITV), supply-chain management, and distribution.

Referring to the chart, the OSD report specifically states, "each step in the chain is fully capable of executing its functional objective, but end-to-end warfighter support is not the primary objective." Processes at each of the nodes must be designed to be interoperable, and managers within the nodes must have the tools to perform their jobs in the context of an integrated solution.[18] In a sense, all of the supply chains are optimized to support the individual Service requirements. However, one can draw the conclusion that Joint or interoperability support is difficult in the current setup because of fragmented or stovepiped logistics information systems. This issue is highlighted in the Services after-action reports as well.

This is an area where using EAs to provide common commodity support has great potential. According to DoD 5101.1, "The DoD EA's authority takes precedence over the authority of other DoD Component officials performing related or collateral

Joint or multicomponent support responsibilities and functions."[19] Essentially, commodity EA's have the potential to be more effective and efficient in optimizing common item support across the Services than the traditional service stovepipes that are not interoperable,

A GAO audit report released in December 2003 also noted similar logistics problems that occurred during the Gulf War and during OIF. The report specifically noted that the "failure to apply lessons learned from previous operations such as the Gulf War and the operations in Kosovo may have contributed to the logistics support problems encountered during OIF."[20] The GAO report cited four specific areas that led to logistics challenges during OIF.

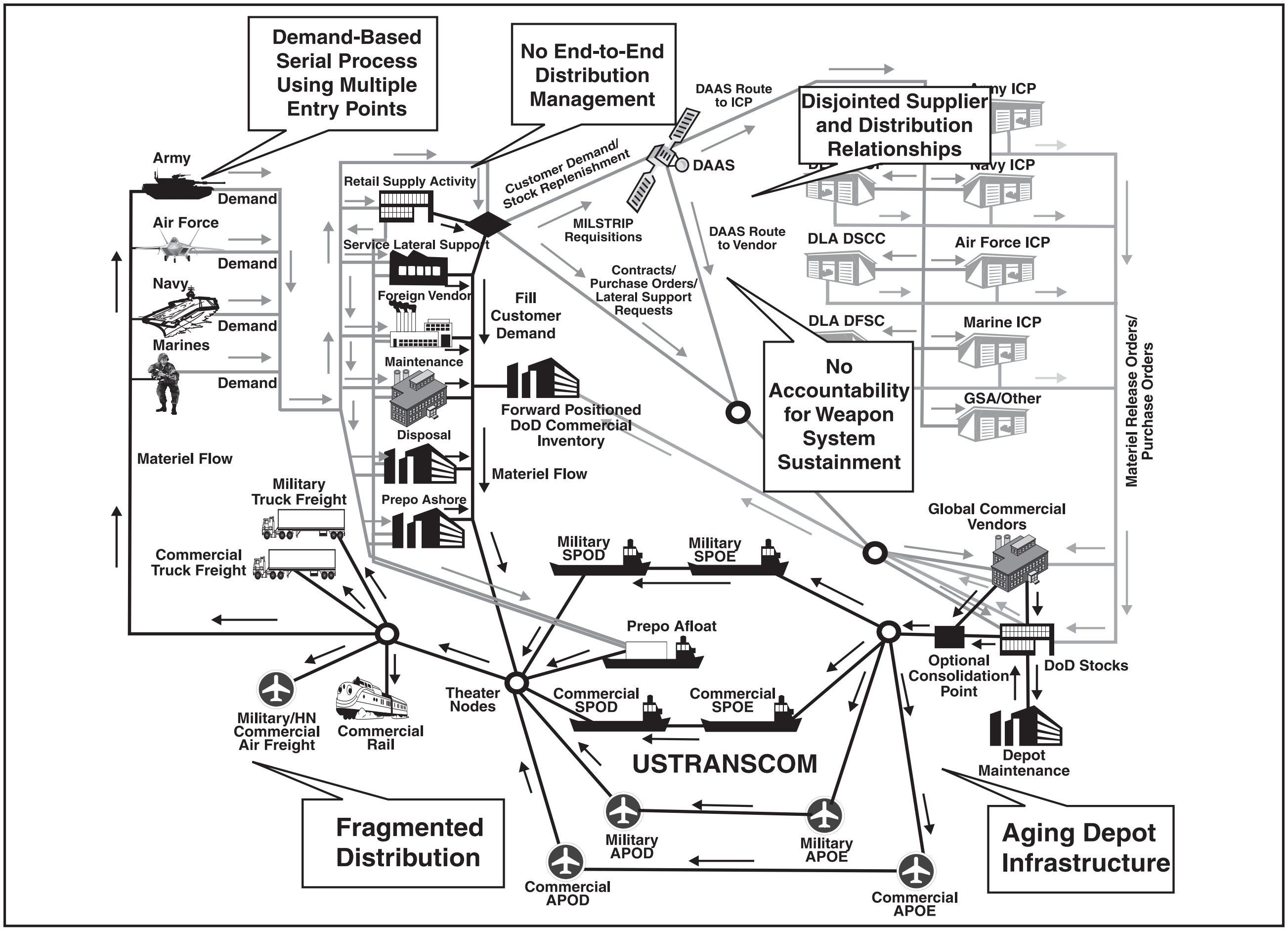

Figure 1. Current DoD Distribution[17]

Logistics Executive Agents: Enhancing Support to the Joint Warfighter

The report questioned whether the process used by the Air Force was really intended to provide the type of support outlined in the combatant commander's objectives or was the Air Force intent on providing support through brute force logistics?

- Poor asset visibility
- Insufficient and ineffective theater distribution capability
- Failure to apply lessons learned from previous operations
- Other logistics issues

While citing the logistics challenges, the GAO report also noted the sheer magnitude and volume of supplies shipped to support the war effort. For OIF, DoD obligated $28.1B of which $14.2B was for operating support costs and $4.2B was for transportation costs.[21]

Anthony Cordesman of the Center for Strategic and International Studies also wrote about some of the logistics challenges in OIF in a report entitled, *The Lessons of the Iraqi War: Main Report*, Mr Cordesman writes,

> Advances in logistics allowed the United States to fight halfway around the world with an unparalleled tempo of operations … the ability to refuel aircraft, move fuel and water, maneuver units, maintain and repair equipment in the field, and rearm and sustain was critical to every aspect of the war.[22]

However, Mr Cordesman noted that the operation was not without its share of problems. He observed that,

> US Forces did a great job of improvising and adapting; however, logistics and sustainment need to be better integrated into net-centric warfare and more attention is needed to improve the quality of communications in order to improve the tracking and force management capability at the battalion level and below.[23]

Mr Cordesman's comments were similar to those noted in the OSD report.

Military Services and Agency Findings

A Headquarters Air Force, Installations and Logistics-sponsored *Capstone* report published in June 2003 cited numerous issues from OIF that fall into a category of lessons learned which the report characterizes as "enduring potholes." The findings applicable to this article fall into the categories of insufficient ITV, fuels restraints, and inadequate prepositioned assets. The report questioned: (1)was the process used by the Air Force really intended to provide the type of support outlined in the combatant commander's objectives, or (2) was the Air Force intent on providing support through brute force logistics?[24] Again, the words brute force emerge. The report went on to cite "the single largest failure was the failure to provide end-to-end (Port of Embarkation to final destination) ITV." [25]

The Air Force after-action report listed two other areas that were found deficient and needing immediate attention. These two areas, fuels support and base operating support (BOS), have relevance to the EA initiative which will be discussed further in this article. The capstone report indicated that Air Force planners were unaware of the type of host nation support that would be available in the various operation locations required in the operational plan. The planners failed to properly conduct site surveys in these areas and the lack of fuel support could have potentially caused serious mission degradation.[26] Further, the report cited confusion in the area of BOS in locations occupied by Joint forces. In some cases, units could not properly perform their assigned missions because of the lack of resources and adequate supplies. The report indicated that most of the problems occurred because of a lack of coordination, a difference in philosophy and definitions, and a fundamental understanding of what Joint BOS really meant among the Services.[27] The report concluded that these logistics issues led to inadequate support and mission degradation at those sites hosted by the Army.[28] Several key recommendations emerged from the Air Force report. The Air Force recommended that "cross functional and interagency planning efforts in regards to fuel need to be reviewed and executive agent responsibilities need to be reviewed by the combatant commander for his area of operations."[29] The Marine Corps faced similar logistics challenges during OIF. Most notably, the Corps faced problems that were related to outdated logistics information systems. The outdated systems caused problems with ITV and distribution. Lieutenant General Kelly, Deputy Commandant, Installations and Logistics, indicated that the Corps needed to replace its old legacy systems that were not responsive enough during the initial phases of OIF.[30] The general indicated the old stovepipe systems and processes caused problems with tracking and distributing parts and supplies as the units moved out from Kuwait.[31] The general also commented that, "the days of putting mountains of Marine Corps logistics on a beach are over and the Corps is now focusing more on seabasing and rapid Joint operations."[32]

In the February 2004 issue of the *Defense Transportation Journal*, an article entitled "Army Logistics White Paper—Delivering Material Readiness to the Army," listed four focus areas that the Army will use to change its future logistics systems. The four focus areas are as follows.

- Connect army logisticians
- Modernize theater distribution
- Improve force reception
- Integrate the supply chain [33]

Three of the focus areas correlate directly with the logistics lessons learned from OIF. First, the Army has identified that its legacy logistics information systems are inadequate because of the lack of ITV. The lack of ITV limits the customers' visibility of the items ordered. In many cases, the customer reorders the same items. This results in a redundancy in items ordered and an inefficient use of scarce resources.[34]

The second focus area deals with the problem of theater distribution. The white paper notes the "Army cannot respond rapidly and precisely when support requirements are identified … effective theater sustainment relies solely on the fundamental concepts of distribution-based logistics."[35] The Army is working with its material command and the Defense Logistics Agency to integrate its logistics information systems to enable a more effective logistics distribution system.[36] The

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fourth focus area deals with the integration of the supply chain. In this effort, the Army is working toward a Joint solution to provide the type of end-to-end supply-chain management that is intended to increase speed and deliver focused logistics.[37] A quote noted in the *Torchbearer National Security Report* in April 2004 from Michael Wynne, Deputy Under Secretary of Defense for Acquisition, Technology, and Logistics summed up the problems associated with the military's old way of doing business in the following statement:

> Whether push or pull, our current logistics are reactive. At best, unless we embrace a new paradigm, we will still be depending on the warfighters to tell [the logisticians] what they need, then trying to supply it as fast as [they] can. This amounts to an industrial age vendor struggling to satisfy an information age customer. Reactive logistics—the old logistics—will never be able to keep up with warfare as we know it.[38]

The Army is working diligently to change its logistics support concept from one designed to fight the Cold War to one that is more Joint and expeditionary in nature. Major General Terry Juskowiak and Colonel John Wharton wrote in an article for the Army Logistician, "The Army needs to be able to provide the combatant commanders an army that has logistics capabilities designed to support the commander across the spectrum of military operations."[39] They also claim that the Army's logistics capabilities must be joint, flexible, and have a logistics infrastructure that can support simultaneous operations such as deployment, employment, sustainment, and also be integrated to provide a responsive end-to-end distribution system.[40]

Another author wrote that during OIF, the Army's combat service support units had to perform "miracle after miracle" in the area of distribution just to keep up with combat units.[41] This author also made another more poignant comment by saying that, "the majority of the distribution challenges encountered in OIF were the very same ones faced in Operation Desert Storm 12 years earlier."[42] These comments further underscore the point that in order for the Army to be responsive and agile, it must transform its logistics support structure, which in the past relied on a massive logistics tail to support combat operations. General Juskowiak injects that the Army's transformation strategy must undergo a cultural change and the logistics capabilities of all the Services must be fused with clear lines of command and control across DoD.[43] He further adds that the seams and gaps between the Services and Defense Agencies must be removed.[44]

DLA, a $25B enterprise, supplies more than 90 percent of the US military repair parts and 100 percent of its food, fuel, medical, clothing and textile, construction, and barrier material. DLA played an integral part in providing logistical support to OEF and OIF. According to Mr Allan Banghart, DLA's director of enterprise transformation, the Agency started its transformation processes in the mid 1990s to build and sustain a logistics system that is capable and has agility to ensure warfighter readiness and sustainment.[45] Colonel Leonard Petruccelli, Director of Contingency Plans and Operations, states that "DLA has gotten out of the business of warehousing huge mountains of items but now manages small hills of high demand items.” [46]

In planning for OIF, DLA attempted to get out in front of the challenges associated with supporting the military forces over time and distance by working hand-in-hand with the combatant commander’s planning staff to build and push sustainment packages prior to the beginning of the campaign.[47] In preparation for the enormous logistics support packages for OIF, OSD allowed DLA $924M of obligation authority to procure and acquire numerous types of supplies and equipment that would be in high demand once operations started.[48] DLA’s director, Vice Admiral Keith Lippert indicated that “DLA used this effort to validate a new business model that moved away from large warehouses of material to one that now relies on technology and contractors to provide inventory as needed.”[49]

DLA’s effort to lean forward in planning logistics support with the combatant commander paid big dividends in many cases. However, the OSD report cited numerous examples where the level of support did not have the anticipated impact as expected. More specifically, the OSD report indicated that the planning tool used by DLA, the Integrated Consumable Item Support Model, did an adequate job in determining fuel requirements but was less effective in determining requirements for repair parts and other commodities such as food, medicine, and so forth.[50] In addition, the OSD report indicated that United States Central Command and DLA’s effort to forward position huge quantities of construction barrier material had less impact than expected due to the limited visibility of those items by the units that needed them. Consequently, many of the items were needlessly purchased locally.[51] The OSD report also implied that the huge allocation of funds to DLA may have hampered the Services’ ability to procure advanced funds for their service-unique requirements.[52]

Despite the tremendous efforts of DLA, the agency also sees the need to continue to transform its processes to better support the warfighter. The problems noted in the OSD report associated with ITV, supply-chain management, end-to-end distribution, and collaborative planning all have implications for DLA. Admiral Lippert indicated that the agency is “reviewing the lessons from OIF to develop its strategies for the future to ensure improvements in the end-to-end process by improving its technological infrastructure and streamlining its business process in an effort to fully integrate the supply chain.”[53]

The Need to Apply Lessons Learned and Transform Logistics Practices

The OSD assessment, GAO report, Air Force capstone report, the *Torchbearer National Security Report*, and numerous articles written about the successes and failures of logistics operations during OEF and OIF all point to a couple of central themes. The Services and the combat support agencies must work to transform and integrate their logistics support activities. The *Torchbearer report* sums up the

The OSD assessment, GAO report, Air Force capstone report, the Torchbearer National Security Report, and numerous articles written about the successes and failures of logistics operations during OEF and OIF all point to a couple of central themes. The Services and the combat support agencies must work to transform and integrate their logistics support activities.

Logistics Executive Agents: Enhancing Support to the Joint Warfighter

Logistics transformation requires that the Services and Agencies learn from past practices and institute reforms to be more responsive and agile to support the warfighter across the full spectrum of the battlefield.

Army's initiatives through the following statement:

> Army logistics has worked to reduce the iron mountains through better business practices and enhanced supply and distribution automation efforts which, to a large degree, have paid off … what has not been realized is the end-to-end visibility over the supply chain and a responsive distribution-based transportation system focused on customer readiness.[54]

The Marine Corps is changing its philosophy by no longer looking to put large logistics footprints on the beach. The Air Force has identified the need to get more involved in collaborative planning with the Army and wants a better definition concerning executive agent responsibility. DLA no longer manages large warehouses but instead stores smaller quantities of high-demand items and relies heavily on technology, contractors, and vendor support in order to be more responsive to warfighter requirements.

The key word spoken and written by all is transformation. Logistics transformation requires that the Services and Agencies learn from past practices and institute reforms to be more responsive and agile to support the warfighter across the full spectrum of the battlefield. The Joint Staff's *Focused Logistics Campaign Plan* seeks to mitigate the myriad of logistics challenges identified in the various after-action plans. In the agile sustainment section of the plan, the Joint Staff has identified the use of EAs as a way to mitigate some of the inefficiencies and problems associated with current Service logistics practices. The plan specifically states: "A robust EA process for coordinating and providing common support to the warfighter can improve efficiency, reduce waste, and minimize duplication of effort among Services and Agencies."[55] Figure 2 poses a question worth considering: How many times must the logistics community continue to learn the same the lesson? This author would argue that the designation of EAs provides DoD a real opportunity to not only learn from previous lessons, but also an opportunity to implement an effective means to enhance warfighter support.

Taken from a briefing delivered by Ms Diane K. Morales in November 2003, Figure 2 illustrates a point addressed earlier. It addresses the fact that many of the very issues that DoD continues to tackle have been prevalent for over a 10-year period. In a speech given to the Conference of Logistics Directors in November 2003, Ms Morales used the chart to emphasize the point that the logistics community has been dealing with these issues since Desert Shield and Desert Storm but it is now time to build upon the current momentum in transformation and work to resolve these issues quickly.[57]

Much of this section of the article was based on the OSD Assessment, which provides a more elaborate and detailed list of findings. Many of the report's findings are not new to the logistics community but the findings illustrate that much work is still required. More specifically, the report cites the following.

- Gaps in the supply chain (supply-chain management) due to Service-unique stovepipes and organization alignments

- Lack of extensive collaborative planning
- Lack of a single controlling element for intratheater movement (end-to-end distribution)
- Unreliable or inoperable logistics communications process (lack of ITV) [58]

All of these findings, along with some lessons previously cited in the past, drive the need to transform DoD's logistics processes. Finally, the OSD report cites the need to change Joint doctrine for logistics support of combat operations. Joint Publication 4.0 specifically states, "logistics planners must focus on seamless deployment, distribution, and sustainment in order to properly enable the employment concept of the mission or task."[59] The OSD report cites that Joint doctrine for logistics is inconsistent and not directive in nature thereby causing the Services to relearn the same lessons each time they go to war.[60]

What Are We Doing Now

Introducing change in any organization is never an easy process. Many in the logistics community have readily recognized the need to transform current logistics processes and practices to ensure better support to the warfighter. John P. Kotter, a noted author on leadership writes "Transformation requires sacrifice, dedication, and creativity … only leadership can get change to stick quickly by anchoring it in the very culture of an organization."[61] OSD, the Joint Staff, and the military Services and Agencies are all engaged in transformation processes. The Joint Staff's *Focused Logistics Campaign* and OSD's Office of Force Transformation's *Operational Sense and Respond Logistics* concepts provide a backdrop for all of DoD's transformation efforts in logistics.

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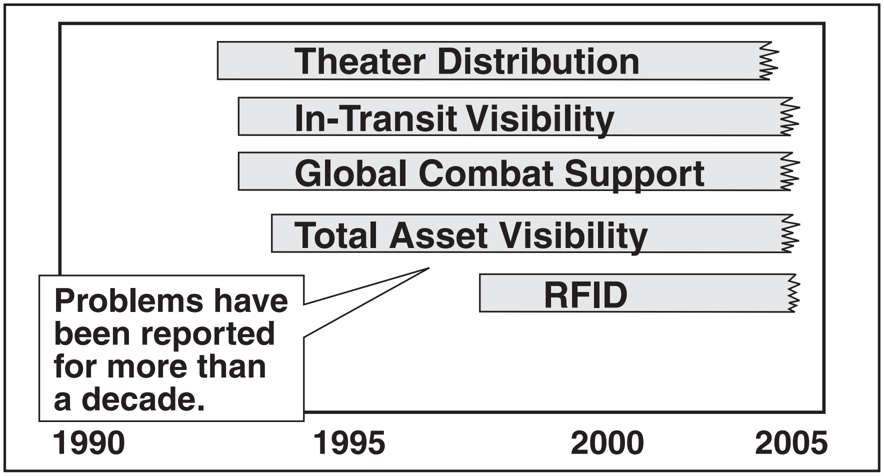

Figure 2. How Many Times Must We Learn the Same Lesson?

Logistics Executive Agents: Enhancing Support to the Joint Warfighter

The sheer magnitude of DoD logistics introduces impediments to transformation, but change is necessary in order to support the goals introduced in the Focused Logistics Campaign Plan.

DoD logistics is complex and enormous. Mr Alan Estevez, Assistant Deputy Under Secretary for Defense (Supply-Chain Integration) described DoD logistics in a briefing on DoD Logistics Transformation in April 2003. Mr Estevez iterates that "DoD logistics employs over one million personnel, engages over 80,000 industrial providers, consumes over $85B a year and is still structured to win a Cold War due to its multi-echelon inventories and maintenance and its large capital-intensive footprint."[62] During OEF and OIF, the Defense Logistics Agency alone provided more than 66 million individual meals ready to eat and over 2.6 billion gallons of petroleum and lubricants.[63] The sheer magnitude of DoD logistics introduces impediments to transformation, but change is necessary in order to support the goals introduced in the *Focused Logistics Campaign Plan*. The campaign plan states "that transformed logistics capabilities must support 1) future Joint forces that are fully integrated, expeditionary, networked, decentralized, adaptable, capable of decision superiority, and increasingly lethal, and 2) support future Joint operations that are continuous and distributed across the full range of military operations."[64]

Logistics transformation has been underway for a number of years. Paul Needham writes that the "transformation of military doctrine, strategic and operational concepts, and logistics processes began in the aftermath of the first Gulf War when the Joint Staff published *Joint Vision 2010* and later *Joint Vision 2020*."[65] Each Service has adopted new transformation strategies to ensure support to the Joint warfighter. Figure 3 provides a good depiction of the many *change drivers* that provide the underpinning for DoD's transformation efforts.

According to Needham, focused logistics is "intended to refocus the Services and the combatant commanders toward reducing forward inventories to a minimal amount and relying instead on consistent resupply."[67] Under Secretary of Defense Morales commented in November 2002 that the *Quadrennial Defense Review* (QDR) provides the "blueprint for DoD to transform our forces to meet the threats of the 21st century by establishing a set of requirements for DoD logistics." [68] The logistics transformation guidance from the QDR is as follows:

> As we contend with the difficult challenges of the war on terrorism, we must proceed on the path of transforming America's defense. Our commitment to the nation will be unwavering and our purpose clear: to provide for the safety and well being of all Americans and to honor America's commitments worldwide. As in generations before, the skill of our armed forces, their devotion to duty, and their willingness to sacrifice are at the core of our nation's strength. We must provide them with the resources and support they need to safeguard peace and security not only for our generation but also for generations to come.[69]

Accordingly, the requirements set by the QDR include the following.

- Project and sustain the force with minimal footprint
- Implement performance-based logistics to compress supply chains

- Improve weapon system readiness, and improve the availability of commodities
- Reduce cycle times to commercial industry standards[70]

One of the outgrowths of the requirements established by the QDR is the mandated use of performance-based agreements (PBA) between DoD entities that are sources of supply and the customers at major command levels. In March 2003, OSD levied a requirement upon these parties to sign collaborative agreements that would employ a customer-focused supply-chain strategy.[71] These PBAs would serve as a baseline for determining the sustainment requirements for the warfighter during execution of operational plans and also serve to codify realistic expectations between the customer and the supplier in terms of levels of support.[72] The use of PBAs is also an attempt to provide end-to-end customer support and puts the onus for providing that support on the supplier to oversee the process from requirements planning to acquisition and onward to distribution to the customer.[73] This OSD guidance applies to program managers, weapons-system managers, [commodity EAs], combat support agencies, and the Services' material commands that are responsible for execution of a supply chain. A key part of the initiative is the requirement for collaboration between the source provider and the customer (warfighter). In addition, the supplier efforts to meet the customer's requirements have associated metrics that have been formally agreed upon.[74]

One of the outgrowths of the requirements established by the QDR is the mandated use of performance-based agreements between DoD entities that are sources of supply and the customers at major command levels.

Paul Needham injects that "logistics transformation is essential to the defense transformation efforts that have been labeled the revolution in military affairs (RMA)."[75] Needham suggests that the operational concepts being introduced by RMA which include Joint response strike forces, enhanced information networking, swifter power projection, realigned overseas presence, accelerated deployment, maritime littoral operations and so forth, require a transformed logistics support

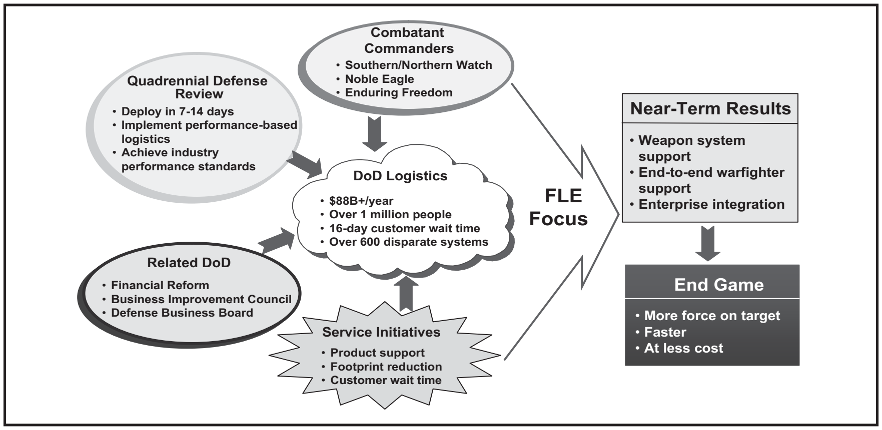

Figure 3. Change Drivers [66]

<table>
<tr><th rowspan="2">Memorandum Issue</th><th rowspan="2">Analysis</th><th colspan="2">Responsive Capability</th></tr>
<tr><th>Number</th><th>Capability</th></tr>
<tr><td>Distribution and logistics in the initial phases of OIF were chaotic, inefficient, and generated unacceptable risk to operations.</td><td>The primary focus of logistics operations should be achievement, in all phases of operations, of commander’s intent, focusing on speed and quality/effectiveness of support versus mass and efficiency.</td><td>OIL-2</td><td>Synchronize logistics operations with commander's intent, operations functions, and ISR by maintaining and exploiting total situation awareness based on: evolving commander's intent; the strategic, operational, and tactical situation; the operational environment; and force capabilities.</td></tr>
<tr><td>Unclear that better, or even good planning would have made any difference.</td><td>Static, history-based planning factors are not adequate: dynamic adaptation of logistics support must be provided.</td><td>OIL-3</td><td>Anticipate force capability and logistics needs to proactively sustain the force and alter initial conditions.</td></tr>
<tr><td>DLA involvement in theater logistics operations needs to be formalized.</td><td rowspan="3">A single perspective of logistics, from point-of-effect to source-of-supply, and focused on achievement of commander’s intent, must be developed, and should eliminate process and structure lines associated with hierarchical organizations.</td><td rowspan="3">SSPE-5</td><td rowspan="3">Permit the direct correlation of logistics resource demand to sustaining base suppliers and manufacturers, connecting point-of-effect to source-of-support, and enabling autonomic logistics.</td></tr>
<tr><td>Joint, multi modal, nodal and functional distribution organizations are necessary.</td></tr>
<tr><td>Distribution community requires an integrated, vertical view of the supply chain starting with a view of the supported commander’s requirements.</td></tr>
<tr><td rowspan="2">Need to base distribution decision making on operational situational awareness. Move towards distribution metrics that are “effects based” rather than business based.</td><td rowspan="2">Commander’s intent, including its expression in the form of desired effects, must be the predominant measure and factor in logistics support.</td><td>OIL-2</td><td>Synchronize logistics operations with commander's intent, operations functions, and ISR by maintaining and exploiting total situation awareness based on: evolving commander's intent; the strategic, operational, and tactical situation; the operational environment; and force capabilities.</td></tr>
<tr><td>OIL-5</td><td>Implement commander's intent, expressed in effects, missions, and tasks, in every aspect of logistics, across the full range of military operations, and for the full set of force capabilities.</td></tr>
<tr><td>Disconnect evident between US Army Combined Arms Support Command and Department of the Army view on configured loads.</td><td>A single perspective of logistics, from point-of-effect to source-of-supply must be developed, and should eliminate process and structure lines associated with hierarchical organizations.</td><td>ASRL-3</td><td>Permit rule-based, adaptable, peer-to-peer, autonomous demand and supply of logistics resources across battle space elements in all organizations, services, and allied, coalition, and treaty organization forces.</td></tr>
</table>

Table 1. US Army OIF Logistics Issues (Rock Drill) Versus Capabilities [81]

process and logistics organizational structure.[76] OSD, Joint Staff, and all of the services and support agencies recognize the need to transform.

In the updated *Focused Logistics Campaign Plan*, Vice Admiral Holder, Joint Staff Director of Logistics asserts that the very nature of future Joint warfighting will demand improvements in logistics support processes, systems, and organizations in order for the logistics community to effectively deploy and sustain Joint forces.[77] The lessons from OIF and OEF identified by OSD and the lessons from previous engagements, along with the change agents discussed earlier, all signify and necessitate the need for DoD logistics to transform. The *Focused Logistics Campaign Plan* sets the overall vision and outlines the strategy and direction for the logistics community to follow. As John P. Kotter noted in his book *Leading Change,* "reengineering, restructuring, and other change programs never work over the long run unless they are guided by visions that appeal to most of the people who have a stake in the enterprise: employees, customers, stockholders, suppliers, communities."[78] Although Kotter talks in business terms, one can easily substitute the American people and Congress as stakeholders, the warfighters as customers, and the logistics community as the suppliers and understand the gist of Kotter's point. DoD logistics transformation efforts have started with a clear vision and all parties in the logistics community are working on different aspects of the plan to shape logistics for the future.

The Focused Logistics Campaign Plan sets the overall vision and outlines the strategy and direction for the logistics community to follow.

Operational Sense and Respond Logistics

Complementary to the *Focused Logistics Campaign Plan* is the *Operational Sense and Respond Logistics Concept Plan* (S&RL) under development in the OSD, Office of Force Transformation. This concept expands or broadens the current logistics transformation efforts already underway. S&RL conceptually looks to use technology to *sense* customer needs and provide a rapid *response* to the customer demands.[79] According to the concept plan, "the resultant logistics structure created using sense and respond technology is a mosaic of suppliers, services, commodities, facilities, operations, distribution assets, tactics, techniques, procedures, and so forth, that operate in a coherent, coordinated, self-synchronized, dynamically adaptive manner to meet commander's intent."[80]

The concept paper also ties a number of lessons learned from OIF to the need for the type of sense and respond logistics advocated by S&RL. Again, the central themes (end-to-end distribution, total-asset visibility, and supply-chain management) emerge as focus areas that S&RL will be designed to improve. Table 1, taken directly from the S&RL concept document, lists some of the logistics issues from a US Army Rock Drill that will be addressed within the envisioned capabilities of S&RL. In essence, the capabilities being designed in S&RL to address these issues are complimentary to efforts being employed under the *Focused Logistics Campaign Plan*.

Logistics Executive Agents: Enhancing Support to the Joint Warfighter

The QDR requires the warfighter to shift focus from a threat-based mentality to a focus that now centers on a capabilities-based approach to deter and defeat potential adversaries.

Conceptually, S&RL will have the types of technology embedded that will help the logistics community adapt its processes and structures to be more flexible and adaptive to supporting the warfighter across the full spectrum of military operations. Though still in the concept phase, S&RL is being designed with some key enabling concepts that can be directly tied to the EA initiative. The enabling concepts of S&RL fall under six categories: adaptability and speed, effectiveness, flexibility, modularity, integration, and options for military tasks and effects. Figure 4 depicts key and enabling S&RL concepts.

For purposes of this article, three of the enabling concepts (adaptability and speed, effectiveness, and flexibility) have direct applicability to the recurring themes mentioned—end-to-end distribution, total-asset visibility, and supply-chain management. First, S&RL will be designed to achieve adaptability and speed. The enabling concept is that "logistics networks will be designed to self-synchronize through a common environment and set of shared objectives to achieve satisfaction of operational requirements at the point of effect."[83] In other words, the logistics system will be designed to readily respond to changing customer needs by identifying requirements based on usage trends and abnormal demand patterns in real time.[84] This is counter to present day logistics processes that are designed for simple and procedural responses to customer demands.[85] Second, S&RL will be designed to make logistics support more effective by continually monitoring the evolving strategic, operational, and tactical situations and then tailoring logistics support packages to optimize support for the warfighter.[86] Third, S&RL will improve sustainment of the warfighter's requirement by employing a network that is highly flexible and includes a detailed knowledge base for asset visibility.[87] S&RL will be designed to "broaden the logistics resource base and assure visibility of all the elements and components of logistics assets from all potential sources to achieve full spectrum asset visibility."[88]

S&RL is intended to be "implemented as a cross-service, cross-organizational capability that provides end-to-end, point of effect to source of support network of logistics resources and capabilities."[90] The enabling concepts of S&RL will complement the work already underway under the *Focused Logistics Campaign Plan*.

Focused Logistics Campaign Plan

The 2001 QDR provided the impetus for our military to take the necessary steps to transform in order to meet the challenges of a very different threat. The QDR requires the warfighter to shift focus from a threat-based mentality to a focus that now centers on a capabilities-based approach to deter and defeat potential adversaries.[91] The guidance from the QDR and OSD has galvanized efforts to transform our logistics support strategies to support the warfighter in all types of operations regardless of whether the threat is symmetrical or asymmetrical. Two of the major initiatives in the *Focused Logistics Campaign Plan,* Joint deployment/rapid distribution and agile sustainment provide the goals and strategies needed to rectify the many logistics challenges noted over the past decade and from recent assessments of OEF and OIF. The recurring logistics challenges were documented previously. The problems with global combat support (supply-chain management), distribution (end-to-end distribution), in-transit visibility, and total-asset visibility have been well documented and debated. The campaign plan lays out a strategy to combat these issues.

Under Joint deployment/rapid distribution, one of the basic goals is to improve the distribution process. In an effort to make the distribution process more interoperable in terms of deployment, sustainment, and redeployment the Secretary of Defense named United States Transportation Command (USTRANSCOM) as the DoD process owner for distribution.[92] Why is this important? This designation essentially puts a single entity in charge of the entire strategic distribution process. The idea behind this initiative is to synchronize the deployment and distribution capabilities of the Services and Agencies. After USTRANSCOM gained this designation, it partnered with DLA and the Services to establish a Deployable Distribution Operations Center (DDOC). The DDOC focuses upon providing improved total-asset visibility—in-transit visibility of force flow, sustainment, and

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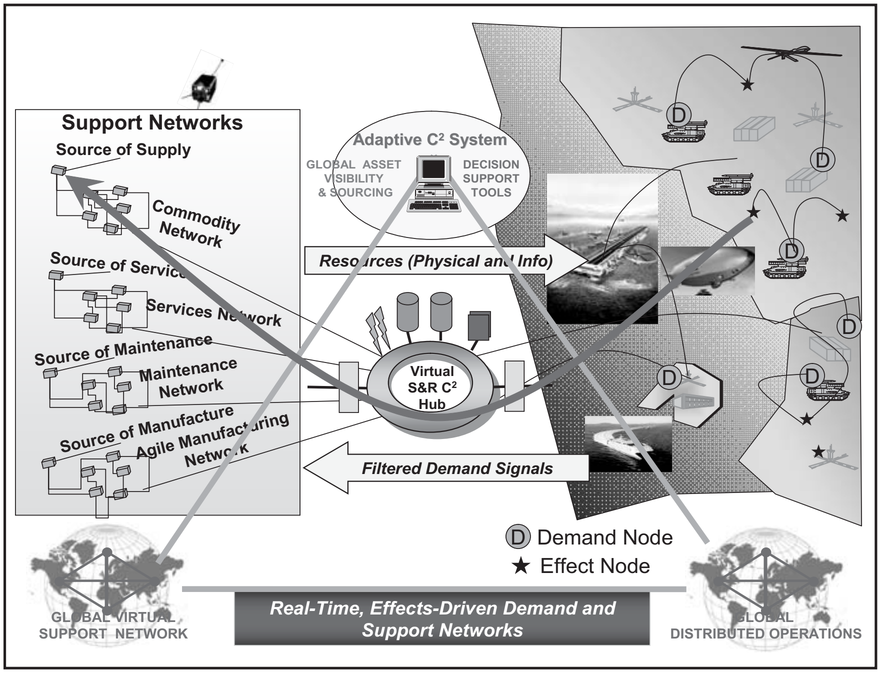

Figure 4. End-to-End Sense and Respond, from Point-of-Effect to Source of Support[82]

Logistics Executive Agents: Enhancing Support to the Joint Warfighter

retrograde.[93] Major General Dan Mongeon, Director of Logistics Operations, DLA commented,

> The partnership between USTRANSCOM and DLA brings together complimentary capabilities and skills essential to effectively and efficiently support our military services … it has allowed the synchronization of force deployment and the supply chain integration to support combat operations.[94]

The agile sustainment initiative focuses upon material management, prepositioned war reserve stocks, critical commodities, and force structure (combat support). Some of the goals of this initiative include implementing performance-based logistics, integrating the supply chains, reengineering the executive agent process, improving subsistence support, and employing the single fuel concept, to name a few.[95] As discussed earlier, the Service material commands, support Agencies, and the operational communities have already started the process of establishing performance-based agreements based on warfighter requirements.

Reengineering the EA process provides DoD the opportunity to improve efficiency in providing common item support, reduce redundancy and duplication of requirements, and reduce the demands on scarce resources.[96] Transforming DoD logistics is a massive undertaking that will continue to evolve over the years through continual changes in technologies, better information systems, and more thorough integration of Service and Agency capabilities. The transformation process did not just start but is moving forward as a result of several change agents—QDR, Joint Staff and Service Initiatives, and the changing threat environment that has caused our military to shift its focus to be more agile, flexible, and expeditionary in nature. Transforming logistics will require large investments of funds to improve old legacy information systems and stovepiped business processes. However, some transforming initiatives can be realized through changing organization structures, designation of process owners, and utilization of the executive agency process.

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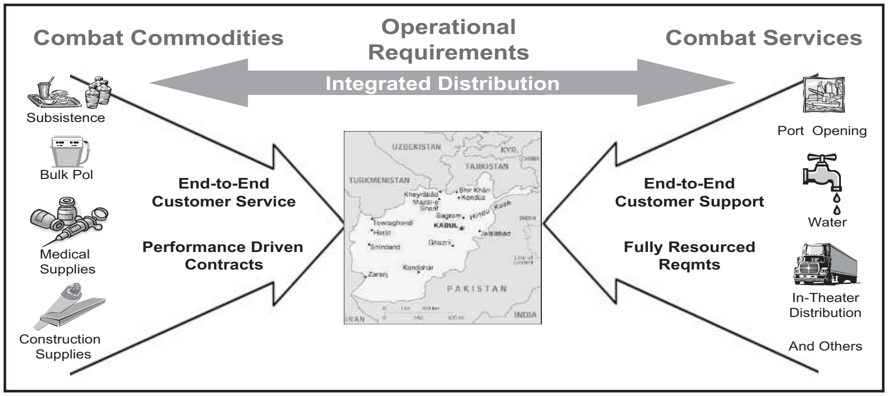

Figure 5. Executive Agents[101]

Logistics Executive Agents: Short-Term Wins in the Transformation Process

The overall strategy for transforming DoD logistics will employ the use of long- and short-term goals. Short-term goals can be realized or implemented in shorter durations than many of the more elaborate goals, which are reliant upon improvements in technology or funds. In fact, many commercial businesses use short-term goals or *quick wins* to build momentum toward achieving the organization's long-term goals. John Kotter writes, "short-term wins are important because they allow an organization to test its vision against concrete data."[97] He also believes that short-term wins allow the organization to adjust its vision and strategies. Without the concentration on short-term wins, developing problem areas may not have been realized until it was too late in the game.[98] The use of executive agents will allow DoD to gain short-term wins in the logistics transformation process.

As explained in the introduction, DoD Directive 5101.1 defines a DoD executive agent as "The head of a DoD component to whom the Secretary of Defense or the Deputy Secretary has assigned specific responsibilities, functions, and authorities to provide defined levels of support for operational missions, administrative, or other designated activities that involve two or more of the DoD components."[99] The directive also states that the designation of EA responsibility is conferred when DoD resources need to be focused on a specific area or areas of responsibility as a means to minimize duplication or redundancy.[100]

Future logistics enterprise, one of the pillars of agile sustainment, includes a number of short-term goals. In a briefing presented to the Supply-Chain World Conference and Exposition held in April 2003, Mr Alan Estevez, Assistant Deputy Under Secretary of Defense (Supply-Chain Integration) identified three near-term goals to transform logistics. These were weapon system support, end-to-end customer support, and enterprise integration.[101] The designation of EAs for common use commodities (food, medicine, fuel, and construction barrier material) across the military services incorporates the objectives of end-to-end customer support. Figure 5 depicts the integrated process embodied in the EA initiative.

OSD published the *Future Logistics Enterprise, The Way Ahead*, in June 2002. The document states the "desired result of the EA initiative is to align EA responsibilities that support the warfighter across the full spectrum of operations including support on an end-to-end basis and rapid response to all deployments, improved crisis and deliberate planning to include EA responsibility, and alignment of the resource (budget, force structure, and so forth) responsibilities associated with the EA."[103]

The "desired result of the EA initiative is to align EA responsibilities that support the warfighter across the full spectrum of operations including support on an end-to-end basis and rapid response to all deployments, improved crisis and deliberate planning to include EA responsibility, and alignment of the resource (budget, force structure, and so forth) responsibilities associated with the EA."

Another benefit associated with the designation of EAs is there will be associated metrics and performance indicators that will give the users and suppliers feedback on the level of support being provided. For example, the EA for bulk petroleum is required to establish PBAs with the Components "to set mutually agreed upon expectations."

Applying the EA Concept to Rectify Previous Lessons Learned

The actual designation of commodity EAs provides DoD with an opportunity to address some of the problems cited earlier. The OSD and GAO reports both cite numerous logistics challenges associated with end-to-end distribution, supply-chain management and in-transit visibility. DoD has officially designated DLA as the EA for bulk fuel, subsistence, and medical material. In each of the directives, DoD Directive 5101.8, *DoD Executive Agent for Bulk Petroleum*, DoD Directive 5101.9, *DoD Executive Agent for Medical Material*, and DoD Directive 5101.10, *DoD Executive Agent for Subsistence*, the EA has been charged with the responsibility to manage the supply chain, ensure effective end-to-end distribution, and provide visibility of the various commodities throughout the supply chain. These designations are touted as short-term wins because they provide a potential *fix* to resolve some of the problems associated with only three of the ten classes of supply required to support the warfighter. However, these designations are relative to initiatives that are conceptualized in both the *Focused Logistics Campaign Plan* and S&RL.

The OSD report and other authors cited in this report characterized support to OIF as *brute force logistics*. The general impression gained from these reports and articles is that DoD needs to reengineer its logistics support processes and truly move away from logistics practices that were carried over from the old Cold War support structure. This is an area where EAs can provide a measure of improvement and help to move DoD away from the use of brute force logistics. For example, the EA for bulk petroleum is required "to engage with the DoD components including sharing and leveraging of DoD resources to reduce costs and avoid unnecessary redundancies."[103] The EA for medical material is required to work with the Joint Staff, the Combatant Commanders, and the military Services to consolidate medical material requirements for surge and sustainment, and to execute sourcing and distribution plans to support the warfighter in theater operations.[104] And finally, the DoD components are required to coordinate subsistence requirements with the DoD EA to "assure material availability during peace and war, and prevent duplication of resources."[105] The designation of EAs will therefore allow DoD to reduce costs and duplication of resources, consolidate requirements, and ensure availability of these critical commodities in both peace and war.

Application of the EA initiative has relevance to some of the military Service findings as well. It was noted in the Air Force after-action report that the planners were not aware of what host nation support was available at some locations and that site surveys were not properly conducted. The poor planning could have led to lack of fuel support and degraded mission capability at those locations. In addition, part of the problem cited in this particular case had to do with lack of clarity in which of the Services (Army or Air Force) had responsibility for base operating support. This is an area where the EA for bulk petroleum could have significant impact. The EA is required to "acquire, store, and distribute bulk petroleum to all DoD customers [wherever] and [whenever] it is needed across the full range of operational situations."[106] Further, the EA is required to "coordinate with all DoD components, provide visibility for US Government, allied, coalition, host nation, and commercial bulk petroleum assets."[107] The key words in the directive require the EA to provide bulk fuel whenever and wherever the fuel is needed. In this case, the designation of the EA will alleviate some of the challenges associated with planning for fuels support in joint operations in austere environments.

In the OSD after-action report, four logistics challenges were noted that lend themselves to some resolution by using EAs for common commodities. These four areas addressed gaps in the supply chain due to service-unique stovepipes, limited collaborative planning, lack of a controlling element for end-to-end distribution, and lack of ITV. These four areas are addressed in the three commodity EA designations. More specifically, the EAs are required to collaborate requirements across all DoD components, manage the supply chain, provide visibility of all available assets and ensure end-to-end distribution of assets across a full range of military operations.

Another benefit associated with the designation of EAs is there will be associated metrics and performance indicators that will give the users and suppliers feedback on the level of support being provided. For example, the EA for bulk petroleum is required to establish PBAs with the Components "to set mutually agreed upon expectations."[108] The EA for medical material is required "to assess and report Class VIII supply-chain performance and readiness to include a clear definition of surge and sustainment requirements and material on hand or under contract to meet Class VIII requirements."[109] In the case of the EA for subsistence, the combatant commander is required "to provide timely and accurate forecasts of requirements and feedback to the DoD EA for subsistence regarding the types and quantities of subsistence items to be procured and delivered across the full spectrum of military operations."[110] The responsibilities assigned in the commodity EA directives are fully in line with the requirement for the suppliers and the customers to establish PBA as required by OSD guidance and logistics transformation guidance from the 2002 QDR.

The designation of DLA as the EA for three commodities provides the logistics community with some short-term wins in the transformation process. The EAs for these commodities now provide a single face to the customer and they are also responsible for end-to-end customer support and can eliminate gaps in the supply chain.

The designation of DLA as the EA for three commodities provides the logistics community with some short-term wins in the transformation process. The EAs for these commodities now provide a single face to the customer and they are also responsible for end-to-end customer support and can eliminate gaps in the supply chain. This designation also requires collaborative planning between the EA and the commodity users, which in the long term, reduces duplication of effort and reduces unnecessary expenditure of critical funds for scarce resources. The designation of these commodity EAs will only address a small portion of the logistics

Transformation is a long-term process that will require huge investments in technology, organizational restructuring and realignments, and improvements in logistics processes and procedures. However, there are some areas that can have immediate impact without massive changes. The designation of executive agents for common use commodities such as fuel, food, medical material, and construction barrier materials is a near-term solution that has merit.

challenges noted in the various OSD, GAO and Service-sponsored reports. However, these designations are one means to support the Joint warfighter.

Conclusion

Transformation of DoD logistics is a huge undertaking and has been in progress for a number of years. The logistics community is transforming to ensure it can fully support the warfighter across the full spectrum of military operations. One of DoD's greatest challenges is transforming a military that was designed, structured, and funded to fight a Cold War enemy that no longer exists. Today's threat environment poses a very different enemy than our military was geared to fight. Consequently, the 2001 QDR, the national security strategy of 2002, and guidance from the Secretary of Defense have all established the requirement for transformation of our military forces. These change agents have spurred a series of initiatives intended to provide full spectrum logistics support to the warfighter.[111] The use of EAs for common commodities is one means that is fully in line with the logistics transformation initiatives that will allow the logistics community to improve support to the Joint warfighter.

DoD logistics has to adapt to be more agile, expeditionary, and flexible in nature. The Joint Staff's *Focused Logistics Campaign Plan* provides an overarching integrated approach to transforming Joint logistics capabilities. OSD's *Operational Sense and Respond Logistics Concept Plan* seeks to exploit new technologies that will allow logisticians to sense the requirements of the warfighter and respond in a more expeditious manner. The military Services have all instituted transformation initiatives as well to improve end-to-end customer support, in-transit visibility, total-asset visibility and theater distribution. However, as mentioned earlier, many of the transformational changes have yet to have the impact intended. After-action reports and assessments from our recent experiences in OEF and OIF indicated that many of the logistics lessons identified from operation Desert Shield and Desert Storm are still plaguing our military today. The recurring themes fall into the categories that are all part of the transformation initiatives underway that DoD is working to resolve.

Transformation is a long-term process that will require huge investments in technology, organizational restructuring and realignments, and improvements in logistics processes and procedures. However, there are some areas that can have immediate impact without massive changes. The designation of executive agents for common use commodities such as fuel, food, medical material, and construction barrier materials is a near-term solution that has merit. The designation of DLA as the EA for these commodities is smart business. DLA already procures and manages the supply chain for these commodities. In essence, this designation will reduce duplication of effort on the part of the Services, improve the procurement process through consolidation of requirements, and provide for more efficient use of scarce resources (dollars). Several authors referenced in this report alluded to the fact that during OEF and OIF, the Services resorted to brute force logistics to support the military operations. This characterization of logistics support is reflective of an era when the Services pushed massive stockpiles of material and equipment to the theater of operations. This type of logistics support wasted critical funds and resources. EAs can alleviate these types of problems for the commodities noted. The designation of EAs requires that the supplier collaborate across the Services and Agencies to determine requirements through mutual agreements. In doing so, brute force logistics for these three commodities should ultimately be a thing of the past.

The *Focused Logistics Campaign Plan* and the *Operational Sense and Respond Logistics Concept Plan* are solid roadmaps for transforming logistics. The basic tenets of the two plans include the need to make logistics more agile, more responsive, more accurate, and more reliable across the full spectrum of military operations. The designation of logistics EAs is but one small step in the overall logistics transformation process. It is, however, one means to enhance support to the Joint warfighter. Additionally, after DoD reviews the merits of these EA designations over time, DoD may find it prudent to designate EAs for other common commodities such as military clothing, and repair parts (consumable items). It is therefore the recommendation that DoD continues to designate logistics EAs for common use commodities where the benefits can be readily realized.

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Logistics and Change

Over the past several years the Air Force has embarked upon a major journey of transformation. The Air Force has a long and sometimes difficult history of trying to apply commercial practices to our military functions. Many *old-timers* still remember the good old days of the *Quality* Air Force and spending hours on-end locked in a conference room trying to hash out things like mission statements or the dreaded COPIS (customer, output, process, input, and supplier). These *things* were then put into a book or on a bulletin board where they had no real impact on the way we did our business. Air Force quality was more about strict adherence to a series of steps than it was about empowering our people. Now let's fast-forward to today and look at our latest efforts to apply commercial practices to our Air Force logistics functions with *Transformation*.

It all starts with Expeditionary Logistics for the 21st Century, or as it's more commonly known, eLog21. eLog21 is "the Air Force's new level of commitment to boldly transform current logistics processes to better support the warfighter."[1] As we go through this period of transformation the end goal is "an integrated Air Force-wide logistics system that delivers consistent capabilities to the warfighter in a flexible, scalable, modular, and expeditionary manner, and exploits our nation's total capabilities in the most cost-effective manner."[2] The roadmap for eLog21 is the Logistics Enterprise Architecture (LogEA). LogEA provides "a single authoritative strategic map of future logistics business practices, systems, and organizations."[3] "Companies such as Boeing, Lockheed Martin, Procter & Gamble, and Eastman Kodak have defined future supply chain architectures, to guide their transformations by detailing the steps necessary to achieve the end-state, the resources required, and how to marshal those resources via a series of initiatives to deliver on the organizational goals."[4] This effort will eliminate existing systematic and functional stovepipes and develop a single integrated enterprise solution. Finally, the *glue* that will hold our transformation efforts together is the Expeditionary Combat Support System (ECSS). ECSS is the *system* piece of the LogEA. ECSS is a commercial-off-the-shelf (COTS) enterprise resource planning (ERP) system. Using the ERP as the core of ECSS will create standard business processes and tools across the Air Force logistics enterprise, regardless of program or location.[5]

Notes

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Thinking About Logistics

Understanding the elements of military power requires more than a passing knowledge of logistics and how it influences strategy and tactics. *An understanding of logistics comes principally from the study of history and lessons learned.* Unfortunately, despite its importance, little emphasis is placed on the study of history among logisticians. To compound matters, the literature of warfare is replete with triumphs and tragedy, strategy and tactics, and brilliance or blunders; however, far less has been written concerning logistics and the tasks involved in supplying war or military operations.[1]

Logistics is the key element in warfare, more so in the 21st century than ever before. Success on the modern battlefield is dictated by how well the commander manages available logistical support. Victories by the United States in three major wars (and several minor wars or conflicts) since the turn of the century are more directly linked to the ability to mobilize and bring to bear economic and industrial power than any level of strategic or tactical design. The Gulf War and operations to liberate Iraq further illustrates this point.

> As the machinery of the Allied Coalition began to turn, armchair warriors addicted to action, and even some of the hastily recruited military experts, revealed a certain morbid impatience for the "real war" to begin. But long before the Allied offensive could start, professional logisticians had to gather and transport men and materiel and provide for the sustained flow of supplies and equipment that throughout history has made possible the conduct of war. Commanders and their staffs inventoried their stocks, essayed the kind and quantities of equipment and supplies required for operations in the severe desert climate, and coordinated their movement plans with national and international logistics networks. *The first victory in the Persian Gulf War was getting the forces there and making certain they had what they required to fight* [Emphasis added]. Then and only then, would commanders initiate offensive operations.[2]

Unfortunately, the historical tendency of political and military leadership to neglect logistics activities in peacetime and expand and improve them hastily once conflict has broken out may not be so possible in the future as it has in the past. A declining industrial base, flat or declining defense budgets, force drawdowns, and base closures have all contributed to eliminating or restricting the infrastructure that made rapid expansion possible. Regardless, modern warfare demands huge quantities of fuel, ammunition, food, clothing, and equipment. All these commodities must be produced, purchased, transported, and distributed to military forces. And of course, the means to do this must be sustained. Arguably, logistics of the 21st century will remain, in the words of one irreverent World War II supply officer, "The stuff that if you don't have enough of, the war will not be won as soon as."[43]

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Coalition Warfare: Lessons from the American Expeditionary Force

I would rather try to persuade a man to go along, because once I have persuaded him, he will stick. If I scare him, he will stay just as long as he is scared, and then he is gone.

—Dwight D. Eisenhower, President of the United States

Introduction

The United States entered World War I as the relatively new and minor military force in the war. Both Britain and France wanted the United States to fulfill the role as a force provider with American troops being amalgamated into their armies as troop replacements. The United States wanted to enter the war on equal footing with both Britain and France and thereby establish a voice in world affairs.

The United States' rationale for wanting to make its voice heard was rooted in its limited dealings with coalitions and the wars it fought with foreign powers in the 1800s. The War of 1812 saw the United States battling Britain for two reasons. The first reason was the impressing of American sailors into the British Navy, and the second was the American belief that British agents in Canada were inciting Indian attacks across the border. The United States was not directly in a coalition during the conflict, but was taking advantage of conflicts occurring between Britain and France. As a result, France indirectly supported the United States.[1]

A decade later, President Monroe issued the Monroe Doctrine (December 1823). Again the United States was in an indirect coalition as President Monroe announced that any further European domination in the Americas would not be tolerated. He said that knowing full well that the British Navy would defend Latin America from

In 1917 Britain and France, the dominant Allied powers, were in desperate, almost terminal conditions with respect to manpower.

other European powers.[2] In both the Mexican-American War in 1846 and the Spanish-American War in 1898, the United States entered into coalitions where it dominated its allies. In the war with Mexico, the United States supported the revolt of settlers in California.[3] In the war with Spain, the United States sided with the people of Cuba, the Philippines, and Puerto Rico. The United States dominated those partners, but eventually let them gain independence. Cuba gained independence in 1902, the Philippines in 1946 (after World War II), and Puerto Rico in 1952 when its citizens voted for commonwealth status.[4]

With its entry into World War I, the United States was directly involved in coalitions and wanted to protect itself from foreign domination—the same type it inflicted on Cuba, the Philippines, and Puerto Rico. To put the United States on an equal footing with France and Britain, the Secretary of War, Newton D. Baker, and General Pershing wanted to create an American army fighting under American commanders. Secretary Baker directed General Pershing via a letter of instruction to create and lead a *separate and distinct* American army, "the identity of which must be preserved."[5] Conflicts arose out of the Allies' differing perspectives on the use of American troops.

In 1917 Britain and France, the dominant Allied powers, were in desperate, almost terminal conditions with respect to manpower. France wanted 500,000 untrained men sent immediately to England to receive infantry training, then be drafted into the French armies.[6] On the other hand, the United States as the up-and-coming power, was pushing for a more active role in building and leading its own forces in battle from the divisional level up. This article will first examine the individual allies and coalition's aims in deciding the best use of American troops, the confrontations of the key leaders, and the final resolutions that enabled the United States to create an independent AEF in World War I. The United States and General Pershing insisted on creating its own armies and corps, commanded by American generals, versus having its forces built into division-level blocks and having those divisions under the corps and armies commanded by Allied generals. The discussion will then apply relevant lessons to current conflicts where the United States is the dominant military power and integrates minor powers to build effective coalitions.

Background and AEF Buildup

When the United States entered World War I, France and Britain had sustained multiple defeats that decimated their armies. The overall size of the United States military was 208,034, including active and guard units.[7] When General Pershing arrived in France in June 1917, he landed with just 191 officers and men.[8] American troops did not arrive en masse until September 1917, and then the contingent was only comprised of the 1st Division with 14,000 men.[9] Additional American troops flowed in slowly as there was both a shortage of trained forces and ships to transport them from America. This slow influx of troops was insufficient to both stand up an American Army and to bolster Allied divisions. A year later, American troop strength was 1,400,000[10] and climbed to approximately two million by the Armistice.[11]

The high demand for troops raised the first major conflict between the Allies. In dealing with all the manning amalgamation issues, General Pershing quickly realized that British and French government and military leaders were primarily looking out for their own interests versus that of the coalition. Additionally, General Pershing believed that the coalition needed a Supreme Allied Commander to provide an overall unity of action and coordinated control to eliminate the disjointed strategies.[12]

Each coalition member was theoretically on the same footing as the others. The Entente early in the war was comprised of Britain, France, Russia, and Italy. Of those four, France was the unofficial lead on the Western Front as the front was in France and it provided the majority of forces. As Russia fell out of the war, the United States stepped in to fill the gap. France, and primarily Premier Clemenceau, tried to dominate the coalition throughout the war. The Supreme Allied Command Agreement signed by the respective government leaders gave each of the commanders-in-chief of the British, French, and American armies *tactical conduct of their armies* and *the right to appeal to his government* requests and demands of the other coalition members.[13] In essence this agreement balanced the hierarchy in the coalition.

AEF Amalgamation

One of the greatest issues facing the Allies in 1917 was a severe manpower shortage. America's entry into the war seemed to end that dilemma. America was unable to immediately send the hundreds of thousands of troops that the Allies needed. America needed to mobilize, and it would take almost a year before the numbers required by the Allies would show up en masse. Where to place those critical assets created a hot and heavy debate among the Allies. Britain and France endorsed amalgamation, where American troops would first flow to them as replacements for their divisions. The Allies' position was that it was a temporary measure to take advantage of European experience in training and leadership and to bring infantry forces to bear more quickly in the conflict. Once manpower conditions stabilized, it would then be possible to create American armies. They also argued that several other benefits would be attained by taking this course of action—American casualties would be lower under tried and true Allied leaders, amalgamation would relieve logistic support structures and associated support troops by using the Allied systems, and it would season American forces that were untried and untested against experienced German forces. In the end, the American commanders would get back their forces that could then be assimilated into a combat ready army.[14]

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Allied experience with amalgamation in World War I comprised of folding weakened battalions and regiments together to reconstitute combat units. The British folded in units from different British units and their commonwealth to build

Another contentious issue between the American and Allied leaders was the doctrine of trench warfare. General Pershing objected to the frontal assault and trench warfare mentality of the Allies. He believed that open warfare, taking advantage of soldiers' initiative, and their associated reliance on the rifle, would reduce casualties and break trench warfare.

their combat power. France combined different French units to make fully manned divisions. Looking to use other major powers, such as America, to fill in the gaps had not occurred on a large scale until 1917.

America, on the other hand, wanted to create its own standing armies commanded and led by American officers. General Pershing presented his own justification for not amalgamating American troops with the Allies—national pride, language difficulties, and negative impact to the US war effort from home (if foreign commanders ran up high American casualty counts as they were doing to their troops), and most importantly, downplaying America's role in the war and the subsequent peace negotiations. General Pershing would and did provide American forces to both the British and French commanders during times of crisis situations, but then only temporarily.[15]

Another contentious issue between the American and Allied leaders was the doctrine of trench warfare. General Pershing objected to the frontal assault and trench warfare mentality of the Allies. He believed that open warfare, taking advantage of soldiers' initiative, and their associated reliance on the rifle, would reduce casualties and break trench warfare.[16] Trench warfare relied on the following:

- Decisions made at the army or corps level with strict large-to-small unit interdependence
- Highly controlled, overarching intelligence on the enemy
- Firepower and artillery dominated battles
- Frontal assaults with detailed tactics
- Limited objectives with highly specific guidelines

Open warfare depended on the following:

- Decisions made at the tactical unit level with small unit independence and initiative
- Reliable and up-to-date combat intelligence on the enemy
- Maneuvers dominated by the use of rifle formations, flanking assaults, deep objectives with vague guidelines to allow the foot soldier to maximize effectiveness

While discussing the ability of American troops to execute open warfare, General Pershing stated, "In my opinion, no other Allied troops had the morale or the offensive spirit to overcome successfully the difficulties to be met in the Meuse-Argonne sector."[17] General Pershing referenced the Battle of Saint Mihiel, to validate the capability of open warfare in actual combat, stating, "For the first time wire entanglements ceased to be regarded as impassable barriers and open-warfare training, which had been so urgently insisted upon, proved to be the correct doctrine."[18] General Pershing's open warfare doctrine influenced future American commanders (such as General Eisenhower) in World War II. Rebecca Grant writing on General Eisenhower, showcased the open warfare lessons learned and the value General Eisenhower placed on them in the following statement:

> The act of writing the guidebook steeped Eisenhower in the intricacies of what Pershing liked to call *open warfare*. These American battles did not feature the stalemate, trenches, and meat-grinder artillery duels that virtually defined combat on the Western Front for most of World War I. By the time American forces fought their major engagements, the conflict had changed, and doctrine stressed the advantages of speed and mobility.

The beginning of May 1918 was very stressful on Allied leaders, and the coalition was showing signs of breaking up. The French felt the British were husbanding manpower in England and wanted it committed. Although England had a population base of 48,000,000 people compared to France's base of 39,000,000 people, France had 1,000,000 more troops committed than Britain. France wanted Britain's untapped reserves committed and they wanted the British to expand their front lines. The British felt they held more of the active front lines and that they were committed to other fronts.[19] Both agreed that the United States needed to pick up more of the load, and so they approached General Pershing to support the amalgamation of infantry and machine gunners into the Allied armies. The amalgamation issue was an ongoing controversy until 1 month prior to the Armistice.

Secretary Baker, bending to Allied pressure, received approval for Joint Note Number 18 from President Woodrow Wilson on 19 April 1918 giving preferential shipment of 120,000 infantry and machine gun troops during the months of April, May, June, and July for amalgamation into Allied armies. The troops were to be transported by both United States and British transports.[20] On his own, General Pershing, worked a separate deal (later called the London Agreement) with the British in which he agreed to supply 126,000 for the month of May only.[21] The following month in Abbeville, France, General Pershing argued with Premier Clemenceau, Marshal Foch, Prime Minister Lloyd George, and Lord Alfred Milner over the London Agreement versus the earlier Joint Note Number 18 agreement. General Pershing honored the London Agreement for April and May, allowing American troops to amalgamate with the Allies. He held out committing to amalgamation of forces in June and July until later to see if lending troops was really necessary based on more up-to-date German threat analysis. He finally proposed a compromise of continuing troop movement to the Allies in June with the option to expand to July at a later time.[22] This process of give-and-take persisted for the rest of the war. Obviously, Pershing could not stand by and let the Allies continue to be defeated when he had manpower to give.

French Premier Clemenceau put the most pressure of any ally on General Pershing and Marshal Foch to amalgamate American troops into British and French divisions.

French Premier Clemenceau put the most pressure of any ally on General Pershing and Marshal Foch to amalgamate American troops into British and French divisions. Premier Clemenceau stated his position in these comments, “For me, the French Minister of War, who day by day saw our ranks grow thinner and thinner after

Marshal Foch did not technically have the power to either direct the amalgamation of American forces or direct the formation of an American Army. He simply quit pushing the issue. According to the Supreme Allied Command Agreement, no one had overriding authority over another nation.

sacrifices unmatched in history, was there any task more urgent than to hasten, as far as possible, the effect of the intervention of America?"[23] Marshal Foch also pressured General Pershing to amalgamate American forces for two purposes—first, to strengthen Allied divisions, and second, to season American forces. Early American success fighting along side coalition divisions influenced Marshal Foch's approach to integrating American forces in the war as described by Michael Neiberg: "Their early successes were a pleasant surprise and Foch finally agreed to allow the Americans to fight *unamalgamated*, that is, under their own flag and officers."[24]

Marshal Foch did not technically have the power to either direct the amalgamation of American forces or direct the formation of an American Army. He simply quit pushing the issue. According to the Supreme Allied Command Agreement, no one had overriding authority over another nation. The supreme Allied command could only suggest their desires to American civilian and military leadership. Both President Wilson and Secretary Baker had given their full support and deferred all such matters to General Pershing.[25] General Pershing specifically addressed Marshal Foch's powers in the statement, "Marshal Foch, you have no authority as the Allied commander in chief, to call upon me to yield up my command of the American Army, to have it scattered among the Allied forces where it will not be an American Army at all."[26]

British commanders also wanted to utilize American forces in their armies. In 1918, the British transported, fed, clothed, and trained five American Divisions. After the German spring offensives were stopped, General Pershing asked for the American forces back from the British. Marshal Haig was incensed when General Pershing asked for the divisions back without them participating in battle under British command. Marshal Haig, after being in several meetings with General Pershing, knew there was little use in arguing with Pershing to try to keep the divisions.[27] Marshal Haig put up an amenable front on the sending of the five AEF divisions back to General Pershing with the comment, "I also wrote to General Pershing who thanked me for dispatching the American divisions (over 150,000 men) from me at the height of battle, they would, owing to the present tired and demoralized state of the Germans on this front, have enabled the Allies to obtain immediate and decisive results."[28] The comments show a lack of confidence in American commanders and that Haig believed British commanders could make the best use of the American troops.

As the Allies began to switch from the defensive to the offensive in 1918, Premier Clemenceau became firmer in directing Pershing to commit troops to the Allies. Clemenceau drafted a letter on 11 October 1918 to General Pershing and Marshal Foch advocating the immediate amalgamation of American forces. He stated that, "The letter was certainly pretty strongly worded—it was the hundreds of thousands of dead, the superhuman efforts made for years by our glorious soldiers, that dictated it. It was *harsh* both to Pershing who did not want to obey, and to Foch who did not want to command."[29] Premier Clemenceau presented the letter to Raymond Poincaré, the President of the Republic, who twice had him tone down the letter. The original draft addressed to Marshal Foch contained such language as, "It is our country's command that you shall command."[30]

Premier Clemenceau believed it to be in Marshal Foch's power as the Supreme Allied Commander to command General Pershing to comply with his orders. Marshal Foch did not agree with Premier Clemenceau and commented as follows, "On October 21, he wrote me an urgent letter telling me of the cares that laid heavy on his mind" and that, "Clemenceau finally urged me not to hesitate to appeal to President Wilson himself if indulgence were no longer of any avail."[31] Marshal Foch instead followed his own approach in working with General Pershing. Marshal Foch stated, "As I had daily dealings with the American Army, I obviously had some knowledge of its imperfection. I knew that they were rooted in its youth and inexperience of war, not in the actions or inaction of any of its leaders."[32]

Marshal Foch continued his attempts to persuade General Pershing to amalgamate troops to the last Allied offensive. General Pershing had been positioning the American Army to attack and eliminate the Saint Mihiel salient in the Allied lines. Marshal Foch developed alternative plans splitting the American Army into First and Second Army and having the French Second Army in between and directing American actions. General Pershing thought Marshal Foch was trying to downplay both the Saint Mihiel offensive and America's role in the war. General Pershing responded with, "I absolutely decline to agree to your plan. While our army will fight wherever you may decide, it will not fight except as an independent American Army."[33] Marshal Foch left the conference and tried a different tact as relayed by Michael Neiberg:

> True to his nature, Foch resolved the impasse with tact and compromise rather than by trying to force Pershing to see the war his way. When Pershing suggested that the Americans had enough men to participate in both the Saint Mihiel and a Muese-Argonne offensive, Foch agreed and promised to keep the American Army together. He then went one step further, placing all supporting French troops for the Saint Mihiel operation under Pershing's overall command. Instead of Americans under French control, French soldiers would be under American control. Foch also placed all Allied aircraft under American control. With one brilliant stroke of diplomacy, Foch averted a crisis with his American allies and saved the critical Saint Mihiel Offensive.[34]

Marshal Foch's understanding of how to work with coalitions and waiting until General Pershing had time to study the proposal was key to swinging General Pershing's support. Marshal Foch's understanding of each coalition member's overall political and military objectives along with their constraints increased his capabilities to lead as the Supreme Allied Commander.

General Pershing and Marshal Foch both reached the conclusion early on that the coalition needed a supreme Allied commander to provide an overall unity of action and coordinated control to eliminate their disjointed strategies.

Creation of the Supreme Allied Commander

General Pershing and Marshal Foch both reached the conclusion early on that the coalition needed a supreme Allied commander to provide an overall unity of action and coordinated control to eliminate their disjointed strategies.[35] For a long time, coalition members looked out primarily for their own interests rather than the good

A temporary fix to improve cooperation was to establish the Supreme War Council. The council was comprised of and headed by the prime ministers of France, Britain, and Italy. Nonvoting military members were Marshal Foch from France, General Bliss from the United States, General Luigi Cadorna from Italy, and General Sir Henry Wilson from Britain.

of the coalition. The Germans could be attacking a French sector and the British would not intervene until the situation turned critical to the coalition's survival. The Allies would not coordinate their attacks to put the maximum pressure on the Germans. As General Pershing put it, "When one was attacking, the other was usually standing still…. The Germans were thus left free to concentrate their reserves against the threatened point."[36] The allegations that each country was not pulling its fair share of the load fragmented their efforts.

This conflict was happening not only with the commanders but with the troops as well. Major James Harbord of General Pershing's staff witnessed a fight in a cafe between 40 French and 40 British officers that required the police to break up. Ambassador Walter Page reported friction even between the British forces and their commonwealth forces of Australians and Canadians when he stated, "Nothing could keep these nations together a week but dire necessity."[37]

On 24 October 1917, the Germans attacked Italian forces at Caporetto, Italy where they soundly defeated them. Using storm trooper tactics, the Germans took 300,000 Italian prisoners. A complete disaster was averted when British and French divisions reinforced the Italian's front. This defeat was a prelude that emphasized the necessity for inter-Allied cooperation. If the Allied team did not work together, the German armies would chew them up one at a time. A temporary fix to improve cooperation was to establish the Supreme War Council (SWC). The council was comprised of and headed by the prime ministers of France, Britain, and Italy. Nonvoting military members were Marshal Foch from France, General Bliss from the United States, General Luigi Cadorna from Italy, and General Sir Henry Wilson from Britain. The SWC mission was "to watch over the general conduct of the war," and orchestrate the military operations of the coalition.[38]

The next major setback to the coalition was the March 1918 offensives. The Germans pushed back both the British lines towards the English Channel and French lines towards Paris. The German offensive made it clear that the Allies must work in concert to survive. Coalition national pride was finally set aside and the appointment of a supreme Allied commander became a reality.[39] The British and French selected Marshal Foch to fill that position as the French had the preponderance of forces and Marshal Foch had previously showed the ability to direct coalition efforts when he stopped a German offensive earlier in the war at Flanders. At Flanders, he had successfully used persuasion versus coercion to rally and inspire both British and French division commanders and their troops to stand their ground on the battlefield and repel further German attacks.[40] On the other hand, General Pershing believed selecting Foch was a mistake, as he put it, "an accident." Marshal Foch, at the time, was the head of the SWC's military advisory committee and just happened to be available. Pershing said his selection "was certainly not because of any particular military ability he had displayed up to that moment."[41] As the events of 1918 would prove, Marshal Foch was the right man for the job as he effectively orchestrated the Allies' defeat of Germany.

The Supreme Allied Command Agreement concluded by Premier Clemenceau and Lord Milner gave broad powers to Marshal Foch. Premier Clemenceau stated that the agreement provided Marshal Foch "with *the strategic command*, and the formula was accepted."[42] The text of the new agreement was as follows.

> General Foch is charged by the British, French, and American Governments with the duty of coordinating the action of the Allied armies on the Western Front, and with this object in view there is conferred upon him all powers necessary for its effective accomplishment. For this purpose the British, French and American Governments entrust to General Foch the strategic direction of military operations.

At the request of the English the following phrase was added.

> The Commanders-in-Chief of the British, French, and American armies shall exercise in full the tactical conduct of their armies. Each Commander-in-Chief shall have the right to appeal to his Government if, in his opinion, his Army finds itself placed in danger by any instruction received from General Foch.[43]

The United States, Britain, and France signed the agreement. It clearly gave Marshal Foch more power as he now could direct the "strategic direction of military operations."[44] However, by giving Allied commanders the right to appeal to their government, Marshal Foch could not order them to follow his directions.[45] Contrary to Premier Clemenceau's desires, the additional wording inserted by the British showed words do matter. The British gave themselves an out that allowed them not to follow Marshal Foch's direction if desired. General Pershing used the clause to his advantage in deciding when and if he would amalgamate his troops into Allied divisions.

The Supreme Allied Commander Model of World War I set precedence for future conflicts involving the United States.

The fact that Allies will protect their interests over the coalition's interests points to the criticality of having good relations between nations and understanding each nation's aims. Not fully understanding the differing goals of France and the United States caused some of the confrontations between Premier Clemenceau, Marshal Foch, and General Pershing on the issue of amalgamating American troops. Marshal Foch being on friendly terms with the British Expeditionary Force's and AEF commanders proved essential to the Allies in defeating Germany.

The Supreme Allied Commander Model of World War I set precedence for future conflicts involving the United States. Forrest Pogue described General Marshall's view on the validity of having a supreme Allied commander in World War I and its applicability to World War II. Pogue wrote, "Marshall asked that one officer command the air, ground, and naval forces in each theater. He added that the Allies had come to this conclusion late in World War I but only after the needless sacrifice of 'much valuable time, blood, and treasure...."[46] The appointment of General Eisenhower as the Supreme Commander, Allied Expeditionary Force expanded on the World War I model. The World War II directive which further clarified roles and responsibilities is detailed as follows.

Directive To Supreme Commander, Allied Expeditionary Force—Dwight D. Eisenhower

1. You are hereby designated as Supreme Allied Commander of the forces placed under your orders for operations for liberation of Europe from Germans. Your title will be Supreme Commander Allied Expeditionary Force.

2. Task. You will enter the continent of Europe and, in conjunction with the other United Nations, undertake operations aimed at the heart of Germany and the destruction of her armed forces. The date for entering the Continent is the month of May, 1944. After adequate channel ports have been secured, exploitation will be directed towards securing an area that will facilitate both ground and air operations against the enemy.

3. Notwithstanding the target date above you will be prepared at any time to take immediate advantage of favorable circumstances, such as withdrawal by the enemy on your front, to effect a reentry into the continent with such forces as you have available at the time; a general plan for this operation when approved will be furnished for your assistance.

4. Command. You are responsible to the Combined Chiefs of Staff and will exercise command generally in accordance with the diagram at appendix. Direct communication with the United States and British Chiefs Of Staff is authorized in the interest of facilitating your operations and for arranging necessary logistical support.

5. Logistics. In the United Kingdom the responsibility for logistics organization, concentration, movement, and supply of forces to meet the requirements of your plan will rest with British Service Ministries, insofar as British forces are concerned. So far as United States forces are concerned, this responsibility will rest with the United States War and Navy Departments. You will also be responsible for coordinating the requirements of British and United States Forces under your command.

6. Coordination of operations of other Forces and Agencies. In preparation for your assault on enemy occupied Europe, Sea and Air Forces Agencies of sabotage, subversion and propaganda, acting under a variety of authorities are now in action. You may recommend any variation in these activities which may seem to you desirable.

7. Relationship with United Nations Forces in other areas. Responsibility will rest with the Combined Chiefs of Staff for supplying information relating to operations of the Forces of the USSR for your guidance in timing your operations. It is understood that the Soviet Forces will launch an offensive at about the same time as OVERLORD with the object of preventing the German forces from transferring from the Eastern to the Western Front. The Allied Commander in Chief, Mediterranean Theater, will conduct operations designed to assist your operation, including the launching of an attack against the south of France at about the same time as OVERLORD. The scope and timing of his operations will be decided by the Combined Chiefs of Staff. You will establish contact with him and submit to the Combined Chiefs of Staff your views and recommendations regarding operations from the Mediterranean in support of your attack from the United Kingdom. The Combined Chiefs of Staff will place under your command the forces operating in Southern France as soon as you are in a position to assume such command. You will submit timely recommendations compatible with this regard.

8. Relationship with Allied Governments. The reestablishment of civil governments and liberated Allied territories and the administration of enemy territories. Further instructions will be issued to you on these subjects at a later date.[47]

Coalition Relationships

Clearly the most critical element contributing to the success of the Allies was the strength of their coalition. What made the coalition work was the relationship each Allied leader developed with the others. The relationships were not always sterling as the poor rapport between Premier Clemenceau and General Pershing would attest. Both Premier Clemenceau and General Pershing sometimes pushed their own independent agendas versus overall coalition agendas. However, the Allies did meet the overriding goals as a coalition, which were the survival of each nation and the defeat of Germany. No matter what obstacles the Allies faced, they maintained a constant dialogue addressing key issues.

General Pershing displayed an uncanny talent for winning the respect of the French with his actions and sense of humility. He did not roll into Paris as the conquering hero coming to save the day, but instead showed his respect to the French flag and Napoleon's tomb.[48] Showing respect due the Allies was a highly diplomatic move on his part as it would take several months before American troops would arrive, be trained, and serve in offensive operations.[49] General Pershing respected leaders who were direct and laid the issues clearly on the line. According to Marshal Haig, General Pershing respected him for always being frank and forthright.

> When he was going he thanked me for being quite outspoken to him. [Haig speaking] At any rate, I always know when I am dealing with you what your opinion is on the question at issue. This is not always the case with the French.[50]

Even though he was cognizant of respecting the Allies' culture and traditions, General Pershing was extremely hard to work with. Marshal Haig commented on the turbulent relationship with Americans.

> At the Conference of the Supreme War Council a great deal of time was wasted discussing the agreement made by Lord Milner and General Pershing regarding bringing 120,000 American Infantry to France in May to join the British Army. I thought Pershing very obstinate, and stupid. He did not seem to realize the urgency of the situation.[51]

Marshal Haig recognized what General Pershing wanted to accomplish with an American army, but had no confidence in the American leadership's capability to build an effective force. Marshal Haig documented:

> He [General Pershing] hankers after a great self-contained American army but seeing that he has neither commanders of divisions, of corps, nor armies, nor staffs for same, it is ridiculous to think such an army could function unaided in less than 2 years' time.[52]

The total picture of General Pershing's personality varies from the hard line, highly-disciplined, and hard-to-work-with officer above to a dynamic, innovative, and compassionate leader. He continually strived to gain knowledge through education. Prior to entering the military he was a schoolteacher. He earned a bachelor of arts degree prior to attending West Point. Assigned as a professor at the University of Nebraska, he reshaped the cadet program, earned a law degree, and entered the bar. He eventually taught at West Point as an assistant instructor of tactics. Doctor

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Frank Vandiver summed up his approach to academic life and also military life in the following statement. “Pershing learned from every experience and turned knowledge to good purpose.”[53] General Pershing’s approach to dealing with friends and enemies varied with the situation at hand. He preferred a tactful approach, but would also use a harsher, more unyielding approach to meet his goals and missions.

General Pershing spent the early part of his military career putting down an insurgency in the Philippines after the Spanish-American War. There he demonstrated how to successfully treat an enemy or friend from both a chivalrous manner and a position of power. Instead of initially confronting the Moro warriors and sultans with force, he sent letters written in Arabic advocating friendship and mutual assistance. Several of the Moro natives that accepted the proposal grew to trust General Pershing. He subsequently stormed the forts of the Moros that continued the insurgency and soundly defeated them. He treated all Moros, both friend and enemy, with dignity, eventually gaining their cooperation. General Pershing’s obituary emphasized the point in the statement, “When at last they [the Moros] came to know he meant to help rather than humiliate them they, too, trusted.”[54]

On such a critical issue to him as the amalgamation of American forces, he stood firm against the Allies. That firmness and dedication to building an American Army paved the way for America to become a premier world power. America’s prominent position in world affairs today is largely the result of Pershing’s activities in Europe. His obituary also addresses that contribution in the following words:

> If he had less firmly insisted on an independent American Army, and American soldiers were divided among English and French forces, the power of the American government at the peace conference would have been negligible and the American nation would not likely be the world power it is today.[55]

Even though personalities made relationships more complicated, the Allied leaders always interfaced and together, arrived at solutions to issues. During the Versailles Conference in June 1918, there was a deadlock with Pershing on giving priority shipment of infantry for June and July. Pershing wanted to ship both combat and combat support forces to build up the American Army. The impasse was resolved and a compromise occurred when General Pershing suggested that Marshal Foch, Milner, and himself meet privately. The Allied viewpoint was that Pershing was inflexible and focused too narrowly on his army and not the coalition’s best interests. Overall, the Allied leaders and their staff felt that dealing with General Pershing was always a painful affair.[56]

Marshal Foch’s tact in working with each Ally went the furthest with maintaining cooperation among the leaders. Marshal Foch stated his philosophy on working with the Allies and the American Expeditionary Force (AEF) after the war with the comments,

> Thanks to my interpretation of the Supreme Command, I maintained continuous contact with my colleagues, and we worked together intelligently in an atmosphere of friendliness

> and even affection. I thereby succeeded in obtaining the utmost efforts out of various foreign armies under my orders.[57]

He also added:

> We have to treat men, and especially men of a different nation, according to what they are, and not according to what we would like them to be. I therefore continued my method of patience and persuasion as opposed to severity and constraint.[58]

Marshal Foch was not without his detractors and received criticism from not only his own country, but from Britain and America as well. Marshal Foch attempted to play the honest broker with all the Allies and took shots from all sides as he mediated and directed strategic and operational issues. "Balancing French and British interests proved to be one of his most difficult tasks. Every decision he made appeared to French generals to benefit the British, while those same decisions appeared to British generals to help France."[59]

Premier Clemenceau wanted Marshal Foch to take a harder stand with General Pershing by ordering him to comply. Premier Clemenceau chastised Foch's actions and threatened him over the approach he took as referenced in the statement, "M. Clemenceau upbraided me for showing him too much patience and indulgence" and declaring, "You will answer to France for it he told me one day."[60] The success of the American Army in the Saint Mihiel offensive and subsequent operations vindicated Marshal Foch's judgment and approach to dealing with the American Army and General Pershing.

Premier Clemenceau did not necessarily care to understand his allies and their requirements or aims as a sovereign nation. He preferred using a brute force approach to get what he wanted for France. He wanted more out of America in terms of amalgamation, and the earlier America complied with his wishes the better. He saw no utility in an American Army as a fighting force. Additionally, he was not necessarily excited about America gaining a powerful post war voice as a result of having an independent army. He became very impatient with General Pershing toward the later half of 1918 as relayed by Marshal Foch,

> Yet towards the end of the War, M. Clemenceau deemed that the American Army was not putting forth all possible effort. He attributed this to its commander, General Pershing. According to M. Clemenceau, the American general was seeking to constitute an autonomous army with a large and important staff, which was to act on its own accord without it paying sufficient attention to the operations of the other forces.[61]

Premier Clemenceau did not necessarily care to understand his allies and their requirements or aims as a sovereign nation. He preferred using a brute force approach to get what he wanted for France. He wanted more out of America in terms of amalgamation, and the earlier America complied with his wishes the better.

What enraged Premier Clemenceau about General Pershing was the slow introduction of American troops into battle. Premier Clemenceau saw France's manpower and its future decimation with each battle that passed. He wanted America to share the burden and troop losses. He articulated that in this statement, "General Pershing, in a friendly but obstinate fashion, was asking me to wait until he was in possession of an army complete in every part, and I went on insisting, in a state of nervous exasperation, while my country's fate was every moment at stake on the battlefields, which had already drunk the best blood of France."[62] Clearly one nation

The most effective method for motivating and leading a coalition was Marshal Foch's approach of understanding, persuading, and compromising with allies. Premier Clemenceau's hard-nosed approach and Marshal Haig's semi-confrontational-at-first-then-resignation approach when others did not agree with his position did not get the results they desired—the amalgamation of American forces and their earlier commitment to battle.

cannot demand that another nation act against its best interests as Premier Clemenceau tried to do. There needs to be some give and take to benefit both nations. Neither can a nation turn away from aiding its allies at critical times, as General Pershing seemed to do.

The hard-nosed relationship General Pershing had was not just with superiors and the upper command structure, but also with his peers. General Pétain, Commander-in-Chief, French armies, whom General Pershing confided in as a peer and who often agreed with his position on amalgamation and the leading of an army, had difficulty in dealing with Pershing. He observed that General Pershing was, "inexperienced and difficult to handle" and that he had "a time bomb in his brain; it took time for him to understand."[63] General Pétain also credited early failures of the American forces in battle and their poor logistic operations to General Pershing. He attributed the "American failures to Pershing's inexperience and seeking in vain to effect some form of fusion between the untried Americans and the experienced French.

Pétain was joined in this uphill struggle by Foch and Clemenceau, who blamed Pershing's *invincible obstinacy* for the inability of the Allies to make maximum use of these fine troops."[64] General Pétain attempted several avenues to aid the Americans and integrate them into operations. The confrontation finally culminated in General Pétain seeking higher authority to make General Pershing comply as documented in the statement, "In October [1918], Franco-American differences came to a head. Because it was clear that Pershing would not take orders from Pétain, invoking his status as commander in chief of an army of his own, Pétain suggested to Clemenceau that the American commander be placed directly under Foch."[65]

Of the approaches above, the most effective method for motivating and leading a coalition was Marshal Foch's approach of understanding, persuading, and compromising with allies. Premier Clemenceau's hard-nosed approach and Marshal Haig's semi-confrontational-at-first-then-resignation approach when others did not agree with his position did not get the results they desired—the amalgamation of American forces and their earlier commitment to battle. Marshal Foch summed up his successful approach with,

> Thanks to the plans to which I was determined to adhere, I succeeded in winning the confidence, goodwill and enthusiasm of General Pershing and his subordinates, which steadily increased. In the end, they acted entirely on my instructions and did exactly what I wanted—and did it with pleasure.[66]

The fruit of the approach was seen when Marshal Foch convinced General Pershing to attack and eliminate the Saint Mihiel salient, then disengage and attack west of the Meuse at a point 60 miles away in less than a 2-week period with an untested army.[67] The Saint Mihiel and Meuse offensives stretched the limits of the American forces. Luckily, the gamble paid off with the American operations helping to expedite the armistice.

Coalition Way Ahead

Coalition shortcomings did not end with World War I. Some examples from recent operations illustrate the issues involved. For example, during Operation Desert Shield and Desert Storm, Lieutenant General Horner attempted to integrate Saudi fighter pilots into the *Black Hole* planning shop of his Air Operations Center. He assumed that by just adding the Saudi pilots to the Black Hole, his staff would automatically integrate them to their best use. At the end of the war he saw the pilots and asked them how they were treated. Colonel Mohammed Al-Ayeesh, the senior Saudi pilot replied, "They treated me like a dumb officer. The moment I walked in, they shunted me to the side."[68]

Colonel Stig Ermesjoe gives a Norwegian *Post 9/11* perspective on the dilemma a small nation faces when working with a larger dominant nation as each strives to meet its national aims. He stated:

> Large nations with global interests will typically use alliances to actively pursue their national interest and if possible make any alliance a way in which they can employ means in the pursuance of their strategic objectives. Small nations, however, may develop security strategy on their own, but find themselves squeezed between their own nation's interests that at any time are developed through the alliance framework. And small nations usually do not have the material resources to employ national instruments of power decisively.[69]

General Tommy Franks, in testifying before the Senate Armed Services Committee, stated how critical positive working relationships between coalition partners are in influencing everything from forward basing and power projection to combat operations. He stated, "Our influence in the region is directly related to an active security cooperation program. USCENTCOM's [United States Central Command] program builds relationships that promote US forces with access and enroute infrastructure."[70]

Relationship lessons from World War I projected forward and reinforced in current models provide tools to overcome potential coalition conflicts such as the ones above. The coalition interactions of General Pershing, Premier Clemenceau, Marshal Foch, and Marshal Haig reemphasized the importance of positive relationships among key leaders to create and sustain effective interface and cooperation among allies.

The coalition interactions of General Pershing, Premier Clemenceau, Marshal Foch, and Marshal Haig reemphasized the importance of positive relationships among key leaders to create and sustain effective interface and cooperation among allies.

Two reinforcing models that are appropriate were examined during this research. Both models follow more of Marshal Foch's approach of working hand-in-hand with and persuading your allies. The first model to develop and maintain a good relationship with coalition partners follows Michael Fullan's *Framework for Leadership Model.*[71] Starting with a *moral purpose*, American commanders establishing coalitions in the future need to emphasize that the United States' actions are intended to improve world security and the security of our coalition members. With that accomplished, American commanders would continue through the model to *Understanding Change*. American commanders would help the coalition fully understand the complexities of the mission at hand, their part in it, and our commitment to assist them in any way possible.

One lesson that became a standard in all coalition operations is the requirement for a supreme Allied commander to provide an overall unity of action and integration of forces at the strategic and operational levels of war.

The key step, especially at the strategic level, is *relationship building*. Relationship building helps with innovation and implementation, and reduces resistance at combined headquarters and with member nations. *Knowledge Creation and Sharing* would be directly correlated to the trust developed in the earlier stages. With a high degree of trust, the parties would be more willing to share insights, plans, and recommendations, therefore improving the coalition command and control (C2) structure and the integration of forces.

The last stage of the model, *Coherence Making,* would need to be carefully managed by the United States. America would need to be highly cognizant of trying not to strong-arm junior coalition partners into decisions and courses of action (as Premier Clemenceau did) and instead rely on persuasion (as Marshal Foch did). As the stronger coalition partner, America needs to take into account everyone's needs and goals and work to blend them into what is best for the coalition. The goal for America and its allies is to have a functioning and engaging C2 and force structure that is willing to intervene in resolving security crises around the world. Maintaining trust with coalition partners and not aggressively directing strategic and operational actions will help meet US goals in the long run.

The second model that could be used to help resolve issues as they arise is T. Owen Jacobs' *Principled Negotiation Method*.[72] Under principled negotiation, each partner's aims and constraints are discussed. Here bargaining, or solution resolution, is based on merit. The key to principled negotiation is mutual trust, a positive relationship, attacking the problem and not the parties, finding mutual gains, and maintaining objectivity. Mutual gains in security that all parties can easily recognize are as follows.

- Expanded interface and improvement in commonality of tactics, training, procedures, and C2 for coalition partners
- Improved infrastructure and support cooperation
- Enhanced combat reach for all forces.

Marshal Foch effectively used the concepts of mutual trust and mutual gains to achieve consensus between World War I commanders, and therefore proved this model's validity.

Conclusion

This discussion on World War I leadership provided a critical look at the relationships between the United States and its coalition partners throughout the conflict. Some of the lessons have been ingrained in every operation since. One lesson that became a standard in all coalition operations is the requirement for a supreme Allied commander to provide an overall unity of action and integration of forces at the strategic and operational levels of war. The selection of General Eisenhower to be the Supreme Commander, Allied Expeditionary Force during World War II is the best example. Other lessons presented need to be retaught and reinforced with each new conflict.

One of the lessons that needs to be reinforced is to treat allies and enemies with respect. General Pershing demonstrated that concept in dealing with the Moros in the Philippines and the French people on his arrival to Paris. Enemies of today may become allies in the future. This was profoundly demonstrated after World War II with West Germany and Japan becoming staunch allies.

Reteaching the lesson to trust and allow innovation in your soldiers is equally important. Open warfare worked for General Pershing predominately because of the ability and initiative of the American soldier. General Pershing's statement brings that home, "In my opinion, no other Allied troops had the morale or the offensive spirit to overcome successfully the difficulties to be met in the Meuse-Argonne sector."[73]

Another key lesson needing emphasis is not to pursue your goals to the detriment of the overall coalition efforts. General Pershing, in not allowing the amalgamation of American troops in the Spring of 1918, increased the risk of the Allies losing the war with Germany before an American Army could be established. At the same time, Premier Clemenceau's one-sided focus on insisting on amalgamation could have denied the Allies an effective new fighting force in the American Army.

The most important lesson from World War I, however, was the importance of relationships among Allied civilian and military leaders. What General Pershing quickly realized was that British and French government and military leaders were primarily looking out for their own interests versus those of the coalition overall. Positive relationships at the key coalition leadership level overcame the self-interest issues. General Jacob L. Devers commenting on World War II coalitions observed the same lesson and stated it clearly:

> The theater commander must bear in mind that he has under command professional soldiers and experienced commanders of several nations other than his own, who owe their first allegiance to their own governments. It is only natural that representatives of another nation will examine critically every directive received and decision taken by the theater commander, from the viewpoint of their national aspirations—political, economic, and military.[74]

Commanders should use the Framework for Leadership and the Principled Negotiation Models as points of departure to build positive relationships with coalition partners.

Commanders should use the Framework for Leadership and the Principled Negotiation Models as points of departure to build positive relationships with coalition partners. They should look at the leadership styles of past leaders. Premier Clemenceau, in demanding unconditional support from weaker coalition partners, ignored the national needs and aims of coalition partners. Civilian leadership will continue to ask for more than coalition partners can deliver. General Pershing's overprotection of America's national interests with respect to the amalgamation issue nearly jeopardized the coalition overall. Marshal Haig, just resigning to go it alone somewhat in isolation, versus actively engaging the coalition partners when he needed help, also took a poor approach. Marshal Foch, effectively playing mediator between all the other coalition leaders, provided the best approach. His method of attempting to understand each coalition partner's position and using persuasion to bring everyone together made the best use of each Ally and reached the Allies' goal of defeating Germany.

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Concentration and Logistics

To win in battle we must concentrate combat power in time and space. Strategy and tactics are concerned with the questions of what time and what place; these are the ends, not the means. The means of victory is concentration and that process is our focus here. There are only four key factors to think about if we seek success in concentration. This is not a simple task. Although few in number, their impact, dynamics and interdependencies are hard to grasp. This is a problem as much of perspective as of substance. It concerns the way we think, as much as what we are looking at. The factors are not functions, objects or even processes. They are best regarded as conditions representing the nature of what we are dealing with in seeking concentration. They are as follows. Logistics is not independent. It exists only as one half of a partnership needed to achieve concentration. Why is understanding this so important? Logistics governs the tempo and power of operations. For us, and for our enemy. We have to think about the partnership of operations and logistics because it is a target. A target for us, and for our enemy. Like any target, we need to fully understand its importance, vulnerabilities and critical elements to make sure we know what to defend and what to attack. All military commanders, at all levels of command, rely on the success of this partnership. How well they understand it will make a big difference concerning how well it works for them and how well they work for it.

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Mending a Seam: Joint Theater Logistics

Introduction

Aptitude for war is aptitude for movement.

—Napoleon I

The United States is extremely capable of waging war, but its capability for moving, tracking, and controlling resources could be an Achilles heel during future conflicts if, as the military is transformed, the logistics system to create a seamless logistics capability that fully supports the warfighter is not also transformed.

In an effort to begin logistics transformation, the Secretary of Defense designated United States Transportation Command (USTRANSCOM) as the single distribution process owner for the Department of Defense (DoD), and charged USTRANSCOM with the overarching responsibility of ensuring the delivery of resources from point of origin to point of consumption with total-asset visibility (TAV). There are many logistics seams between the *factory and the foxhole*, but the largest seam is where strategic logistics meets theater (operational) logistics. This article posits that by creating a Joint weapon system out of the Deployment and Distribution Operations Center (XDDOC) concept, the DoD can mend the strategic-to-operational logistics seam and provide true Joint theater logistics.

Joint theater logistics is a complicated issue and involves many players, technology issues, and command relationships. This article will not address all the issues involved in mending the seam between strategic and theater logistics, but will concentrate on the United States Central Command (USCENTCOM) Deployment and Distribution Operations Center (CDDOC) Spiral 1 and what the report concerning the CDDOC describes as a way ahead.

A historical review of US wars is replete with examples of a logistics system very capable of delivering strategic resources, but often failing in getting those resources from the port of debarkation to the actual point of consumption in a timely manner.

Historical Perspective Leading to the CDDOC

The current logistics apparatus was suited ideally to the battlefields of the Cold War, with more clearly defined front lines. It is not enough to ship supplies just to the nearest seaport or airfield. Nor can we solely depend on just-in-time concepts for fast-moving tactical forces. The current scenarios require a logistics infrastructure that can deliver supplies to the "last tactical mile…"

—Lt Gen Lawrence P. Farrell, Jr, USAF (Ret),
President, National Defense Industrial Association

Logistics During World War II, Korea, Vietnam, and Desert Storm

A historical review of US wars is replete with examples of a logistics system very capable of delivering strategic resources, but often failing in getting those resources from the port of debarkation (POD) to the actual point of consumption in a timely manner. During World War II, Operation Overlord was ultimately a success, but the all important Normandy breakout came to a grinding halt because critically needed supplies could not reach lead echelons.

> …when the breakout from Normandy came and a tactical success was scored, full exploitation could not be achieved for lack of sufficient transportation…. In September, 1944 the allied armies halted their advance toward Germany because of lack of logistical support to the front, although there were ample supplies ashore in Normandy Base area, 300 miles away.[1]

Additionally, one can look at the Korean War for evidence of logistics struggles to get supplies to the *foxhole*. Joint Publication (JP) 4-01.3, *Joint Tactics, Techniques, and Procedures for Movement Control* cites the following example from the Korean War.

> Repeatedly [recalling the experiences of World War II], supplies were landed in such an excess of tonnage over the capabilities of the local logistic organization to cope with it, that pretty soon many things could not be found at all. The next thing, the Zone of the Interior had to rush out a special shipload of something which was right there in the theater—and always at a time when ships were worth their weight in gold. Soon the war moved on and supplies were left behind, which are still being gathered up and sorted out to this day [1953]. Two years after the Korean War started, I visited Pusan. They had been working hard, and by that time they had sorted out probably 75 percent of the supply tonnage there. Twenty-five percent of the tonnage on hand was not yet on stock record and locator cards; they did not know what it was or where it was.[2]

World War II and Korea provided numerous lessons observed but not learned as many of the same mistakes were made during the Vietnam War. Once again the logistics system did a good job of creating *iron mountains* of supplies. However, it eventually choked the PODs and was unable to get resources to the end user in a timely manner. The logistics system used in Vietnam was very stovepiped as "each

Service requested and shipped its own equipment and supplies…" with no Joint oversight until the establishment of the Traffic Management Agency (TMA) in 1967.[3] General Heiser writes,

> …the zeal and energy and money that went into the effort to equip and supply US forces in Vietnam generated mountainous new procurements, choked supply lines, overburdened transportation systems, and for a time, caused complete loss of control at depots in Vietnam.[4]

Similarly, Desert Storm was an example of good strategic logistics capabilities and lack of the ability to properly execute operational logistics. Almost 25 years after Vietnam as the US military executed Operations Desert Shield and Desert Storm, *iron mountains* reappeared because of the requirement to have 60 days of supply for all combat forces prior to launching the attack.[5] Sustainment was also an issue for Desert Storm and was based on "…a push system that tried to push too much into Saudi Arabia too fast, and almost splintered it. Military Airlift Command went from 100 to 115 outloads at 35 locations in the US to 3 offload sites in Saudi Arabia."[6] It goes without saying, theater logistics hampered the warfighter.

Desert Storm also saw the first employment of the Joint Movement Center (JMC) where it was responsible to the combatant commander for theater logistics. According to JP 4-01.3, *Joint Tactics, Techniques, and Procedures for Movement Control*, the JMC "should coordinate the employment of all means of theater transportation (including that provided by allies or the host nation) to support the concept of operations … and is the combatant commander's single coordinator with USTRANSCOM for intertheater movements."[7] The JMC was created to fix the seam between strategic and theater logistics, but was unable to do this during Desert Storm and is still today an organization created for the execution of Joint movement control, but not properly staffed and equipped to manage current theater logistics.

Present Day Logistics and the Creation of the CDDOC

In comparison to Desert Storm, when Operation Iraqi Freedom (OIF) was executed in March of 2003, the US military had made no major changes to doctrine, organization, personnel, and training relative to theater logistics support. It was better at strategic intransit visibility (ITV) and had prepositioned stocks, but still relied on the ad hoc-manned JMC to handle theater logistics. Logistically, it had not transformed. However, the way OIF was fought was transformational and unlike the previous Gulf War. To execute OIF and future wars, US forces would rely on speed, maneuver, and Joint or combined operations to mass effects versus massing forces. Instead of the 60 days of supplies on hand for Desert Storm, 5 to 7 days of supplies were on hand for OIF.[8]

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The Secretary of Defense decision to cut the force structure for OIF by half, only 4 months prior to execution, caused the military to scrap the time-phased force deployment data used to identify the arrival schedule of forces required, with the support forces taking the brunt of that cut.[9] In the end, the US had a smaller theater

Mending a Seam: Joint Theater Logistics

The CDDOC was created to link strategic deployment and distribution processes to operational and tactical functions in support of the warfighter, with the ultimate goal of improving logistics from the point of origin to the point of consumption.

logistics footprint providing support to a fast moving military force that covered two-thirds of the distance from the Iraq-Kuwait border to Baghdad (300 miles total) in only 36 hours, and eventually reached the capital 10.5 days later.[10] The Army's review of logistics during OIF summarizes logistics lessons learned. "The present supply system, while significantly more efficient than that which existed a decade earlier during the first Gulf War, lacks the flexibility, situational awareness, communications capacity and delivery means to fully meet the challenges of this new way of warfare with a reduced in-theater footprint."[11] After action studies pointed out that logistics during OIF and its play in the war's outcome "stemmed more from luck than design."[12]

Using logistical luck is not a strategy to "rapidly and decisively project power at great distances against all manner of adversary anywhere in the world."[13] The Secretary of Defense attacked the logistics problem head-on. On 16 September 2003, he designated the commander of USTRANSCOM as the distribution process owner and charged him with responsibility to "direct and supervise strategic distribution and synchronize all participants in the end-to-end supply, transportation, and distribution pipeline."[14] The USTRANSCOM Commander was given the overall responsibility to ensure that *stuff* made it from point of origin to point of consumption in order to support the theater warfighter.

Based on the historical analysis previously provided and a look at OIF logistics, it is not hard to realize the part not working in the US end-to-end logistics system was a part over which USTRANSCOM had very little control. USTRANSCOM's main task was to help the regional combatant commanders fix the theater logistics process by mending the seam between strategic and operational logistics.

To solve this problem, USTRANSCOM helped create the USCENTCOM Distribution and Deployment Operations Center (CDDOC). The CDDOC would be staffed with logistics professionals possessing the appropriate skill sets and would have reachback capability to the continental United States. The CDDOC gives USTRANSCOM an input to theater logistics and provides the theater commander with resources to help solve logistics at the operational level. On 12 December 2003, USCENTCOM approved USTRANSCOM's concept for a CDDOC, and the CDDOC was deployed in early 2004 for Spiral 1 of the new pilot program.[15]

What is the CDDOC?

The CDDOC was created to link strategic deployment and distribution processes to operational and tactical functions in support of the warfighter, with the ultimate goal of improving logistics from the point of origin to the point of consumption.[16] In order to do this, the CDDOC is staffed with members from USTRANSCOM, Joint Forces Command (Joint deployment process owner), Defense Logistics Agency (DLA), Army Material Command (ArmyMC), Air Mobility Command (AMC), Joint Munitions Command, Army Field Services Command (AFSC), and the individual Services. Discussions between USTRANSCOM J-3, USCENTCOM J-4, and DLA G-4 created a CDDOC mission statement.

> Confirm CENTCOM deployment and distribution priorities, validate and direct CFACC [Combined Force Air Component Commander] intratheater airlift requirement support to components and CJTFs [combined Joint task force], monitor/direct CFLCC [Combined Forces Land Component Command] intratheater surface distribution support to components/CJTF's, adjudicate identified CENTCOM distribution and intratheater shortfalls, coordinate for additional USTRANSCOM support, provide TAV and ITV for intertheater and intratheater forces and materiel, and set the conditions for effective theater retrograde.[17]

So, what is the difference between the CDDOC and the USCENTCOM JMC? The CDDOC is collocated with the CFLCC at Camp Arifjan, Kuwait and integrated into the JMC with tactical control provided by the USCENTCOM J-4. JP 4-01.3, *Joint Tactics, Techniques, and Procedures for Movement Control,* defines the mission of the JMC: "The JMC is in charge of movement control in the theater" and "must plan, apportion, allocate, coordinate, and deconflict transportation, as well as establish an ITV system to assist in tracking theater movements."[18] Based on the mission statements, the purpose of the CDDOC and JMC is essentially the same. The difference is that the CDDOC brings personnel with the correct skill sets and information technology to execute reachback to better perform strategic to operational synchronization in deployment, sustainment, and distribution of resources to the warfighters. In the author's opinion, the CDDOC properly staffs the JMC to perform its defined functions in a theater of war.

The CDDOC brings personnel with the correct skill sets and information technology to execute reachback to better perform strategic to operational synchronization in deployment, sustainment, and distribution of resources to the warfighter.

Evaluation of the CDDOC Spiral 1

> *US logistics systems can track all shipments and deliveries from the United States to overseas port of debarkation. But it lacks full "factory-to-foxhole" visibility of the supplies once they enter a theater of war. That visibility is essential in today's battlefields. The point of failure is at the seam between the strategic and operational level.*
>
> **—Lt Gen Gary H. Hughey**
> **Deputy Chief US Transportation Command**

What Worked

The *CDDOC Spiral 1 After Action Report* provides insight into CDDOC initiatives that are working to improve end-to-end logistics for the warfighter. Prior to the CDDOC's standup in the USCENTCOM area of responsibility (AOR), the USCENTCOM commander and his component commanders were continuously frustrated by the lack of visibility and oversight of forces deploying to the theater. This was primarily a problem because the lack of visibility did not give enough lead time to proactively posture to accept forces, but required commanders to react after forces arrived. Once again, forces could be efficiently and effectively deployed from the aerial port of embarkation to the aerial port of debarkation (APOD), but the coordination for follow-on movement (a Joint movement request) did not occur until after arrival at the APOD. This created unnecessary delays at the APOD and forced a reactionary measure versus proper planning.

This problem was solved through a CDDOC initiative called *Single Ticket.* Single Ticket enforces a single Joint Operation Planning and Execution System process for all passenger movements, across strategic and theater action agencies, and eliminates redundant tasks."[19] Not all forces are able to move via Single Ticket, but those that do, "move directly through strategic into theater lift and to the final destination while providing total visibility of the forces and reducing loiter time at interim locations…." A measure of the improvement after Single Ticket was initiated is that loiter time at interim locations was reduced by over 200 percent.[20]

In addition to helping provide more efficient and synchronized theater airlift, the CDDOC was responsible for helping save money throughout the theater distribution process.

In addition to improved force deployment, CDDOC was responsible for two initiatives that aided delivery of cargo. The first centered on intermodal diversion of cargo pallets. In this case, when direct delivery via airlift to Balad was unavailable due to higher national priorities, cargo was diverted via commercial air to Kuwait and then moved via truck to the theater distribution center where it was processed for movement via convoy north to Balad. The CDDOC synchronized and metered cargo flow to accommodate ground movement constraints. Cargo movement from Kuwait to Balad averaged 2.6 days, ensuring timely delivery of priority cargo.[21] The second cargo initiative was *Pure Pallets*. This initiative centered on the realization that it was better to wait a couple of extra days to build pallets at the depot or aerial port of embarkation, instead of using break-bulk/sort/distribution operations in the field.[22] Once again the CDDOC assisted this process with oversight and synchronization.

In addition to helping provide more efficient and synchronized theater airlift, the CDDOC was responsible for helping save money throughout the theater distribution process. The biggest money saver came through helping USCENTCOM logistics better manage its vast number of commercial containers used to distribute and store supplies throughout the theater. "When the CDDOC arrived in theater, it identified 23 sources for container data, thousands of containers missing from the ITV system, and detention charges accruing at $15M per month."[23] The carrier owned containers were being used, in locations that lacked permanent infrastructure, as storage facilities, protective barriers, brigs/stockades, and sometimes as temporary base exchanges. The CDDOC was able to help synchronize container reporting and merge the multiple sources of container data. After collecting the concerns of all theater container managers, the CDDOC helped develop a statement of work (SOW) and standard operating procedures for better contractor execution and monitoring of containers throughout the USCENTCOM AOR.[24]

Containers were not the only theater distribution resource needing better management. The backbone of airlift logistics, 463L pallets and nets, needed some *attention to detail* to improve theater logistics and the overall Defense Transportation System (DTS). Much like the containers, there was insufficient visibility, control, and maintenance of 463L pallets and nets throughout the USCENTCOM AOR.[25]

The CDDOC implemented a Web-based AOR tracker by modifying existing Air Mobility Command software that facilitates pallet and net asset tracking. The program "enables pallet and net monitors within the AOR to report assets on hand in relation to authorizations."[26] Because the system was Web-based, visibility for all concerned parties was increased, which led to more effective and responsive asset management—over 6,000 pallets and 11,000 nets were returned to the DTS.[27]

Along with better net and pallet management, the CDDOC also was responsible for helping to ensure better maintenance of these assets. Dirty pallets and nets will clog the logistics system much like dirt in a pipe can clog or slow the flow of water through that pipe. The CDDOC drafted a SOW to establish a contractor-operated pallet and net cleaning service. This was a first of its kind SOW and allowed pallets and nets to be consolidated at central locations and cleaned and prepared by local contractors for return to the DTS. This relieved the cleaning burden from the overworked and undermanned aerial ports staffs, allowing them to improve and provide better port service.[28]

Another first of its kind was the CDDOC's testing of the Talon Reach Iridium device. The Talon Reach Iridium device is a tracking device attached to surface logistics movements to provide real time location and cargo manifest data. The CDDOC was able to bring together all the required players to carry out this test, and during a 2-day test successfully tracked priority cargo, location, and content without any user intervention.[29] This kind of TAV and ITV is a key ingredient in creating a Joint theater logistics system.

By providing personnel with the correct skill sets and reachback capability, the CDDOC was better able to synchronize and direct theater logistics than had been the case with the JMC. Many of the CDDOC's Spiral 1 initiatives were successful, but there is still a long way to go to reach the goal of true Joint theater logistics.

Problems Still Persist

Based on all written accounts of Spiral 1, the CDDOC was successful at achieving its four primary goals of improving theater asset and intransit visibility for forces and supplies, synchronizing strategic and operational distribution systems, developing performance measures, and focusing on container and air pallet management and accountability.[30] The CDDOC was successful to the point that other geographic combatant commanders are establishing XDDOCs. Although CDDOC Spiral 1 achieved its goals, there are still problems that persist.

Based on all written accounts of Spiral 1, the CDDOC was successful at achieving its four primary goals of improving theater asset and intransit visibility for forces and supplies, synchronizing strategic and operational distribution systems, developing performance measures, and focusing on container and air pallet management and accountability.

In the author's opinion, the number one overarching issue that still persists throughout the theater logistics system is customer confidence. When customers have problems acquiring needed supplies, they attempt workarounds that may do more harm than good in relation to the theater distribution system. The customer may order twice the quantity required, or resubmit an additional requisition. In addition, the customer's immediate theater supplier, in an attempt to *better* support

Mending a Seam: Joint Theater Logistics

A Joint theater logistics system with complete theater ITV must have one boss that speaks and enforces *for the good of all. The current logistics system, and something the CDDOC struggled with, is a logistics system too stovepiped for today's warfare.*

a unit, may go into a *push* mode by sending more than required or items not requested. This type of logistics cannot support warfare that requires units to be light, lethal, and very mobile. For a unit to have confidence in the logistics system, the supplies they request must arrive in a timely manner or they must have accurate and up-to-date information on supply status, in order to continue, or alter operations accordingly.

In the author's opinion, to begin to improve customer confidence, one must begin by solving the problem of theater intransit visibility. JP 4-01.3, *Joint Tactics, Techniques, and Procedures for Movement Control* defines intransit visibility as: "The ability to track the identity, status, and location of Department of Defense units, and nonunit cargo, and passengers; medical patients; and personal property from origin to consignee or destination across the range of military operations."[31] ITV allows the customer to monitor requests and plan accordingly, but it also allows more efficient use of theater distribution assets. The capability for logisticians to locate and track, in real time, over two-thirds of strategic logistics destined to a theater such as USCENTCOM's exists, but once it arrives in theater much of this visibility is lost.[32] The CDDOC has helped improve ITV for the theater, but improvements are needed in order to create better customer confidence in the theater logistics system.

A Joint theater logistics system with complete theater ITV must have *one boss that speaks and enforces* for the good of all. The current logistics system, and something the CDDOC struggled with, is a logistics system too stovepiped for today's warfare. The Army's logistics chief, Lieutenant General Claude V. Christianson, accurately described this condition.

> When the Army, Navy, Air Force, and Marines work side-by-side in the same region, as they did in Iraq, the combined supply system is a clashing mismatch of different cultures, incompatible communications systems, different stock numbers for similar items, even different vocabularies. Keeping track of a spare Marine Corps tank transmission as it moves from a Marine Corps depot to an Air Force cargo plane to an Army truck, for instance, is one of our biggest challenges.[33]

In its statement on command relations and directive authority during its pilot test, the *CDDOC Spiral 1 After Action Report* shows how the Services remain very parochial and stovepiped in theater logistics.

> …although CDDOC had directive authority for intratheater airlift, it was never provided with official 'directive authority' over theater surface transportation resources and assets that would have helped to synchronize the inbound and outbound cargo and passengers. The directive authority over those transportation assets rested with the CFLCC C-4, and the 143[d] Transportation Command.[34]

Not only are there stovepipe and compatibility issues within the logistics community, but the community also has compatibility issues with the warfighters it supports. Retired Vice Admiral Arthur K. Cebrowski, director of the Pentagon's Office of Force Transformation, described this dysfunction. "Supply problems in

Iraq resulted, in part, because logisticians use separate information and command and control systems apart from those that the warfighters use."[35]

To successfully continue to transform the US military into an expeditionary Joint force, theater logistics capability must be simultaneously transformed. The CDDOC concept is a good start at improving theater logistics, but in order to provide the customer confidence required to fight today's wars, theater logistics must provide complete intransit visibility and speak coherently to the warfighters with one voice.

Upgrading Theater Logistics

Forget logistics and you lose.

—Gen F. M. Franks Jr, USA

XDDOC as a Joint Weapon System

The US military has done well at placing emphasis on strategic logistics. What it has not done is place that same emphasis and importance on theater logistics. Historically, the US military has a record of waiting until a contingency erupts to produce a theater logistics operation that gets the job done. It was not until 2 years into the Vietnam War that an attempt was made at Joint oversight of theater logistics with the TMA. Then it was not until Desert Storm that the JMC was employed to try to improve on the TMA. In the author's opinion, creation of the CDDOC is a result of inadequate performance by the JMC and theater logistics. If we fail to improve on the CDDOC initiative, the US military will continue to fight at less than its full potential.

When looking for models that could provide an example of how to upgrade the CDDOC and theater logistics, one only has to look to what the Air Force has done in making the air operations center (AOC) a weapon system in order to improve command and control of airpower. A spin-off of the CDDOC Spiral 1 was the creation of an XDDOC that could be used as an organizational concept for other theater areas of responsibility. The XDDOC is scalable, based on the requirement for each theater or contingency, and it is built around the *core* of a properly staffed JMC. The current problem is that geographic combatant commanders all have JMC Joint manning documents, but when they stand up for a contingency, the JMC is never fully manned and many times the personnel deployed require additional training to be fully mission capable.[36] Originally the AOC had much the same problem when it would stand up for a contingency, until the Air Force categorized it as a weapon system and placed the proper emphasis on the AOC being able to perform its wartime mission. As an Air Force weapon system, the AOC is much like an F-16 with standard training, equipment, and manning for all personnel qualified to employ or maintain it. Treating the XDDOC as a weapon system provides a scalable organization that can be properly resourced to provide required logistics and ensure customer confidence.

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DOTMLPF

It takes more than just calling something a weapon system in order to produce results. When creating a new weapon system, it is important to look at it across the full spectrum of all that goes into making it a working reality. One way to analyze possible upgrades to theater logistics through the XDDOC is to look at doctrine, organization, training, material, leadership/education, personnel, and facilities (DOTMLPF) for the XDDOC, and what it requires to provide Joint theater logistics. Looking at the XDDOC through these lenses will allow one to see some of the associated problems, issues, technology, management, and implementation opportunities associated with successfully employing such an organization to manage and control Joint theater logistics.[37]

Doctrine

US Joint doctrine for logistics provides direction for creating and operating Joint theater logistics and would require only slight changes to include the XDDOC concept. The two main publications for theater logistics are JP 4-01.3, *Joint Tactics, Techniques, and Procedures for Movement Control*, and JP 4-01.4, *Joint Tactics, Techniques, and Procedures for Joint Theater Distribution.* The primary change to these documents would be to incorporate the XDDOC concept and organization as a replacement for the JMC.[38] Other logistics doctrine will need to be updated to integrate the XDDOC concept. Incorporating the XDDOC concept would have ripple effects throughout all publications that support the US military logistics system.

Organization

The XDDOC concept creates an organization properly staffed to perform the duties of a JMC. This new organization brings in personnel with the appropriate skill sets and reachback capabilities to properly manage theater logistics. The changes to the original JMC structure are minor, but the emphasis will be on the organizations that will be required to provide deployable personnel to the XDDOC as it is stood up and expands based on the contingency.[39] National partners required to provide personnel include USTRANSCOM, JFCOM, DLA, ArmyMC, AMC, JMC, AFSC and the individual Services. These national partners will require personnel trained and capable of deploying to multiple theaters that might stand up an XDDOC. Organizational change will be more of a burden on the national partners than the combatant commanders.

Training

Training to support the XDDOC concept, much like the burden of organizational change, will reside with the national partners to ensure they have personnel trained to support an XDDOC throughout all possible theater AORs. An XDDOC weapon system would support that training effort. Much like learning to maintain or employ any weapon system, the XDDOC weapon system would have commonality that would allow anyone trained on the basic version to quickly adapt and operate an upgraded system. Looking at how personnel are trained to operate the AOC weapon system could provide insight into training XDDOC personnel.

Material

The three tenants of theater distribution are visibility, capacity, and control.[40] Until complete visibility and control exists, actual capacity is not known and there is a good chance the capacity available is not being used efficiently. Looking at the XDDOC's current ability to control theater logistics highlights the need to upgrade command and control (C2) systems. As previously discussed, the theater logistics C2 systems do not *speak* the same language as the warfighter's command and control system, making C2 less efficient. Along with C2 issues, problems exist with the information systems that provide ITV. JP 4-01.4, *Tactics, Techniques, and Procedures for Theater Distribution,* dated August 2000, discusses intransit visibility and states:

> "Technologies exist today that provide the capability to conduct continuous near-real-time tracking of logistic assets. This visibility is provided through the use and implementation of commercial off-the-shelf technology known, in commercial industry, as movement tracking system."[41]

If the technology existed in 2000, it begs the question, where was the robust capability to track theater logistics in 2005? To create the XDDOC weapon system, Joint logistics systems to command and control, distribute, and monitor theater logistics must be purchased or developed. This must include satellite allocation and enough bandwidth to provide C2 and ITV down to the unit level. It also is important to recognize that waging war often extends beyond pure Joint operations and must include the purchase of systems that can expand and grow to support allies and coalitions.

Leadership/Education

Leadership and ownership of XDDOC is essential in order to ensure it is properly staffed and equipped. This is key for it to grow to a level comparable to the AOC weapon system. Based on the Secretary of Defense designating USTRANSCOM as the distribution process owner, and charging it to ensure efficient and effective solutions for synchronizing the distribution of resources from point of origin to point of consumption, USTRANSCOM would be a logical choice to be the owner of the XDDOC weapon system. Education concerning the capabilities and requirements to support the XDDOC will be another important action for USTRANSCOM.

Personnel

The personnel issue is at the heart of the problem. Previously, the organization charged with oversight of theater logistics has been staffed ad hoc, *out of hide*, and with *warm bodies*.[42] It was only after USTRANSCOM was designated the distribution process owner and the CDDOC was created that an organization was staffed with personnel capable of providing theater logistics oversight. The personnel issue for the future is to ensure trained personnel are assigned to positions on the combatant commander's staff in order to make up the core of an XDDOC. In addition, the national partners who provide personnel to round out the XDDOC must maintain trained and deployable personnel to meet potential contingencies. It will be essential to create a Joint manning document to ensure everyone is on the same *play sheet* and knows who provides what when it comes time to expand the XDDOC for contingency operations.

The XDDOC concept is not a panacea, but does provide great promise toward improving theater logistics. Although the CDDOC Spiral 1 was very successful, problems still persist due to the lack of total ITV and absence of a C2 structure that worked logistics hand-in-hand with the warfighter.

Facilities

Because an XDDOC could stand up in a variety of infrastructure environments (theaters range from immature to very mature), facilities need to be mobile and deployable to all geographic areas of responsibility. Much like the Air Force's AN/USQ-163 Falconer AOC weapon system, creating enough XDDOC weapon systems for every geographic combatant commander would provide the basic facilities to stand up an XDDOC.

Conclusion

> *Strategy is to war what the plot is to the play; Tactics is represented by the role of the players; Logistics furnishes the stage management, accessories, and maintenance. The audience, thrilled by the action of the play and the art of the performers, overlooks all of the cleverly hidden details of stage management.*
>
> **—Lt Col George C. Thorpe**
> ***Pure Logistics*, 1917**

Theater logistics from World War II to OIF is replete with examples of overlooking *all the cleverly hidden details of stage management* involved in theater logistics. In World War II, the breakout from Normandy, during Operation Overlord, was held back because of the inability to move resources through the theater logistics pipeline. Korea and Vietnam were examples of the capability to push supplies to theater APODS and sea ports of debarkation, but then an inability to move the *iron mountains* and get the *right stuff* to the *right place* at the *right time*. Iron mountains reappeared during Desert Storm and the JMC concept was employed to fix the theater logistics issue. Desert Storm was successful, and the inadequate results of JMC efforts to direct theater logistics were overlooked until post OIF analysis of the US military's ability to perform Joint theater logistics. This analysis showed a logistics system that was not the force enabler required for today's lean, lethal, and mobile military.

The US military is transforming, but the transformation to get resources the *last tactical mile* remains unsolved. High-level interest, with an eye on Joint theater logistics, occurred when Secretary of Defense Rumsfeld designated USTRANSCOM as the distribution process owner with overarching responsibility for ensuring delivery of supplies from point of origin to point of consumption—factory to foxhole.

In order to carry out this responsibility, the commander of USTRANSCOM proposed the DDOC concept and, with the concurrence of USCENTCOM, deployed the CDDOC to Kuwait as a pilot program in January 2004.

The CDDOC was staffed with personnel armed with information technology and reachback capability that could link the strategic deployment and distribution process to theater logistics in support of the warfighter. The CDDOC merged with CENTCOM's JMC to create an effective team in support of theater logistics. Many of the CDDOC initiatives were very successful.

The XDDOC concept is not a panacea, but does provide great promise toward improving theater logistics. Although the CDDOC Spiral 1 was very successful, problems still persist due to the lack of total ITV and absence of a C2 structure that worked logistics hand-in-hand with the warfighter. Creating a Joint weapon system out of the XDDOC concept, with doctrine to guide its employment, personnel properly trained and equipped, and leadership to direct and educate throughout the growth of this weapon system is a great start toward a Joint theater logistics capability. The next step in a long-term vision might be to look at a Joint Force Logistics Component Commander (JFLCC). A JFLCC, with oversight and decision authority at the component level, could ensure that the XDDOC weapon system is properly employed and a warfighting enabler. The XDDOC weapon system with up to date ITV technology and an upgraded C2 system will mend the seam between strategic and operational logistics and help provide a way ahead to Joint theater logistics.

The next step in a long-term vision might be to look at a Joint Force Logistics Component Commander.

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Military Logistics and the Warfighter

I think we can all agree there is a relationship between the function of military logistics and the warfighter. What is that relationship, and is it correctly defined? In the early 1960s, there was a stated relationship between logistics and the weapons systems: military logistics "support"' the weapons system. At that time, the subject of military logistics was fairly new and, with little ongoing research, very slow in providing greater *understanding* about it. Therefore, during that period, this definition of relationship seemed appropriate. It was not until the late 1970s that several advocates of military logistics came to the realization that logistics *support* of the weapon system was actually creating and sustaining warfighting capability. This warfighting capability was provided to the combat forces in the form of continuing availability of operational weapon systems (the tools of war). This new awareness set up another definition of the relationship: *military logistics creates and sustains warfighting capability.* While many heard the words, few realized their implications.

The level of warfighting capability that logistics provides the combat forces determines the extent to which war can be waged. This, in turn, limits and shapes how the war will be waged. Warfighting capability is *embedded* in the design of all weapon systems. Advancing technology increases speed, range, maneuverability, ceiling, and firepower, all of which provide more lethal and accurately guided munitions, stealth, and other offensive and defensive warfighting capabilities. They will be embedded into the design of future weapon systems. It is the weapon systems that contain the warfighting capability of military forces. The strength of military forces is no longer measured by the number of men *under arms*. Today, military forces are measured by the number—and warfighting capabilities—of their weapon systems. The Department of Defense has yet to adequately define and manage the total logistics environment (those activities and resources required to create and sustain warfighting capability). While it is said that armies travel on their stomachs, what is usually left unsaid is they perform on the basis of their logistics competency.

Today, as most of you are aware, we have another, more recently defined relationship: *military logistics supports the warfighter*. We know military logistics creates and sustains warfighting capability. We can assume the warfighter fights wars. It would, therefore, appear reasonable to suggest that in order for one to be a warfighter (a pilot in this case) he or she must have the capability to wage war. While weapon systems are designed and created to wage war, people are not. Therefore, in order to become warfighters, pilots must be provided with some level or amount of warfighting capability. I would submit that by providing the pilot with an operational weapon system, which allows him or her to utilize its warfighting capability, *military logistics creates the warfighter*. It does not *support* the warfighter; it *creates* the warfighter. This transformation occurs when a checked-out pilot starts the engine. At that point, the pilot is in control of the weapon system and its warfighting capability. The pilot is now the warfighter. Without the warfighting capability, which the weapons system provides, a pilot is a pilot.

Military logistics creates and sustains warfighting capability; by doing so, military logistics creates and sustains the warfighter.

Colonel Fred Gluck, USAF, Retired

Logistics Stuff—Five Things to Consider

- **The operations/logistics partnership is a target for our enemy—protect it.** We must try always to think of an enemy's looking for the decisive points in the partnership. What we want to make strong, they will try to weaken. Where we want agility, they will want to paralyse us. What we can do to our enemy, we can do to ourselves by lack of attention. So all concerned with operations and logistics must protect and care for the partnership and the things it needs for success. This includes stuff and information and people. Also, we must not forget the corollary is just as important: the operations/logistics partnership of the enemy is a target for us; we must attack it.
- **Think about the physics.** Stuff is heavy, and it fills space. Anything we want to do needs to take account of the weight that will have to be moved, over what distance, with what effort. Usually this all comes down to time, a delay between the idea and the act. If we think about the physics we can know the earliest time, we can finish any task and we can separate the possible from the impossible. It is crucial to determine the scope of the physical logistics task early in any planning process. Planners must know how long things take and why they take that long.
- **Think about what needs to be done and when—and tell everybody.** Once we have given instructions and the stuff is in the pipeline, it will fill that space until it emerges at the other end. The goal is to make sure that the stuff coming out of the pipe is exactly what is needed at that point in the operation. If it is not, then we have lost an opportunity—useless stuff is doubly useless, useless in itself and wasting space and effort and time. Moving useless stuff delays operations. Also, priority of order of arrival will change with conditions and with the nature of the force deploying. For example, the political need to show a presence quickly may lead a commander to take the risk of using the first air transport sorties to get aircraft turn-round crews and weapons into theatre before deploying all the force protection elements.
- **Think about defining useful packages of stuff.** Stuff is only useful when all the pieces to complete the jigsaw are assembled. Until the last piece arrives, there is nothing but something complicated with a hole in it. It is vital to know exactly what is needed to make a useful contribution to the operational goals and to manage effort to complete unfinished jigsaws, not simply to start more. Useful stuff often has a *sell-by* date. If it arrives too late, it has no value, and the effort expended has been wasted. The sell-by date must be clear to everyone who is helping build the jigsaw. And it is important to work on the right jigsaw first. In any operation, there is a need to relate stuff in the pipelines to joint operational goals, not to single-service or single-unit priorities. It is no good having all the tanks serviceable if the force cannot get enough aircraft armed and ready to provide air cover or ensuring that the bomber wing gets priority at the expense of its supporting aircraft.
- **Think about what has already been started.** The length of a pipeline is measured in time not distance. There will always be a lag in the system, and it is important to remember what has already been set up to happen later. Constantly changing instructions can waste a lot of energy just moving stuff around to no real purpose. Poorly conceived interventions driven by narrow understanding of local and transitory pain can generate instability and failure in the system.

Group Captain David J. Foster, RAF

Yool Kim, PhD
Colonel Stephen Sheehy, USAF
Commander Darryl Lenhardt, USN

A Survey of Aircraft Structural-Life Management Programs in the US Navy, the Canadian Forces, and the US Air Force

Introduction

Since 1958, the Air Force has relied on its Aircraft Structural Integrity Program (ASIP) to achieve structural safety of its aircraft. The ASIP's overarching objective is to prevent structural failures cost effectively and without the loss of mission capability. The ASIP provides a framework for establishing and sustaining structural integrity throughout the aircraft's life. During the acquisition phase, ASIP activities involve design, analysis, and tests to ensure that the aircraft structure is adequate to operate as intended. During the sustainment phase, the ASIP activities involve data collection, analysis, and tests needed to continually plan the sustainment activities such as maintenance and modifications to ensure that the structure remains safe until retirement. These activities provide information about structural conditions that can be used to help in fleet management decisions. As such, the ASIP is a key contributor to the Air Force's Force Management processes.

In recent years, some concerns have been raised about ASIP's capability to continue meeting the future needs of the Air Force due to the impact of an aging force, budget pressures, and diminishing ASIP regulatory power. The Air Force owns and operates approximately 6,000 aircraft to meet its force requirements. The average age of the force is approximately 22 years old, and the average age is expected to continue rising.[1] Many of the older aircraft face aging issues, such as structural deteriorations of the airframe, and many aircraft are expected to encounter them as the Air Force plans to keep the aircraft in service for an extended period of time. Meanwhile, there are growing concerns in the Air Force that structural deteriorations in aging aircraft will lead to increased maintenance workload, declining aircraft readiness, and increased safety risk.[2]

A Survey of Aircraft Structural-Life Management Programs in the US Navy, the Canadian Forces, and the US Air Force

At recent ASIP conferences, the engineering community also expressed that one of the main challenges in structural-life management processes has been communicating structural integrity issues to decisionmakers.

Because the Air Force plans to fly many aircraft for an extended period of time, there is an increasing demand for more accurate knowledge about the current and future structural condition of aircraft and the associated risks of structural failure. The need for engineering capabilities both in terms of research and development and engineering analysis is increasing as age-related problems grow. The 1997 National Research Council study on the Air Force's aging force, as well as the engineering community at recent ASIP conferences, have voiced concerns that budget pressures, rather than structural needs, are driving the level of ASIP implementation as fleet managers need to allocate their resources between sustainment of aging airframes and other aging aircraft subsystems (for example, modernization of avionics).[3, 4]

Moreover, ASIP's regulatory power has diminished over the years as a result of reforms in the 1990s to minimize government regulations in acquisition.[5] Prior to these acquisition reforms, Air Force regulation (AFR) 80-13 (rescinded 1 June 1994 and replaced with Air Force Instruction (AFI) 63-1001, *Aircraft Structural Integrity Program*) and the ASIP standard, MIL-STD-1530, were used to enforce ASIP. However, with the acquisition reform, the AFR was converted to an Air Force instruction, and the Air Force converted the ASIP military standard (MIL-STD-1530) to a military handbook (MIL-HDBK-1530B) that could no longer be cited as a contractual requirement. As a result, the industry and the contractors, as well as the System Program Offices (SPOs) who carry out the ASIP, interpret the former requirements as guidelines.

At recent ASIP conferences, the engineering community also expressed that one of the main challenges in structural-life management processes has been communicating structural integrity issues to decisionmakers. Several potential causes were cited.

- Lack of technical understanding by decisionmakers
- Insufficient data on structural conditions
- Lack of resources to gather sufficient information on structural conditions
- Lack of outlet for communicating key structural integrity issues to decisionmakers

As a result, decisionmakers may not have full visibility regarding structural conditions and may lack understanding of the consequences of inadequate ASIP implementation.

From the decisionmakers' perspective, there may be no concern regarding ASIP's effectiveness, since there have not been catastrophic structural failures in recent years. However, as we look prospectively, the concern is that inadequate ASIP implementation (for example, omission of or incomplete ASIP tasks) may degrade the effectiveness of ASIP and adversely impact the force's operational effectiveness, aircraft safety, and sustainment costs.

The Air Force has initiated several actions to address some of these challenges. For example, in February, 2004 the Aeronautical Systems Center's Engineering Directorate (ASC/EN) converted MIL-HDBK-1530B back to a military standard that can once again be used as a contractual requirement. This will reestablish some standardization and control of the ASIP.

Scope

In our research, we surveyed aircraft structural-life management programs in the Navy, the Canadian Forces (CF), and the Air Force to provide insights and guidance on how the Air Force can continue to strengthen the ASIP to meet its objectives in the presence of current challenges and needs. We focused on these Services' approaches to regulations, communications between structural-life management authorities, and resource management to qualitatively assess the implications of the different approaches. We focused on ASIP during the sustainment phase to address current ASIP challenges in sustaining the aging force. Hence the research scope is also limited to aircraft that are no longer being procured.[6]

Technical Basis of Aircraft Structural-Life Management

Fatigue is one of the primary damage mechanisms that cause an aircraft structure to deteriorate during its lifetime. It is a process in which damage accumulates in the material subjected to alternating or cyclic loading, such as landings, takeoffs, and various maneuvers.[7] This damage may culminate in cracks, which will eventually lead to complete fracture after a sufficient number of cycles of loads. Thus one of

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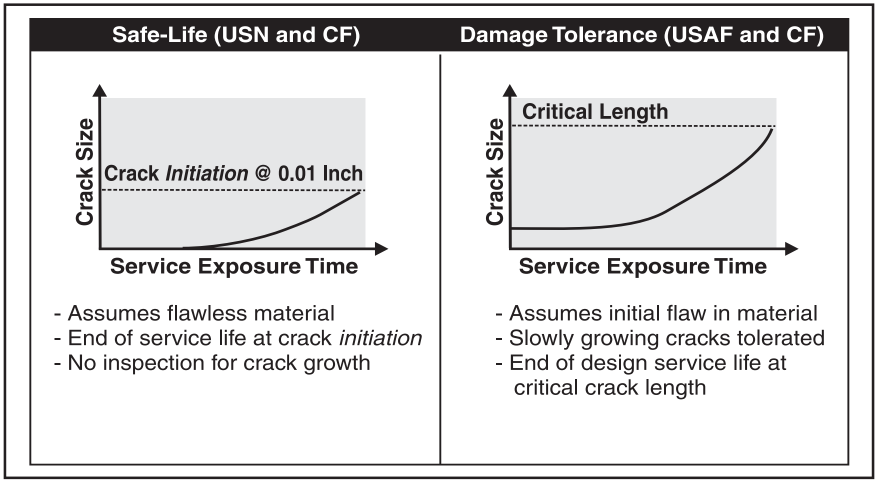

Figure 1. Comparison of Safe-Life and Damage Tolerance Fatigue Design Concepts

There are two fatigue-based design concepts that may be used to account for fatigue damage in aircraft: safe-life and damage tolerance.

the key design criteria for an aircraft is that it endures accumulated fatigue damage over its service life to prevent structural failures.

There are two fatigue-based design concepts that may be used to account for fatigue damage in aircraft: safe-life and damage tolerance (Figure 1). These fatigue design approaches differ in their models of the damage growth process, their assumptions about the initial material condition, and the failure criteria used to establish the aircraft's original design service life.

The Navy and the CF's safe-life approach assumes that no fatigue cracks will exist in the structure during the specified lifetime for safe operation, and the design service life ends prior to crack initiation. The Navy and the CF define the crack *initiation* state as the point where a crack length reaches 0.01 inch. As a result, the safe-life approach requires minimal routine inspection for fatigue cracks.

The mean time for a 0.01-inch crack length to develop is determined from full-scale fatigue tests, in which expected service loads are simulated and applied to an aircraft in a laboratory environment. This test-demonstrated fatigue life (time to *failure*, which the Navy and the CF define as the crack "initiation") is divided by a life reduction factor of 2 to arrive at the design service life. The life reduction factor accounts for variability in material properties and fatigue loads.

The damage tolerance concept assumes that potential fatigue cracks may exist in critical locations in fracture-critical parts due to defects from manufacturing and in-service activities (for example, during repair), and that these flaws will result in crack growth during the aircraft service life.[8] Under damage tolerance, the assumed initial flaw in the structure must not grow to a critical size to cause structural failure

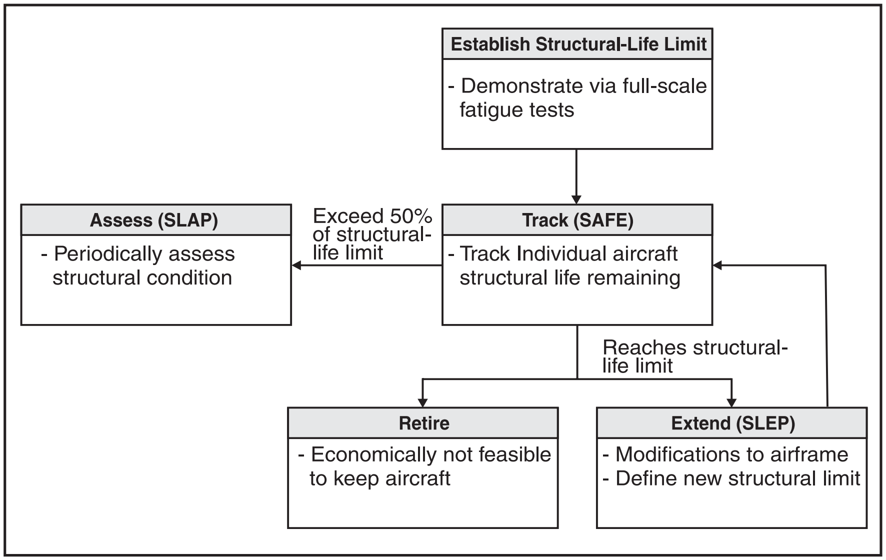

Figure 2. The US Navy Aircraft Structural-Life Management Process

for a period of unrepaired service usage. The critical size is determined based on the minimum residual strength required for the structure to withstand the relatively rare occurrence of a design limit load. The test-demonstrated fatigue life, the time it takes for an initial flaw to grow to a critical size, is divided by a life reduction factor of 2 to arrive at the design service life. Inspection intervals are then determined to ensure that a crack does not reach its critical size without being detected.

The US Navy's Aircraft Structural-Life Management Process

The Navy operates approximately 2,000 fixed-wing aircraft and about 20 different aircraft types, many based on carriers.[9] The Navy takes the safe-life approach to structural-life management partly because of the limited space and facilities on carriers for inspection and repairs. Implementation of the safe-life approach provides a maintenance-free operation period without compromising safety.

The Navy has an explicit policy on structural-life management. The governing policy behind the Navy's approach to structural-life management is that the aircraft must not exceed the structural life limits during service to ensure structural safety. A Naval Air Systems Command (NAVAIR) instruction outlines the policy, rules, and procedures on establishing and maintaining structural integrity of all Navy aircraft.[10] The instruction describes the principal elements of the structural-life management and assigns responsibilities to various organizations. A centralized program, the Aircraft Structural-Life Surveillance (ASLS) Program, carries out the majority of the structural-life management tasks for all Navy aircraft. The ASLS Program has three components: Structural Assessment of Fatigue Effects (SAFE) Program, Structural Life Assessment Program (SLAP), and Service Life Extension Program (SLEP).

The Navy has an explicit policy on structural-life management. The governing policy behind the Navy's approach to structural-life management is that the aircraft must not exceed the structural life limits during service to ensure structural safety.

The program manager for Air (PMA) is responsible for the total life-cycle management of the designated fleet. The PMA has the ownership and decision authority on structural-life management of the fleet (except for fatigue life tracking). The NAVAIR structures division under the NAVAIR air vehicle department supports the PMAs in structural-life management of their aircraft and carries out the ASLS Program. The NAVAIR structures division also has a regulatory responsibility on the technical aspect of structural-life management.

All of the NAVAIR structures engineers and the PMAs work in a single facility at Patuxent River, Maryland.[11] The geographic collocation of these structural-life management authorities and the centralized ASLS Program promote information sharing and cross-fertilization across different program offices with respect to structures.

The Navy's structural-life management process is illustrated in Figure 2. The Navy establishes strict structural life limits for each aircraft type, or type/model/series, based on the fatigue life limits of the airframe and the critical components. To ensure that the aircraft do not exceed the fatigue life limits during service, the SAFE Program tracks individual aircraft fatigue life for all aircraft in terms of a standard quantifiable

After the fleet has been in service for a period of time or if the usage of the aircraft has significantly changed from the original design, the ASLS Program evaluates the current structural condition and verifies the remaining fatigue life of the fleet under the SLAP.

metric, fatigue life expended (FLE).[12] The FLE is the primary indicator in conveying the structural condition to those operating and supporting the aircraft. An FLE of 100 percent is the fatigue life limit.

The SAFE Program disseminates the individual FLE information for all aircraft in a formal report (SAFE report) every 3 months to a wide range of Navy organizations. Because the FLEs for all aircraft are visible to all the organizations involved in aircraft operation and support, as well as senior leadership, they have continual visibility of the state of each aircraft. The SAFE report is a key document in assisting decisionmakers in structural-life management. The report provides the fleet profile in terms of FLE distribution and thus it helps the PMAs in prioritizing modifications and phasing in and phasing out of a fleet.

Rigorous and accurate monitoring of fatigue life is critical to the Navy because under the safe-life approach, there is no routine inspection for cracks to validate the structural condition. The SAFE program has a dedicated funding line to enable an independent assessment of the aircraft's fatigue life and to ensure that this critical task is carried out.

After the fleet has been in service for a period of time or if the usage of the aircraft has significantly changed from the original design, the ASLS Program evaluates the current structural condition and verifies the remaining fatigue life of the fleet under the SLAP. A SLAP may involve a wide range of activities to reassess a fleet's structural life limit, such as an assessment of in-service usage, a teardown inspection, laboratory tests, and an analysis update. In some cases, a full-scale fatigue test may be conducted for the structural life assessment. A SLAP can be a multi-year effort, especially if a full-scale fatigue test is involved.[13]

In the past, SLAP results have shown that fatigue cracks have occurred earlier than predicted. As a result, the ASLS Program recommends a SLAP when a majority of the fleet has reached 50 percent FLE, such that there is sufficient lead time, in the event a service life extension is needed.

Upon reaching the structural life limit or 100 percent FLE, the Navy either chooses to retire the aircraft or extend the structural life by modification or replacement of critical components under the SLEP. Inspection is not a viable option in extending

Technical Airworthiness Authority (ASIP Regulator)	Weapon System Manager (ASIP Implementer)
Establishes general rules and standards	Customizes ASIP plans for his/her weapon system
Assesses compliance and audits personnel and organization	Chooses suitable method of compliance
Accredits organization and delegates authorities	Authorizes funding of structural integrity-related tasks

Table 1. Responsibilities of the Canadian Forces' Structural-Life Management Authorities

structural life because of the safe-life philosophy. Additionally, depending on the extent of the modifications or replacements, a new full-scale fatigue test is conducted to establish the extended structural life limit. Due to the explicit policy on structural-life limit, planning a SLAP and a SLEP in a timely manner is critical to minimize the risk of aircraft reaching the structural-life limits prior to a completion of necessary modifications.

The NAVAIR structures division is the final authority on structural integrity and must certify any structural changes to ensure that structural integrity is maintained until the structural life limit is reestablished. The Structures division determines the criteria for certification on a case-by-case basis (for example, structural analysis, component testing or full-scale fatigue tests). The division's role in certification of structural integrity provides an independent technical assessment on the PMA's resource allocation decisions, promoting checks and balance in the resource management process.

The Canadian Forces' Aircraft Structural-Life Management Process

The CF operates approximately 350 fixed-wing aircraft and about a dozen different aircraft types in a land-based environment.[14] Because they are based on Navy designs, the CF had originally implemented the safe-life approach to structural-life management. As the CF has sought to extend the service lives of their aircraft, however, they have adopted the damage tolerance approach to ensure safety beyond the original design service life (beyond crack initiation). Unlike the Navy, the CF does not have carrier-based aircraft and thus implementing a routine inspection for cracks, as a result of the adoption of the damage-tolerance approach, was not a significant barrier.[15]

The CF's governing policy regarding structural integrity is broad and based on the concept of airworthiness.

The CF's governing policy regarding structural integrity is broad and based on the concept of *airworthiness*. The CF defines *airworthiness* as demonstrating the achievement of minimum acceptable level of aviation safety.[16] This acceptable level is based on a compilation of requirements defined for each aircraft type in its *basis of certification*. With respect to structural integrity, the basis of certification is effectively the ASIP requirements. Every aircraft type must develop a basis of certification and comply with the standards in the basis of certification throughout its service life to demonstrate that the aircraft is airworthy. If the aircraft falls out of compliance with these standards, for example, by exceeding its fatigue life, a new basis of certification is required.

The CF takes a regulatory approach to structural-life management. An independent regulatory authority, the Technical Airworthiness Authority (TAA), provides regulations and oversight for all weapon systems' ASIPs and assesses compliance (Table 1). The basis of certification is used as a means to assess compliance. The weapon system managers (WSM) are responsible for the fleet management of their aircraft and are accountable for implementing ASIP. The WSM

The CF uses multiple types of information to convey the structural condition because airworthiness with respect to structural integrity requires meeting multiple requirements.

tailors the ASIP to the specific weapon system being managed, complying with the structural integrity-related regulations. Each WSM has an ASIP manager who executes the ASIP and supports the WSM on structural-life management. The TAA, the WSMs, and the ASIP managers are centrally collocated in a single site in Ottawa, Ontario.

The TAA evaluates ASIP compliance on a case-by-case basis via formal airworthiness monitoring and approval processes. Every aircraft type must initially receive an airworthiness approval prior to entering service via the airworthiness certification process. The TAA grants flight authority based on the airworthiness certification. Additionally, fleet management plans that impact the structural integrity, such as modifications and operational changes, require formal approvals by the TAA via the design change certification process. Because the initial basis of certification is only applicable to the initially specified configuration and usage, a design change (change in maintenance program, configuration, or mission) requires a new basis of certification.

The CF also incorporates formal program monitoring processes. During the annual Airworthiness Review Board meetings, the board, consisting of senior regulatory authorities, reviews the airworthiness status of all fleets and other airworthiness issues. The TAA also plans to conduct annual reviews of all fleets' ASIPs to monitor compliance.

The CF uses multiple types of information to convey the structural condition because airworthiness with respect to structural integrity requires meeting multiple requirements. Similar to the Navy, the CF-18 and CP-140 weapon system offices track remaining fatigue life of critical components for every aircraft.[17] The CF uses the fatigue life index (FLI) or fatigue life expended index (FLEI), which is equivalent to the Navy's FLE metric. However, unlike the Navy, there is no threshold on the FLI/FLEI due to the later adoption of the damage tolerance approach. As a result, exceeding an FLI of 100 percent does not mean that the aircraft is no longer airworthy. Airworthiness can be achieved by implementing a modified inspection program to monitor the component that has exceeded the FLI of 100%. Both CP-140 and CF-18 document the FLI/FLEI in their quarterly ASIP reports. The CF also uses risk (in terms of probability of structural failure) as a metric to convey the state of the structural condition.

The CF conducts periodic assessments to verify the aircraft structural condition during the service life, as necessary. For example, if the actual usage of aircraft is significantly altered from the design usage, reverification of structural condition may be required to substantiate airworthiness. The WSM and the ASIP manager choose the method of compliance by proposing tests or analysis procedures that the TAA must approve.

The ASIP manager updates the ASIP Master Plan at least annually. The plan outlines all of the required structural-life management tasks for both the near and long term. The master plan is based on the current and predicted future condition of the structure as well as the requirements in the basis of certification. These plans include updates in inspection, maintenance, and modifications. The WSM must approve the ASIP Master Plan, as the WSM authorizes and allocates the funds for ASIP and fleet management tasks.

The regulatory processes such as reviews and certification processes provide independent assessments on the WSM's resource allocation decisions as well as guide the WSM's prioritization of resource allocation. The regulatory processes also require much information to be communicated formally, such as documentation of critical information for traceability and planning purposes, as well as for compliance finding. In addition to formal communications, informal communications between the WSMs, the ASIP managers, and the TAA occur in various decision-making processes due to the working relationship. Although ASIP implementation is decentralized, geographic collocation leads to informal information sharing between ASIP managers, providing visibility across fleets and cross-fertilization across the ASIPs.

The Air Force Aircraft Structural-Life Management Process

The Air Force operates about 6,000 aircraft and about 40 different aircraft types in a land-based environment.[18] It uses the damage tolerance approach to manage the structural life and to establish the maintenance plans for its aircraft.

The governing policy on ASIP is established in Air Force Policy Directive (AFPD) 63-10, *Aircraft Structural Integrity.* The policy is broad in that it requires the Air Force to "establish an ASIP for each aircraft weapon system it is acquiring or using," tailored to a specific weapon system. The corresponding Air Force Instruction 63-1001, *Aircraft Structural Integrity Program,* defines procedures for implementing and sustaining the ASIP, as well as specific organizational responsibilities. The ASIP program is described in the military standard MIL-STD-1530B, and the standard provides technical direction in managing and executing ASIP. [19]

The governing policy on ASIP is established in Air Force Policy Directive (AFPD) 63-10, Aircraft Structural Integrity. *The policy is broad in that it requires the Air Force to "establish an ASIP for each aircraft weapon system it is acquiring or using," tailored to a specific weapon system.*

Multiple organizations are involved in the ASIP process at various levels—the Assistant Secretary of the Air Force for Acquisition (SAF/AQ), the engineering directorate in the Aeronautical Systems Center (ASC/EN), system program directors (SPDs), ASIP managers, and lead commands (Table 2).[20] Due to the sheer size of the Air Force's organization, the authorities in ASIP are dispersed geographically. The SPDs and ASIP managers (for aircraft that are no longer being procured) operate at one of three air logistic centers depending on their particular aircraft type or mission, design, or series (MDS), while the corresponding lead command operates elsewhere.

Each SPD is responsible for implementing an ASIP for its fleet and for ensuring that ASIP is continued throughout the fleet's operational life. The ASIP manager establishes the program, tailored to the aircraft type following the direction provided in the MIL-STD-1530B, and carries out the ASIP for their weapon system. The SPD must approve the ASIP. The lead command has the funding and decision authority

A Survey of Aircraft Structural-Life Management Programs in the US Navy, the Canadian Forces, and the US Air Force

The Air Force's approach to structural-life management is to prevent structural failures by implementing an effective maintenance plan that inspects for fatigue damage and subsequently conducts timely repairs and modifications for cost-effective life-cycle management.

ASIP-Responsible Organizations	Primary ASIP Role	Location
SPDs	Ensure ASIP is implemented throughout MDS life Approve MDS ASIP	Warner Robins ALC, GA Oklahoma City ALC, OK Ogden ALC, UT
ASIP Managers	Carry out ASIP	Warner Robins ALC, GA Oklahoma City ALC, OK Ogden ALC, UT
Lead Commands	Fund ASIP	Langley AFB, VA (ACC) Randolph AFB, TX (AETC) Hurlburt Field, FL (AFSOC) Scott AFB, IL (AMC)
ASC/EN	Advise on policies and procedures for technical direction of ASIP Provide ASIP oversight	Wright-Patterson AFB, OH
SAF/AQ	Ensure ASIP is established for all MDS Establish ASIP policies	Washington, DC

Table 2. Roles and Geographic Locations of the Air Force's ASIP-Responsible Organizations

for the management of multiple fleets within the command, including ASIPs. As a result, the lead command has a significant influence on ASIP implementation.

ASIP regulatory responsibilities have been assigned to SAF/AQ, ASC/EN, and the SPDs, but ASIP has not been strictly enforced, partly because the ASIP military standard was a guideline that was not enforceable prior to February 2004 (Table 2).[21] These organizations had no regulatory authority over the lead commands' decisions on ASIPs. Additionally, according to the AFPD, the measure of ASIP compliance is the number of Class A and B accidents due to structural failures.[22] This metric can be problematic because it is a lagging indicator of ASIP compliance and thus it is not useful in proactive ASIP management. As a result, compliance with the ASIP policies has been primarily self-managed by the individual SPO.

The Air Force's approach to structural-life management is to prevent structural failures by implementing an effective maintenance plan that inspects for fatigue damage and subsequently conducts timely repairs and modifications for cost-effective life-cycle management. The inspection program monitors fatigue damage (cracks) at critical locations in the aircraft to ensure that the accumulated fatigue damage does not reach the failure threshold (critical crack size) during the service life. Based on the inspection results, the Air Force continues to inspect, repair, or replace the damaged component. The Air Force retires the fleet when continuing to maintain the fleet becomes uneconomical or degrades the fleet's operational effectiveness. For example, rapid growth in the number of cracks in fatigue-critical areas may require multiple major modifications that could significantly impact aircraft availability and sustainment costs.

One of the principal elements in the ASIP process is the development of the Force Structural Maintenance Plan (FSMP), as outlined in MIL-STD-1530B.[23] It provides a schedule for performing maintenance actions (inspection, repair, and modifications) necessary to sustain structural integrity throughout the service life of a fleet (Figure 3). The FSMP is developed using predicted crack growth and critical crack sizes at fracture-critical locations in the aircraft. The FSMP also provides cost estimates of the maintenance actions, whenever possible. Thus the FSMP is a key element in fleet management, as it can be used for maintenance planning, budgetary planning, and retirement planning (based on costs).

Almost always, the actual usage of the aircraft is different from the assumed design usage. The Air Force tracks aircraft usage to update the FSMP and inspection plans to ensure that fatigue damage in critical locations is detected and repaired in a timely manner. The Air Force tracks aircraft structural usage via two programs: Loads and Environmental Spectra Survey (L/ESS) and Individual Aircraft Tracking (IAT). The L/ESS program determines the fleet-wide baseline operational spectrum. It

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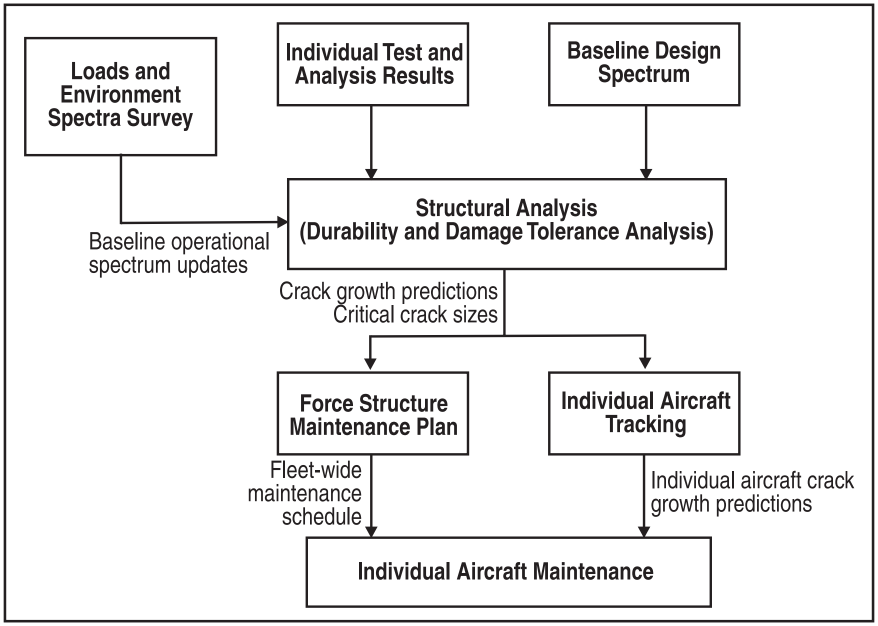

Figure 3. Force Structural Maintenance Plan Development Process, US Air Force

Explicit policy on ASIP provides clarity on ASIP compliance but limits flexibility in structural-life management. Broad policy on ASIP, on the other hand, enables flexibility in ASIP implementation for tailoring, but there is a potential risk of unclear understanding about acceptable ASIP compliance level. The policy should be sufficiently explicit to provide a general guidance on ASIP compliance, but rely on an independent assessment of ASIP compliance on a case-by-case basis to enable tailoring.

monitors the actual usage of a fleet sample (15-20 percent) during the first few years of operation. The IAT program tracks individual aircraft by tail number to monitor any variation from the fleet-wide baseline throughout the aircraft's service life. Any significantly different usage would be captured and the individual aircraft maintenance plans updated accordingly. Each SPO is responsible for ensuring that the FSMP is up-to-date and for determining the adequate level of tasks for updating and validating the FSMP, such as collecting adequate L/ESS and IAT data and assessing the structural analysis.

The budgetary process, that is, the program objective memorandum (POM) process, is a formal outlet for the SPD to communicate structural sustainment needs (for example, ASIP tasks, maintenance actions) to the lead command on an annual basis.[24] The lead command reviews what each SPD within its command forwards as the proposed POM inputs; POM inputs include program elements for ASIP as well as other program elements required for sustaining the fleet. The lead command then balances the operational needs (an improved radar) and structural integrity needs (repairing corroded fuel tanks) across multiple fleets to allocate the resources.

The budgetary planning for ASIP can be challenging for the lead command for several reasons. First, the lead command does not have the expertise in ASIP and structural needs. Second, it is difficult to compare the relative needs of the different fleets within a command due to the varying methods and measures of structural condition that each SPO uses for its own MDS. There is no standard metric that conveys the state of the structure. The assessment of the structural condition is left to the judgment of the ASIP manager and the SPD. Finally, communication between the SPD and the lead command regarding ASIP and structural condition is limited. This is because of the limited involvement of the lead command in the ASIP process and the geographic separation between them. Some lead commands have an office of primary responsibility for ASIP to facilitate communications with the SPDs regarding fleet management decisions and ASIP tasks.

Observations

Based on this survey effort, we summarize our observations about the approaches in regulations, communications, and resource management in each service's aircraft structural-life management program in Table 3.

Explicit policy on ASIP provides clarity on ASIP compliance but limits flexibility in structural-life management. Broad policy on ASIP, on the other hand, enables flexibility in ASIP implementation for tailoring, but there is a potential risk of unclear understanding about acceptable ASIP compliance level. The policy should be sufficiently explicit to provide a general guidance on ASIP compliance, but rely on an independent assessment of ASIP compliance on a case-by-case basis to enable tailoring.

Regulations in ASIP can provide checks and balances in structural-life management, enable clear and timely communication, and promote stable and adequate resources for ASIP. Regulations can also lead to complex processes and inefficiencies in ASIP management. Therefore, ASIP regulations should focus on elements of ASIP that are critical to the viability of ASIP and ensure a balance between control and flexibility of ASIP.

Organizational centralization enables standardization in ASIP management and a force-wide view of ASIP compliance and fleets' status, while decentralization enables tailoring to a specific weapon system to achieve a cost-effective ASIP. Centralization of a set of selective ASIP tasks, where standardization is useful, could still allow tailoring of other aspects of ASIP for cost effectiveness.

Regulations, communications, and resource management approaches are highly interdependent and need to complement each other within the context of the program (for example, safe-life versus damage tolerance) to achieve ASIP effectiveness. Operational factors such as the force size may also present certain scalability challenges. For example, the Air Force's large-scale force with a wide range of different aircraft types may pose some challenges in standardizing or centralizing certain aspects of ASIP across the force.

Options for Consideration

The Air Force has opportunities to enhance ASIP by adopting and adapting some of the approaches used by the Navy and the CF. The Air Force may wish to consider the following options.

Regulations, communications, and resource management approaches are highly interdependent and need to complement each other within the context of the program (for example, safe-life versus damage tolerance) to achieve ASIP effectiveness.

US Navy
- Explicit policy on structural-life management - Central regulatory authority on technical aspect of structural-life management - Standard, quantifiable metric to convey structural condition - Rigorous fatigue life tracking and frequent dissemination of formal fatigue life report - Close working relationship and geographic collocation to facilitate communications - Dedicated funding line for structural-life monitoring
Canadian Forces
- Broad policy based on *airworthiness* concept - Independent, centralized regulatory authority - Regulations to ensure communications and sharing of critical information - Geographic collocation and working relationship to facilitate informal communications - Single funding authority in structural-life management of a designated fleet - Formal planning of resource management via ASIP Master Plan
US Air Force
- Broad policy based on a broad objective - Flexible, decentralized regulatory structure with minimal regulation and oversight - Limited command-wide view of ASIPs and structural conditions - Limited communications with the lead command on ASIP and structural issues - Single funding authority for structural-life management of multiple fleets in a command

Table 3. Summary of Key Characteristics of the US Navy, Canadian Forces, and the US Air Force's Aircraft Structural-Life Management Programs

- Provide clarity in ASIP policy and extend existing processes to enable independent assessment of ASIP compliance
- Formalize key ASIP processes and assign an independent assessment authority to continue enforcement of ASIP and to enhance communications
- Facilitate communications between the lead command and the SPO by establishing a close working relationship
- Instill standardization for command-wide view
- Dedicate a separate funding line for critical ASIP tasks

Notes

1. Raymond A. Pyles, *Aging Aircraft: USAF Workload and Material Consumption Life-Cycle Patterns*, Santa Monica, California: RAND Corporation, MR-1641-AF, 2003, 1-2.
2. *Ibid.*
3. National Research Council, Committee on Aging of U.S. Air Force Aircraft, National Materials Advisory Board, Commission on Engineering and Technical Systems, *Aging of U.S. Air Force Aircraft - Final Report*, NMAB-488-2, Washington, DC: National Academy Press, 1997, 20-21.
4. USAF Structural Integrity Program Conference 2003, Savannah, GA, December 03.
5. National Research Council, 46.
6. The research also does not include the modified commercial aircraft in the USAF and the USN that were designed to meet the FAA requirements because these aircraft may follow FAA maintenance requirements and other FAA regulations that differ from each service's own structural-life management program.
7. For additional details on fatigue, see, David Broek, *The Practical Use of Fracture Mechanics*, Boston: Kluwer Academic Publishers, 1988; Alten F. Grandt, Jr., *Fundamentals of Structural Integrity: Damage Tolerant Design and Nondestructive Evaluation*, New York, New York: John Wiley and Sons Inc., 2003.
8. J.P. Gallagher, F.J. Giessler, A.P. Berens, and R.M. Eagle, Jr., *USAF Damage Tolerant Design Handbook: Guidelines for the Analysis and Design of Damage Tolerant Aircraft Structures*, AFWAL-TR-3073, Wright Patterson Air Force Base, Ohio, 84.
9. "United States Navy Fact File," [Online] Available: http://www.chinfo.navy.mil/navpalib/factfile/ffiletop.html.
10. NAVAIRINST 13120.1, *Fixed Wing Aircraft Structural Life Limits,* 20 October 97.
11. The only engineering staff that is detached from the Patuxent River staff is the Fleet Support Team (FST) engineers located at the various depots. The PMAs are not a part of the NAVAIR chain of command. They maintain their statutory lines of authority reporting to the Program Executive Officers (PEOs).
12. The FLE is the complement of fatigue life remaining, that is, FLE of 100 percent is equal to 0 percent fatigue life remaining.
13. For example, the P-3C SLAP spanned 5 years. See, Bharat M. Shah, "P-3C Service Life Management," *Proceedings of 2004 USAF ASIP Conference*, December, 04.
14. "General Information," [Online] Available: http://www. airforce.forces.gc.ca/today5_e.asp.
15. As a result of adopting the damage tolerance approach, the CF aircraft are being modified to enable inspection of critical areas. Because the safe-life approach does not require inspection for crack growth, these aircraft were not initially designed to allow access to critical locations for inspection.
16. Canada Department of National Defence, *Technical Airworthiness Manual*, October, 2003.
17. CF-18 and CP-140 are the CF's version of the USN's F-18 and the USN's P-3, respectively.
18. "USAF Almanac 2004," *Air Force Magazine: Journal of the Air Force Association*, May 04, Vol 87, No.5 [Online] Available: http://www.afa.org/magazine/May2004/default.asp.

19. The Air Force released MIL-STD-1530C in November, 2005, as this article was being prepared for publication. These changes do not significantly affect our findings.
20. AFI 63-1001, *Aircraft Structural Integrity Program*, 18 April 02.
21. AFMC has delegated ASC/EN as the AFMC Office of Primary Responsibility for ASIP, in accordance with AFI 63-1001, AFMC Supplement 1, April 2003.
22. AFPD 63-10, *Aircraft Structural Integrity*, 1 November 97.
23. MIL-STD-1530B, *Aircraft Structural Integrity Program*, 20, February 04.
24. The POM process is a part of the programming phase of the DoD budget process, where each DoD component develops a POM and submits to the Office of the Secretary of Defense for a review. The POM entails a six-year funding plan to accomplish overall program goals and milestones.

General Kenny on Far East Supply Concepts

When we went into the Philippines, it was at a time when Europe seemed to be needing more shipping than it had ever needed before and that minor war over there was surely absorbing a lot of everything. So they cut down the number of boats that we had, and we were really in tough straits. When we first went into New Guinea, we had this bright idea that you couldn't do anything unless you had a 120-day stockage of everything. We cut that down to 90, with some misgiving on the part of MacArthur's supply crowd, and then I cut it to 60 and even to 30, and even the Air Force began to howl about 30 until they saw that Air Transport could pick up the slack.

When we started into the Philippines, the shortage of shipping was so acute that we landed on the island of Leyte with 5 days' stockage, and we never got more than 5-day stockage. We didn't want more than that because, by this time, we had air supply. We were flying gasoline, we were flying bombs, we were flying food, we were flying stuff for the infantry as well as ourselves. We were really doing a job with air transport. Where in the original part of the game we had to build warehouses and set up a depot and build terrific warehouses to stock stuff in and the stuff would get spoiled and that bad weather and everything, now we didn't have any stockage in there at all to amount to anything. These depots were largely depots repairing wrecks, and if we needed a spare part, we would fly the thing in. We would fly engines in. We were overhauling engines in Australia, and as the thing got off the test stand, it went right into an airplane. And inside of 5 or 6 hours, they were putting it in a bomber up in New Guinea.

Suppose, on the other hand, you do it the old-fashioned way. You take the silly engine off here and disassemble half of it and wrap it up in little packages, and they get lost when they open the crate. Everything is supposed to be proof against this damp tropical weather and proof against the salt spray that they get, because they always put out stuff on the decks.

These big heavy crates are made so you can drop them from the crane to the bottom of the hold, in case they did put them in the hold, and not break anything. Everything is filled up full of cosmoline, and then they load these boats until they have enough for a convoy. A month goes by. This thing has gotten all rusted, and the pistons won't move, and the crankshaft has red spots on it. When you do get the cosmoline off it, you haven't an engine until 2 months have gone by.

There was no doubt, as soon as we started in doing this stuff, that was the way to run a fast-moving war, especially when you were on a shoestring. And we finally found out that the way to run a war was on a shoestring anyhow, that was modern war, faster, and the whole Pacific campaign that MacArthur had would still be going on trying to get out of Port Moresby if it hadn't been for the transport.

General George C. Kenney, Speech for Air Force Association, 1952

Lieutenant Colonel Patrick H. Donovan, USAF

Oil Logistics in the Pacific War

Oil's Role in Japan's Decision for War

The shortage of oil was the key to Japan's military situation. It was the main problem for those preparing for war, at the same time, the reason why the nation was moving toward war.... Without oil, Japan's pretensions to empire were empty shadows.

—Louis Morton, *Command Decisions*[1]

Oil played a crucial, if not the key, role in the Japanese decision to go to war with the United States in 1941. Because of the deteriorating political situation with the United States, United Kingdom, and Netherlands East Indies, the future of Japan's oil reserve and supply was in danger. When diplomatic efforts failed to resolve the political impasse, Japan made plans to seize militarily what it could not achieve diplomatically. An inevitability of this military option was war with the United States. With this in mind, the Japanese planned to terminate any short-term American threat quickly and seize needed oil at the same time. Time, like the Japanese oil supply, was running out quickly.

Oil Available in the Netherlands East Indies

June 1941 was a pivotal month for the future of Japanese oil supplies. The Japanese had been in economic negotiations with the Netherlands East Indies (NEI) Government in Batavia since September 1940 and were seeking a special economic position in the Netherlands East Indies. Previous embargoes of aviation fuel, iron, and scrap steel by the United States in July and October 1940 (to counter the Japanese occupation of northern French Indochina) had sent the Japanese searching for alternative sources of raw materials. Also, the entrance of Japan into the Tripartite Pact with Germany and Italy on 27 September 1940, a pact that was aimed directly against the United States, further exacerbated US-Japanese relations. The Netherlands East Indies seemed to fit this bill, the Nazis (a putative partner of the

Japanese) had overrun the NEI's parent country, and its geographic location put the Japanese closer to the Netherlands East Indies than any of the latter's allies. Thus, the Netherlands East Indies was deemed to be more malleable to Japanese desires than the increasingly recalcitrant United States. Some of Japan's demands included participation in NEI natural resource development and freedom of access and enterprise in the Netherlands East Indies, as well as a steady supply of oil. However, Japanese aspirations were about to receive a serious setback.[2]

The move into southern French Indochina was not without some internal debate in Japan. In the end, however, it was decided that the military occupation of the territory was too good an opportunity to pass up.

The NEI Government was willing to negotiate with the Japanese, but Batavia was not willing to yield special economic concessions to the Japanese (there were to be increases of nonpetroleum products). Although these increases were less than what was sought, they did fulfill Japanese needs. Japanese requests for larger exports of oil were passed on to the NEI oil companies, but these requests were deferred. Also, Japanese requests to conduct military and political activities in the Netherlands East Indies were also rejected. On 17 June 1941, economic talks were broken off between Japan and the Netherlands East Indies.[3]

Almost directly on the heels of the breakdown in talks between Batavia and Tokyo was an announcement from the United States on 20 June 1941 that, henceforth, no petroleum would be shipped from the US east coast, or gulf coast ports, outside the Western Hemisphere. There was a shortage of fuel for domestic use on the east coast of the United States in June 1941. To ship fuel out of areas with shortages to semibelligerent foreign governments was politically untenable for the US Government. Thus, from Japan's point of view, the commodity most desired by them was being choked off.[4]

Because of this reversal of fortunes, Japan felt it must make a move toward securing a source of oil in Southeast Asia:

> Consequently, at an Imperial conference on 2 July, Japan decided to adopt the "Outline of the Empire National Policy to Cope with the Changing Situation." By executing a daring plan calling for the occupation of southern French Indochina, Japan hoped to gain dominance over the military situation in the southern areas and to force the Netherlands East Indies to accede to her demands.[5]

Japan Needs a Secure Source of Oil

The move into southern French Indochina was not without some internal debate in Japan. In the end, however, it was decided that the military occupation of the territory was too good an opportunity to pass up. By occupying the southern half of French Indochina, the Japanese would consolidate their strategic position; it would stop the encroachment of the ABCD powers on her economic life line. Also, the occupation would be a blow to the Chungking government and help settle the China issue; it would also put pressure on the NEI Government to come to terms with Japanese demands.[6] The Japanese were not making this move as a step toward provoking the United States, Britain, or the Netherlands East Indies to war; Tokyo wished economic negotiations to continue. The move into southern Indochina was a preemptive action that would help the Japanese if conflict with the ABCD powers became inevitable.[7] One wonders if the Japanese later realized that their actions eventually turned into a self-fulfilling prophecy.

The Japanese did not consider how the ABCD powers would react to Tokyo's move into southern Indochina.[8] Indeed, Tokyo felt that this move was possible because it believed the threat of US economic sanctions to the Japanese move to be less than 50 percent. The Japanese still moved forward, even though President Franklin D. Roosevelt had hinted to Kichisaburo Nomura, the Japanese Ambassador to the United States, that sanctions would occur if Tokyo moved troops into southern Indochina.[9] However, the Japanese felt that the United States would not follow through with such a move because it would provoke a war at a time when the United States was not ready to fight.[10]

There was some logic in the Japanese thought process. Since March 1941, the United States and Japan had been in dialogue to avoid such a war. However, as much as the United States wanted to avoid war, it would not do so at the sacrifice of basic principles of international conduct.[11] Therefore, reaction from the United States was swift. With the Japanese movement into southern French Indochina, the United States froze all Japanese assets on 25 July 1941.[12] The governments of Great Britain and the Netherlands East Indies soon followed with their own freezing actions.[13]

With this freezing action came a complete embargo of all oil products into Japan by these countries. It was not the intent of Roosevelt to bring about a complete embargo of oil to Japan.[14] He felt that such an action would cause the Japanese to invade the Netherlands East Indies and Malaya to seize the oilfields there. This would possibly suck the United States into an early conflict in the Pacific, a conflict the United States was not prepared for and which would be at the expense of devoting energy toward the European conflict.[15] Roosevelt's freeze order allowed the Japanese to apply for export licenses for oil; however, hard liners within Roosevelt's administration acted as if the freeze were total, so no licenses were ever approved.[16]

This situation put the Japanese into a quandary; they did not gain any oil by moving into southern Indochina. Now they had isolated themselves from 90 percent of their annual requirements. The Japanese did have a strategic reserve in place that they had been building up since the early 1930s. So some time was available to try and find a diplomatic way out of the impasse.[17]

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Oil in the Netherlands East Indies Cannot Be Secured without US Intervention

Throughout the summer and into the fall of 1941, Japanese negotiators and the United States were at loggerheads. The US-led embargo would not be suspended until the Japanese stopped their militaristic expansion; indeed, Japan would have to roll back some of its gains. Included in the US demands were calls for a retreat from all French Indochina and China. This demand was unacceptable to the Japanese.[18] Likewise, *As far back as 1909, the United States was identified as one of the principal enemies of Japan.*

the minimum demands of the Japanese stated that the United States must accept the current status quo in east Asia with vague promises that the Japanese would withdraw from disputed areas once peace had been established in the Far East on a fair and just basis.[19]

Meanwhile, Japanese oil stocks were dwindling. If the Japanese could not get oil by negotiation, they would have to use force. The nearest available source was in the Netherlands East Indies. Would it be possible to seize the oil there without involving the British and the Americans? There were numerous reasons why Tokyo felt this was not the case.

The Japanese had come into possession of British War Cabinet minutes that stated the British would fight alongside the Dutch if the Japanese invaded the Netherlands East Indies.[20] The Japanese were also aware that any conflict involving them and the British would draw the United States into conflict on the side of the British.[21] The director of the War Plans Division of the Navy Department, Admiral Richmond Kelly Turner, confided this policy to Nomura "that the United States would not tolerate, in view of its policy of aiding Britain and its interpretation of self-defense, a Japanese threat to the Malay barrier."[22] The United States was not limiting its interest to the British. In a note handed to Nomura from Roosevelt, the United States stated any further aggression by Japan against its neighbors and the United States would be forced "to take immediately any and all steps which it may deem necessary" to safeguard US interests.[23] Finally, the Japanese foreign office believed some type of military understanding had been reached among Washington, London, and Batavia. The Foreign Office produced two reports that supported its claims that a joint ABCD defense understanding existed and was being implemented.[24]

Even with this potential alliance arrayed against them, could the Japanese afford to dismiss the warnings as bluster? As appealing as the thought was, the B-17s based at Clark Field and the Cavite Naval Base in Manila Bay were too much of a strategic threat to the Japanese lines of communication. Any shipments of raw materials that the Japanese might acquire in the Netherlands East Indies or Malay Barrier could potentially be attacked by US forces stationed in the Philippines. Because of this, those US forces would have to be dealt with if the Japanese could not get the resources they needed diplomatically.[25]

All these factors played into the Japanese belief they eventually and inevitably would come into conflict with the United States. As far back as 1909, the United States was identified as one of the principal enemies of Japan.[26] Indeed, the Japanese realized fairly soon after the oil embargo was imposed that the Japanese and American positions were mutually exclusive. At the 6 September 1941 Japanese Imperial Conference, materials addressing such a question were distributed to the participants.

> *Is War with the United States Inevitable?*…it appears that the policy of the United States toward Japan is based upon the idea of preserving the status quo and aims, in order to dominate the world and defend democracy, to prevent our empire from rising and

> developing in Eastern Asia. Under these circumstances, it must be pointed out the policies of Japan and the United States are mutually inconsistent and that it is historically inevitable the conflict between the two countries, which is sometimes tense and moderate, should ultimately lead to war.
>
> If we should ever concede one point to the United States by giving up a part of our national policy for the sake of a temporary peace, the United States, its military position strengthened, is sure to demand tens and hundreds of concessions on our part, and ultimately, our Empire will have to lie prostrate at the feet of the United States.[27]

It should be noted that these were not the views of one individual alone but those of the government and the supreme command of the Japanese military. If Japan were to obtain the oil and other resources it needed, it would have to control the Netherlands East Indies and the Malay Barrier. Japan also would have to remove the US threat to this plan.

Pearl Harbor and the Southern Operation

Japanese naval strategy was built around the premise that when the United States and Japan went to war it would be a one-time decisive battle. The Japanese believed a large American fleet, as much as 40 percent larger than the Japanese fleet because of restrictions imposed by the Washington Naval Treaty, would drive across the Pacific to attack the Japanese. During this drive, the Japanese would initially send out submarines to whittle down the size of the US fleet. Closer in, the Japanese would throw land- and carrier-based aircraft into the battle. Once the reduced US fleet was far enough into the western Pacific, the Imperial Japanese Navy (IJN) would sortie out and engage in a classic ship of the line battle that the Japanese would inevitably win.[28]

Japanese naval strategy was built around the premise that when the United States and Japan went to war it would be a one-time decisive battle.

The problem with this strategy was that it was passive. Japan would have to devote the majority of its fleet to support amphibious landings if the Southern Operation of seizing the Netherlands East Indies and Malay Barrier were to succeed. The decisive battle plan left the initiative and time of the conflict up to the US Navy. This left Japanese forces even more at risk after the US Pacific Fleet's move to Pearl Harbor. If that fleet could be neutralized or destroyed at Pearl Harbor, it would deprive the US fleet of any initiative and allow the Japanese to run unhindered in the southern area.[29] This line of thought ran totally counter to 30 years of navy doctrine, and ordinarily, it would have been dismissed.[30] However, this proposal came from the current head of the Combined Fleet, Admiral Isoroku Yamamoto, and could not be easily brushed aside.

Origins of the Pearl Harbor Attack

Yamamoto was opposed to conflict with America. He felt that, given the material and technological strength of the United States, Japan would have no hope of ultimate victory over America. If it came to blows though, Yamamoto would put forth every effort to ensure the goals of his homeland were achieved.[31] He had doubts

There was disagreement as to the feasibility of the Hawaii Operation from not only the Naval General Staff but also officers within the First Air Fleet staff that would be tasked to carry out the Pearl Harbor attack plan.

whether the Japanese Navy could seize the vast southern areas with the majority of its forces and fend off a flank attack by the US Navy at the same time. The solution that Yamamoto came up with was to take out the Pacific Fleet with one quick action. Then the Southern Operation could proceed unmolested and new Japanese gains consolidated. Yamamoto placed heavy emphasis on aerial warfare because of an earlier posting with the air arm of the Japanese Navy. With the advances the Japanese Navy made in aerial warfare, Yamamoto began contemplating an aerial strike on the fleet at Pearl Harbor. This plan, or the Hawaii Operation as it came to be known, became the means to achieve that goal.[32]

Yamamoto built a planning staff to address the possible Hawaii Operation. One of the first officers tasked was Commander Minoru Genda, the man who brought forth a feasible plan for the strike. Among other things, Genda stressed the need for a surprise attack by a six-carrier task force, which would refuel at sea to make the long voyage. His plan would concentrate the IJN's aerial attack on US Navy carriers and Pearl Harbor's land-based aircraft. These targets were to be the primary ones; other strategic targets—such as the oil storage facilities, drydocks, and so on—were not mentioned at all.[33]

There was disagreement as to the feasibility of the Hawaii Operation from not only the Naval General Staff but also officers within the First Air Fleet staff that would be tasked to carry out the Pearl Harbor attack plan.[34] The plan was finally put before the Japanese Naval General Staff in wargames from 10 to 13 September 1941 at the Tokyo Naval War College. The exercise demonstrated the practicality of the Pearl Harbor attack, but it was felt by the general staff that the chance of the strike force's being detected was too high, thus putting almost all Japan's aircraft carriers at risk.[35] Yamamoto's staff was not deterred. They stressed Yamamoto's argument:

> The present situation—*i.e.*, that of the US fleet in the Hawaiian Islands, strategically speaking—is tantamount to a dagger being pointed at our throat. Should war be declared under these circumstances, the length and breadth of our Southern Operation would immediately be exposed to a serious threat on its flank. In short, the Hawaii Operation is absolutely indispensable for successful accomplishment for the Southern Operation.[36]

Yamamoto's personal feelings were best summed up in a letter to a friend:

> I feel, as officer in command of the fleet, that there will be little prospect of success if we employ the normal type of operations.… In short, my plan is one conceived in desperation … from lack of confidence in a perfectly safe, properly ordered frontal attack; if there is some other suitable person to take over, I am ready to withdraw, gladly and without hesitation.[37]

It was the same argument he used with the Naval General Staff, in a sense "my way or the highway." No one was willing to let the commander in chief resign, so after about a month of deliberations, the plan to attack Pearl Harbor was approved.[38]

Securing the Eastern Flank

Along with the Hawaii Operation, ancillary plans were drawn up to seize the US bases at Wake, Guam, and the Philippines.[39] Occupation of these territories would complement Japanese island holdings in the Central Pacific that were acquired after World War I. These seizures would help build an impregnable barrier against the Americans when such time arose that the US Navy would finally be able to sortie a fleet against the Japanese.

It was a strategy built on sound principles. Because of the Washington Naval Treaty's limitations, the United States was forbidden to build up any bases west of Pearl Harbor. After the Japanese withdrew from the Washington Accords,[40] proposals were made by a Navy board, in late 1938, to beef up its defenses west of Hawaii. However, the appropriations never made it through Congress.[41] Thus, if the Japanese attacked, these bases would fall relatively quickly. This would leave no US bases in the entire Pacific west of Hawaii.[42] Any operations planned by the Navy would have to be run out of and supported from Pearl Harbor.

Time Is Oil

The Japanese felt they had a finite amount of time in which to solve their oil problem. It was decided at the 5 November 1941 Imperial Conference that Japan would go to war with the United States (and Great Britain) if negotiations to break the diplomatic impasse were not successful by 1 December 1941. Guidance from this same meeting directed the Army and Navy to complete plans for the Hawaii and Southern Operations.[43]

There were many reasons this stance was adopted at the conference. First, every day the Japanese delayed the Southern Operation, ABCD forces were growing larger. For example, Army strength in Malaya and the Philippines was being reinforced at the rate of 4,000 men every month; air strength and infrastructure were also increasing. It was also feared that the ABCD powers would become closer politically, economically, and militarily in the interim.[44] There was also concern that the Soviet Union possibly would attack Japan in the springtime. If this occurred, the Japanese wanted to be sure the Southern Operation had been completed.[45] Another concern was the weather. The northeast monsoon would make the amphibious landings required in the Southern Operation increasingly difficult after December.[46] It also would affect ships in the Hawaii Operation. Refueling at sea was an absolute necessity for the First Air Fleet to have the range to strike Pearl Harbor. Meteorological studies showed there were only 7 days, on average, that refueling could be accomplished in December.[47] That number could be expected to decrease with the onset of the winter season.

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However, the ultimate factor that decided the start of offensive operations was the status of the Japanese fuel stockpile. The Japanese realized that oil was the bottleneck in their fighting strength; any lengthy delay in securing an oil source would be disastrous.[48] Indeed, it was stated at a conference in late October 1941

Like the Japanese, the Pacific Fleet had its own oil problems. The only major base for the US Navy in the Pacific was located in Hawaii. All major fleet logistics, repair, and storage were at the naval base at Pearl Harbor. The Navy also suffered from a severe shortage of oilers, which limited the operations radius of the fleet.

that Japan needed to occupy the oilfields in the southern areas by March. If this did not occur, adding in such factors as normal stockpile depletion and getting the oilfields back into production, the Japanese would run out of oil in about 18 months.[49] By September 1941, Japanese reserves had dropped to 50 million barrels, and their navy alone was burning 2,900 barrels of oil every hour. The Japanese had reached a crossroads. If they did nothing, they would be out of oil and options in less than 2 years. If they chose war, there was a good chance they could lose a protracted conflict. Given the possibility of success with the second option, versus none with the first option, the Japanese chose war. [50]

There are many critical points of this preconflict period. The Japanese realized the importance of oil to their modern military machine, and any operations undertaken in the vast Pacific theater would require large amounts of oil. They were willing to send a huge task force of irreplaceable ships thousands of miles into hostile waters (and all the attendant oil this operation would consume) to attack a formidable enemy fleet to help achieve oil self-sufficiency.[51] The concurrent plan to seize the US possessions in the Central Pacific would ensure the Japanese would control all the oil-producing regions between the west coast of the United States and the Persian Gulf. Finally, there is the planning of the Pearl Harbor raid; without oil tankers, it would have been impossible for the Japanese Navy to accomplish that mission. Armed with this knowledge, would the Japanese realize this same need for oil applied to the US Navy?

Oil, Pearl Harbor, and the US Navy

> *The thing that tied the fleet to the base [Pearl Harbor] more than any one factor was the question of fuel.*
>
> **—Admiral Husband E. Kimmel,**
> ***Joint* Committee on the Investigation of the Pearl Harbor Attack**[52]

Like the Japanese, the Pacific Fleet had its own oil problems. The only major base for the US Navy in the Pacific was located in Hawaii. All major fleet logistics, repair, and storage were at the naval base at Pearl Harbor. The Navy also suffered from a severe shortage of oilers, which limited the operations radius of the fleet. The Japanese were well-informed on the strengths and logistics necessities of the Pacific Fleet. With the known vulnerabilities of the Pacific Fleet's logistics train, the Japanese, nevertheless, chose to attack military combatants only, such as the US battleships. This operational strategy was going to come back and haunt the Japanese.

Japanese Intelligence on the US Navy and Pearl Harbor

Extensive intelligence gathering by the Japanese informed them of the abilities, limitations, and makeup of the Pacific Fleet and those areas and facilities required for its support. No scrap of information was too small. No scrap of information was too small. Detailed intelligence on the Pacific Fleet was the linchpin of the Hawaii Operation.[53]

> The information received from the Japanese after the war shows that their methodical observations and espionage kept them well informed of everything concerning the defenses of Hawaii and the activities of the Pacific Fleet. In our open democratic society Japanese agents were free to observe fleet practices, take photographs with their high-powered equipment, and solicit almost any information desired,… High-powered binoculars were hardly necessary, but they showed particular details, which, in large measure, were unknown even to any single officer of the fleet.[54]

The IJN intelligence officer at Pearl Harbor was Ensign Takeo Yoshikawa. From the spring of 1941, he was in charge of intelligence gathering in Hawaii. Yoshikawa had been studying methods and operations of the Pacific Fleet for the previous 7 years.

> I read a vast amount of material in that period, from obscure American newspapers to military and scientific journals devoted to my area of interest … I studied *Jane's Fighting Ships* and *Aircraft*… devoured the *US Naval Institute Proceedings* and other US books … and magazines…. In addition to this mass of seemingly innocuous information on the Navy and its bases, I had access to the periodic reports of Japanese agents in foreign ports, particularly Singapore and Manila….
>
> In any event, by 1940, I was the Naval General Staff's acknowledged American expert—I knew by then every US man-of-war and aircraft type by name, hull number, configuration, and technical characteristics; and I knew, too, a great deal of general information about the US naval bases at Manila, Guam, and Pearl Harbor.[55]

Extensive intelligence gathering by the Japanese informed them of the abilities, limitations, and makeup of the Pacific Fleet and those areas and facilities required for its support. No scrap of information was too small.

It should be noted that the ship information being collected on the west coast also included commercial traffic, especially petroleum shipments. Radio intercepts of Japanese diplomatic messages showed that in mid-1941, Japanese agents operating out of Los Angeles reported the departure of five tankers carrying 400,000 barrels of high-octane fuel to Vladivostok.[56]

The result was a vast intelligence tome, *The Habits, Strengths, and Defenses of the American Fleet in the Hawaiian Area*. In addition, detailed maps of Pearl Harbor were drawn up showing all the information reported above, to include the locations of fuel-storage depots.[57] Yamamoto and the Japanese Navy had the required information to target the Pacific Fleet at Pearl Harbor. Since the purpose of the Hawaiian Operation was to eliminate the Pacific Fleet as a threat, the question was whether Yamamoto would use this information to hit the most vulnerable center of gravity to achieve that goal.

The Primary Targets of the Pearl Harbor Attack Are Ships

On the morning of 7 December 1941, there were 86 ships of the Pacific Fleet in Pearl Harbor. At the end of that day, nine of the ships were sunk or sinking, and ten others were severely damaged in the raid. [58]

Horrible and devastating as the Pearl Harbor raid was, it was by no means a knockout blow to the Pacific Fleet.

The most important targets among the ships of the Pacific Fleet were the aircraft carriers. Intelligence indicated there would be no carriers in Pearl Harbor that morning, however, so Battleship Row on the east side of Ford Island would be the initial focal point of the raid.[59] The 352-plane raid[60] lasted from 0755, when the first bomb exploded near the seaplane ramp on Ford Island, to approximately 1000 Hawaiian time when the last Japanese planes headed north to their carriers.[61] By the time the raid ended, the Japanese had caused significant injury to the Pacific Fleet; eight battleships, three light cruisers, three destroyers, and four auxiliary vessels were sunk or damaged. There were also major losses among Army and Navy air forces on the island of Oahu and nearly 3,600 US casualties. The Japanese, on the other hand, lost 29 aircraft and 5 midget submarines.[62] Surprise, the key tenet to the success of the Hawaii Operation had been utter and complete.[63]

Horrible and devastating as the Pearl Harbor raid was, it was by no means a knockout blow to the Pacific Fleet. It is true that all eight battleships attacked on 7 December were either sunk or damaged. However, many factors mitigated the overall results of the attack. It is probably most important to note that the majority of sailors, less those who were killed outright in the attack or in the capsized *Oklahoma*, were easily rescued because the attack took place in a relatively small, landlocked harbor. Another factor was the physical state of the ships located on Battleship Row that morning. Professor Thomas C. Hone best stated this condition: "The American battleships were all old; several were nearly overage; most were overweight. None of the battleships in Pearl Harbor was a first-line warship in a material sense; all had recognized deficiencies."[64] They were also a good 10 knots slower than the US aircraft carriers.[65] These details were not unknown to the hierarchy of the Pacific Fleet. When Vice Admiral William F. Halsey was asked whether or not he wanted to take any battleships with him on his reinforcement trip to Wake Island, he retorted "Hell, no! If I have to run, I don't want anything to interfere with my running!"[66] Last, but not least, because of the shallowness of Pearl Harbor, which had an average depth of only 40 feet, all but two battleships eventually would be salvaged.[67] The Japanese were well aware of the depth of the harbor and the fact some ships would be salvaged. However, the Japanese felt American salvage efforts would take a lot longer than the time required to complete IJN operations in the Southern Area.[68]

Commander Mitsuo Fuchida, airborne leader of the Pearl Harbor attack force, verbally reported strike results to Vice Admiral Chuichi Nagumo after landing on the carrier *Akagi* following the raid:

> Four battleships definitely sunk.… One sank instantly, another capsized, the other two may have settled to the bottom of the bay and may have capsized. This seemed to please Admiral Nagumo who observed, "We may then conclude that anticipated results have been achieved."
>
> Discussion next centered upon the extent of damage inflicted at airfields and airbases, and I expressed my views saying, "All things considered, we have achieved a great amount

of destruction, but it would be unwise to assume that we have destroyed everything. There are still many targets remaining which should be hit."[69]

As far as Nagumo was concerned, though, his primary mission had been accomplished. Now his concern turned to the missing US carriers and their threat to his task force. There was no provision in the Pearl Harbor attack plan to remain in the Hawaiian area to search for US ships not at anchor at the time of attack. Nagumo, who had opposed the Hawaii Operation at its inception, was ready to withdraw. His

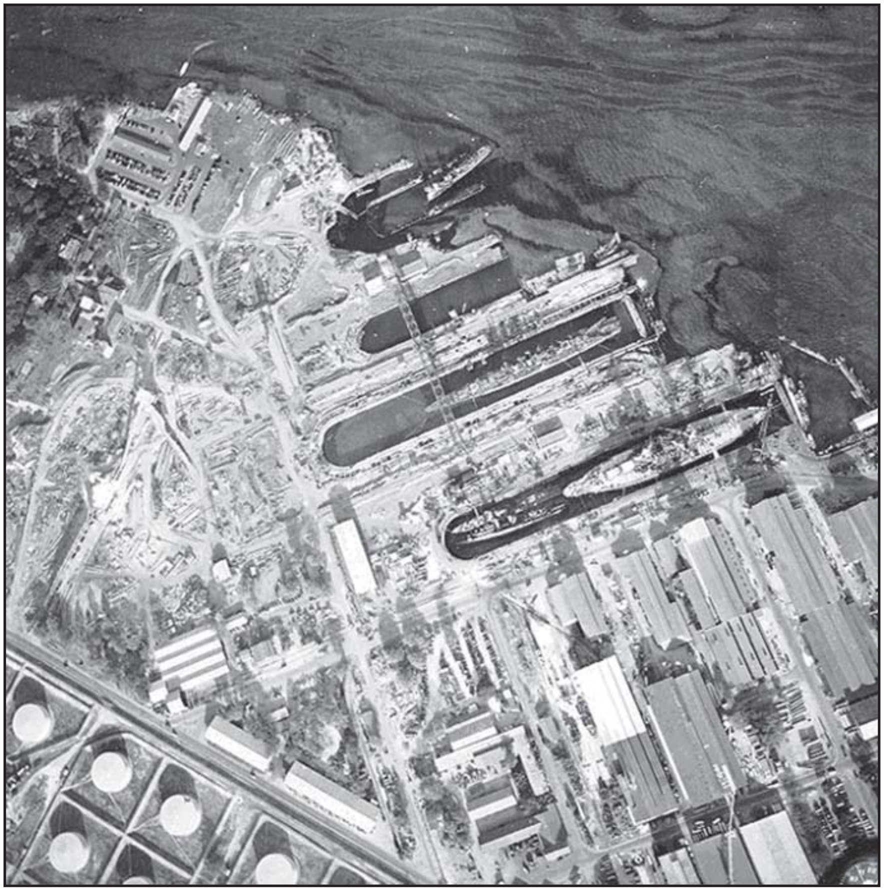

Figure 1. Aerial View of Pearl Harbor Drydock, 10 December 1941. Note the improvised antitorpedo barriers located near the drydock openings. *USS Pennsylvania* and the sunken destroyers *Cassin* and *Downes* are in the lower, No 1, drydock. The **USS *Helena* occupies the middle drydock. The *USS Shaw* and the sunken drydock *YFD-2* are on top. Numerous support shops and base facilities are located in the lower right corner. Also, note the black oil streaks on the harbor surface.** [77]

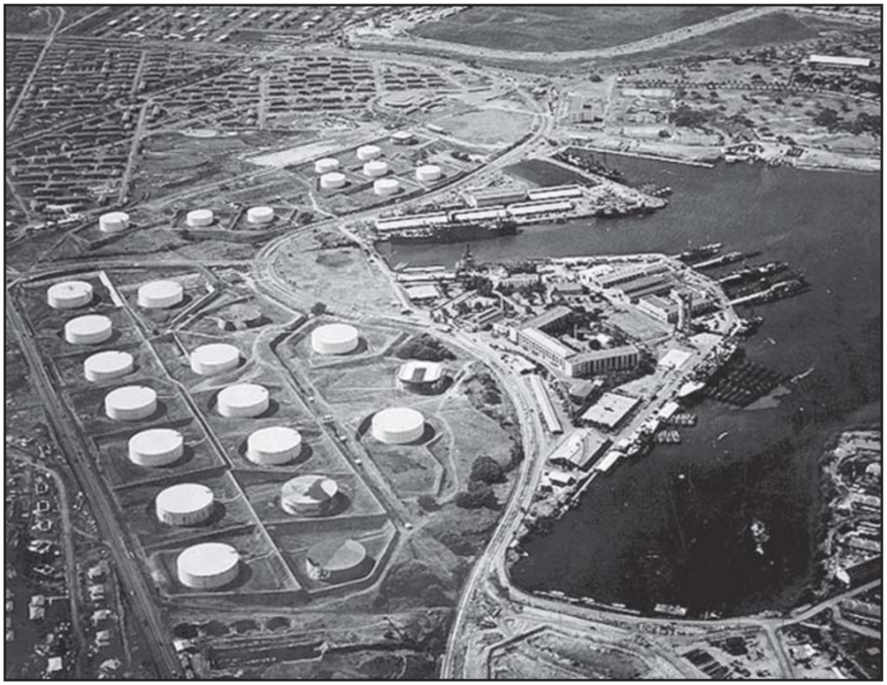

Figure 2. Submarine Base, Pearl Harbor and Adjacent Fuel Tank Farms, 13 October 1941. This is a view of the upper oil tank farm located on the east side of the Pearl Harbor naval base. The lower tank farm was located between Hickam Field and the naval base (see Figure 1 for oil tanks in the lower farm). Note the attempts at camouflage. Two of the tanks in the foreground are painted to resemble terrain features. The third, closest to the submarine base, is painted to resemble a building.[87]

chief of staff, Rear Admiral Jin'ichi Kusaka, had held the same opinion. Kusaka recommended to Nagumo that the fleet withdraw to Japan. Nagumo immediately concurred. A second strike on Pearl Harbor—which would have focused on the dockyards, fuel tanks, and remaining ships—was canceled.[70]

Drydocks, Repair Shops, and Oil Storage Areas Spared

Nagumo did not realize the magnitude of his error in not completing the destruction of Pearl Harbor by attacking the base and fuel facilities. His pedantic and traditional view of naval strategy blinded him to the opportunity of a lifetime.[71] Never again would the Japanese Navy be in a position to deliver such a mortal blow to the US Fleet.[72]

Ironically, the Japanese missed their opportunity to strike at the drydocks during the initial attack. Torpedo bombers approaching from the west over Ford Island commenced their run on the battleship *Pennsylvania*. Once they came over the island, the Japanese pilots saw that it was moored in drydock No 1. Seeing this, the torpedo bombers shifted their attack runs toward a cruiser, the *USS Helena*, and the destroyer *Ogala* (actually a minesweeper).[73] They would have been served better by attacking the drydocks. Torpedo strikes on the drydock gates would have rendered these essential repair facilities inoperable until those gates were repaired or replaced. It certainly was a fear of the Navy that the Japanese would return and do just that (Figure 1). As can be seen in Figure 1, salvage operations were up and running almost immediately. The targeted specifically. The only bombs that fell near these critical facilities were intended for ships on or near these facilities.[74] Had Nagumo returned with a third wave, he could have leveled the navy yard's support facilities,[75] thereby destroying the Navy's industrial capacity and setting back salvage operations.[76] This oversight would come back to haunt Nagumo in a most personal fashion.

The *USS Yorktown* utilized drydock No 1 after the mauling it had received on the Coral Sea. In a turnaround that can be described nothing short of miraculous, essential temporary repairs were made, and it was sent back out to sea within 72 hours for the critical Midway battle. There, its aircraft were crucial in sending all four of Nagumo's carriers to the bottom of the sea.[78]

By far, the most surprising target oversight of the Japanese attack was the oil and gas storage tanks. The entire fuel supply for the Pacific Fleet was stored in above-ground tanks on the eastern side of the naval base (Figure 2).

As can be seen in Figure 2,, these tanks were perfectly visible to the naked eye; ergo, perfect targets.[79] These tanks were particularly susceptible to enemy action; none of the tanks had bombproof covers.[80] Even a few bombs dropped amongst the tanks could have started a raging conflagration.[81]

Why were these crucial targets not hit? Their loss essentially would have starved the Navy out of the Central Pacific.[82] Did the Japanese not know they were there?

> The Japanese knew all about those oil storage tanks. Their failure to bomb the Fleet's oil supply reflected their preoccupation with tactical rather than logistical targets.… Nagumo's mission was to destroy Kimmel's ships and the airpower on Oahu. If Yamamoto and his advisers chose the wrong targets, or insufficiently diversified ones, the mistake rests on their shoulders.…[83]

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Pearl Harbor Was the Only Filling Station in Town

Pearl Harbor was the only refueling, replacement, and repair point for ships operating in the Hawaiian area.[84] Part of Pearl Harbor's duty of being the Pacific Fleet's chandlery was the stocking and disbursing of oil. To that end, the Navy had just finished restocking its tanks in Pearl Harbor to their total capacity of 4.5 million barrels of oil.[85] The loss of this amount of oil would have effectively driven the Pacific Fleet back to the west coast and effectively knocked almost all ships of the Pacific Fleet out of contention, instead of just 19.[86] The Japanese knew the importance of oil to a fighting fleet; after all, they had just started a war to achieve a secure source of oil. Why did they not see that the US Fleet needed a secure source of oil if it was to operate in the vast reaches of the Pacific?

Genda later wrote that the question of demolishing the oil tanks only arose after the attack's amazing success. "That was an instance of being given an inch and asking for a mile."[87] He insisted that the objective of the plan was to destroy American warships so they could not interfere with the Southern Operation; oil tanks did not enter into the original idea.

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As no one could charge Genda with lacking either imagination or vision, this uncharacteristic obtuseness could be due only to failure to understand the importance of logistics. Most Japanese naval planners apparently suffered from this same myopia toward the less glamorous necessities of modern warfare.

> The Hawaiian Islands produced no oil; every drop had to be tanked from the mainland. Destruction of the Pacific Fleet's fuel reserves, plus the tanks in which it was stored, would have immobilized every ship based at Pearl Harbor, not just those struck on December 7.… "We had 4-1/2 million barrels of oil out there, and all of it was vulnerable to .50 caliber bullets."[88]

The state of Allied oil supplies in the rest of the Pacific theater was extremely poor. The Japanese rapidly captured the bases at Wake and Guam in pursuit of their Southern Operation goals. This geographically isolated the Philippines and made the US naval base there untenable.[89] A sampling of four other ports in the Pacific highlights this problem. Brisbane had 12,000 tons of fuel available in January 1941, Sydney and Melbourne both had 8,000, and Port Moresby had none. Other bases, in the Netherlands East Indies, for example, could not be counted on for oil supplies because of their proximity to Japanese airpower and imminent Japanese invasion.

Once the Japanese seized the oilfields in the Netherlands East Indies and Burma, they eliminated all potential oil supplies in the Pacific between the Americas and the Middle East.[90]

For the Allies, geography had become almost as a big an enemy as the Japanese.[91] The fuel supplies at Pearl Harbor were crucial for the Navy to bring the war to the Japanese Navy. Admiral Chester W. Nimitz summed up the situation best, "Had the Japanese destroyed the oil, it would have prolonged the war another two years."[92]

A Lack of US Oil Tankers

It is interesting to note that only one ship located on Battleship Row on 7 December received no damage at all. Yet, had the Japanese sank or severely damaged this ship, its effect on the Pacific Fleet would have been almost as great a loss as sinking an aircraft carrier. That ship was the fleet oil tanker, *USS Neosho*.[93]

The lack of fleet oilers, like *Neosho*, hung like a large cement albatross around the neck of Navy planners contemplating operations in the Pacific before and after the Pearl Harbor raid.[94] This dearth of oilers was a key vulnerability of the Navy. The Japanese Navy, who had just seen how it would have been impossible to carry out the Pearl Harbor attack without tanker support, should have targeted these ships that were so crucial to the Navy.

In the years from 1925 to 1940, the quantity of most surface combatants in the Navy had doubled in size; the size of the auxiliary force had not. Although there had been an increase in the number of fleet oilers, they were all kept busy ferrying fuel between bases.[95] On 7 December, the Pacific Fleet had two oilers in Pearl Harbor and three at sea and six others in ports on the west coast; only four of these were capable of at-sea refueling.[96] This shortage of tankers effectively limited the radius of the Pacific Fleet.[97] It was also a key reason so many ships were located in Pearl Harbor on 7 December. Kimmel was unable to keep less than half his fleet at sea without starting to deplete the oil reserves at Pearl Harbor; his limited supply of oilers could not keep up with the deficit.[98]

Because of this lack of oilers, the fleet could not have even exercised its primary war plan (even if most of its battle line was not at the bottom of Pearl Harbor). The total capacity of the Pacific Fleet's oilers was 760,000 barrels of oil. In the first 9 days after Pearl Harbor, the fleet had expended 750,000 barrels of this sum. Thus, the fleet was tied to its oil supply at Pearl Harbor,[99] and if the Japanese had attacked the oil storage and the associated oilers at Pearl Harbor on 7 December, they would have driven the Pacific Fleet back to the west coast.[100]

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If the Pacific Fleet were forced back to the west coast, would it have been effective in opposing the Japanese? The short answer is no, especially if the Japanese began targeting oilers. To give an example, the *USS Lexington* was dispatched from California to assist in the search for Amelia Earhart in July 1937. First, the *Lexington* had to top off its bunkers on the west coast.[101] It then proceeded on a high-speed run of about 30 knots to the Hawaiian Islands. Here, it had to refuel again from the fleet oiler *USS Ramapo* off Lahaina Roads, Maui. The result was that the *Lexington* did not arrive in the search area off Howland Island until 11 days after its departure from the west coast and could not even have done that without the support of the *Ramapo*.[102]

Ships *sortieing* from the west coast would be adding 2,000 nautical miles to their patrols into the Pacific just to get to Hawaii.[103] This number would have to be doubled, obviously, because these same ships would have to get back to the west coast if no oiler support were available and the oil storage at Pearl Harbor no longer existed.

The cruising ranges of the Pacific Fleet simply could not meet this necessity. The best range of the *Yorktown*-class carriers was 12,000 nautical miles at 15 knots, while older carriers had even less endurance.[104] Battleships had much less endurance and were slower. They averaged out at 8,000 nautical miles at 10 knots.[105] Cruisers were a little better off than the carriers; they averaged 14,000-14,500 nautical miles at approximately 15 knots. Destroyers, depending on their class, could go 6,000-9,000 plus nautical miles at 15 knots.[106] Looking at the carriers' and cruisers' endurance capabilities, the situation does not seem so bad. However, there are other factors that need to be thrown into the equation.

First, ranges needed to be decreased by a minimum of 15 percent whenever antisubmarine steering measures were taken.[107] Also, a prudent commander might want to avoid a suspected submarine-operating area altogether, if time and circumstances permitted such a detour. This too, would decrease overall endurance. Another factor was ship speeds. Higher speed means more fuel burned. Task force operations require much high-speed steaming for the launch and recovery of aircraft, search tasks, antisubmarine patrol, and so forth. This process, as can be seen by the previous *Lexington* example, burns a prodigious amount of fuel.[108]

The equation all boils down to the availability of oil and sufficient tankers to transport this precious commodity. Kimmel summed up this essential truth when he testified:

> A destroyer at full power exhausts its fuel supply in 30 to 40 hours, at medium speed in 4 to 6 days. War experience has proven the necessity of fueling destroyers every third day, and heavy ships about every fifth day to keep a fighting reserve on board. To have kept the entire fleet at sea for long periods would not have required 11 tankers but approximately 75, with at least one-third of them equipped for underway delivery.[109]

The Japanese operational strategy of focusing only on symmetric targets, like warships, was adhered to even when asymmetric US vulnerabilities were present.

Oil Logistics After Pearl Harbor

The Japanese followed up their attack on Pearl Harbor with submarine operations off the west coast of the United States. These operations were planned to concentrate on striking warships versus logistical support ships and merchantmen. Although the Japanese managed to sink some ships, their submarine operations were a rather feeble effort compared to German U-boat operations against US commercial shipping in the Atlantic. The Germans committed wholesale slaughter along the east coast of the United States after Pearl Harbor. The number of available German submarines for these operations was even less than the Japanese deployment. Yet, the Germans' success was much higher because of their operational strategy of targeting Allied merchantmen, with an emphasis on oil tankers. The Japanese operational strategy of focusing only on symmetric targets, like warships, was adhered to even when asymmetric US vulnerabilities were present. This window of opportunity began to close slowly after Pearl Harbor. The Japanese lost all ability to exploit this weakness by late 1942; by then, they had lost the ability for the offensive, which was never to be recovered.

War Comes to the US West Coast

Japan's geographical situation determined that war in the Pacific would be, in large measure, a war to control the sea so as to exploit its new territorial gains in the Southern Operation. One of the items in its arsenal to help accomplish this task was the submarine.[110]

The overall strategic mission of the Japanese submarine force was to serve as an adjunct to the main battle force. This is to say, when an enemy fleet (the US Pacific Fleet) was bearing down on Japanese waters, the IJN submarines would sortie and intercept the Americans. The Japanese subs would maintain a reconnaissance of the enemy, reporting movements to the Japanese battle fleet, while reducing the enemy force by attrition. When the two fleets met, there would be a great Jutland-style clash that would determine everything.[111] The Hawaii Operation's whole tenet was to nullify the need for this strategy, at least for the first 6 months. However, the submarine was too valuable a tool to be withheld from operations, so the Japanese submarine force was included in the planning of the Hawaii Operation. It would be used for prestrike reconnaissance, to attack targets that escaped the airstrike, and to interdict a counterattacking force.[112] Thirty large fleet boats from the Sixth Fleet were to take part in the attack. Three were to operate as a screen for the Pearl Harbor strike force, 20 others were to position themselves around Oahu, and 5 others each were to carry a two-man midget submarine. The remaining two submarines were to conduct reconnaissance around the Aleutian Islands and other US possessions in the Pacific. Following the attack, 12 of the submarines would remain in the Hawaiian area, and 9 would proceed to the US west coast.[113] There, they were to interdict US lines of communication by destroying enemy shipping.[114]

Although it was part of the original Japanese grand strategy to vigorously prosecute attacks against US commercial shipping, this was not reflected in IJN submarine operations or tactical thought.[115] The Japanese submarines off the west coast of the United States were primarily there to strike at US naval assets.[116] The Japanese hamstrung themselves with their own rules of engagement when it came to merchant traffic. They only were allowed to use one torpedo per merchant ship. Because of this, they often surfaced to engage merchant vessels with their deck guns.[117] This action denied them the use of two of the best weapons the submarine possessed. First, they sacrificed the relative accuracy and lethality of their primary weapon, the torpedo.[118] Second, this tactic sacrificed one of the submarine's greatest commodities—stealth.

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Nevertheless, the Japanese submarines did score some victories on the west coast of the United States The *I-17* damaged one freighter with shell fire and caused the tanker *Emidio* to beach itself off Crescent City, California.[119] The submarine *I-23* attempted a surface attack on another tanker near Monterrey, California, but achieved no hits. The tanker *Agriworld* was able to get off a distress call to the Navy. Two surface attacks by the submarine *I-21* yielded no results. However, its luck was about to change. It torpedoed and sank the tanker *Montebello* 20 miles from Avila, California, on the morning of 23 December. Two other torpedo attacks were made farther down the coast near Los Angeles by *I-19*; one was ineffectual, the other hit the freighter *Absaroka*. With the help of a nearby Navy tug, *Absaroka* was beached right below Fort MacArthur. An order for the subs to shell west coast cities was rescinded at the last minute, and the subs withdrew to Japanese waters in late

Overconfidence, poor tactics, and a mentality that stressed commerce and logistical targets were not worthy of destruction let a golden opportunity slip through the Japanese's fingers.

December.[120] This order for a premature withdrawal (the subs had hardly made a dent in their torpedo stocks) possibly was due to overconfidence on the part of the Japanese. It was decided to recall subs in the eastern Pacific to support the Southern Operation.[121]

A few more attacks were made on west coast targets later in 1942. One strike that had merit was an attempt to start a large forest fire with bombs dropped by a sublaunched seaplane. Unfortunately for the Japanese, unseasonable rain and fog managed to keep the fire from spreading beyond a small area, and it burned itself out.[122] Another attack against a California oil refinery and tank farm was motivated more personal than military strategy; in any case, that attack was also ineffectual.[123] From December 1941 to October 1942, Japanese submarines attacked just 19 merchant ships between Hawaii and the west coast; 15 of these were in December 1941.[124]

Overall, the Japanese submarine campaign on the west coast had meager results. Overconfidence, poor tactics, and a mentality that stressed commerce and logistical targets were not worthy of destruction let a golden opportunity slip through the Japanese's fingers.[125] Such would not be the case with their new partners one ocean over.

Roll of the Drums

For reasons probably known only to him, Hitler declared war on the United States on 11 December 1941.[126] For the scope of this article, why he declared war is not important; only the immediate results of that action are reviewed here. The German Navy no longer had any constraints on attacking American shipping. Since he was given such short notice of the imminent declaration of war, Admiral Karl Doenitz, head of Germany's submarine fleet, could only muster five submarines for this first foray into US waters. Operation *Paukenschlag* (Roll of the Drums) effectively began on 12 January 1942 with the sinking of the steamer *Cyclops* by *U-123*, 300 miles off Cape Cod.[127] The primary targets of *Paukenschlag* were to be Allied tankers. As Doenitz summed it up, "Can anyone tell me what good tanks and trucks and airplanes are if the enemy doesn't have the fuel for them?"

Doenitz' *Grey Wolves* fell on Allied shipping as if it was an unprotected flock of sheep. The Germans were aided by the fact the Americans were not at all prepared for what was about to occur. This lack of preparedness aided the Germans, and many mistakes were made. There was no blackout on the east coast, maritime navigational aids were still operating, and ships lacked communications security discipline.[128] From 13 to 23 January 1942, *Paukenschlag* subs sank 25 ships.[129] Seventy percent of the *Paukenschlag* losses were tankers, at an average of 130,000 barrels. If this attrition rate were kept up, the Allies would lose half their tanker fleet in 1 year.[130] The Germans came through *Paukenschlag* without any losses; in fact, not even one German submarine was ever attacked. The American antisubmarine warfare response was pitiful. There existed no plans to deal with the possibility of a submarine assault and no forces to implement them had they existed.[131] This is ironic because the Atlantic Fleet received 18 destroyers in a transfer from the Pacific Fleet in May 1941.[132]

German submarines eventually sank 391 ships in the western Atlantic, 141 of which were tankers. One quarter of the US tanker fleet was sunk in 1942. Even though US shipyards were beginning to produce new merchant ships in record numbers, there was still a drop in overall available merchant and tanker tonnage. This came at a time when every ship was needed to help support offensives around the globe in a two-ocean war.[133]

Unswerving Devotion to the Decisive Battle Strategy

"The massacre enjoyed by the U-boats along our Atlantic coast in 1942 was as much a national disaster as if saboteurs had destroyed half a dozen of our biggest war plants," wrote Samuel Elliott Morison. Petroleum shipped from the gulf coast to east coast ports dropped fourfold from January 1942 until it began to climb in mid-1943. Tanker tonnage was woefully short.[134]

The Germans, to their credit, realized the importance oil played in the Allies' war plan. As early as 3 January 1942, the Germans were urging the Japanese to concentrate their submarine efforts on a *guerre de course* strategy of commerce warfare. If the two Axis partners could concentrate their submarine efforts on Allied logistics, it would severely limit the Allies' ability to launch any type of offensive.[135] The German naval attache to Japan, Vice Admiral Paul H. Wenneker, repeatedly would urge such a change in strategy. The Japanese would listen courteously, but they were not willing to change their strategy of focusing on warships. Wenneker stated later:

> The Japanese argued that merchant shipping could be easily replaced with the great American production capacity but that naval vessels represented the real power against which they fought and that these vessels and their trained crews were most difficult to replace and hence were the logical targets. If, therefore, they were to hazard their subs, it must be against the Navy.[136]

The Japanese remained slavishly addicted to their decisive battle doctrine. Despite the success of German U-boats off the east coast of the United States (and even their success in World War I), the Japanese would not change their strategy of using subs to support fleet operations.[137]

Unfortunately for the Germans and the Japanese, the Axis alliance was a political arrangement based on self-opportunistic motives. Neither the German nor the Japanese Navy considered mutual cooperation in war planning a matter of much importance when Germany and Japan entered into their alliance with each other.[138]

The Japanese should have concentrated all their submarines off the US west coast oil ports and off Hawaii. While in these patrol areas, the subs should have systematically hunted down and destroyed US tankers and Navy oilers. The Japanese Navy also should have run a shuttle-type operation where some subs could be

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The fuel state in the first half of 1942 was straining the logistics support system to the breaking point.

operating in these patrol areas at all times.[139] Had the Japanese followed such a strategy, there would have been much less chance that the Navy would have been able to launch any type of offensive in the Pacific in 1942.

Oil and South Pacific Ops

> During the first year of war in the Pacific, the United States Navy was forced to fight a war that it was unprepared for. It had neither enough ships, storage facilities … nor petroleum. But with a lot of hard work, hasty improvisation, sound leadership, and some honest good luck, it managed (with great difficulty at times) to supply its fighting forces with enough fuel for combat operations. Although the supply system was strained to the breaking point, it never collapsed.[140]

The fuel state in the first half of 1942 was straining the logistics support system to the breaking point. As previously mentioned, shortly after Pearl Harbor, the Pacific Fleet had, for all purposes, expended almost all the fuel stored aboard its oilers. With the Pacific Fleet's oilers supplying fuel to ships in the Hawaiian area, it meant new supplies were not being brought in from the mainland. Fuel and tankers became so scarce in the spring of 1942 that oil was scavenged from the unsalvageable battleships still resting on the bottom of Battleship Row.[141]

The fuel and tanker shortage became an operational factor almost immediately in the Pacific. The *Neches* was part of Task Force 14 sent to relieve Wake Island in December 1941. *Neches*' slow speed (task forces could proceed only as fast as the accompanying oiler), along with some bad weather, meant the Wake Island relief force was not in position to attack Japanese forces prior to the island's being overrun.[142] A later, planned airstrike by the *Lexington* task force against Wake in January 1942 had to be canceled when the Japanese submarine *I-72* sank that same oiler, *Neches*.[143] Pacific Fleet raids on Japanese-occupied islands in January and February 1942 would have been impossible without support from Navy oilers. In a precursor of events, one carrier raiding force that had *sortied* against Rabaul was forced to retire after the Japanese had discovered it, and much fuel was used up during high-speed maneuvering while fending off Japanese air attacks. The Doolittle raid on Tokyo, which was to have immense strategic implications for the Pacific war, also would not have been possible without tanker support.[144]

The absence of tankers also was becoming a real concern for operations in the South Pacific in early 1942. Although it was merely a question of time before larger IJN forces overwhelmed US and Allied naval vessels during this period of the Southern Operation, the situation was aggravated by the loss of all available ABCD oil sources in that region by mid-February 1942. The loss of the fleet oiler USS *Pecos* to Japanese action exacerbated the situation further.[145]

The lack of fleet oilers also was a secondary factor from the Pacific Fleet's turning from a battleship-centric navy to one formed around aircraft carrier task forces. Even after Pearl Harbor, the Navy still had a sizable battleship force. Seven battleships were available at west coast ports in late March 1942. However, since the Navy tanker shortage was so acute, there were none available for duty with this force.[146] This force *sortied* on 14 April 1942 to help stem the Japanese advance in the South Pacific. The battleships were loaded down with so much fuel, food, and ammunition that armored belts and decks were below the waterline. If these ships had sailed into harm's way, they would not have lasted long. Fortunately, the Coral Sea action was decided before they could participate, and the force was ordered back to the west coast.[147]

The oilers that could not be spared for the battleships were supporting carrier forces engaged in the Coral Sea. Again, fleet oilers were indispensable to operations. Coral Sea fueling operations were aided by the oilers *Tippecanoe* and *Neosho* (Figure 3).

The fleet oiler *Neosho* supported Task Force 17, led by Rear Admiral J. Jack Fletcher aboard the carrier *Yorktown*. This was the same *Neosho* that was so pointedly ignored by the Japanese during the Pearl Harbor raid. Although sunk by Japanese aircraft on 7 May 1942, the *Neosho* had already played its critical role in dispensing fuel oil to Task Force 14. Had Fletcher needed more fuel, the situation might have gotten a little sticky.[149] Ironically, the Japanese ran into their first fuel problem. A lack of tanker support for their task force, as well as a lack of fuel for its aircraft, caused the Japanese Navy to halt its task force short of its goal, Port Moresby.[150]

Following the miraculous success at Midway, the Pacific Fleet was finally able to go on the offensive in August 1942 with Operation Watchtower, the invasion of Guadalcanal in the Solomon Islands. Inadequate fuel logistics were still a major concern.[151] Fuel and support depots had been set up in Tonga and New Caledonia to support the operation, but they were 1,300 and 500 miles away, respectively, from the action on Guadalcanal.[152]

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Preliminary plans to supply oil for this operation were made based on the past experience of normal operations. The officer in charge of the operation, Admiral Robert L. Ghormely, tried to factor in problems that might arise, such as unforeseen losses or changes in operations. However, his logistics staff was small and had no experience. So a supply of fuel thought to be a comfortable margin for the Guadalcanal operation turned out to be an inadequate amount.[153]

With such a tenuous logistics situation, Operation Watchtower became known derisively as Operation *Shoestring* by the Marines who were surviving on captured enemy rations. Inadequate fuel supplies meant the aircraft carriers covering the Marine landing forces could not stay in place and, after 2 days, withdrew 500 miles to the south to refuel. Operations were touch-and-go on Guadalcanal for the next month. The US position could have been put in jeopardy by a concerted attack on fuel supplies, but this never occurred.[154] In September, Ghormely finally started to get a handle on his logistics requirements, with detailed fuel requests being forwarded up the chain. His actions alleviated much of the fuel problem for the rest of the South Pacific Operation.[155]

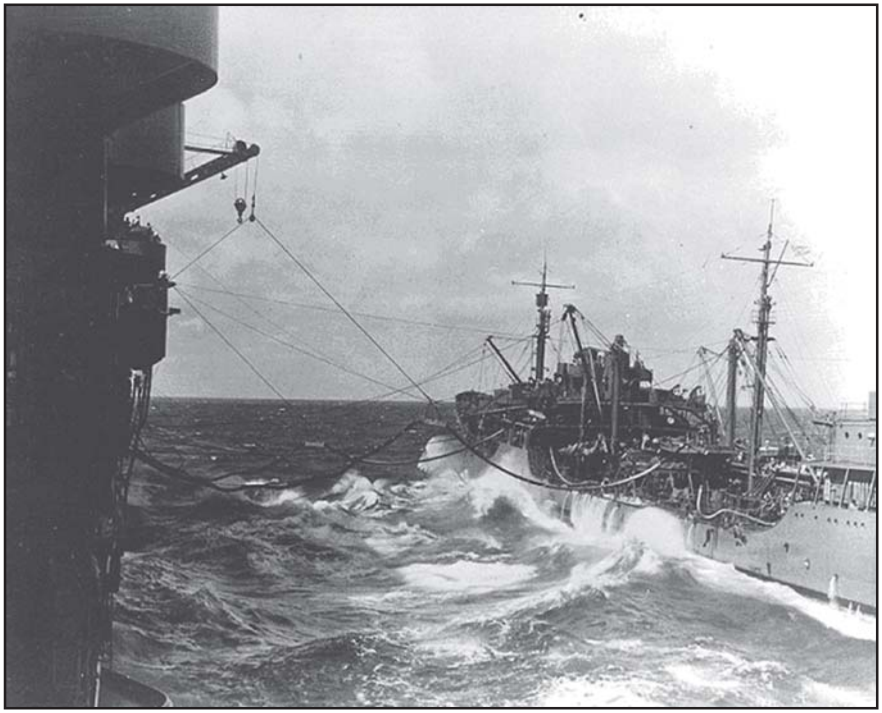

Figure 3. *Neosho* Refueling the *Yorktown*, Probably on 1 May 1942. *Neosho* and its escort, the destroyer *Sims*, were sunk by Japanese aircraft on 7 May 1942 after being misidentified as an aircraft carrier and a cruiser. However, by then, the *Neosho* had dispensed enough fuel to Task Force 17 for it to complete its mission of stopping the Port Moresby invasion force. Note the use of the *Yorktown* aircraft crane to support the refueling hose.[148]

With the increase of fuel supplies and the inability of the Japanese to dislodge the Marine defenders on Guadalcanal, the tide had truly begun to turn in the Pacific. From this point on, the Pacific Fleet's fuel situation grew stronger, while the Japanese position grew weaker. The Japanese had lost their opportunity to strike at the key vulnerability of the United States in the Pacific—fuel logistics.

Conclusions

God was on the side of the nation that had the oil.

—Professor Wakimura
Tokyo Imperial University in Postwar Interrogation[156]

The IJN's devotion to an outdated operational strategy, rather than focusing on what effects needed to ensure their national strategy was met, proved to be their downfall.

The Japanese knew that if they did not find a secure and stable source of oil they eventually would have had to comply with US prewar demands. Once it was realized that diplomatic measures would be ineffective, the Japanese plan was to seize and secure as much oil and other resources as possible. The raid at Pearl Harbor was but a branch to achieve that overall goal.

As effective as Japanese intelligence and initial military actions were, they never were focused on the destruction of the key target that might have let them achieve their goal of keeping the Navy out of the Pacific. The Japanese strategic disregard of the fragile US oil infrastructure in the Pacific was an incredible oversight on their part. The Japanese should have attacked the US oil supply at Pearl Harbor and followed up that raid with attacks on US oilers and tankers in the Pacific. Japanese attacks, in conjunction with German strikes, on the oil supply and infrastructure would have bought the Japanese much valuable time—time that could have been used consolidating gains in its newly won territories, time that might have allowed Japan to build up such a defensive perimeter that the cost of an Allied victory might have been too high.

The Japanese were not the first to ignore the importance and vulnerability of logistics. As long ago as 1187, history shows that logistics played a key part in the Muslim's victory over the Crusaders at the Battle of Hittin. The Muslim commander Saladin captured the only water source on the battlefield and denied its use to the Crusaders. The loss of water severely demoralized and debilitated the Crusaders, contributing to their defeat and eventual expulsion from the Holy Land.[157]

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The vulnerability and importance of logistics remains evident today. The terrorist bombing of the destroyer *USS Cole* occurred while it was in port, fueling, at Aden, Yemen, on 12 October 2000. Had it not required fueling, the *USS Cole* would not have put in at Aden, 17 sailors would not have been killed, and the Navy would no temporarily have lost a valuable maritime asset.[158] There is an old saying, "Amateurs talk strategy, and professionals talk logistics." Commanders and their staffs must remember the importance of logistics to achieving the overall goal, for friendly forces as well as the enemy.

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16. Goralski, 101.
17. Feis, 268.
18. Nobutaka Ike, *The International Political Roots of Pearl Harbor: The United States-Japanese Dyad, Translations of the Records of the Liaison Conferences 19 through 75;* and *Four Imperial Conferences*, report to Dr Thomas W. Milburn, Behavioral Sciences Group, China Lake, California: United States Naval Ordnance Test Station, 30 Mar 64-15 Jun 65, 16-17.
19. *Japanese Monograph N, 147*, 46-48.
20. Iriye, 128.
21. *Papers Relating to the Foreign Relations of the United States*, *Japan: 1931-1941,* Vol II, 137-143. In this correspondence, the Counselor of the US Embassy in Tokyo related to the Japanese Vice Minister for Foreign Affairs that any nation that was to prejudice British lines of communication could expect to come into conflict with the United States. When asked by the Japanese minister that if the Japanese attacked Singapore there would be war with the United States, the counselor replied that the situation would "inevitably raise that question." The US Ambassador, Joseph Grew, later confirmed this position to the Japanese Prime Minister.
22. Congress of the United States, Hearings before the Joint Committee on the Investigation of the Pearl Harbor Attack, Part 6, Washington: US Government Printing Office, 1946, 2866.
23. *Papers Relating to the Foreign Relations of the United States, Japan: 1931-1941,* Vol II, 556-557. It is interesting to note that, although these were rather explicit warnings sent by Roosevelt to the Japanese, Roosevelt himself questioned whether the United States had the political will to back them up. When asked by the Chief of Naval Operations, Adm H. R. Stark, what the US response would be in the event of an attack on British possessions in the Far East, Roosevelt responded, "Don't ask me these questions." See *Investigation of the Pearl Harbor Attack, Part 5,* 2231-2232.
24. Feis, 190.
25. Kent Roberts Greenfield, ed, *Command Decisions*, 106; also see Larrabee, 91.
26. Military History Section, Headquarters, Army Forces Far East, Japanese Monograph No 150, *Political Strategy Prior to Outbreak of War Part IV*, Washington: Office of the Chief of Military History, Department of the Army, 1947, 1.
27. Nobutaka Ike, *The International Political Roots of Pearl Harbor,* Imperial Conference, 6 Sep 41, 33-34.
28. John Buckley, *Air Power in the Age of Total War*, Bloomington, Indiana: Indiana University Press, 1999, 95.

29. Dr David C. Evans, *The Japanese Navy in World War II*, 2[d] ed, Annapolis Maryland: Naval Institute Press, 1986, 8-9.
30. Hiroyuki Agawa, *The Reluctant Admiral*, New York: Kodansha International, 1979, 197-198. The author relates two stories: one that shows how independent operational thought that ran counter to naval general staff policy was frowned upon. He also relates an incident during fleet map maneuvers that showed minor trivialities, such as logistics, could be discounted if overall results were negative to the desired outcome.
31. Gordon W. Prange, *At Dawn We Slept: The Untold Story of Pearl Harbor*, New York: McGraw-Hill, 1986, 10.
32. Prange, *At Dawn We Slept,* 12-14.
33. Prange, *At Dawn We Slept,* 20-28.
34. Shigeru Fukudome, "Hawaii Operation," *US Naval Institute Proceedings*, Dec 55, 1318. It is interesting to note that the two men who were to carry out the tactical part of the plan at Pearl Harbor—Nagumo and his chief of staff, Rear Adm Ryunosuke Kusaka—felt that the Hawaii Operation was too risky, and this apprehension stayed with them throughout the planning and execution of the attack. See also Agawa, 263-264.
35. *Command Decisions*, 109.
36. Fukudome, 1320.
37. Agawa, 235. This letter was written after the Naval General Staff approved the Pearl Harbor attack plan.
38. *Ibid*.
39. Military History Section, Headquarters, Army Forces Far East, Japanese Monograph No 152, *Political Strategy Prior to Outbreak of War, Part V,* Washington: Office of the Chief of Military History, Department of the Army, 1947, 50-51.
40. *Events Leading up to World War II*, 54.
41. Senator David I. Walsh, *The Decline and Renaissance of the Navy 1922-1944*, Washington: US Government Printing Office, 1944, 4-7.
42. Arthur Zich, *The Rising Sun*, Alexandria, Virginia: Time-Life Books, 1977, 87 and 89-97. When the Japanese attacked Guam on 10 Dec 41, the garrison of a little more than 425 men surrendered in less than 1 day. When attempts were made to increase the defenses of Wake and the Philippines in the second half of 1941, it was too little, too late. Wake fell on 23 Dec 41. Although the Philippines took longer to conquer (the Americans didn't formally surrender until 6 May 42), their demise was a forgone conclusion. The United States could not relieve the Philippines because there were no reinforcements available and no way to protect them even if they were.
43. The International Political Roots of Pearl Harbor, Imperial Conference, 5 Nov 41, 22-23.
44. *Japanese Monograph No 150*, 87-88.
45. *Japanese Monograph No 147*, 15.
46. Ronald Spector, *Eagle Against the Sun,* New York: The Free Press, 1985, 83.
47. Fukudome, 1319.
48. *The International Political Roots of Pearl Harbor*, Imperial Conference, 6 Sep 41, 37.
49. *Japanese Monograph No 150*, 20.
50. Goralski, 102.
51. Gordon W. Prange with Donald M. Goldstein, and Katherine V. Dillon, *Pearl Harbor: The Verdict of History,* New York: McGraw-Hill, 1986, 490.
52. *Investigation of the Pearl Harbor Attack*, *Part 6,* 2569.
53. Prange, *Pearl Harbor: The Verdict of History*, 482.

54. Homer N. Wallin, *Pearl Harbor: Why, How, Fleet Salvage and Final Appraisal,* Washington: Naval History Division, 1968, 60.
55. Takeo Yoshikawa and Norman Stanford, "Top Secret Assignment," *US Naval Institute Proceedings,* Dec 60, 27-29 and 33.
56. Goralski, 85.
57. John Costello, *The Pacific War,* New York: Quill, 1982, 84.
58. Homer N. Wallin, "Rejuvenation at Pearl Harbor," *US Naval Institute Proceedings*, Dec 46, 1521-1523. This total includes the floating drydock, YFD-2. It is also important to note that there were many ships of the Pacific Fleet that were not in Pearl Harbor that Sunday. For example, the carriers *Enterprise* and *Lexingto*n were ferrying USMC aircraft to Wake and Midway Islands in anticipation of war starting in the Pacific. Numerous other ships were patrolling in the Pacific or were in ports on the west coast.
59. Prange, *At Dawn We Slept*, 25 and 374. An interesting note of controversy exists over the primacy of battleships versus aircraft carriers as the primary targets of the Pearl Harbor raid. Genda had been pushing for carriers as the primary targets since Feb 41. Testimony made by Capt Mitsuo Fuchida during his interview with the US Strategic Bombing Survey team backs up Genda's statement (see *United States Strategic Bombing Survey* [Pacific], Interrogations of Japanese Officials, No 72, Vol. I, 122. However, those statements do not jibe with "Carrier Striking Task Force Operations Order No 3" sent to the Pearl Harbor attack force on 23 Nov 41 (see Japanese Monograph No 97, *Pearl Harbor Operations: General Outline and Orders and Plans,* 14). In this order, Yamamoto specifies that both battleships and carriers will be attacked but battleships will be the priority targets for the first wave of attacking aircraft. Carriers were the priority of the second wave. Although the Japanese knew there were not any carriers in Pearl Harbor as of 6 Dec, there was a chance that one or more might return that night. "If that happens," said Genda, "I don't care if all eight of the battleships are away." "As an airman," remarked Oishi (Nagumo's senior staff officer), "you naturally place much importance on carriers. Of course, it would be good if we could get three of them, but I think it would be better if we get all eight of the battleships." (See Mitsuo Fuchida, "I Led the Air Attack on Pearl Harbor," *US Naval Institute Proceedings*, Sep 52, 944). Since no carriers did come into Pearl Harbor during the night of 6-7 Dec, the point is moot. However, it does give insight to the prioritization of potential targets in the eyes of the IJN leadership. It also gives pause to wonder what those Japanese airmen would have targeted first if the carriers had been in Pearl Harbor.
60. Fuchida, 945 and 951.
61. Prange, *At Dawn We Slept*, 506 and 538.
62. Prange, *At Dawn We Slept*, 539-540.
63. Prange, *At Dawn We Slept*, 25 and 503-504.
64. Prange, *Pearl Harbor: The Verdict of History*, 537.
65. Spector, 147.
66. Prange, *At Dawn We Slept*, 401.
67. Wallin, "Rejuvenation at Pearl Harbor," 1521. In addition, the target battleship *Utah* was not raised because of her age and the time and effort salvage would entail. Although she tends to be overshadowed by the memorial of her sister ship *Arizona* and the USS *Missouri* floating museum, a small monument to the *Utah* and the 58 men still entombed can be found on the west-northwest shore of Ford Island behind a family housing area. See also E. B. Potter, ed, *Sea Power—A Naval History*, Englewood Cliffs, New Jersey: Prentice-Hall, 1960, 651, for information on the *Arizona* and *Oklahoma*. Also, because of the shallow depth of the harbor, the Japanese had worked feverishly to develop a torpedo that would not dive to 60 feet before leveling out. By the addition of wooden stabilizers, they only were able to solve this problem in Oct 41 (see Prange, *At Dawn We Slept*, 160 and 321).

68. Prange, *At Dawn We Slept*, 374. The Japanese Ambassador to the United States, Nomura, who had no fore knowledge of the Pearl Harbor attack, saw this as a key tactical flaw in the Hawaii Operation (see Prange, *Pearl Harbor: The Verdict of History*, 538).
69. Fuchida, 952.
70. Prange, *At Dawn We Slept*, 542-545.
71. Prange, *At Dawn We Slept*, 545.
72. Evans, 40.
73. Fuchida, 950. See also Wallin, *Pearl Harbor: Why, How, Fleet Salvage and Final Appraisal*, 141.
74. Wallin, "Rejuvenation at Pearl Harbor," 1524.
75. In defense of Nagumo, machine and repair tools were notoriously hard to destroy. Industrial plants targeted by the US Army Air Forces in Europe would be destroyed, but the machine tools inside the buildings showed more durability. See the *United States Strategic Bombing Survey*, Maxwell AFB, Alabama: Air University Press, 1987, 15, 17-18.
76. Wallin, *Pearl Harbor: Why, How, Fleet Salvage and Final Appraisal,* 175. The salvage and repair operations at Pearl Harbor were nothing short of Herculean. A short summary will show the reader how quickly some temporary repairs were made. The *Pennsylvania* sailed to the west coast 2 weeks after the attack. The *Maryland* and *Tennessee* were ready for combat the same day. The destroyer *Shaw*, whose bow was blown off in a spectacular explosion, left for California under her own steam on 9 Feb 42. The *Nevada,* which Nimitz doubted would ever sail again, was in drydock by mid-February and en route to the west coast by mid-April (see Prange, *Pearl Harbor: The Verdict of History*, 538-539).
77. Naval Historical Center, Department of the Navy, Various photographs, 40-41. [Online] Available: http://www.history.navy.mil/photos/images, Feb 01. Drydock photos [Online] Available: http://www.history.navy.mil/photos/images/g380000/g387598c.htm.
78. Robert Cressman, *That Gallant Ship USS Yorktown* CV-5, Missoula, Montana: Pictorial Histories Publishing Co, 1985, 115, 117, and 118. To be filed under the heading of ironic justice, all four carriers had participated in the Pearl Harbor attack; see Gordon W. Prange's *Miracle at Midway*, New York: McGraw-Hill, 1982, for an excellent review of that conflict.
79. *Investigation of the Pearl Harbor Attack, Part 6*, 2570. The upper tank farm was clearly visible next to the southeast loch of Pearl Harbor as Figure 2 shows. The lower tank farm was next to the Hickam Field water tower, an approximate 150-foot high obelisk, that was visible from up to 5 miles away (see *Investigation of the Pearl Harbor Attack*, *Part 38,* Item 117).
80. *Investigation of the Pearl Harbor Attack*, *Part 6,* 2812.
81. Wallin, "Rejuvenation at Pearl Harbor," 1524. The Navy realized the vulnerability of the oil supply and was in the process of building some underground storage tanks; however, these would not be completed until late 1942 (Gunter Bischof and Robert L. Dupont, ed, *The Pacific War Revisited*, Baton Rouge, Louisiana: Louisiana State University Press, 1997). There was to be a total of 15 underground tanks (100 feet wide by 285 feet high) with a storage capacity of approximately 4.5 million barrels, the same amount as the above-ground tanks. See I*nvestigation of the Pearl Harbor Attack, Part 23*, 966. Also see William M. Powers, "Pearl Harbor Today," *US Naval Institute Proceedings*, Dec 81, 52.
82. Prange, *Miracle at Midway*, 4.
83. Prange, *Pearl Harbor: The Verdict of History*, 485.
84. *Investigation of the Pearl Harbor Attack*, *Part 6,* 2506.
85. Goralski, 154. It should be noted that there are several discrepancies in the total amount of fuel in storage and total capacity available at Pearl Harbor on 7 Dec 41. Kimmel testified that there were 4 million gallons in storage (see *Investigation of the Pearl Harbor Attack, Part 6,* 2812). Adm Claude C. Bloch, commander of the 14th Naval District at the time of the attack, testified to the Hart Commission that there were approximately 4 million barrels in storage that morning (*Investigation of the Pearl Harbor Attack, Part 26*, 101). Goralski states that

there were 4.5 million barrels stored. Since the purpose of the inquiries following the Pearl Harbor attack were to find out why the US Armed Forces on Hawaii were caught unawares and Goralski's work is more focused on the role of oil in war, his numbers will be used.

86. *Investigation of the Pearl Harbor Attack*, *Part 6,* 2570.
87. Photos [Online] Available: http://www.history.navy.mil/photos/images/g100000/g182880c.htm. The earthen berms located between the tanks were used to contain potential oil spills.
88. Prange, P*earl Harbor: The Verdict of History*, 509-510. The quote at the end is from Nimitz.
89. Duncan S. Ballantine, *US Naval Logistics in the Second World War*, Newport, Rhode Island, Naval War College Press, 1998, 39. Japanese aircraft destroyed the Cavite naval base on 10 Dec 41 (see *Dictionary of American Naval Fighting Ships,* Vol VII, Washington: Naval Historical Center, Department of the Navy, 1981, 282).
90. Bischof and Dupont, 61-62.
91. Bischof and Dupont, 43. By Mar 42, at least one navy tanker was sent to Abadan, Iran, to get oil to support operations in the South Pacific (see D*ictionary of American Naval Fighting Ships*, Vol VII, 282).
92. Prange, *Pearl Harbor: The Verdict of History*, 510.
93. Wallin, *Pearl Harbor: Why, How, Fleet Salvage and Final Appraisal,* 103-104. Also see Commanding Officer *USS Neosho*, "Report on Raid on Pearl Harbor, T. H., 7 Dec 41 [Online] Available: http://www.ibiblio.org/hyperwar/USN/ships/logs/AO/ao23-Pearl.html, 5 Mar 01.
94. Bischof and Dupont, 57. The Navy classified its oil tankers as fleet oilers. For the purposes of this article, Navy oilers is synonymous with tanker or oil tanker.
95. Ballantine, 4.
96. *Investigation of the Pearl Harbor Attack*, *Part 6*, 2504. Also see *Investigation of the Pearl Harbor Attack, Part 12*, 345-346. In addition, there were two other oilers in the Cavite Navy Yard the morning of the Pearl Harbor attack; they were attached to US Asiatic Fleet (see *Dictionary of American Naval Fighting Ships,* Vol VII, 282).
97. Prange, *Pearl Harbor: The Verdict of History*, 547.
98. *Investigation of the Pearl Harbor Attack*, *Part 6,* 2504, 2569, and 2732.
99. *Investigation of the Pearl Harbor Attack*, *Part 32,* 593.
100. *Investigation of the Pearl Harbor Attack*, *Part 6,* 2570. The Japanese knew the oilers were in Pearl Harbor; the Japanese consulate kept them informed on all ship arrivals and departures (see Fuchida, 943). The Japanese attack force made a conscious decision to not attack the *Neosho*. She was berthed at the F-4 fueling dock at Ford Island. In their planning, the Japanese had a torpedo bomber of the initial strike force tasked against the ship in this berth (torpedo track 3); the *Neosho* was not torpedoed. Later, when the *Neosho* was backing up the East Loch of the harbor, she was purposefully not attacked by a Japanese bomber who held its fire in order to strike the battleship *Nevada*. Strangely, the oiler at the F-4 berth was marked as sunk in Fuchida's post battle report (see Prange, *At Dawn We Slept*, 385, 512, 518, and 536). The Japanese were also aware that there were two oilers at Cavite; they even knew their names (see *Investigation of the Pearl Harbor Attack, Part 12,* 302-303). It is also a fair assumption that the Japanese knew the locations of the other oilers that were in port on the west coast on 7 Dec 41.
101. B. Orchard Lisle, "The Case for Aircraft-Carrying Oil Tankers," *US Naval Institute Proceedings*, Nov 42, 1555. There is debate on where Lexington departed from on the west coast, but there was a delay in her departure. Given the desire among naval officers to have as much fuel in their bunkers as possible, with time available to the *Lexington* prior to her departure from the west coast, it is assumed she topped off her fuel bunkers.
102. Susan Butler, *East to the Dawn*, Reading, Massachusetts: Addison-Wesley, 1997, 414. Also see Elgen M. Long and Marie K. Long, *Amelia Earhart,* New York: Simon & Schuster, 1999, 220. Ironically, the *USS Ramapo* was the other oiler at Pearl Harbor the morning of 7 Dec 41 (see *Investigation of the Pearl Harbor Attack*, *Part 12,* 348-349); also see

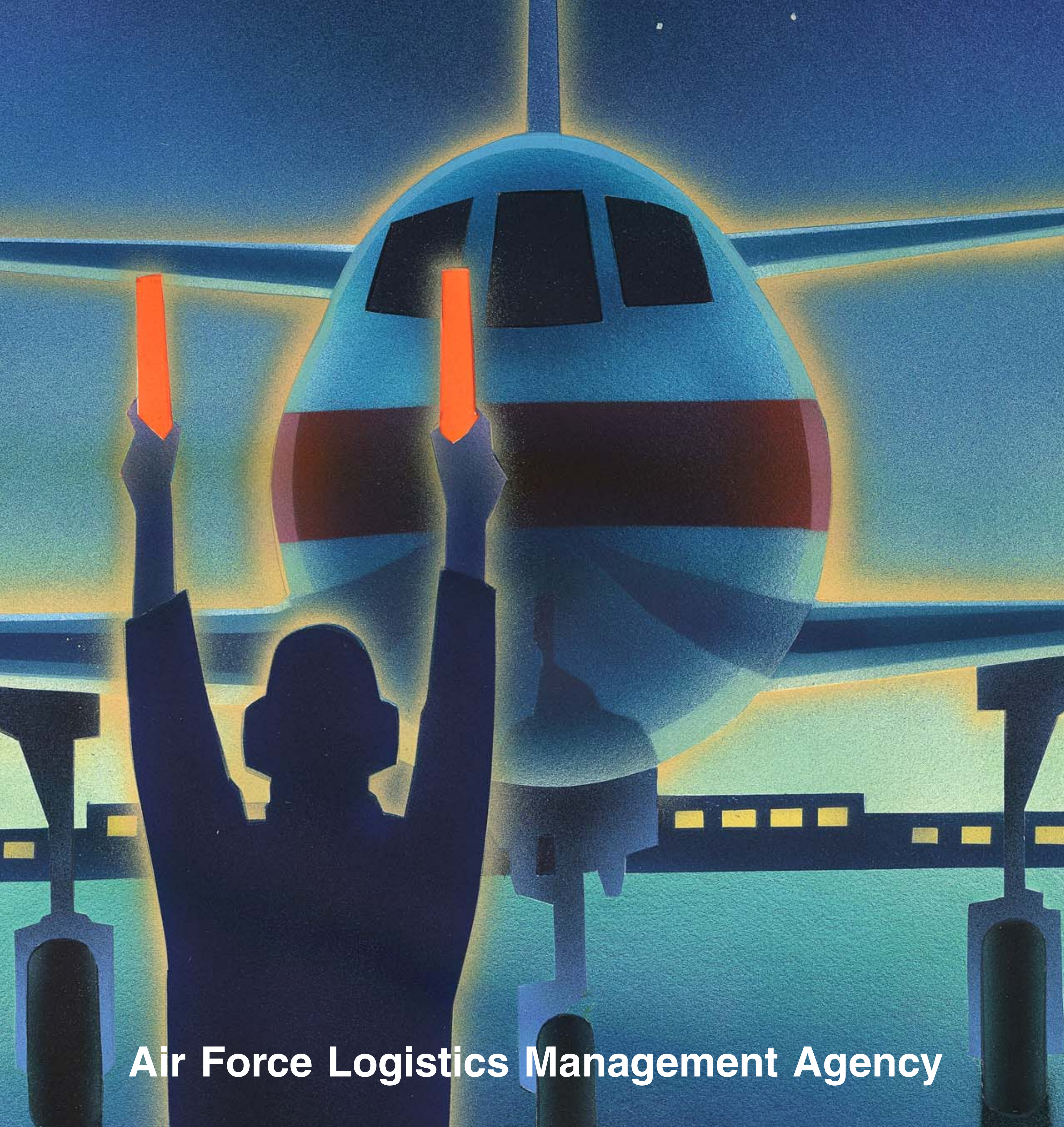
Commanding Officer USS Ramapo. "Report on Raid on Pearl Harbor," 7 Dec 41 [Online] Available: http://www.ibiblio.org/hyperwar/USN/ships/logs/AO/ao12-Pearl.html, 5 Mar 01.

103. Ballantine, 40.
104. Roger Chesnau, *Aircraft Carriers of the World, 1914 to the Present*, Annapolis, Maryland: Naval Institute Press, 1984, 201, 205, and 206.
105. Ian Sturton, ed, *Conway's All the World's Battleships 1906 to the Present,* Annapolis, Maryland: Naval Institute Press, 1987, 160, 164, 168, 172, and 176.
106. James C. Fahey, *The Ships and Aircraft of the US Fleet*, New York: Ships and Aircraft, 1945, 15, 18, 23-25.
107. "The Zig-Zag Course as a Defence Against Submarines," *US Naval Institute Proceedings*, Professional Notes, Aug 17, 1836. Although a dated article, this technique, which was a proven defense at the end of World War I, could be expected to be used at the start of World War II.
108. Bischof, 70.
109. *Investigation of the Pearl Harbor Attack*, *Part 6,* 2504.
110. *Strategic Bombing Survey*, 108.
111. Norman Polmar and Dorr Carpenter, *Submarines of the Imperial Japanese Navy,* Annapolis, Maryland: Naval Institute Press, 1986, 1.
112. Polmar and Carpenter, 12-13. Also see Potter, 796.
113. Polmar and Carpenter, 13-14. The midget submarines were to attack US warships in Pearl Harbor in conjunction with the air raid. Following the attack, none of the five midget submarines ever made it back to the mother ship.
114. Military History Section, Headquarters, Army Forces Far East, Japanese *Monograph No 108, Submarine Operations in the First Phase Operations, December 1941 to April 1942,* Washington: Office of the Chief of Military History, Department of the Army, 1947, 1.
115. Japanese Monograph N. 150, *Political Strategy Prior to Outbreak of War, Part IV*, 47.
116. Polmar, 11. The prewar strategy of the primary role of fleet attack remained unchanged until Apr 42. After this point, submarines switched to commercial shipping; however, most of these attacks seemed to concentrate in the Indian Ocean area, which had minimal effect on Pacific Fleet operations.
117. Donald J. Young, "For a week in December 1941, Japanese submarines prowled the Pacific coastline, searching for merchant ships to sink," *World War II*, Jul 98.
118. William Scheck, "Japanese submarine commander Kozo Nishino gained personal satisfaction from shelling the California coast." *World War II*, Jul 98, 18. Among other items, the article mentions the difficulty of keeping the submarine deck gun trained on targets while the submarine was constantly moving. Also the Japanese torpedo, a 24-inch, oxygen-driven weapon, had characteristics that more than doubled the nearest US model (see Prange, *At Dawn We Slept*, 394).
119. Young, "For a week in December 1941, Japanese submarines prowled the Pacific coastline, searching for merchant ships to sink," 27-29. It should be noted that the *I-17* attempted to shell the *Emidio* first, and the tanker was able to send out a distress call. Responding aircraft were able to drop depth charges on the sub—twice. Although the sub suffered no damage, the surface attack shows the increased risk the Japanese took.
120. Young, 29-32.
121. Carl Boyd and Akihiko Yoshida, *The Japanese Submarine Force and World War II,* Annapolis, Maryland: Naval Institute Press, 1995, 68-69.
122. William H. Langenberg, "A floatplane launched from an Imperial Japanese Navy submarine dropped its bombs in September 1942—the first time the continental United States was bombed from the air." [Online] Available: http://www.theistorynetcom/AviationHistory/articles/1998/11982_text.htm, 7 Mar 01.
123. Scheck, "Japanese submarine commander Kozo Nishino gained personal satisfaction from shelling California coast," 16-18. The sub commander Kozo Nishino had visited the refinery

during the prewar period as the commander of a Japanese tanker. In a welcoming ceremony, he slipped on some oil and ended up in a cactus patch, much to the amusement of local refinery workers. Nishino, insulted by the laughter, saw his chance to get revenge in Feb 42. He peppered away at the refinery for 45 minutes with his 5.5-inch gun. He did not cause any significant damage, but apparently, it was enough to settle a personal score.

124. Juergen Rohwer, *Axis Submarine Successes 1939-1945,* Annapolis, Maryland: Naval Institute Press, 1983, 278-281.
125. Potter, 799.
126. *Events Leading up to World War II*, 310.
127. Ladilas Farago, *The Tenth Fleet,* New York: Ivan Oblensky Inc, 1962, 46-47, 55.
128. Goralski, 103-104.
129. Farago, 58. Estimates range from 25 to 44 ships sunk, depending on the source. It should also be note that the Germans sank 74 ships within 300 miles of the American coast in Mar 42 alone; again, a high proportion of these were tankers. Losses were so bad that if the rate continued there would not be enough fuel to carry on the war (see also Goralski, 106-112).
130. Goralski, 106.
131. Farago, 58
132. *Investigation of the Pearl Harbor Attack*, *Part 6,* 2505. The destroyers (along with other ships transferred) were to be used in neutrality patrols to keep German naval forces out of the western Atlantic.
133. Goralski, 116.
134. Goralski, 109-111. The tanker shortage became so acute that some Liberty-type dry cargo ships were converted into tankers with most being delivered in 1943 (see L. A. Sawyer and W. H. Mitchell, *The Liberty Ships,* Cambridge, Maryland: Cornell Maritime Press, 1970, 161.
135. *International Military Tribunal for the Far East,* Vol 256, Tokyo, Japan, 1 Dec 47, 34257.
136. Goralski, 186-188.
137. Potter, 796.
138. John W. Masland, "Japanese-German Naval Collaboration in World War II," *US Naval Institute Proceedings*, Feb 49, 179 and 182.
139. Boyd and Yoshida, 189-190.
140. Bischof and Dupont, 78.
141. Wallin, "Rejuvenation at Pearl Harbor," 1545. About 1 million gallons of oil were recovered from the Oklahoma alone.
142. Bischof and Dupont, 66.
143. Bischof and Dupont, 77.
144. Worrall R Carter, *Beans, Bullets, and Black Oil,* Newport, Rhode Island: Naval War College Press, 1998, 17-20. The raid was a boost for American morale after a steady diet of defeat. It also confirmed to Yamamoto the need for the upcoming Midway operation, where the defeat of the Japanese Navy later proved to be the turning point in the Pacific war (see Prange, *Miracle at Midway*, 24-27).
145. Carter, 15-16. The *Pecos* was attempting to join her sister ship *Trinity* in the Persian Gulf when she was sunk. The oil situation became so critical that the Australian cruiser *Hobart* could not participate in the Java Sea battle on 27 Feb 42 because of a lack of fuel. Another factor in fueling operations was the excruciating pace of refueling operations. The 1938 standard tanker could pump only 200 tons of fuel per hour. The newer T-2 tankers could pump approximately 700 tons an hour. At the end of 1941, the Navy only possessed six of these T-2 types (Cimarron class) with four in the Pacific Fleet (see Lane C. Kendall, "Tanker Operation and Management," *US Naval Institute Proceedings*, Apr 57, 425. Also see Fahey, 48.
146. Spector, 158 and 168.
147. Carter, 11.
148. Photos [Online] Available: http://www.history.navy.mil/photos/images/g460000/g464653c.htm. Also see Carter, 20-21, and see Zich, 69.

149. Carter, 21.
150. Goralski, 156. This was the first time the Japanese were to run into a fuel supply problem. It was an awful portent of the IJN's future operations.
151. George C. Dyer, The Amphibians Came to Conquer: The Story of Admiral Richmond Kelly Turner, Washington: US Government Printing Office, 1972, 311-312.
152. Carter, 21, 23-24.
153. Carter, 24-25.
154. Goralski, 157. Japanese bombing and naval gunfire came close to putting the US airstrip Henderson Field out of action when critical fuel supplies were destroyed. Another time, the arrival of four tankers was said to have turned the battle, "If they hadn't arrived when they did, we wouldn't have Guadalcanal" said Ghormely.
155. Carter, 28, 30, and 32.
156. Goralski, 304.
157. Gerard Chaliand, ed, *The Art of War in World History,* Los Angeles, California: University of California Press, 1994, 400-404.
158. Speaker remarks and press coverage. Lecture to AY 01 students and faculty, Air Command and Staff College, Maxwell AFB, Alabama, 15 Mar 01.


Air Force Logistics Management Agency