SCHOOL OF ADVANCED AIRPOWER STUDIES

THE AIRSHIP'S POTENTIAL FOR INTERTHEATER AND INTRATHEATER AIRLIFT

By

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THE AIRSHIP'S POTENTIAL

FOR

INTERTHEATER AND INTRATHEATER

AIRLIFT

LIEUTENANT COLONEL DONALD E. RYAN, JR

SAN ANTONIO, TEXAS

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ABSTRACT

This paper asserts there exists a dangerous GAP in US strategic intertheater transportation capabilities, propounds a model describing the GAP, and proposes a solution to the problem.

Logistics requirements fall into three broad, overlapping categories: Immediate, Mid-Term, and Sustainment requirements. These categories commence and terminate at different times depending on the theater of operations, with Immediate being the most time sensitive and Sustainment the least. They are:

1. Immediate: War materiel needed as soon as combat forces are inserted into a theater of operations in order to enable them to attain a credible defensive posture.

2. Mid-Term: War materiel, which strengthens in-place forces and permits expansion to higher force levels.

3. Sustainment: War materiel needed to maintain combat operations at the desired tempo. US strategic transport systems divide into two categories: airlift and sealift. Airlift is ideally suited for immediate requirements and sealift for Sustainment, but an intermediate strategic transport system suited for Mid-Term requirements is presently unavailable. This shortcoming forces USTRANSCOM to either use airlift for Mid-Term needs or defer them to the Sustainment phase. This tension causes airlift to be unnecessarily expended to move Mid-Term requirements to crisis theaters, accelerating airlift service life exhaustion and jeopardizing US interests by rendering them vulnerable to hostile actions in other theaters.

Using the Gulf War logistics flow as a model, the three phase points are shown and their airlift/sealift tradeoffs discussed. Other logistics support options, which figured in the war, such as prepositioning and host nation support, are discussed and the Kuwaiti Theater of Operations shown to be, in many ways, a fortuitous theater of operations. This serendipitous combination of circumstances contributed greatly to our successful logistics buildup and is unlikely to recur.

The airship is recommended as a suitable solution to the Mid-Term strategic transportation di lemma (GAP). The fundamentals of airship operation[11] are described, its history in both war and peace discussed, and some current private and military airship activities mentioned. Recent technological breakthroughs in materials technology are discussed and the potential for government-sponsored research and development yielding equally great propulsion and cargo capacity dividends explored. A discussion of the potential threat environment of the early twenty-first century shows the airship, properly constructed and used, would likely be no more vulnerable than jet air lifters while offering transportation capabilities currently unavailable.

The airship's advantages as an inter/intratheater transporter are so great as to deserve further investigation for addition to the US strategic airlift fleet. Their use would greatly increase the flexibility, availability, and service life of the strategic jet airlifter fleet and greatly enhance US ability to quickly project sustainable combat force into distant theaters.

BIOGRAPHY

Lieutenant Colonel Donald E. Ryan Jr. (BS, Sul Ross State University; MA, University of Northern Colorado; MS, University of Southern California) is a Communications Officer. A recent graduate of the inaugural class of the School of Advanced Airpower Studies, he was just assigned to Headquarters USAF/SCXI, The Pentagon. Also a graduate of Air Command and Staff College, his previous assignment was Deputy Director, Programs and Acquisitions, Electronic Security Command, Kelly AFB, Texas. Previous assignments in communications operations and maintenance were at Lackland AFB, Texas, Clark AB, Philippines, and Kelly AFB, Texas; he was also on the ATC IG team, Randolph AFB, Texas, served an ASTRA tour at the Pentagon, and commanded a communications squadron.

CHAPTER ONE

LOGISTICS FLOW DURING THE GULF WAR

INTRODUCTION

Like all wars, logistics was key to Desert Storm. Granted, when it was time to expel the Iraqis from Kuwait, men and machines did the fighting; however, victory is not lessened by acknowledging the extensive logistics infrastructure built in the Kuwaiti Theater of Operations (KTO) in the six months prior to actual combat is what made victory possible. The simple truth is modern, high-technology weapons systems and the highly-trained men and women who operate and maintain them have voracious logistics support requirements.

Logistics support and its impact on military operations has been a fact of life in armies since the dawn 0 f time. For instance, in the ancient Middle East, military campaigns were conducted during non-harvest periods to ensure adequate manpower at harvest times. This logistical constraint meant operations proceeded only as long as provisions were available--their exhaustion ended the campaign, since the army promptly melted away. When an invader invested fortified cities he was particularly vulnerable since the enemy, ensconced behind walls [1] with his store house’s and wells, could usually outwait the him.

All military commanders know, sense, or learn (the hard way, usually), that inadequate attention to logistics requirements dooms extensive military operations. One needs look no further than the misfortunes of the eleventh century Crusaders, starving before Antioch's walls or, more recently, Rommel's seesaw North Africa campaigns, for proof. It's said when Hitler decided to invade Russia Napoleon's ghost stood at his side and at the elbow of every general involved in Barbarossa's planning and execution; it may not be far from the truth to say

Rommel's was an uninvited guest at every Coal it ion staff meeting. Regardless, logistics was seen as the necessary steppingstone to Coalition victory from the beginning and our campaign plan was shaped accordingly. Coalition sensitivity to logistics constraints is seen in the official firestorm touched off by Lt Gen Calvin Waller's (deputy commander, CENTCOM) 19 December 1990 statement that "Every unit will not be combat-ready until after 1 February 1991". When one considers offensive ground operations commenced 24 February 1991, it is evident logistics indeed was a major, if not the major, determinant of the ground war start date. Apparently, General Waller's remark detracted from the Coalition deception campaign designed to make the Iraqis believe our forces were better prepared logistically for combat than they actually were. A successful deception would discourage Iraqi ground incursions and complicate their military preparations. With respect to logistics two types of strategic intertheater transportation are available: airlift and sealift. The one chosen is a function of time, distance, lift system carrying capacity (size (or volume) and weight), and urgency of need. Obviously, if war materiel is needed tomorrow, airlift is warranted. This is expensive, but that is what airlift is for. Conversely, if war materiel is not needed for several weeks, then sealift is appropriate.

The kinds of materiel transported, however, appear to fall into three categories, which I will define as Immediate, Mid-Term, and Sustainment. Immediate requirements may be thought of as materiel needed as soon as combat forces are inserted into an endangered theater in order that they be able to defend themselves. Sustainment requirements are materiel needed to maintain combat operations tempo at the desired level. Mid-Term requirements, therefore, fall between these extremes--materiel which strengthens in-place forces and permits expansion to higher force levels. Therefore, Mid-Term requirements may be thought of as any materiel the requestor does not need right away in order to project a credible defense posture, but must have prior to commencing sustained combat operations. Consequently, while airlift can meet Mid-Term needs, sealift will usually take too long. It is difficult to point at something and say "This is and always will be a Mid-Term requirement" since urgency of need is a theater-dependent variable. For example, sunscreen lotion might be an immediate requirement for the KTO, justifying precious airlift to get it there, but not even a Sustainment requirement in a Korean conflict. Consequently, Mid-Term requirements identification is situational and theater-driven. However, once a Mid-Term requirement is identified, what are the transportation options? Again--airlift or sealift

Under my model, then, the dilemma facing logistics planners is moving war materiel which, based on urgency of need, falls into three rough categories, via only two delivery systems whose tonnage capability's are inversely proportional to their speed of delivery.

Airlift can carry practically anything, but is load-limited: a C-5 would make 250 or more round trips to the KTO to carry the equivalent of one Roll-on/Roll-off (ro/ro) fast sealift ship [3]

(FSS). Considering three days was the minimum round trip for a CONUS-based C-5, depending solely on airlift for a massive force buildup obviously will not work. Nor is flying the entire C-5 fleet simultaneously to the KTO a solution: this would have saturated the Saudi airfields, paralyzed operations, and snarled unloading and onward movement. Considering Saudi Arabia has an extensive airport and seaport infrastructure, one sees immediately the nightmare awaiting logisticians in some other potential theaters (Latin America? South America? India/Pakistan?).

Sealift is also unlikely to be a suitable strategic lift system for Mid-Term requirements. The exception would be a theater close enough for sealift to deliver materiel within required timeframes. In this special case, there would be no Mid-Term phase--only Immediate and

Sustainment. Based on the foregoing discussion, there appears to be a "GAP" in the US strategic transportation architecture which, in most scenarios, will force airlift expenditure on war materiel not meeting Immediate criteria simply because there is no other way to move it in time; sealift will not meet the desired Mid-Term timeframe (which will vary depending on scenario). The US needs an intermediate strategic transportation system, which can carry more cargo tonnage and volume than jet airlifters and address this GAP in our transportation architecture. The Gulf War is a springboard for discussing this GAP and suggests a possible

STRATEGIC LIFT PHASING

In his Gallic wars Julius Caesar said, "Gaul comprises three parts..." As previously discussed (and with apologies to Caesar) strategic lift, like Gaul, comprises three phases: Immediate, Mid- Term, and Sustainment. A proper understanding of these phases is crucial if the US is to develop the strategic transportation doctrine needed to project military power into distant theaters to defend vital national interests and redress the current GAP in strategic lift capabilities. Thus far the US has Immediate and Sustainment capabilities (i .e., strategic airlift and sealift) but no true Mid-Term transportation mode. Had there been a more aggressive adversary in the KTO, this GAP could have jeopardized Coalition operations, if not caused their failure.[4]

A logical question is: What constraints did logistics impose on operations and how were they overcome? The answer is simple: the greatest constraint was insufficient strategic transportation (airlift and sealift) to move everything needed where it was needed. Given the expense of strategic transportation systems, it is unlikely the US will ever have sufficient strategic lift to take care of its military "wants"--therefore, it is crucial to be able to meet the military "needs." In a military operation requiring force projection over time into distant theaters, logistics needs fall into three categories: (1) Things needed immediately, (2) Things needed later, and (3) Things needed much later. These categories define the Immediate, Mid-Term, and Sustainment phases.

Immediate Phase. The Immediate phase begins when the US begins a rapid force buildup in a theater and ends when sufficient combat power and combat support is in-theater to credibly threaten a prospective foe's operations. Due to the situation's urgency and the concomitant need to move as much as possible as quickly as possible, this build up will be effected primarily through strategic airlift.

Mid-Term Phase. The Mid-Term phase commences at the immediate phase's conclusion and runs until steady, reliable sealift support is established. Further force buildup may continue, but it will be more structured, with logistics support phased in along with the combat forces. While combat force deployment will still be important, logistics infrastructure establishment will receive much more emphasis than was possible in the Immediate phase. This phase will see the arrival of the first sealift, which, depending on scheduling may close it out. Any prepositioned equipment and supplies are part of this phase. If available, logistical support from the nation hosting our forces (Host Nation Support, or HNS) will be developed.

Sustainment Phase. The last phase, Sustainment, commences when sealift becomes the primary means of logistics support for the deployed force. During Sustainment, strategic airlift cuts back to a less intensive tempo, relying on sealift to deliver up to 95 percent of all materiel. Most personnel entering or leaving the theater will still be airlifted. Barring a sudden escalation of combat operations (such as the 1968 Tet Offensive) the airlift/sealift ratio should remain at this level for the deployment duration.

According to my model, the Gulf War phase transition points occurred as follows:

a. Immediate Phase: days 0-7. This phase began when President Bush, responding to Saudi King Fahd's request, ordered deployment of US ground forces to defend the Kingdom of Saudi Arabia. It began 6 August 1990 with deployment of the 82nd Airborne Ready Brigade and ended with the 14 August debarkation of the I Marine Expeditionary Force (I MEF). [5]

b. Mid-Term Phase: days 7-28. This phase commenced with the arrival of the Maritime Prepositioning Ships (MPS) and Afloat Prepositioning Ships (APS) from Diego Garcia on 15 August. [6]

Additional MPS arrived from Guam seven days later. The first ro/ro vessel arrived 27 August at Dammam. [8] This phase concluded when the MPS/APS unloading was completed on 6 September, by which time the sealift bridge was established.

c. Sustainment Phase: day 28+. By this date, the initial deployment was complete and the noncombat " earlier.[9] This is revealed by the following strength 10 statistics:

> "As of September 16, 1990, over 150,000 personnel from all services were deployed to the Middle East. The Air Force contingent included over 30,000 USAF personnel from many major commands operating from over two dozen airfields in support of more than 400 combat aircraft and over 200 support aircraft."

Various types of logistics support are available in each phase; predictably, transportation/support modes overlap. In the KTO, the force buildup was supported (Immediate phase) by airlift. The Mid-Term phase was characterized by continuing force buildup and sustainment of personnel already in-theater. Part of the force buildup was emplacing the logistics infrastructure to support protracted combat operations of modern high-technology weapons systems. During this phase the US depended on airlift (still), HNS (which continued to mature), prepositioned military supplies and equipment (APS and MPS), and, near the end, some sealift. Since a single FSS carries the equivalent of 250 or more fully-loaded C-5s, [11] one sees why sealift accounted for 95 percent of all tonnage transported to the KTO and, also, why establishing the sealift bridge as soon as possible was so important. The KTO's remoteness dictated lengthy sea voyages ("FAST" sealifters took nearly 2-3 weeks to make the voyage). Since the first sealift vessel (excluding the APS and MPS vessels moved from Diego Garcia) did not arrive until 27 August, airlift remained the primary flexible strategic transporter throughout this phase as well. It was flexible because, unlike APS and MPS, its cargo loads could be tailored to theater requirements--APS and MPS are preloaded, simply awaiting the call.

The prepositioned items were the APS and MPS stationed at Diego Garcia in the Indian Ocean--approximately seven days steaming time from Saudi Arabia. [12]

The APS contained Air Force and Army materiel and equipment, while the MPS were earmarked for Navy requirements, containing sufficient equipment and supplies for a Marine Expeditionary Force (MEF). [13] HNS is always a possibility, its utility depending on factors such as: host nation infrastructure, systems compatibility (Metric system vs English), host nation resources, cultural sensitivities, etc. It is also a function of regional development. A wealthy oil kingdom such as Saudi Arabia could make far more HNS available on short notice than a host nation in a poorer theater of operations (Latin America, for instance). In this regard, the tremendous economic and technological development of the past generation in Saudi Arabia enabled the US to obtain critically needed materiel locally, relieving the need to transport it to the KTO. [14]

The Sustainment phase commenced when the sealift bridge was firmly in place, allowing maritime supply to begin displacing airlift as the primary logistics mover. After 6 September 1990, airlift increasingly shifted to its traditional role of moving short-fused requirements (mission critical small supplies, MEDEVAC operations, tactical airlift, and personnel transport).

The foregoing clearly shows Gulf War logistical support fell very nicely into the Immediate, Mid-Term, and Sustainment phases and meshes well with the model. It is now necessary to discuss the various means by which the required logistical support reached the theater of operations.

TRANSPORTATION/SUPPORT MODES

A variety of logistics support options were available to logistics planners. These transportation/support modes were:

Airlift, Sealift, Host Nation Support, and Prepositioning. Each had advantages and disadvantages.

Airlift. Airlift's primary advantage is responsiveness; strategic airlifters can deliver their cargoes anywhere on the globe virtually (and, often, literally) overnight. No matter how desperate the need, however, if it's too bulky for an airlifter, then the only way it can be airlifted is by disassembly for shipment and reassembly upon arrival. With respect to major hardware items, the C-5 can carry (weight-wise) everything the Army fields. [15] With appropriate preparation, every major Army weapon system system can be carried by the C-5, which, if necessary, can land on short, unimproved airfields in forward operating locations (FOLs). Once it enters the USAF inventory, the C-17 will be like wise capable. Congress permitting, the next generation airlifter, the C-17, will begin production in the mid- 1990s and can operate both as a tactical and a strategic airlifter. When immediate inland power projection is required, the strategic airlifter is indispensable.

However, strategic airlift's I imitations make over reliance on it logistically unwise. The obvious limitations are: fleet size, cargo volume, vulnerability and expense, service I ife, and airfield restrictions.

Fleet Size. The strategic airlifter fleet size is fixed: the US has 111 C-5s (A and B models) and 227 C-141s (A and B models). [16] Of course, in wartime the Civil Reserve Air Fleet (CRAF) is available and it was used in Desert Shield (the first CRAF activation since its 1951 creation). [17] CRAF added 17 passenger and 21 cargo aircraft in STAGE I alone. [18] The subsequent STAGE II CRAF activation on 6 November added another 117 aircraft, bringing total CRAF resources tapped to 155 aircraft--approximately 31 percent of the 500 available under full STAGE III CRAF activation. [19] Without CRAF activation, peacetime and wartime 000 airlift requirements are met by the C-5s and C- 141s, supplemented by civilian aircraft under 000 contract. However, without CRAF activation, these military airlifters are all that is immediately available to project and sustain combat power rapidly into short-fused brushfires in distant theaters.

Cargo Volume. Cargo volume is another way to say "There's no free lunch." Overnight deployment of military power has its price--only so much can be loaded on an aircraft. The maximum payloads, under optimum conditions, of the C-5 and C-141 are 130.5 tons and 47.5 tons, respectively. [20] While impressive, they pale when one considers a typical mechanized infantry division requires the following daily tonnages to operate: [21]

Operations in Reserve (no combat)	557 tons/day
Pursuit Operations	2079 tons/day
Attack Operations	2473 tons/day

From the above figures, the US airlifter fleet would have been hard put to sustain even Reserve operations; building the sixty-day stockpile General Schwarzkopf wanted prior to opening hostilities and maintaining forces in-theater, with airlift alone, would have been impossible. [22] Sustaining combat operations would have been unthinkable.

Vulnerability Expense. Vulnerability and expense are a blanket term for two considerations: armament (i .e., its lack) and production costs.

Armament. Strategic airlifters are not armed, maneuverable, or replaceable (within a reasonable time). They are vulnerable not only to enemy aircraft, but to small arms fire and artillery while landing, taxing, or loading/unloading. Their cargoes are indispensable to the troops at the other end; lose a strategic airlifter and a great deal of combat power goes, too. Therefore, they are used only in a permissive air environment; i.e., secure main operating bases (MOBs) well away from the action, whose security is ensured by friendly air superiority. [23] This means their cargoes must be transloaded to intratheater transport (tactical airlift, trucks, trains, etc) and moved to their destinations, all in order to minimize the strategic airlifter's vulnerability. Such was the case throughout Desert Shield and Desert Storm, with tremendous intratheater airlift underway at all times. [24]

Production Costs. Strategic airlifter production costs are very high: $149 million for a C-5, unknown for a C-141 (since the production line is closed down, it is irreplaceable), and estimates range from $170-$240 mi II ion for the C-17. [25] This, too, argues against such expensive assets being used in a risky environment. 26 Consequently, despite the C-5 and C-17 being designed for tactical operations, they will probably be used only at fixed, secure, rear-area MOBs. [27]

Service Life. Service life (an algorithm equating flying hours and tonnages as a function of airframe stress) estimates how long an airframe can be used before it must be replaced. [28] Consequently, service life is conserved to ensure it is available in a crisis. Both the C-5 and C-141 have 30,000-hour service lives; however, the "stretched" C-141B was assessed as having a 45,000-hour service life. [29] The C-141 was programmed to commence phase-out in the mid-1990s before the Gulf War changed the service life picture completely. Now, retirement must begin sooner if the service life factor is observed, or else a service life extension program must be implemented to keep it flying longer.

Airfield Restrictions. Airfield restrictions figured prominently in Desert Shield, with airlifters sharing the ramp with large numbers of warplanes. This caused saturation, frequently requiring off loading and subsequent aerial refueling in order to vacate the ramp for another inbound airlifter. [30] At times, there was an arrival every ten minutes. [31]

Sealift. The next transportation mode, sealift, carries the lion's share of logistics support to any deployed force. Sealift provides, over the long-haul, at least 95 percent of all logistics support to distant theaters (this was exactly the percentage in the Gulf). [32] Again, there are advantages and disadvantages.

Sealift is slow, more easily interdicted, loaded and unloaded much more slowly, and is limited in where it can berth. Additionally, depending on the size of the logistics operation, the US Merchant Marine and the US Navy's Ready Reserve Fleet (RRF) may be in adequate, requiring charter of foreign-flagged ships. [33]

Sealift Types. The shipping used in strategic sealift is the same as that used on a daily basis worldwide: ro/ro's, container ships, break bulk cargo, and tankers.

Roll-on/Roll-off. Ro/ro's are most preferred due to simplicity of loading/unloading and speed (30-35 knots). However, they are expensive and in short supply. Considered "fast" sealift, ro/ro's usually made the trip to the KTO in about three weeks.

Container Ships. Container ships use standardized lightweight steel, aluminum, or reinforced plywood modular containers either 20 or 40 feet long, 8 feet high, and 8 feet wide to move prepackaged materials. Containerization's advantage is ease of movement through an integrated system of truck, rail, and ship (known in the shipping industry as "intermodalism"). Previously, the average loading rate of a cargo ship (breakbulk) was 10 tons per hour. However, the largest containers can hold up to 35 metric tons and a single container can be loaded or unloaded in three minutes. The tremendous boon to shipping (especially rapid military deployments) is that the average container ship has to spend less than 10 percent of its voyage time in port as opposed to as much as 60 percent for the older breakbulk ships.

Breakbulk. Breakbulk cargo ships are the ones seen in World War II movies--the ships with the cargo holds and cranes lowering palletized cargoes into them. Loading is a tedious, time- and manpower-intensive operation. As already mentioned, turnaround time on these ships in port (as a percentage of their total voyage) is atrocious, running as high as 60 percent of the total voyage. Most of those in operation today (or, in the case of the RRF, available for emergency mobilization) have antiquated propulsion plants; requiring specialized skill is usually available only from retired mariners.

Tankers need little explanation; however, the capacity range is large. Today's tankers evolved from 12,000 ton, 15 knot (British) and 16,800 ton, 16 knot (US) ships built after World War II into the huge 250,000-275,000 ton supertankers of today.

Limitations. Sealift has four primary I imitations: speed, interdictability, berthing, and load/unload times.

Speed/Interdictability. Because it is slower and operates in a medium, which can conceal enemy submarines, sealift is more easily interdicted en route than a strategic airlifter. Also, since so much-'of our supply tonnage moves via this mode, it is a lucrative target. While the USSR has the only submarine fleet capable of offering real danger to convoyed merchantmen, any nation with primitive diesel submarines can threaten unescorted commercial ships. None of the merchantmen crossing to the KTO traveled in convoys: had Iraq actually had her rumored midget submarines convoys; had Iraq actually had her rumored midget [34] or the active support of a nation with submarines (Korea? China?) interdiction could have been a problem.

Berthing. Berthing is another drawback, since ships need harbors to offload. Good harbors, with well-developed berthing, quays, service facilities, and extensive cargo handling equipment are not plentiful in the developing world. Saudi Arabia, and the United Arab Emirates (UAE), with several excellent ports, was a fortuitous theater.

Load/Unload Time. Another factor is the time it takes to load and unload a cargo ship. First, the cargo has to be delivered to the sea point of embarkation (SPOE), built up for loading, then loaded. This can take up two weeks, depending on transit time from various CONUS points to the SPOE. After the voyage (which, for the KTO, took 2-5 weeks, depending on the vessel), off loading at the sea point of debarkation (SPOD) took a good deal of time, based simply on cargo volume. Finally, the cargo then moved to its final destination, requiring more time.

Desert Shield/Storm requirements swiftly exhausted available US merchant shipping. [35]

Additionally, the RRF proved unequal to the task; despite requirements for 96-hour readiness, several ships were unable to be ready within timelines. [36] Critical skills needed for the older steam-powered vessels were lacking in today's merchant marine, requiring the Navy to tap the skill is of numerous retired seamen. [37]

The shortfall in US-generated shipping prompted chartering of foreign-flagged ships. This resourceful move bridged the sealift gap, but raised another issue: how would foreign crews react when the line between war and peace was crossed? For the most part, no difficulty was encountered; however, in at least one instance, a foreign crew refused to enter the war zone once war started.

Host Nation Support. The third method of supplying the logistics needs of deployed forces is HNS. However, its viability depends on the host nation's technological sophistication and existing infrastructure. In the Gulf, the US military deployed to a theater with a large in-place infrastructure (around the cities, at least) of airfields, ports, and a developed road system. Surprisingly, the item one would have expected to be abundant (POL) had to be imported. [38]However, a great deal of war materiel, such as heavy trucks, construction materials, medical supplies, and spare parts, was already available in various quantities. In other potential theaters, South America or Africa, for example, these would have to have been brought in. Their in-theater availability reduced strategic transportation requirements considerably.

Prepositioning. Recognizing our strategic transportation shortfalls, the US developed a prepositioning program in the late 1970s. Under this program, equipment and supplies needed by deploying forces were "pre-positioned" in or near theaters where they were most likely to be needed in a future crisis. Prepositioned materiel falls into three categories: Afloat Prepositioned Ships (APS), Maritime Prepositioned Ships (MPS), and Prepositioned Overseas Materiel Configured for Unit Sets (POMCUS).

A float Prepositioned Ships. APS contains Air Force and Army equipment and 'supplies and all 12 ships are based in Diego Garcia.

Maritime Prepositioned Ships. MPS contains Naval and Marine equipment and supplies. It consists of 13 ships, organized into three squadrons in three different locations.

Prepositioned Overseas Materiel Configured POMCUS is located in Europe and oriented toward NATO contingencies.

The principle behind prepositioning is simple: avoid the "crunch" with respect to crisis strategic transportation by emplacing needed materiel in-theater in peacetime. If a crisis erupts in the theater, the troops can be sent into the theater (sans equipment) and married up with the prepositioned stocks. For instance, the MPS squadrons at Diego Garcia, Guam, and the US east coast had sufficient equipment and supplies (including tanks, armored vehicles, ammunition, etc) to fully equip a 45,000 man Marine Expeditionary Force (MEF); this was equivalent to 2,100 C-5 flights. [39] In fact, so abundant were the stores the Marines loaned many tanks to the Army's 82nd Airborne upon their arrival. [40] This was fortunate since the 82nd was airlifted into the KTO with minimal equipment. As essential as it was to Desert Storm, it is worthwhile to keep in mind that prepositioned stocks may not always be where needed. As it was, the APS/MPS in Diego Garcia were seven days from the action; the other squadrons were even further, and future crises could be further still from prepositioned assets.

MOBILITY STUDIES

Prepositioning grew out of three previous mobility studies done by the Department of Defense, which identified shortfalls in our strategic transportation architecture. They were: the Congressionally Mandated Mobility Study (CMMS), the DOD Sealift Study, and SABER CHALLENGE LIFT.

Congressionally Mandated Mobility Study. The CMMS is the seminal document from which current strategic and intratheater transportation force requirements were derived. Required by the Defense Authorization Act of 1981, its purpose was to "..determine the mix of airlift, sealift, and prepositioning which would provide an acceptable US response capability for military contingencies in the 1990s.. .", The study, published in April, 1981, postulated four scenarios requiring rapid US military buildup. They were: single theater conflicts in Saudi Arabia, Iran, and NATO; the fourth scenario was a conflict in Saudi Arabia followed by a Soviet invasion of NATO. The CMMS identified significant shortfalls in all mobility areas and recommended substantial improvements in airlift, sealift, and prepositioning. It concluded:[42]

> "Rapid deployment in support of US force projection strategy is essential. The ability of the US to move forces quickly, while maintaining the capability for large reinforcement later not only enhances deterrence, but if deterrence fails, may make the difference between defeat and a successful defense."

DODQ Sealift Study. The DOD Sealift Study of March 1984 focused on shipping, prepositioning, and cargo offload capabilities needed to meet Defense Guidance FY 85-89 deployment objectives under various scenario and parameter variations. It recognized that in the period before sealift can deliver forces, airlift and prepositioning are the only possible delivery modes. It examined intertheater mobility (including prepositioning) and cargo offload requirements for a worldwide conventional war. The war begins with a US/Soviet Southwest

Asian (SWA) confrontation and escalates to a NATO/Warsaw Pact war, spreading eventually to Korea. It assumes allied and normally friendly nations allow overflight and assumes adequate capacity to support aircraft flow exists at en route bases. It found: [43]

> "Planning for these two scenarios in sequence resulted in projections of significant shortages in sealift After this study was completed, Secretary [of Defense] Weinberger decided.. .DOD would not program sealift to meet requirements in theaters in which US allies could contribute shipping to the common defense, but would instead seek the commitment of allied shipping. This policy change is reflected in current DOD mobility goals, including the requirements for sealift to [SWA]."

SABER CHALLENGE. SABER CHALLENGE LIFT examined the utility of procuring various mixes of C-17s, C-5s, and/or commercially available wide-body aircraft to solve the airlift shortfall. [44]

It analyzed aircraft cargo capacities in terms of the three types of cargo: bulk, oversize, and outsize. It found:

1. Shortfalls occur in all three areas, therefore aircraft suitable for all three must be added.

2. Oversize/bulk requirements are satisfied more cost- effectively with CRAF assets than with DOD-owned and operated aircraft.

3. An aircraft mix which favors direct delivery capable aircraft would reduce the airlift system's dependence on "vulnerable,.. .saturation-prone, major airfields."

4. There was no "overriding cost advantage" between the C-5 and the C-17, so airlifter acquisition should be driven by operational flexibility, which, in this case, favored the C-17. [45]

Across the board, the studies found deficiencies in airlift and sealift capabilities. The CMMS articulated-goal of 66 mi II ion ton-mi les per day (MTM/D) falls far short of the actual JCS European requirement (150 MTM/D) and does not even meet the SWA estimate (98 MTM/D).[46] The DOD Sealift Study recognizes the trends of past decades by postulating foreign charter in order to meet sealift requirements; in other words, inadequate US sealift and little likelihood of getting enough. SABER CHALLENGE LIFT found "no cost advantage" between the C-5 and C-17 (although recent cost figures on the C-17 may make this arguable), pitching the C-17 as the most desirable based on operational flexibility. Ultimately, all three studies tell what the Gulf War demonstrated conclusively--the US has inadequate strategic transportation capabilities to meet its military "needs", much less address its "wants."

Logistically speaking, the KTO was a very fortuitous theater of operations. [47] The host nations were wealthy and, because they used mostly US-made military systems, offered a great deal of compatibility between support structures. Additionally, very elaborate air and naval facilities provided modern ramp, revetment, and berthing facilities which would probably be unavailable (on such a grand scale) in Saudi Arabia for nearly twenty years, [48] other potential theaters. Also, the US has maintained a low-profile military presence in so deployed forces did not jump into the dark with respect to area knowledge--they knew what was available and, equally important, what was not. Lastly, the US had a "cooperative" for who gave us six months to construct the hammer to flatten him.

There are, however, other potential crisis areas (Korea, China/India/Pakistan, and Central/South America), which, had old grievances, flared up, would have placed the US in a very uncomfortable position. [49] For instance, had North Korea decided this was the time to reunify the peninsula, the US would have been hard put to honor its South Korean commitments (recall TEAM SPIRIT was cancelled because Desert Shield monopolized strategic airlift and sealift). [50] Nor would this have been the first time a Korean incident proved distracting in the midst of a US military action-- the Pueblo was taken in 1968, at the very height of the Vietnam

War. During the Gulf War, India and Pakistan nearly came to blows over Kashmir, with both sides conducting aerial, naval, and troop movements. A flare-up in either region could have been fraught with US-involvement potential at a time when the means to support a swift US buildup (strategic airlift) was almost entirely dedicated to the KTO.

SUMMARY

Thus far, strategic lift phasing, logistic support systems/modes and their advantages/disadvantages have been examined and three past strategic lift studies considered. Considered in light of recent Gulf War experience, these have much to say about strategic airlift's possible future direction.

USTRANSCOM's immediate requirements usually go via airlift, while sustainment usually goes via sealift USTRANSCOM can move men and materiel to the KTO virtually overnight (via airlift) or within 4-6 weeks (via sealift). Consequently, virtually all troops and materiel needed on days 1-28 (and not already in theater) had to be airlifted to be available at all. Factored into the equation is the combat support and combat services support (CS/CSS) requirements of modern weapons systems. However, airlift is always in short supply, and, as already discussed, sealift is the preferred shipping mode for materiel, accounting for 95 percent of all shipping to the KTO. [51] In order to get the maximum combat power into the KTO as soon as possible, CENTCOM elected to deploy as many combat elements as possible at the expense of logistics and combat services units. [52] Lack of an intermediate transportation capability to move bulk/outsized cargo in the 1-4 week time frame prompted USTRANSCOM to expend airlift to move war materiel which might otherwise have moved via sealift, except 4-6 weeks was too long to wait. Items moved by airlift during the first 6 weeks that could have gone via intermediate transport "burned up" service life needlessly--but there was no alternative. To meet the requirement, the MAC airlifter fleet was monopolized (95 percent of all C-5 and 90 percent of all

C-141 aircraft), [53] activated CRAF STAGE I [54] and, because there was little strategic airlift left, we crossed our fingers with respect to a potential major crisis elsewhere. This is one consequence of the aforementioned GAP in our transport capabilities during the Mid-Term phase. Men and materiel needed in this period must either be airlifted (unnecessarily tying up strategic aircraft) or delayed to the Sustainment phase (when they may be too late). Pre-positioning, by emplacing bulk/outsized materiel in potential crisis areas, is tacit recognition of this GAP--however, materiel may not always be prepositioned where needed, necessitating further inter/intra-theater airlift. [55] The United States needs a means other than strategic airlift to transport bulk/outsized cargo in the Mid-Term phase.

The GAP in US strategic transport capabilities is not a physical gulf dividing material objects but, rather, a GAP in our ability to bridge logistically physical distances in a timely manner. Airlift is best suited for situations wherein an immediate presence is required, but has limited cargo throughput capabilities compared to sealift

Sealift, while slower, can move mammoth cargo volumes, far outstripping airlift. For peacetime operations, the airlift fleet of 903 aircraft (including C-130s) [56] and the sealift fleet of 224 vessels [57] are adequate. However, in wartime these resources are quickly stretched to the breaking point, with all assets supporting the theater of operations and little left over for other crises. The Gulf War confirmed this when 95 percent of the airlifter fleet, 31 percent of the Civil Reserve Air Fleet, and 100 percent of the sealift fleet [58] was dedicated to deploying and sustaining a half mi II ion troops from 6 August 1990 to the 11 April 1991 official ceasefire and beyond. Even these assest were insufficient--USTRANSCOM had to charter foreign shipping as well to get the job done. Had there been another crisis requiring rapid military buildup to counter a threat (Korea, for instance) the resources simply would not have been there.

Desert Storm was a continuous logistics tradeoff wherein men and materiel were constantly juggled in order to insert as much combat power as possible into the Persian Gulf as quickly as possible. However, the tooth to tail ratio required by today's weapons systems mandates a significant logistics infrastructure be emplaced nearly simultaneously with the combat forces to have a credible combat posture. Conversely, the physical realities of airlift carrying capacity (volume and tonnage) limit the total quantity of "stuff" that can be moved through the air pipeline on any given day. If, for instance, the airlift fleet could move 100,000 tons of cargo daily to the KTO, USTRANSCOM could probably move everything--combat troops, combat support, and combat service support, via air (assuming, of course, the facilities were available to accommodate it all at the distant end). However, realities are otherwise and dictate airlift be used to maximize combat power projection and that combat support be pared to the bare percentage required to ensure forces inserted are logistically viable. This arises from our lack of an intermediate transport capability in the GAP. Peter must therefore be robbed to pay Paul. This is where the continuous tradeoff equation comes into play: how much combat support is sufficient during the Immediate and Mid-Term phases to ensure our combat forces are logistically viable throughout the build-up period? The logistician's nightmare is two-fold: fear of sending too much (thereby diminishing combat power) and fear of sending too little (thereby rendering a percentage of the deployed combat power unusable over time). This nightmare is exacerbated by the logistician's knowledge that he has no option but airlift during the first 4-6 weeks of a major deployment. At this point, the GAP yawns very wide and deep.How pressing this problem is was shown by the Desert Shield movement statistics when the needed combat power was deployed and the logistics infrastructure to sustain operations developed. Remember--Desert Shield was conducted in a benign environment: the US had an obliging foe who gave us six months to emplace the sophisticated logistics train needed to support our combat forces, and there were no hostile military moves in other equally remote theaters. Realize, too, secure airfields and seaports were available at each end.

Allowing this GAP to continue jeopardizes DOD's ability to quickly respond to threats to US vital national interests. For better or worse, the disintegration of the USSR as a superpower sets the stage for a return to the pre-World War I multipolar political world. Prior to the USSR's collapse (and dissolution of the bipolar political world extant since 1945) client states (ours and theirs) were at least partially restrained from military adventures against their neighbors. The Gulf War foreshadows a new element: unchecked military adventurism by former Third World Soviet clients willing to test US and UN resolve. Given the possibility of large quantities of Soviet weaponry being sold by former Soviet states, significant military enhancements in nations able to pay for them are likely. This implies an increasing potential for nations to wage expansionist wars previously beyond their military capabilities. Also, it is not unimaginable that, in its retreat from empire, the USSR/Russia could "misplace" some nuclear weapons. It is possible Libya, Iraq, Egypt, Syria, Iran, Pakistan, India, Brazil, and Argentina could suddenly acquire them. All these nations have historical territorial disputes with one another and several have an object of mutual hatred (Israel). War has not become less likely now there is only one superpower in the world. Quite the contrary: the present power vacuum (which the US cannot fill by itself) has engendered what will prove to be a geopolitical free-for-all in regions where the US has no vital interests and, given current US military downsizing, perhaps soon ('a la Desert Storm) in areas where it does. The need to project US military power quickly (no longer forward deployed and now drawn from a smaller force base) into remote regions will be a fact of life for at least another generation. The US cannot afford, militarily or politically, to have a 4-6 week

GAP in our force projection capabilities.

CONCLUSION

In the final analysis, the US does not have enough airlift to accomplish everything needed in the power projection realm. Given airlift's expense, the US is unlikely ever to have as much as it would like, at least, as strategic airlift is presently conceived.

But, could there be an alternative form of airlift, which could close the GAP experienced during the Gulf War deployment? While not as fast as strategic jet airlifters, it would have to be much faster than the fastest sealift Ideally, it should move large tonnages, all outsized pieces of equipment, and, since cost is a factor, should cost significantly less than strategic airlifters. At a minimum, it should provide at least as much delivery capability as strategic airlift; preferably, it will give additional capability.

Surprisingly, such a system is within today's technological grasp. In fact, it was widely used seventy years ago, falling into disuse because of bad press and the rapid progress and short production times of the (then) relatively inexpensive airplane.

However, with the rapidly escalating costs and production times required to bring new generations of aircraft on-line, perhaps this airlift system's applicability to today's strategic military transportation architecture should be reevaluated.

This vehicle is the rigid airship--the dirigible.

NOTES

1. Such indeed was the usual strategy in the ancient Middle East: perhaps we saw a lingering vestige of it when Saddam Hussein crouched behind his Kuwaiti fortifications, hoping to wait out the Coalition.
2. "Tracking the Storm: Chronology of Events," MILITARY REVIEW, vol LXXI, no 9, (September 1991): 70.
3. Jeffrey Record, U.S STRATEGIC AIRLIFT: REQUIREMENTS AND CAPABILITIES, National Security Paper: 2, (Cambridge-;-Mass and Washington, D.C.: Institute for Foreign Policy Analysis, Inc., [January, 1986]), pp. 8-9.
4. Norman Friedman. Desert Victory, (Annapolis: Maryland: Naval Institute Press, 1991), 239.
5. See Murray Hammick, "Lost in the Pipeline," INTERNATIONAL DEFENSE REVIEW_(9/1991): 998 and Friedman, 95-96.
6. Francis, R, Donovan, VADM, USN, "Test of Sealift Planning for MSC," DEFENSE TRANSPORTATION JOURNAL, vol 47, no 3, (June 1991): 60.

   NOTE: More fully, MPS and APS are structured as follows:

   Forces are prepositioned in order to place as much outsized cargo as possible in geographic proximity to anticipated trouble spots. With respect to sealift, the following reflects global prepositioning structure:

   1. Maritime Prepositioning Ships (MPS): Consists of 13 ships organized into 3 squadrons. Each MPS squadron contains sufficient equipment for a Marine Expeditionary Brigade (MEB). MPS squadrons are located as follows:

   a. MPS Squadron One: Four ships, based on US east coast.
   b. MPS Squadron Two: Five ships, based in Diego Garcia.
   c. MPS Squadron Three: Four ships, based in Guam.

   Combined in the KTO, these 13 ships were sufficient to equip a 45,000 man Marine Expeditionary Force (MEF).

   2. Afloat Prepositioning Ships (APS): Consists of 12 ships, based in Diego Garcia. These ships contain ordnance, supplies, and fuel for the Army and Air Force and a field hospital.
7. Vincent C. Thomas, Jr, Capt, USN (ret). "The Sea Services' Role in Desert Shield/Storm," SEAPOWER, vol 34, no 9, (September 1991): 30.
8. Commander George Ashbridge, USN, (OPR) "DESERT SHIELD/DESERT STORM LESSONS LEARNED, 26 March 1991," Letter from Commander, Military Sealift Command (COMSC/ADM F.R. Donovan) to USCINCTRANS (Gen H.T. Johnson), subsection titled "SEALIFT (FSS)"

   NOTE: Document consists of various paragraph-long, unnumbered talking papers. Talking papers are enclosures to basic "LESSONS LEARNED" report are their order is referenced on the cover letter signed by VADM Donovan. Other enclosure categories are:

   1. Fast Sealift Support Ships (FSS)
   2. Ready Reserve Force Ship Mix
   3. Ready Reserve Force Manning
   4. Ready Reserve Force Activation Times
   5. Lack of Firm Cargo Requirements and Priorities
   6. Time Phased Force Deployment Data Listing (TPFDDL) Validation
   7. United States Marine Corps Cargo Prioritization
   8. Lack of Secure Communications in MSC Shipping

9. Ammunition Ship Loading Delays
10. Ammunition Ship Sheathing
11. Chemical/Biological/Radiological Defense (CBR-D) equipment for Military Sealift Command Shipping
12. Augmentation for shipping by allies
13. Government Provided War Risk Insurance 9. Miller, 368.

10. Captain Brent Herold (USA), Major Marc Calvert Sims (USAF), and Lieutenant Commander Donald C. McNeeley, Jr (USN), "OPERATION DESERT SHIELD: Logistics Considerations for Sustained Deployment," LOGISTICS SPECTRUM, Vol 25, Issue 1 (Spring, 1991): 7.
11. Record, pp. 8-9.
12. Donovan, 62.
13. Friedman, 101.
14. Herold, 7.
15. Charles E. Miller, Lt Col, USAF, Airlift Doctrine, (Maxwell AFB, AL: Air University Press 1988), 375.
16. Stewart M. Powell, "They Deliver," FORCE MAGAZINE, vol 74, no 8, August 1991, p. 52.
17. Trevor Nash, "Military Transport Aircraft," MILITARY TECHNOLOGY, no 5/91, (May 1991): 12.
18. Stewart M. Powell, "Desert Duty, "FORCE MAGAZINE, vol 74, no 2, February, 1991, pp. 32-33.
19. Major Sheila L. Tow, USAF, "Airlift-Delivered Victory," DEFENSE TRANSPORTATION JOURNAL, vol 47, no 3 (June 1991): 53.
20. US Superintendent of Documents, Improving Strategic Mobility: The C-17 Program and Alternatives (Washington, D.C.: Government Printing Office, 1986), Table A-1, p. 44 (Hereafter cited as US Superintendent of Documents, Improving Strategic Mobility). NOTE: These tonnages are perhaps overly optimistic if you compare them to the Airlift Master Plan, Table A-2, p A-10 (see footnote 27, below). The AMP projects a long-range (2500 NM) payload capability of 68.9 tons for the C-5A/B and 27.5 tons for the C-141. These figures are significantly lower (47 percent and 43 percent, respectively) than those reflected in the C-17 Program and Alternatives study.
21. Friedman, 386.
22. Charles Q. Cutshaw, "Lessons from the Gulf--A Time for Caution" JANE'S INTELLIGENCE REVIEW, vol 3, no. 7 (July,1991): 317.
23. Record, pp. 23, 28-29.
24. Lieutenant Colonel Robert E. Edmisten. (USAF), "USCENTAF Desert Shield/Storm Transportation: Milestones in the Sand," DEFENSE TRANSPORTATION JOURNAL, vol 47, no 3 (June 1991): 78.
25. Record, p. 15.
26. Ibid, 16
27. Ibid, 28-29
28. USAF Airlift Master Plan (Scott AFB, IL: HQ MAC/XPPB [29 September 1983]), p.ITI-12.
29. Ibid, 111-14
30. Tow, 48.
31. Herold, 8.
32. Friedman, 388.

33. See Leo L. Collar, "Desert Storm and Its Effect on US Maritime Policy," DEFENSE TRANSPORTATION JOURNAL, vol 47, no 3 (June 1991): 67 and Colonel John T. Eanes, (USAF), "USCENTCOM as Focal Point of Mobility Effort," DEFENSE TRANSPORTATION JOURNAL, vol 47, no 3 (June 1991): 73.
34. Friedman, 104-105.
35. Thomas, 33.
36. See Herold, 6 and Friedman, 102-103 [Footnote 24].
NOTE: In footnote 24 to pp 102-103 of Desert Victory, Friedman states "Nor had the [Ready Reserve Fleet] been fully maintained.. .only about half the RRF was activated. Of the first 44 ships.. .11 were ready on time, 13 were 1-5 days late, 10 were 6-10 days late, and 10 were 11-20 days late." Source data attributed to Capt D.M. Norton, USN, "Sealift: Keystone of Support", Proceedings Naval Institute (May 1991).
37. See Herold, 6-7 and Thomas, 30.
NOTE: Herold points out that the age of the RRF ships required the Navy to obtain crewmen from retiree lists; the average age of these crew members was 55. The fact that Herold is stating an average age for his recalled mariners is underscored by Thomas' observation that one of the retirees was 83 years old.
38. Friedman, 388.
39. Thomas, 30.
40. Friedman, 102.
41. Airlift Master pp. 111-2,3.
42. US Superintendent of Documents, Congressionally Mandated Mobility Study, vol 1, Executive Summary (Washington, D.C.: Government Printing Office, 1981), p.40.
43. Andrew E. Gibson and Commander Jacob L. Shuford (USN), "Desert Shield and Strategic Sealift," NAVAL COLLEGE REVIEW, vol XLIV, no 2, sequence 334 (Spring 1991): 9.
NOTE: This recognizes the twin realities of sealift expense and US Merchant Marine Fleet decline since World War II. This sealift shortfall, which Secretary Weinberger realized would likely remain unsolvable within US resources, prompted a "TOTAL FORCE" policy (reminiscent of the US TOTAL FORCE policy of the 1980s wherein allied military forces were factored into total US military strength vis-a-vis the USSR) approach as an alternative to the investment otherwise required to make the needed sealift available. The only difficulty with this logic is that allied sealift availability will always be scenario-driven; i.e., depending on the crisis, some "allies" may see discretion to be the better of valor and deny the US badly-needed sealift
44. Lieutenant Colonel Tommy R. Luce (USAF), Airlift Alternatives Study (SABER CHALLENGE-LIFT) (Washington D.C.: HQ USAF, ACS/Studies and Analysis, [4 February 1982]), p. i ii,
NOTE: The specific tonnages and Required Delivery Dates (RODs) the JCS arrived at are given by Luce as follows:
"In 1980 the JCS specified the following strategic airlift requirements, based on units with RODs within the first 15 days of postulated major contingencies:
-Regional conflict in the Persian Gulf 98 MTM/D
-Soviet invasion of Iran, 102 MTM/D
-Reinforcement of NATO 150 MTM/D"
As you see, the Congressionally Mandated Mobility Study airlift goal of 66 MTM/D falls far short of even the smallest JCS airlift estimate.

45. Ibid
46. Record, p. 17.
47. Powell, p. 34.
48. Ibid
49. Miller, 367 and Airlift Master ' pp, 111-7.
50, TEAM SPIRIT is a yearly joint military exercise conducted in South Korea by US and South Korean forces, The exercise is conducted, not coincidentally, at the time of year best- suited for a North Korean invasion, This has ensured adequate military forces are in-place on the Korean peninsula to discourage North Korean adventurism. Because of the KTO deployment, forces normally involved in TEAM SPIRIT were instead in Saudi Arabia, Also, the airlift and sealift we would have used to deploy them was dedicated to Desert Shield and Desert Storm, Obviously, if North Korea had elected to cause some mischief. this would have been the perfect time.
51. Friedman, 102-103.
52. Hammick, 998.
53. Major General Vernon J. Kondra (USAF), "Desert War Proves Air Fleet's Worth," DEFENSE (March/April 1991): 28.
54. Tow, 47-48.
55. Record, pp. 4-5.
56. US Superintendent of Documents, Improving Strategic Mobility, Table 1, p. 10.
57. Friedman, 101-102.
58. Kondra, 28 and Tow, 53.

CHAPTER TWO

FILLING THE GAP: THE AIRSHIP

PROLOGUE

The colonel looked up from the unfolded map lying on the hood of his command vehicle. He had been earnestly studying it by flashlight and, after conferring with his GPS transponder, concluded his regiment was where it should be. The armored division his regiment was part of had been tasked to penetrate a loosely-held enemy sector and plunge at top speed to grid coordinates X-Ray 14--about 150 mi les behind enemy lines (well behind their third echelon forces), where they would form the "anvil" upon which the enemy, trapped between them, would be "hammered" by an armored corps attack which would commence at 0400. To make the plan work, it was necessary for his division to cut loose from its logistics base, fight its way to the objective with only what it could carry, and be resupplied aerially. This eliminated the ponderous logistic strain, which often limited an armored column's rate of advance and removed the need to maintain a breach in the enemy line in order for fuel, water, ammo, and food to reach them. A tanker's dream come true: under cover of US air superiority, smash through the line, outrun any pursuit, and blast anything in front of you. However, all dreams end and now his troops badly needed that aerial resupply. It was dark, the attack was eight hours away, and his regiment (indeed, the whole division) didn't have the combat logistics support to maneuver and fight in order to block retreating enemy forces.

At this moment, his radio operator informed him Division Headquarters was setting up a scrambled conference between the Division Commander and his regimental commanders. The colonel quickly got on the set, checked in with the net coordinator, and listened intently as the general told them the air resupply was underway and they should get their landing beacons out;

the cargo carriers had just lifted off and were expected in about an hour. The general relinquished the circuit to the division G-4 (Logistics) who passed mission numbers and authentication codes to each regimental commander to guide the shipments in. As soon as he got his, the colonel motioned to his S-4 (Regimental Logistics) who had been waiting quietly with the rest of the staff a few yards away. Giving them to him, he ordered him to make one last check of the landing field to ensure all was ready.

The S-4 quickly made his rounds and confirmed the needed one thousand foot landing strip was outlined by eight portable strobe lights, which would be activated on his command. He also ensured the cargo crews were standing by to break down and distribute the assets once the cargo bird unloaded them and lifted off again. He went back to the colonel and informed him all was ready. About forty-five minutes later the command set crackled to life as a voice with a strong Texas accent identified himself as their mission and requested authentication and precise position coordinates. The S-4 gave the authentication code and passed the requested coordinates (corresponding to the exact center of the landing site, thanks to GPS) and said the strobes would be activated once he was overhead.

Twenty minutes later the command set came to life again as their pi lot requested strobe activation in the pre-established pattern and sequence. This additional safeguard ensured the cargo bird landed at a friendly site rather than a bogus one set up by an enemy force using compromised codes.

The strobes were swiftly activated and the ground crew turned anxious ears skyward. They were soon rewarded with the familiar welcome sound--the whispery whine of a descending cargo ship. About a hundred feet from touchdown, the pi lot radioed he was activating the grounding system; seconds later, directly over the landing site, four flares erupted from the cardinal points of the compass. The rocket-propelled landing harpoons, trailing their steel cables, slammed into the soil below, penetrating, the S-4 knew from experience, at least thirty feet. This done, the cargo bird's engines cycled to a low hum as the pi lot winched her down to a soft landing. Secured at four points, flat on the ground, his engine idling, the pilot released the mating clamps securing the 200 ton cargo in his vessel's belly. Done, he communicated his intention to lift off at the S-4's command. The S-4 looked questioningly at the colonel, who nodded his approval. The S-4 passed this to the pi lot, with a sincerely-felt thanks. A minute later, the pi lot jettisoned the restraining cables, leaving the harpoons buried and the cable reels lying on the ground near them, and, increasing his engines' timbre, quickly lifted his dirigible's eight hundred foot length vertically off the ground and, executing a slow, circling turn, headed home for another load. Mean while, the ground crew swarmed over the pallets containing combat-loaded stores of fuel, ammunition, parts, water, and food--the sinews of armored warfare. The colonel looked at his watch; thirty minutes earlier his regiment had been far behind enemy lines and low on supplies needed to perform its mission. Now, he'd received 200 tons of vitally needed materiel and, according to the campaign plan, would receive another in about thirty minutes. Not bad, he mused--sure wouldn't have wanted to try it in Kuwait when he was a brand new shavetail. In those days an armored thrust's momentum was sustainable only as long as its logistics pipeline could keep up with it; you could outrun your logistics, but not for long. The olonel's face twisted into a wry grin as he silently chuckled at the ingenious way the Air Force had used early twentieth century technology to solve the nemesis of early twenty-first century warfare--direct delivery of combat materiel into the battle area. Ten minutes later, the command set again crackled to life with another pi lot's voice.

INTRODUCTION

The foregoing was a potential scenario involving US power projection into a regional conflict a generation hence. As learned (or, re-learned) in the Gulf War, logistics, the movement of materiel over distance, is the limiting factor in warfare.

Thus it has ever been, thus it will ever be; Caesar's Legions, Wellington's armies, and Patton's tanks marched and fought only as long as they could be fed and equipped: when logistics dried up, combat power withered.

The massive geopolitical changes of the past five years, culminating in the dissolution of the Warsaw Pact and the USSR, removed the traditional threat US armed forces organized, trained, and equipped to combat. These geopolitical changes were reflected in the US by massive pressures to draw down military forces 25-30 percent and to scale down overseas military presence. However, few dispute the new era, while vastly diminishing the likelihood of Great Power war, greatly increases the potential for regional conflicts in areas wherein industrialized nations (especially the United States) have vital interests. Unlike Europe and Korea, which are prepared theaters with prepositioned men, materiel, and logistics infrastructure, future regional conflicts will likely occur in unprepared theaters with Little or no prepositioned men and materiel. US intervention in these regional conflicts will encounter the same challenge faced in the Gulf: quickly moving hundreds of thousands of personnel and mi II ions of tons of materiel to an area unprepared or unable to simultaneously accommodate the delivery vehicles (aircraft and seacraft) in the numbers required to move the troops and tonnages needed for proper reinforcement. In the Gulf sustain ability was traded for combat power in hopes Iraq, would remain north of the Saudi-Kuwaiti border until forces needed to retake Kuwait were built. The bluff worked then; however, what if the next regional conqueror, taking the

Gulf War's lessons to heart, secures his territorial conquests by seizing adjacent territories whose ports and airdromes would figure in a US attempt to reestablish the status quo? US moves to forestall this eventuality would require forces inserted be capable of immediate, sustained combat--something they would have been incapable of during the perilous first days in Saudi Arabia. For thirty days after Saddam's Kuwaiti invasion, the door to Saudi Arabia was ajar--all he had to do was push. The specter of immediate US involvement made him hesitate and that hesitation sealed his fate. The next regional Visigoth will not hesitate.

The challenge is to restructure the US military to enable it to protect US vital interests in the face of reduced CONUS strength and drastically reduced forward deployed forces. A parallel challenge is forces are most likely to deploy to areas unprepared to receive them and unable to support them logistically when they arrive. Presently, people and light cargoes can be moved quickly, but the tradeoff is in sustainability and dependence on vulnerable, fixed airdromes. Sustainability lies in sealift, which is not quick and, like airlift, not direct, instead relying on vulnerable, fixed seaports. Neither method directly inserts "LOGPOWER" where it's most needed: the battle area. In a future regional conflict, the US must be able to project sustainable combat power into distant, unprepared theaters quickly and directly. With sufficient research and development, lighter- than-air (LTA) vehicles, popularly known as airships or dirigibles, could furnish this capability. This possibility will be investigated by first reviewing the history of airship development and use, discuss the technical/physical principles governing their capabilities, and examining potential military roles for advanced airship technology.

THE AIRSHIP IN HISTORY

Airships have a bad reputation. Mention the word and the first image to come to mind is the Hindenburg's fiery crash at Lakehurst, New Jersey, on May 6, 1937. This is about the extent of the average person's familiarity with airships. Aerial historians will remember the World War I military use of airships for reconnaissance and bombing raids. Unfortunately, this is about the extent of the average person's knowledge. Few remember the airship's peacetime role, which overshadowed its wartime uses. Today, the airship is associated with the Goodyear blimp sailing over sports events--an anemic descendant of mighty forebears. The best way to understand the airship's potential role is to discuss briefly the airship's origins, its uses in war and peace, and describe some of its remarkable accomplishments.

Origins. The early airship concept was demonstrated by the Montgolfier brothers in 1783, whose hot-air balloon ascents constitute the first recorded manned conquest of the atmosphere. That same year saw the submission of a design by a French officer in the Corps of Engineers, Jean Baptiste Meusnier, to the French Academy of Sciences entitled "The Equilibrium of Air Machines". This extraordinary document laid out the principles of dirigible technology, which are as true today as then. However, the first recognizable dirigible did not appear until1852, when Henri Giffard built an airship 143 feet long and 40 feet in diameter, which carried a 3hp steam engine, propeller, and pi lot in a gondola suspended below the gas envelope. In September of the same year, Giffard successfully flew his airship from the Paris Hippodrome to nearby Trapps, 17 mi les away, at a speed of about 5 mph. [1]

The next great stride in airship development involved replacing the prohibitively heavy steam engine with an electric motor. This occurred in August 1884, when two French army engineer officers named Renard and Krebs developed a battery- powered electric motor, which enabled their dirigible, La France, 2 to attain an average speed of 14 mph. [2]

Pre-World War 1German Interest. The following year a German, Gottlieb Daimler, developed an internal combustion engine for dirigibles. Developing 2hp and boasting a single cylinder, it made a successful trial flight in August 1888. Subsequently, Daimler's attention was diverted to developing internal combustion engines for the early automobile; further refining of the internal combustion engine for dirigibles was carried on by Dr Karl Woelfert, who flew an airship powered by a two-cylinder, 6hp engine at the 1896 Berlin Trade Fair. This performance was witnessed by Kaiser WiIhelm II, who offered Woelfert facilities to continue development. The German interest in airships dates from this time.[3]

German airship development proceeded under the visionary leadership of the legendary Graf (Count) Ferdinand von Zeppel in. He successfully tied airship development to German national pride, obtaining the Kaiser's support and the German press' enthusiastic backing. Commencing with the launching of his first airship, the Luftschiff Zeppel in No 1 (LZ1) in July 1900, German airship development grew apace. The LZ1 was 420 feet long, 38.5 feet in diameter, and capable of 20 mph. [4]

By 1908 German airship enthusiasm had grown such that von Zeppel in and his partner, Hugo Eckener, founded Deutsche Luftschiffahrts Aktien Gesellschaft (DELAG), which operated a fleet of five airships from dirigible airports allover Germany. [5]

By the eve of World War I in August 1914, DELAG had made more than 1600 passenger flights, logging over 100,000 mi les and carrying over 10,000 passengers. [6]

World War 1 Airship Thanks largely to von Zeppel in and DELAG, Germany was the best-prepared belligerent at the start of the war with respect to airships. By requisitioning the DELAG airships, the German Army and Navy fielded a total of nine dirigibles. Initially, this fleet was used for reconnaissance, but by 1915 their bombing potential in the British Isles was under discussion. Following the first small raids on 13 and 19 January 1915, the Kaiser, impressed by the lack of British opposition, encouraged more energetic attacks. However, attacks were specifically Limited to war materiel, military establishments, barracks, oil and petroleum tanks, and the London docks; London residential areas, especially the royal palaces, were to be avoided.[8] A succession of night airship raids was conducted with varying degrees of success. Encouraged, Germany's Airship Division made concerted efforts to increase airship capabilities. In May 1916, the giant L30 was launched; her length was 650 feet, diameter 78.5 feet, maximum speed was 62mph, and service ceiling over 17,000 feet.

Her armament consisted of 5 tons of bombs and a 10 machine gun defensive armamament.

Throughout the war, improvements continued, attaining lengths of over 700feet, ceilings over 25,000 feet, and unrefuelled ranges of 3,000 mi les.[9] All told, the German airships conducted 51 raids, dropped 196 tons of bombs, killed 557, and injured 1,358. Most German successes were achieved in 1915 before British air defenses were organized.[10] The war pointed to the particular vulnerabilities of the airship when used in an offensive combat role. During the bombing raids against Britain, Germany had 19 airships destroyed and 5 damaged; total crew losses were 253 dead and approximately 50 prisoners. During the war, the German Navy lost 40 percent of its crewmen and 53 of its 73 airships to enemy fire or accidents; the German Army had lower casualties, but lost 26 of 50 airships. British airship interest was produced by the war itself. At war's outbreak, the British airship fleet consisted of five non- rigid (i .e., no internal framework) dirigibles, two of them foreign-built during the war, Britain built about 300 non-rigid airships, using them almost entirely for convoy escort, coastal patrol, and anti-submarine warfare. The British did build a few rigid (i .e., internal supporting framework) airships, but only one, the R29, made any notable contribution by sinking a German submarine in the closing weeks of the war. The British never grasped the airship's war potential, despite Admiral David

Beatty's attributing Germany's successful evasion of the British Grand Fleet at Jutland to the air reconnaissance of its Zeppelins. [11]

The contributions of the remaining belligerents were negligible. French and Italian airships were reluctant to venture over their own lines, where German preponderance in airships made nervous Allied soldiers shoot at any airship they saw. Until the French abandoned airships in 1917, they were continually at hazard from friendly ground fire. [12] The Americans entered the war late and Limited their airship production to non-rigid models, building a total of 35. American airships were used mostly for training, coastal patrol, and anti-submarine warfare. One American accomplishment, however, was the successful launch of a 4,5001b Curtiss JN-4 biplane from a dirigible (the Goodyear C-1) at an altitude of 2,600 feet. [13]

Interwar Period. After World War I, Germany reassumed the mantle of airship dominance, despite having lost the war. This era saw the rise of the giant passenger liners that safely crossed the Atlantic numerous times, circumnavigated the globe, and transmitted the North Pole. Scant weeks after the Armistice, DELAG was reformed and construction begun on two small passenger airships. The first, the Lake Konstanz, was launched in August 1919 providing service between Berlin and Friedrichshafen. In four months Lake Konstanz logged 100 flights and carried 2,300 passengers. This run, completing in 6 hours a journey requiring 24 hours by train, proved so popular DELAG launched a second Zeppel in, the Nordstern (North Star), for operations between Berlin and Stockholm. [14]

In 1924, DELAG built the ZR3 for the US as partial payment of German war reparations. This ship, 658 feet long, 92 feet in diameter, developing a speed of 79mph, crossed the Atlantic from Friedrichshafen to Lakehurst, New Jersey, in 79 hours. ZR3 (renamed Los Angeles) was commanded by the DELAG director, Dr Hugo Eckener, who returned to Germany convinced trans-Atlantic airship service was possible. Embarking on a successful German lecture tour to raise capital, he laid the keel for the Graf Zeppel in 1926. Called the "most beautiful airship of them all", she was 775 feet long, 100 feet in diameter, developed a speed of 70mph, and had a 6,250 mile unrefuelled range. She carried a crew of 44, with accommodations for 20 passengers, and had a dining room and saloon. Launched. in September, 1928, she made over 650 flights, 144 of them across the North and South Atlantic, logged over a Million miles, and carried more than 18,000 passengers. A typical east-west crossing from Friedrichshafen to Lakehurst took about 79 hours, with a return journey averaging about 60 hours due to favorable winds. In 1929, she circumnavigated the globe, traveling 31,000 mi les in 21 days, 12 hours. In 1931 she undertook an aerial survey of the Arctic, carrying out several maritime stopovers in the process. She was retired from service in 1937. [15]

The other famous passenger airship of the period, the Hindenburg, was launched in 1936. The giant of the species, she was over 800 feet long, 135 feet in diameter, and had a maximum speed of 81mph. Like her sister ship, the Graf Zeppel in, she was a flying hotel, with a lounge, dining salon, accommodations for 72 passengers, a smoking room and bar, and even boasted an aluminum grand piano. Fourteen months after her maiden voyage, she exploded over Lakehurst, New Jersey, while docking. The circumstances were suspicious, leading to theories its destruction may have been politically motivated rather than due to any fundamental unsoundness in her construction. Of the 97 people aboard, 62 survived; of the 35 fatalities, 23 were crewmen. The 12 passengers who died on the Hindenburg were the only fare-paying 16 passengers ever to die in an airship accident.

Other than Germany, only the US and Italy figured significantly in the airship field. Britain had a series of disasters, eventually bowing out as part of a postwar economy program. [17]

On the other hand, the US showed considerable interest in airship development, resulting in several innovative experiments. In 1924, the USS Shenandoah successfully moored to the USS Patoka, a mooring mast-equipped naval tanker. [18] In 1928, the Los Angeles, built in Germany as the ZR3 and delivered as partial payment of wartime reparations, successfully landed on the aircraft carrier Saratoga. She also perfected the technique of hooking up scout planes while traveling at her top speed of 80mph. The first US-built airship, the Akron, was 785 feet long and had a gross lifting power of over 200 tons. Launched in 1931, she was designed <is.-an aircraft carrier, having a hangar amidships large enough for five fighter planes. She conducted these experiments successfully. Unfortunately, the US, like Britain, experienced a string of disasters. Akron, Macon, and Shenandoah all crashed in violent storms: Shenandoah in 1925, Akron in 1933, and Macon in 1935. These disasters, coupled with the Great Depression, led to the US discontinuing its rigid airship program. [19]

Italy's contribution to the interwar period centered on the achievements of Umberto Nobile who, with the Norwegian explorer Raould Amundsen, led a successful expedition to the North Pole aboard the Italian-built Norge. After dropping Italian,

Norwegian, and American flags on the Pole, the expedition landed in Teller, Alaska--a total voyage of 3,000 mi les. Subsequently, Nobile attempted a second, all-Italian Polar expedition in 1928 with a new airship, the Italia. Again he was successful, dropping an Italian flag and a cross given him by the Pope. However, shortly afterwards, the Italia struck the ice field in a glancing crash, ejecting Nobile and several crewmen from the control car. The Italia, lightened, subsequently shot into the air and vanished without a trace, taking six crewmen with her. The surviving crew, with Nobile, were rescued a month later. With this accident, Italian airship interest evaporated. [20]

World War II. What airship activity there was in World War II took place in the US. Foreseeing US entry into the war, the Navy commissioned the Goodyear Company to build non-rigid airships for coastal patrol, convoy escort, and submarine hunting. By war's end, Goodyear had built a total of 135 dirigibles for the Navy. They served in Morocco, patrolling the Straits of Gibraltar, and on the Atlantic and Pacific seaboards. Notable during this period was the increasing mission duration and operating ranges. [21]

Post War Use. During the post-war era, the non-rigid airship's wartime role was enlarged. Recognizing its utility as an observation platform, the Navy maintained its non-rigid fleet (although reduced in size) for ocean surveillance. Innovations continued, with the largest-ever (for the time) non-rigid dirigible (the ZPN-1 at 324 feet) being built. Its successor, the ZP3-K, was specifically designed for aircraft carrier operations; the ZP2N-1 was the first designed to be air refuellable. In May 1954, a new Navy blimp, the ZPG-1, stayed aloft for 200 hours. This record was later broken by her sister ship, the ZPG-2, which stayed aloft for 264 hours. [22] Given the growing Soviet threat and the weakness of our early warning system, the Navy's airships were integrated into the North American Air Defense System. Equipped with airborne early warning radar, they patrolled areas beyond the range of eastern seaboard land-based radar. These ships, aloft for as long as 11 days at a stretch, patrolled from the US east coast, across the Atlantic to Portugal, down the west coast of Africa, and back again to Florida. [23] They compiled a superb accident-free record, filling the gap in US radar coverage at a critical time in the Cold War. However, completion of the Ballistic Missile Early Warning chain made them superfluous. By 1964, all 27 had been decommissioned. [24]

Today. Interest in the airship never died; however, it moved back where it originated: into the province of the entrepreneur. From a civilian viewpoint, the jet age, with its commercial passenger inners moving people to any point on the globe in less than -24 hours, made a three-day Atlantic crossing seem a slow boat to China. The growth of the automobile industry, a continent-spanning road network and rail system, and comparatively low fuel prices meant surface transport of large cargo tonnages was more cost-effective than similar movement by airship. Also, unpredictable weather still remained the chief enemy of commercial airship flight. With the decommissioning of the Navy's non-rigid patrol fleet, the ubiquitous Goodyear blimp became the American public's chief acquaintance with the venerable airship--a curiosity, nothing more. However, man's fascination with the airship is experiencing a renaissance of sorts due to rising fuel costs, environmental sensitivities, traffic congestion, and the deterioration of traditional surface transportation media. Also, the technological strides of the past half century promise new propulsion methods and airship designs which could significantly increase speeds and tonnages, decreasing transportation costs to the point that this mode is cheaper than any other. Two promising examples are the CycloCrane and the US Navy's Sentinel 5000.

CycloCrane. The CycloCrane is being developed by Aerolift, Inc. under the auspices of the US Forestry Service and the Defense Advanced Research Projects Agency. A radical new airship design concept, it has a rotating envelope with lifting blades which have engines mounted at the tips. [25] It is being explored as an environmentally "friendly" means of logging remote areas of he US northwest. Its purpose is to eliminate the need for logging roads by using a heavy-lift dirigible to transport men, equipment, and supplies to the logging site and carry cut timber back to milling stations.

Sentinel, 5000 Concerned with sea surveillance, fleet protection, and air defense of the US against air and sea-launched cruise missiles (also known as the Air Defense Initiative, or ADI), the Navy has revived the airship concept it used so effectively during the postwar period.

When fully matured, the Sentinel 5000 dirigibles will carry a crew of 14, housed in a three-story gondola, and be able to stay aloft, with refueling, for 30 days. These dirigibles will have an internally mounted phased array radar and air to surface missiles. They will cruise at 75 knots, have a 3500 mile maximum ferry range, a 30 ton useful 26 lift, a 14,000 foot maximum ceiling, and will be "stealthy."

The prototype is being built in the US by Westinghouse Airship Industries. A scaled down prototype, the Sentinel 1000, will fly in 1993 and is scheduled for an initial operational capability in 2000. [27]

<u>End--and Beginning?</u> From the military stand point (unless the Sentinel 5000 enters the inventory) the airship saga ended when the US Navy decommissioned its airborne early warning dirigibles in 1964. Airships were used for reconnaissance, submarine hunting and (hopefully) destruction, and radar surveillance. Since a European war scenario against the Soviets and Warsaw Pact was the basis of US planning, and since we already had a significant troop presence and logistics infrastructure there, all that was needed to supplement our jet airlift capability was sealift. This was largely due to the underlying assumption that any European war would rapidly escalate to the nuclear stage, negating the need for large-scale resupply and reinforcement. Besides, the Civil Reserve Air Fleet (CRAF) was available for any needed large troop deployments. The possibility of a regional conflict in an area lacking the needed logistics infrastructure to support a rapid force build up was an overlooked possibility. However, our 1951 Korean build up showed rapid deployment to an unprepared theater to counter a conventional assault was a possibility. Fortunately, the still-large US merchant marine fleet was available to move men, equipment, and supplies, and the invader's logistical capabilities were primitive. This combination, plus stabilization of the Pusan Perimeter, gave the-'US the time needed to build the

troop and logistics base to drive back the North Koreans. This was the first indication of the US post-war need to be able to insert massive combat power into unprepared theaters rapidly.

With the shift from the postwar massive retaliation policy to the flexible response of the Kennedy era, US decision makers became increasingly concerned with their capability to perform buildups such as Korea. While a conventional conflict, the Vietnam War was not a true test of this capability owing to the incremental build up and lack of a conventional military threat. Incapable of massive assaults against the few airdromes and seaports available in South Vietnam, the guerrillas had little choice but to permit the US buildup. However, had there been a well-armed foe (similar to the Iraqi military), US ability to rapidly deploy sufficient forces into Southeast Asia to overcome him was questionable at best.

The late 1960s and early 1970s witnessed the growth of an impressive US strategic and tactical airlift capability in the form of C-5A, C-141, and C-130 aircraft. This fleet gave us a superb capability to insert troops, with Limited equipment and supplies, virtually anywhere in the world (as long as the needed airstrip was available) rapidly. However, as seen in Saudi Arabia, the logistics support needed to sustain combat operations could not move exclusively by airlift--there simply was not enough to go around. Even though 95 percent of the C-5s and 90 percent of the C-141s were dedicated to the Persian Gulf, 95 percent of all materiel moved was moved via sealift Significantly, both transport modes are dependent upon vulnerable, sophisticated airdromes and seaports, far behind the lines instead of close to the front (where the combat support is most urgently needed).

AIRSHIP TECHNOLOGY

To grasp the potential applications of lighter-than-air (LTA) technology to military transport, the technological principles of airship construction and operation must be briefly discussed. Unlike many new technologies, LTA technology is not abstruse; however, the adaptation of LTA to transport relies on solutions developed nearly a century ago and has enjoyed none of the concentrated, government-sponsored research and development showered on aircraft and space systems. Grossly stated, airship design is still largely rooted in the "Fokker and Spad" era; use of space and computer age technologies in modern airship design could yield exceptional enhancements in already impressive performance and capability. Even today, some private companies, operating on the proverbial "shoestring", have made promising strides in this field. To obtain a fuller picture of LTA's potential, airship lift, types, construction and operation, propulsion, control, and ground handling will be discussed. Lift is the property of lighter than air gases which makes airships possible by displacing air as they rise. With respect to airships, lift is subdivided into Static, Gross, and Useful Lift. Each will be discussed in turn.

Static Lift. At sea level, 1000 cubic feet of air weighs 80.72 Ibs, whereas equal volumes of hydrogen and helium weigh 5.61 lbs and 11.14 lbs, respectively. This means 1000 cubic feet of hydrogen rising through the atmosphere (in a sealed container, of course) can lift an 80.72 lbs -5.61 lbs = 75.11 load with it; for helium the figure is 80.72 lbs -11.14 lbs = 69.58 lbs. This is called static lift and reflects the total weight the respective gases can lift from a dead rest. [28] This briefly describes how the property of lift operates.

In airship construction, gross lift and useful lift, within the framework of the "Square-Cube Law", determine how much an airship can carry.

Gross Lift vs Useful Lift. Gross Lift is simply the total weight of the air displaced by the lifting gas, minus the weight of the gas itself. Useful lift, on the other hand, is what you have left when you subtract the airship's fixed weights (hull, outer cover, gas cells, fuel tanks, engines, passenger and crew accommodations, etc) from the gross lift. Useful lift (also called useful load) is what is available for cargo, passengers, crew, fuel, oil, water, ballast, spare parts, etc. Thus far, the comparison is similar to conventional aircraft. After all, engines and wing surface provide a given amount of Lift from which we subtract the fixed weight of the aircraft itself. The difference between these two figures is also called the useful load. However, at this point the square-cube law enters, radically altering the comparison.

Aircraft increase their Lifting properties with more and bigger engines, larger wing surfaces, lighter materials, higher speeds, and, occasionally, new design techniques enabling them to extract greater benefit from their Lift. As a general rule, aircraft must increase their size by 50 percent to double their lift. [29]

Square-Cube. Airships, on the other hand, store Lifting gas in leak proof cells to obtain Lift. From the size standpoint, this means bigger is always better: every 1000 cubic feet of gas adds another increment of Lift. Better still, significant Lift increases are obtainable with relatively modest increases in airship size. The square-cube law says doubling the radius of a spherical object quadruples the surface area and increases volume eight-fold. [30] For instance, the famous Hindenburg, the largest rigid airship ever built, could have doubled her Lift by increasing her length only 25 percent. [31]

As a specific example, consider the Hindenburg. Her gas volume was 7,062,150 cubic feet, generating a gross Lift of 242.2 tons. The weight of the hull frame, outer cover, gas cells, power plant, crew and passenger accommodations, tanks for fuel, oil, and ballast (the fixed weight) was 130.1 tons. Subtracted from the gross Lift, her useful Lift was 112.1 tons. [32] This was the amount available for passengers, crew, cargo, oil, water, spare parts, fuel, ballast, etc. To double her gross lift to 484.4 tons, all that would have been needed would be to make her about 28 tons heavier. This could have been accomplished by lengthening her and adding sufficient extra gas cells to generate the desired lift. [33] This was done several times in airship history, most notably during the 1917 relief expedition to the German African colonies, wherein the German airship L-57 had two 49 foot bays for additional gas cells inserted to provide 51 tons of useful lift. Before leaving the discussion of lift, one final characteristic of lifting gases deserves examination: their tendency to expand as they rise.

Gas Expansion vs Pressure Height. At sea level, these gases are compressed by the ambient atmosphere. Consequently, as they rise, decreasing air pressure permits them to expand. However, as they expand, they exert interior pressure against the walls of their gas cells. Above a certain altitude, these gases must either escape in order to relieve the pressure, or else they rupture the cell walls. This altitude is called the Pressure Height and figures prominently in airship construction.

Airship skippers flew with the pressure height constantly in mind. This influenced the amount of gas placed in the cells since they could accommodate only a certain amount of gas expansion before they ruptured. To prevent this, emergency escape valves were included which ensured gas was "valved off" when pressure reached a predetermined danger zone. Airship captains took great pains to avoid this, since they were valving off their gross lift; when the airship descended to a lower altitude, it would have less gross Lift and, hence, less useful Lift. This was especially important since, try as they might, existing technology made an airtight gas cell (of reasonable weight) virtually impossible to build: there was always some gas loss, causing airships to lose buoyancy during long trips. This made varving gas due to exceeding pressure heigt doubly painful.

Airship Types. Having very briefly touched upon the scientific principles underlying airship flight, the three types of airships: non-rigid, semi-rigid, and rigid will be discussed.

Incidentally, the term "dirigible" applies to all three types. Dirigible is a generic term for any LTA vehicle that is engine- driven and steerable.[34]

Non-Rigids. Non-rigid airships are the classic blimp". They have no internal or external support structure, being simply a fabric bag (or envelope) filled with a lighter than air gas. Inside the envelope are one or more "ballonets", or smaller bags, which help maintain the envelope's shape. Air at ambient pressure is pumped into the ballonets, usually by a small pump or by an air scoop mounted directly behind the engine propellor. The inflated ballonets then press against the lifting gas (which, you recall, is in a compressed state at ground level) forcing it against the envelope's interior. In this manner, the air in the ballonets and the Lifting gas in the larger envelope cooperate to keep the envelope taut. As the airship ascends, the expanding gas presses against the ballonets, forcing air out, thereby maintaining the bag's shape throughout. Pressure height is attained when all the air is expelled from the envelope, leaving the ballonets empty.

The non-rigid airships initially attached their loads to the envelope via a net-like arrangement of ropes fitted across the top of the envelope (similar to a lady's hair net). The bottom of the net was an extra-thick rope girdling the envelope, providing a secure surface to attach the load platform, or gondola. The load platform evolved from a simple basket carrying passengers to larger gondolas containing the propulsion system and crew and passenger accommodations. As non-rigid technology became more sophisticated, the external net arrangement was replaced by an interior gondola suspension system called catenary curtains. This suspension system moved the suspension cables for the gondola inside the envelope itself, allowing the gondola to attach directly to the envelope. With modifications, the non-rigid airship has enjoyed the longest life of all, existing today as the familiar Goodyear blimp. The Navy's airship fleet, which provided admirable, dependable service until1962, was all non-rigid, as will be the new Sentinel 5000 series airships.

Semi-Rigids. The semi-rigid airship is a variant of the non-rigid. In this model, a rigid keel runs from nose to tail. Its purpose was to eliminate the catenary curtain and evenly distribute the gondola's weight along the airship's entire length. Semi-rigid--advocates believed the keel would help the airship retain its shape with less gas, saving weight; however, they found the keel's weight offset any weight savings--indeed, the semi-rigid weighed more than the non-rigid. [35] Semi-rigids airships saw Limited use, although some designers worked with it more than others. Umberto Nobile, the Italian designer whose semi-rigid airships Norge and Italia reached the North Pole, was perhaps the best-known user of the semi-rigid design. Following his disastrous second polar expedition, he left Italy in disgrace, taking service with the Soviet government, where he reportedly built several semi-rigid airships. Thus far, little is known of the Soviet program; however, with the collapse of the Soviet Empire, more information may be forthcoming eventually.

Rigids. The rigid airship is the image conjured up when the words "blimp", "dirigible", "Zeppel in", or "airship" are mentioned. These were the true queens of the skies.

Unlike the non-rigid and semi-rigid airships, the rigid had a metal framework to support the gas envelope (hence the name "rigid"). This gas envelope was a sturdy, waterproofed fabric stretched over approximately circular aluminum frames (rings). These rings, cross-braced (for added strength) with tightly-stretched metal wires, were lined up parallel to each other and transversely the length of the airship; they were connected by longitudinal metal girders. Early transverse rings were 17-sided polygons, eventually evolving to 24- and 32-sided affairs in the postwar period. [36] This formed the skeletal framework over which the gas envelope was stretched. Between each pair of transverse rings were gas cells containing the Lifting gas.

Completely inflated, the cells filled the spaces between the transverse rings. Since total inflation brought them into contact with the metal wire cross-bracing the aluminum rings, the possibility of a transverse cable rupturing a gas cell was a concern; great pains were taken to prevent this by enclosing the cells within two nets to anchor them and their shape. More sophisticated methods were later adopted. Control. [37]

Since the rigid airship maintained its shape with a metal frame, ballonets were discarded. The rigid airship had several advantages over predecessors. First, its rigid, streamlined shape enabled greater speed; unlike its antecedents, whose noses could collapse at higher velocities, its aluminum framework maintained structural integrity at all times. Second, the framework allowed crew access to interior areas, even during flight; major repairs were often performed while underway. Later, US designers built airships without transverse ring cross-bracing, enabling crew access to all interior hull areas. However, this required a thicker ring structure, taking up valuable gas space and making US airships less buoyant than comparably-sized German Zeppel ins, even when using the same Lifting gas. The Zeppel in designers resisted this trend, solving the problem of total interior access by installing an axial walkway running the length of the airship to allow interior inspection and further strengthen the frame. [38]

<u>Construction and Operation.</u> The construction and operation of rigid airships will be focused upon rather than trying to be all-inclusive and cover non-rigids as well. This is because some form of low-level, private non-rigid development has continued for over a century. Of course, given the strides in non-rigids even on the shoe-string basis that has characterized it since the Navy terminated its airship fleet, it is tempting to speculate on the effect of concentrated, government-funded and guided research and development on modern versions of the rigid airship. The materials available in the 1930s (when rigid airship construction ceased) and today

for framing, covering, gas cells, and wire bracing will be discussed.

Framing. In the 1930s, the most advanced framing materials available were early aluminum alloy, low carbon steel, and stainless steel. While at the cutting edge of metaillurgical science, their comparatively low tensile strength and flexibility for their weight greatly impacted useful Lift/load. Materials available today are more advanced aluminum alloys, titanium, kevlar, graphite, fiberglass, and modern stainless steel. The implications of kevlar alone are staggering: five times stronger than steel, it weighs 50 percent less than nylon. [39]

Covering. In the 1930s the only covering materials available were doped (i .e., varnished) cotton fabric and the same early aluminum alloy used for framing. The cotton fabric was given multiple layers of varnish to weatherproof it and render it as impermeable as possible. Here the enemy was sunlight and other deteriorating atmospheric conditions. Sunlight's effect upon the doped cotton covering was the reason airships were hangared between flights. However, despite the best doping, the envelope was still just reinforced cloth, which could be torn or punctured under appropriate conditions. US designers attempted to overcome this problem by building the only operational all-metal airship, the metalclad ZMC-2 (also called the "Tin Bubble").

Built in 1929 for the Navy, the ZMC-2 warrants separate consideration because it was a Quantum leap in construction technology. The envelope was all-aluminum (.008 inches thick), enclosed 203,900 cubic feet, and was filled directly with helium. From her introduction to retirement in 1942, she logged 2256.5 flying hours in 752 flights without a single accident. A prototype, her gross Lift was 12,242 pounds (6.1 tons) and he useful Lift was 3127 pounds (1.5 tons). Being of all-aluminum construction, she was not subject to sunlight deterioration or wind damage. A promising concept, the Great Depression prevented further development, although plans existed for a successor, which, at 618 feet length and 154.5 feet diameter, would have carried 7,400,000 cubic feet of helium, developed a gross Lift of 212.5 tons, and had a useful Lift of 140.75 tons. [40] This design proposal is especially significant when one considers the useful Lift, minus a generous 40 tons for crew, fuel, spare parts, and ballast, would have left a 100 ton capacity for cargo. Therefore, as early as 1929, it was technologically feasible to construct an airship with a greater cargo capability than the C-5. Again, modern technology provides several alternatives for covering material. All are light, stronger, and hold up better to sunlight and other environmental conditions. They are: doped dacron fabric, kevlar laminates, advanced aluminum alloys, fiberglass, and sandwich fiber constructions.

Gas Cells. Gas cells are of keen interest, since they are the heart of the airship; without them, the rest was superfluous, since the airship would not leave the ground. The rigid airship of the 1930s had two types of gas cells: gelatin latex/cotton and goldbeaters' skin/cotton. Every effort was expended to make them as impermeable as possible to prevent gas leakage in flight, since loss of lifting gas meant decreasing lift as the flight progressed. During the earlier era, this was an unobtainable goal, since even the best material (goldbeaters' skin, made from cattle intestines) still leaked. Incidentally, it took 50,000 goldbeaters' skins, measuring 39 by 6 inches each, to make one large gas cell. [41]

Again, today's technology offers several alternatives: kevlar/polyurethane, polyethylene film, mylar film, and dacron/polyurethane. All these exceed the impermeability standards available in the 1930s.

Wire Bracing. Throughout the rigid airship era, the only material used to cross-brace the transverse rings were the strongest wire known: piano wire. However, it is steel (i .e., not lightweight). Also, to ensure maximum internal support, each point on the transverse ring was braced by attaching lengths of piano wire to multiple points on opposite sides of the ring. For instance, each point on the Graf Zeppelin's transverse rings was attached to eight opposite points on the same ring by eight varying lengths of piano wire. Multiply this by any number of transverse rings (17 in the Graf Zeppel in, 16 in the Hindenburg) [42] depending on airship size, and the product is an impressive weight. Today, we can use kevlar ropes, which we have seen are half the weight of nylon but five times stronger than steel. Additionally, recall that gas cell rupture due to prolonged contact with the piano wire of the transverse rings was a great concern to airship designers. Kevlar rope would present far less danger in this area.

Propulsion Systems. Little need be said about propulsion. However, it is useful to consider that from the first significant propulsion system attached to a non-rigid airship (Henri Giffard, 1852) to the launching of rigid airships able to span the globe was only 76 years. Giffard's airship had a single 3hp steam engine, developed about 5mph, flew 17 mi les on its best day, and carried only the pi lot. [43] The Graf Zeppel in, launched in September, 1928, had five 530hp Maybach engines, an unrefuelled range of 6250 mi les, cruised at 70mph, and carried 64 people. [44] The Hindenburg, launched seven years later (March, 1936) had four 1050hp Daimler-Diesel engines, a top speed of 81mph, a similar range to the Graf Zeppel in, and carried 100 people. [45] If one considers that heavier-than-air flight was birthed at Kitty Hawk on December 17, 1903 with a 12 second, 120 foot flight, then the strides made in Light-than-air flight snap into perspective. Approximately the same number of years lies between Giffard's airship and the Graf Zeppel in as lie between the Wright Flyer and the C-5A Galaxy. The difference is rigid airship development stopped in 1937 with the Hindenburg while aircraft development has accelerated.

Control Operations. Control operations of the 1930s are best grasped by appraising the crew sizes. The rigids had very large crews. The Graf Zeppel in had a crew of 44, the Hindenburg 38. Likewise, military rigids had large crews: the USS Akron had 76 crewmen, the

USS Shenandoah 43, the USS Los Angeles 45, and the USS Macon 76. The reason for such large crews was the lack of sophisticated flight support systems. Whereas today we use computers to monitor and adjust engines, fuel Supplies, flight attitude, altitude, etc, the 1930s airships had to use crewmen at various stations. Today's airship commander could perform from his chair many functions previously done by crewmen receiving instructions over a telephone. Additionally, much of the equipment was what one would expect to find in the 1930s: bulky and heavy. For instance, radios used numerous vacuum tubes to accomplish functions now performed by a single printed circuit or transistor. Also, navigation was performed visually with landmarks and "shooting the stars" whereas today's airships would rely upon satellite navigation systems such as the Global Positioning System. Much weight, space, and crew billets would be saved if rigid airships were built today incorporating late 46 twentieth century technology.

Ground Handling. A great disparity existed in ground handling techniques even during the 1930s. For example, while DELAG was still using hundreds of ground personnel to moor and hangar its Zeppelins, the British were using high mooring masts and mechanical devices which enabled mooring operations to be conducted with as few as six men. The US Navy experimented with low mooring masts and portable masts, as well as proving the feasibility of mooring an airship to a ship at sea. Additionally, large crews previously needed to "walk out" hangared airships were eliminated by designing special tractor vehicles to pull the airship into or out of its hangar. [47] However, here too, modern technology could make a contribution. From a military stand point, a mooring system will be needed which enables airships to self- moor, thereby eliminating any need for ground personnel to assist. Such a system, a rocket consideration by a private developer.[48] Additionally, modern sun- proof envelope materials eliminate the need to hangar airships between flights. This is important when one considers most airship damage occurred during the "walk-in/walk-out" hangaring operation.

POTENTIAL MILITARY ROLES

Now the airship's history has been reviewed and the technology behind it discussed, its potential military role must be considered. They were used extensively in both world wars and had a significant early warning mission in the first decades of the Cold War. However, at first blush, advocating a military role for airships today is comparable to suggesting a role for the nineteenth century clipper ship in today's international commerce. But--is this a fair analogy?

Airship military roles were: bombing, reconnaissance, anti- submarine warfare, ocean surveillance, and, in the case of the LZ 57 African relief mission, strategic airlift. The first two roles brought them into direct combat with enemy fighters or in range of enemy antiaircraft batteries--missions wherein their inherent vulnerabilities resulted in appalling losses with little return. The latter roles capitalized on their great range and long mission times to obtain greater returns. The key point is airships, used in roles minimizing--their vulnerabilities while maximizing their capabilities (the same criteria we use for jet aircraft), made tremendous contributions. The following questions are, therefore, reasonable:

1. Is there a use for the airship's traditional strengths of range and endurance?

2. Could modern technology provide additional strengths and capabilities, which enhance their military potential?

3. Is there a military role they are uniquely suited for which has been overlooked or neglected?

To answer these questions, I will, based upon the foregoing technological capabilities discussion, extrapolate what the capabilities of a notional twenty-first airship might be. Jet airlifter strengths and I imitations will be discussed, airship's unique strengths considered, as well as some logistics "lessons learned" in the recent Gulf War.

The Airship of the Twenty-First Century. From the earlier discussion of rigid airship construction and operation, it is apparent modern technology can greatly enhance rigid airship performance. This is a reasonable assumption if one merely replaces the heavier construction materials in the Graf Zeppel in or Hindenburg with materials available today. Obviously, if flight control systems were similarly improved, most of the crew could be eliminated. Also, since a notional military airship is under consideration, there is no need for passengers, whose care and feeding took a significant bite out of these earlier airships' useful Lift and added greatly to crew size. I will also posit the notional airship's envelope and gondola is built along the lines of the Navy's planned Sentinel 5000 non-rigid airship: virtually leak proof envelope (and, since this is a rigid airship, virtually leak proof gas cells) and a frame and crew accommodations virtually invisible on radar screens. Finally, assume the propulsion system is as capable as the Hindenburg's (four engines delivering 4200hp), which enabled sustained speeds of 82mph. With these assumptions, what will be the airship's capabilities?

Lift Parameters. It will have as much gross Lift as the Hindenburg: 242 tons. However, its useful Lift will be much greater than the Hindenburg's since her empty weight (130 tons) will have been significantly reduced due to the weight savings discussed above. Exactly how much weight savings could be realized is reasonably approximated as 30 percent based upon using composite materials in hull construction. [49] With respect to envelope and gas cell weight savings, modern materials are about 65 percent Light with respect to envelope construction and 65-94 percent Light for gas cells. [50] Roughly equivalent weight savings are logical with respect to control mechanisms due to equipment miniaturization strides over the past 60 years. Since hull construction was the largest weight consumer in the rigid airship, and since weight savings in other areas exceed the 30 percent figure, an overall assumption of a 30 percent reduction in the airship's empth weight is entirely reasonable. Indeed, this probably errs on the conservative side, since no assumptions on reduction in propulsion system and fuel weights are made. This weight reduction, approximately 40 tons, would herefore add back into the useful Lift, bringing its total to 152 tons: a 36 percent increase. Assuming fuel, water, spare parts, and crew consume 52 tons of the useful lift, then there is 100 tons of uncommitted useful Lift. This figure is 31 percent higher than the C-5A/B. [51]

Range. Its unrefuelled range will be the same as the Hindenburg's (about'6250 mi les). This is a reasonable assumption because the airship's overall gross weight is unchanged--only the proportional distribution between empty weight and useful lift.

Radar Signature. The airship will be very stealthy, therefore hard to locate with hostile radar. This is due to its construction materials, which will be the same as the new Sentinel series airships. The Sentinels will have a radar-absorbent skin which is literally .invisible to radar, while the gondola, fins, engines, and airborne radar will be configured to disperse or absorb hostile radar signals. Of course, the Sentinel is a non- rigid airship, while our notional airship would most likely be a rigid. However, the same advances in materials technology that enable construction of stealthy non-rigids (radar-absorbent skins, non-metallic structures, low infrared signature exhausts) would be beneficial in reducing a rigid airship's radar return.

Airfield Requirements. This notional airship will not need large airfields either in the CONUS or in-theater. All it needs at either end is a mooring capability, which can quite possibly be self-contained.

Operating Radius. This airship can reach any point on the globe in 10 days or less. This assumption is based on the epochal 1929 circumnavigation of the earth by the Graf Zeppel in, which travelled 31,000 mi les in 12.5 days flying time. Given this notional airship capability, the strengths and I imitations of the heavier-than-air jet airlifters will be considered.

Jet Airlifter Strengths and Limitations. Obviously, an airship can never replace the strategic jet airlifter: we will always need the capability to insert massive combat power into remote theaters virtually overnight. However, in Chapter I the possibility of a GAP in the US strategic transportation capabilities, which an intermediate strategic transportation system could fill, if available, was discussed. Materiel falling into this GAP would be combat support items not needed immediately, but urgent enough that waiting four weeks for sealift to begin regularly providing the needed combat support might be unacceptable.

The jet airlifter provides the capability to be anywhere on the globe (assuming secure airfield availability) literally overnight. Also, unlike the notional airship, it can refuel aerially. Additionally, it can move people as well as cargo; the airship would not be an efficient personnel mover, since sustaining troop combat effectiveness during a 6-10 day airship crossing would likely consume so much useful Lift as to make this a poor investment. Furthermore, the round trip time for jet airlifter (i .e., its ability to make repetitive trips) is much greater than an airship. In the time an airship would use to make a single round trip (CONUS-theater-CONUS) a C-5 could probably make 2 or 3 trips (assuming the 6 day round trip airlifters experienced during the Gulf War is a fair baseline). Also, the morale impact of US ability to almost immediately "show the flag" with fleets of airlifters in a potential trouble spot is critical in crisis management. It's unlikely an airship could have the same impact.

Given these strengths, what are the I imitations of jet airlifters?

Load Assembly. Their loads are assembled at main operating bases (MOBs) in the CONUS or overseas. These loads must be tailored for the aircraft and for the specialized needs of the deployment that particular flight is supporting. This is because the equipment and materiel needed early in a force build up is quite often not in a standby mode, but is an integral part of the moving unit's table of allowance; i.e., they are located with and used by their operators on a regular basis. On the other hand, medical supplies, spare parts, tentage, field hospitals, communications vans, trucks, etc, are maintained in a ready state at various locations and are available for short notice deployment. Unfortunately, troops, equipment, and materiel are seldom at convenient locations, but must be brought to airfields, which can handle the airlifters.

Oversized vs Outsized. WhileC-5s can handle oversized and outsized cargoes, they cannot carry large numbers of them and, when they do, there is very little room for anything else. Also, during the early stages of force insertion, combat support items are often deferred to later dates in order to place as much combat power into the theater as possible. Metaphorically speaking, this means delivering lots of guns and not much butter. Given unlimited airlift and ramp space, we would prefer to phase troops, equipment, and supplies into a theater in balanced ratios; i.e., adequate support arrives with the troops. Unfortunately, we do not have unlimited airlift, so any major buildup, especially in areas with inadequate infrastructure, means making hard choices. Invariably (and this was the case during Desert Shield) combat power gets moved first and logistics has to catch up later[52] Security. At the risk of belaboring the obvious, jet airlifters need a secure airfield. While the C-5 and the C-17 are designed to be operable from unimproved fields close to the battle zone, -their expense and long production lead times make it unlikely a theater Commander in Chief (CINC) will risk such valuable assets to deliver a few tanks.[53]

Since this has not been the accustomed use for strategic airlifters, there is no reason to expect it to change on a future battlefield except in the direst need.

Vulnerability. Jet airlifters are extremely vulnerable to missiles and small arms fire, especially when landing. However, airships are surprisingly survivable against small arms and are no more vulnerable to missiles than jet airlifters. The Goodyear blimp, for instance, has been riddled with as many as sixty bullet holes during its flights without suffering buoyancy problems. [54] This is because an airship envelope is pressurized only slightly above ambient air pressure to maintain shape and Lift. When punctured, therefore, the effect is not the same as a plastic balloon puncture: the effect on an airship is a gradual seepage of gas rather than an explosive burst or forceful gushing. With respect to rigid airships, the Lifting gas is retained in numerous gas cells, each individually pressurized; for the same reason, puncturing one of them does not necessarily impair airship operation. Depending on the type of missile used and the extent of the damage inflicted, it is conceivable an airship could survive a missile strike; all that would be necessary is for sufficient gas cells and control mechanisms to survive to enable positive control. For example, the only US airship lost in combat during World War II, the K-74, took three 88mm gun hits and 200 rounds of 20mm cannon fire from a submarine it was attacking before finally going down.

Direct Delivery Capability. Jet airlifters do not provide the direct delivery capability desired for AirLand Battle. [55] The purpose of direct delivery is to shorten the delays inherent in the logistics pipe line by delivering troops and combat support as close to the battle line as possible; i.e., from Main Operating Bases (MOBs) to Forward Operating Bases (FOLs). [56] This is equivalent to the "cavalry riding to the rescue"; i.e., delivering the combat power directly from the MOB to the battle line. Unfortunately, unless the battle lines are immediately adjacent to a MOB, this will not happen. For instance, in Saudi Arabia logistics lines were several hundred mi les long owing to the distance from theater MOBs to the Saudi-Iraqi border. This required transloading of supplies and equipment to trucks or tactical airlifters, causing delivery delays. Ideally, a direct delivery capability would have enabled us to build up in the CONUS cargo loads tailored for specific units and Lift them directly to that unit without landing at a MOB to transload for follow-on shipment.

Airship Roles. The airship's strengths are range, mission duration, operating costs, and, given sufficient size, cargo capacity. A less obvious strength is the ability, with modern construction materials, to make an airship exceptionally stealthy--nearly invisible on radar screens. The Navy's new Sentinel 5000 air defense initiative (ADI) airships will be. [57] Another strength is an outgrowth of the airship's vertical takeoff and landing (VTOL) capability: its freedom from expensive, vulnerable, and, in many remote theaters of operation, unavailable airdromes. This independence of operation suggests a key military strength--a combat logistics direct delivery system which does not require long production lead times and costs far less than \$170- \$240 mi II ion per copy (the C-17's projected price range). These strengths--range, mission duration, operating costs, cargo capacity, stealthiness, direct delivery capability, and low purchase cost offer significant potential benefits in the projected threat environment of the early twenty-first century. Given the threat is likely to remain limited to enemy fighters, ground to air missiles, and small arms fire, then the airship can operate anywhere the modern jet airlifter can; i.e., a permissive air environment with friendly air superiority. However, if the environment becomes less permissive, with enemy opposition a possibility, then the airship, with its stealth characteristics, low infrared signature engines, and VTOL capabilities, can still operate. This is because the airship, unlike the jet airlifter, is not dependent upon fixed airfields which enemy opposition (fighters, missiles, and sappers) can easily target. The airship can insert and offload its cargo wherever desired, greatly complicating enemy targetting. However, losing one to enemy fire, while regrettable, would not be the setback losing a C-5 or C-17 would be, since its lower unit cost and more rapid production rate would enable us to make up any losses much more quickly. I believe a modern version of the rigid airships of the early twentieth century, enhanced by improvements already available, plus whatever further improvements concentrated research and development may provide, is the answer to the US' intermediate strategic transportation shortfall.

The ensuing discussion will focus upon the airship's potential as an inter/intra theater military airlifter rather than its more traditional ASW and surveillance roles. There are two reasons for this restricted focus. First, these missions need no advocacy; the airship's abilities in these traditional arenas are proven and unquestioned. Second, in an era of encroaching budgetary constraints, airships offer leaders an innovative way to stretch shrnking resources to cover mission requirements. This does not mean "Doing more with less"--it means "Using the right tool for the job." In the case of strategic transportation, it means using strategic jet air Lifters for Immediate requirements, sealift for Sustainment, and devising a third way for Mid-Term requirements. From this standpoint, it is useful to ask what an airship's role might be.

The best way .to describe the airship's potential role is to briefly recapitulate the Desert Shield logistics flow and see if there exist weak areas wherein the airship could have played a supporting role. The extrapolated notional airship, recall, has a 100 ton cargo capacity and, from the CONUS, can reach any point on the globe in less than 10 days.

Gulf War Logistics Lessons Learned. The greatest logistics challenges faced during the force build up rior to the Gulf War were, generally speaking, marshalling, embarkation/debarkation, transit time, and transporter availability/vulnerability/cost. The airship is tailor-made for service in these areas.

Marshalling. Marshalling, arranging or setting in order materiel for onward movement, occurred at both ends of the pipeline during the Gulf build up. This time-consuming process involves moving war materiel from where it is stored to the chosen air or sea point of embarkation (APOE/SPOE) by rail, road, air, or sea. Once there, the various items are assembled into pallet loads (for airlift or break-bulk sealift), loaded into containers (if not already so loaded) for container ships, or placed directly aboard ro/ro vessels. Once loaded onto the conveyor (airplane or ship) the cargo is moved to the theater of operations.

The delay caused by marshalling is currently unavoidable (unless we're dealing with Maritime and Afloat Prepositioning Ships) because our CONUS bases are not always conveniently located with respect to our APOEs and SPOEs.[58] However, under the Direct Delivery concept, it is desirable to eliminate any re-marshalling once war materiel enters the theater. In other words, the goal is to tailor the shipment to the specific needs of combat forces at its destination and then "deliver it directly" to the end user. This capability was unavailable during the Gulf buildup, necessitating cargo offloading at the aerial and sea points of debarkation (APOD/SPOD) , cargo breakdown, and subsequent re- marshalling for movement to end users. Critical time is lost at each end and must be added to the transit time between embarkation and debarkation points. The result is a longer wait by the user for needed war materiel.

The airship's advantage is apparent. Needed materiel, marshaled for the specific end users, can be containerized in the CONUS, loaded into the airship, and delivered directly to the user without an intervening APOD. If the needed materiel is located at a single CONUS station, then the dependency upon APOEs becomes a moot point--with an airship, the APOE is wherever the cargo is located. Additionally, the point-to-point delivery capability implies the APOD can be wherever the airship's cargo is needed. Given this capability, enemy interdiction becomes more problematical, since he no longer has large, vulnerable APODs and SPODs to target but, rather, must deal with a multiplicity of targets, since virtually any place friendly forces are located becomes a viable APOD. The advantages for operations in developing nations lacking adequate APODs or SPODs are intriguing. Embarkation/Debarkation. This feature was touched upon in the foregoing marshalling discussion. During the Gulf buildup, marshalling occurred at the APOEs and SPOEs. With respect to airlifters, cargoes are loaded to maximize cubic volume and tonnage. This frequently means moving cargoes that must be broken down and reassembled at the distant end for subsequent onward movement to specific end users. Sealift has greater potential flexibility because of its larger cubic volume and vastly greater tonnage throughput. This means, within reason, loads built for specific end users can be assembled at the SPOE and the entire load (container, pallet, vehicles, etc) earmarked for delivery to a specific unit. In this instance, therefore, cargo breakdown and subsequent reassembly is not needed, greatly simplifying onward movement and saving time into the bargain. However, nothing is free: the marshalling time saved at the SPOD is purchased by using a slower intertheater transporter, thereby canceling any gains.

Again, the airship's advantages are apparent. Its tremendous Lifting capacity, coupled with cubic cargo storage capacities far exceeding jet airlifters, allow it to carry any outsized cargo possessed or planned for the US military. Also, these loads could be quickly embarked as containerized cargoes Built for specific users anywhere on or near the front lines. Of course, cargo movement does not have to be limited to the "one- sites and two-sites" of unit resupply. The airship is equally capable of moving an entire load of munitions, POL, or a modularized jet aircraft maintenance shop to a rear area supply depot or a bare base--the possibilities are endless. Embarkation itself would be a small matter: simply marshal the load at a designated point, bring the airship to it, lower it onto the load, secure the container to (or within) the vehicle, and Lift off. Since this is a military vehicle carrying cargo rather than passengers, simplicity and speed will be the watchwords for embarkation; therefore, it is reasonable to assume the marriage of cargo to transporter will be speedy (probably less than an hour). Debarkation would be even easier and a function of the APOD.

If the APOD is a developed field, then mooring the airship to the landing site would be accomplished via a fixed mooring system installed at the site. If the APOD is an undeveloped or tactical site, as described in the prologue, then the mooring would be done with a tactical system aboard the airship enabling it to self- moor. Once moored, the load would be discharged the same way for both developed and undeveloped sites: release the containers, cast off the lines, and Lift off.

Transit Time. Transit time brings us full circle to the root problem of intertheater transportation. Presently, war materiel can be moved overnight or, in the case of the Persian Gulf, in 4-6 weeks. This defines a GAP in the US strategic transportation architecture, which forces difficult tradeoffs upon military leaders during a rapid military buildup. These tradeoffs caused us to move via precious airlift war materials not needed immediately, but which could not be delayed until the sealift supply line was established. These tradeoffs could be mitigated with an inter/intra theater transport capability enabling war material movement in the 1-4 weeks time frame via something other than precious jet airlifters. By now, the airship's unique capabilities in this area should be apparent.

Recall that the Graf Zeppel in, in 1929, circumnavigated the globe in 12.5 days actual flying time, traveling 31,000 mi les. Without overstating the case, modern technology could probably improve on that record, since it was recognized even then the engines were underpowered. [59] Postulating a modest twenty percent reduction in traveling time, a modern cargo airship could easily carry its load from a CONUS APOE to a Saudi Arabian APOD, unload, and return to its APOE in ten days (probably less). Potentially, a single airship could have made 1.5 to 2.0 round trips, carrying a 100 ton cargo, during the critical GAP period of 1-4 weeks. The astute reader will probably say "So what?" It is difficult, when one thinks in terms of near-overnight deliveries of 50-70 ton cargoes anywhere in the world, to see anything to cheer about in delivering 100 tons in 5 days (remember: a 10 day round trip implies approximately a 5 day one-way trip). This is a fair question. From a Gulf War logistics perspective, the answer lies in asking what would have been moved in the Mid-Term phase that either to move in the Immediate phase (for want of an alternative) or else deferred to the Sustainment phase. The reader will recall .q conscious decision was made to defer much of the logistics support programmed for the immediate phase in order to insert as much raw combat power as possible up front. [60] Deferred items included POL, munitions, medical supplies, etc. Fortunately, some of this could be borrowed from the Saudis; however, if needed war materiel had been unavailable and we had been forced to move everything needed, choices would have been even more difficult. Force sustain ability would have been purchased, in this case, by reducing initial force size and increasing logistics support in the Immediate phase, leading to a longer buildup time period. This could have courted the risk of a continued Iraqi advance. As it was, the six months long force buildup was constrained by the availability, vulnerability, and replacement costs of strategic transporters.

Transporter Availability/Vulnerability Cost. The reader will recall the Gulf buildup monopolized the airlift fleet, requiring 95 percent of our C-5s and 90 percent of our C-141s be dedicated to the Persian Gulf. Also, recall the first sealift (other than the Diego Garcia

MPS/APS) reached the Gulf 21 days after the 82nd Airborne's Ready Brigade arrived. Also, airlifters and sealifters are very vulnerable; strategic air lifters require total air superiority to assure safe arrival and departure, and unconvoyed sealifters can be interdicted by submarines and mines. Lastly, realize air Lifters and sealifters are not easily, quickly, nor cheaply replaced. The unit cost for C-5s is $149 mi II ion, whereas the estimated costs for C-17s range from $170-$240 million; ro/ro vessels are approximately equal to the cost of the C-17, Too, replacement lead times are long: C-5s require at least a year to build, whereas ro/ros typically require three years construction. Obviously, in a protracted war these lead times could be shortened, but US war planning revolves around short- lived, high intensity combat similar to the Gulf War. Obviously, the best possible world would be to have large numbers of readily available airlifters and sealifters. However, the expense of a fleet large enough to provide this level of readiness would be prohibitive. Also, APOD and SPOD availability and saturation would still be a problem, since first class facilities are limited in the developing world. Another solution could be a high capacity strategic transporter which, while not as fast as a jet airlifter, is still much faster than sealift. Also, it should be relatively insensitive to APOD and SPOD availability, inexpensive to build, and capable of swift replacement in the event of wartime attrition. Again, the airship promises a solution.

Airships and APODs. The airship's potential with respect to APODs has been expounded ad nauseam: all it needs is a landing site somewhat larger than itself. Depending on the wishes of the theater commander, this provides a realistic Direct Delivery capability--something he presently lacks.

Airship Cost Estimates. Insofar as expense is concerned, Morris B. Jobe, president of Goodyear Aerospace, in his 1979 Senate testimony, stated it would be possible to construct hybrid airships (marrying helicopters with rigid gas envelopes) possessing a 75 ton useful Lift for $35 mi II ion each. [61] This particular approach would probably be more expensive than rigid airships owing to the need for new technology development and exploitation. With respect to the conventional rigid airship, however, the price would probably be much lower. For example, the Navy's Sentinel 5000 series of non-rigid airships would cost from $40-$67 million each. [62] However, it must be borne in mind these airships will have sophisticated phased array radar systems, computers, data I ink systems, offensive/defensive systems, and accommodations for a 14 man crew for patrols lasting up to 60 63 days. Also, for cost comparisons, consider the conventional fixed wing platform, which the US Navy believes able to provide the same capabilityas the Sentinel (less the offensive/defensive systems) is a modified B-747 with cost estimates ranging from $750-$800 mi II ion. If this 12:1 ratio is a valid baseline for estimating the cost of a rigid airship built strictly for inter/intratheater cargo transport, then, relative to a C-5, the cost is approximately $12 mi II ion per airship; relative to a C-17, the price tag is $20 mi II ion. This is pure speculation; only research and development will yield the right figures and only quantity production will get the costs as low as possible. However, the possibility of constructing even 6-8 airships, each capable of carrying at least 100 tons of war material, for the price of a single C-5 is intriguing.

In this vein, in the early 1920s the Chief Engineer of the British Vickers Airship Department, H. B. Pratt, advocated use of the airship for global passenger and cargo service. He calculated an airship with a useful Lift of 180 tons (10,000,000 cubic foot gas envelope) could be built for 900,000 pounds sterling. [65] If we assume a buying power of $50:1 pound sterling for today, then Pratt's airship would cost $45 mi II ion today. [66] Of course, this assumes we use the same materials and technology available to him and incorporate none of the technological advances discussed in the earlier formulation of our notional 100 ton capacity airship. Even so, Pratt's figures demonstrate an airship Lifting twice the cargo of a C-5 could be constructed for roughly one-third the cost. One wonders what dedicated Department of Defense sponsored research and development could achieve in this area.

Wartime Attrition. As previously discussed, our strategic airlifters are operated only in areas with total, friendly air superiority. This is dictated by their vulnerability, expense, and replacement lead times. Regardless of they're advertised capabilities to operate from forward, unimproved bases, their limited numbers and virtual irreplaceability (at least, within sufficient time to influence a short war) make it highly unlikely any theater commander will risk them. This alone makes implementation of a Direct Delivery capability a dubious enterprise. However, high capacity, inexpensive airlifters, which could be quickly replaced, would be an operational enhancement a theater commander could find extremely valuable. This would be especially true in a fluid battle situation wherein a favorable outcome may hinge upon timely movement of needed war material to a battle zone.

For all their exotic capabilities, airships are a relatively simple technology. While metallurgical, propulsion, and aerodynamics advances may permit improvements in speed, weight, range, guidance, mooring, etc, airships are still I just steerable gas-fi lied bags. The early rigid airships, like their fixed wing counterparts, were almost completely hand crafted--the assembly line approach was unknown. Even so, from the beginning of World War I in August, 1914 to the Armistice in November, 1918, Germany produced 91 huge rigid airships--averaging nearly 2 per month. This feat was achieved with a resource base which had to support a six mi II ion man army, a modern navy, and a two-front war. One speculates that modern manufacturing processes could at least equal (and hopefully surpass) the performance of early twentieth century

German craftsmen. If so, then an industrial nation like the United States should be able to produce, during wartime, at least two, and probably many more, airships per month. Such a production rate would probably be sufficient to make good any wartime losses; indeed, it might permit a wartime expansion, if desired.

CONCLUSION

It is apparent the airship offers some unique advantages with respect to APOD availability, expense, and ability to replace combat losses which our jet airlifters do not offer. While the airship, with its lower speed, will not replace the fixed wing airlifters, it could provide an adjunct capability which would relieve stresses imposed upon our jet airlifters during the early stages of a force buildup. This additional capability would enable the US to rapidly project massive combat power into distant theaters and, with near equal rapidity, emplace the logistics support to sustain them until the sealift, which will provide 95 percent of all support, is established.

In an era when force structure is likely to shrink to pre- Korean War levels in the face of growing economic and military competition from Europe, Japan, and, eventually, a resurgent Russia, our armed services must seek innovative ways to maximize their joint combat power. For the Air Force, this entails devising even faster ways to deploy and sustain tactical wings and support land forces. Given the trend towards reduced overseas basing, it's unlikely the US will have substantial numbers of troops and aircraft forward deployed. Future crises may require building virtually overnight the logistics infrastructure to support forces in an unprepared theater. To accomplish this, the US must be able to move large amounts of war materiel via airlift without significantly reducing the troop deployment rate. If airship technology were afforded a fraction of the research and development funds allocated to developing new fixed wing aircraft technologies, the return on investment could be astounding. This mature, proven technology may be the key that unlocks the power projection challenges of the twenty-first century. We will not know until we give it an honest appraisal.

EPILOGUE

Colonel Jones' eyes scanned the report with a sense of relief mingled with satisfaction. Munitions, POL, rations, medical supplies, tentage--the multitudinous items needed to support a tactical aircraft wing in a forward area: all stock levels were up to par. He still could not believe it. Three weeks ago there were indications of another Iraqi force buildup near the Kuwaiti border and the United States decided not to take any chances this time. The President decided a show of force in the Middle East was needed to prevent another round of Iraqi aggression in the Persian Gulf. Colonel Jones had been a Captain in HQ Military Airlift Command the last time it had been necessary--back in 1991. He remembered all too well the frantic days of trying to play catch up with the logistics support needed to sustain the rapidly growing force presence in Saudi Arabia. Those had been the grim days; everyone's mind held one question: Would Saddam wait, or would he call our bluff? We had to sacrifice logistics support in the early stages in order to put troops and combat aircraft into Saudi Arabia, hoping he would hesitate long enough for us to get the war material into the theater needed to sustain combat operations. Thankfully, we had taken a lesson from those times and addressed our transportation shortfall. Three weeks ago, this desert airstrip had been just another 3000 foot runway near the Saudi-Iraqi border; today it (and four others they had activated simultaneously) housed a tactical wing and all the support needed to sustain combat operations. Wonders never cease.

His eyes lingered on the ARRIVALS block: eight airships inbound today, arrivals staggered an hour apart, 1000 tons of cargo. He skimmed the attached lading sheets and felt another glow of satisfaction when he saw the modular engine repair facility the wing had requested last week would be arriving, along with twenty new engines. Good! He remembered the frantic feeling when his staff real zed the repair facility they had initially deployed was inadequate for the workload. Good thing this was not Desert Shield--he would have been fortunate to get it here in six weeks back then. As it was, it would be ready for operations tomorrow evening: eight days after request. He quickly leafed through the other items on the lading sheets: air-to-air missiles, fuel bladders, water purification system, aircraft tires, forklifts, and auxiliary power units. He noted the communications equipment the comm guys requested at the last minute had made it on this shipment, too. That was good; the air traffic control and landing systems (ATCALS) had taken a beating in the heat.

Chemical gear--MAIL! Outstanding! Maybe Iris had written again. Again, he remembered the Gulf War and the amount of jet airlift volume the mail had eaten up--a price they had no choice but to pay because the morale cost of slow mail delivery had been unacceptable. Now,"the troops got their mail as fast, if not faster, and it came by airship.

He rose from his "desk" (a sheet of plywood sitting on a couple of boxes) and strode to the door of his tent. Looking past the strip and revetments, he gazed, not for the first time, on the airship mooring masts behind the supply compound. Amazing to think what a difference those masts, and the aerial transport concept they represented, had made in bare base operations.

Fifteen years ago this would have been a fantasy--from empty strip to full-blown wing operations in less than three weeks. Thanks to those airships, the POL, munitions, and maintenance support needed for combat operations had been on hand a week after the President said "GO!" Thanks to the wing's rapid response (and that of the other five deployed wings) the Iraqis seemed to be having second thoughts about moving south. Intelligence said the latest reports indicated the force concentrations were breaking up.

Maybe we won't have to fight this one after all.

NOTES

1. A. F. L. Deeson, An Illustrated History of Airships (Bourne End, Bucks: Spurbooks Limited, 1973), 15-20.
2. Douglas Botting, The Giant Airships, (Alexandria VA: Time- Life Books, 1980), 22.
3. Deeson, 24.
4. See Deeson, 34 and Peter W. Brooks, Historic Airships, (Greenwich, CT: New York Graphic Society Ltd., 1973), 52-53, 59.
   NOTE: The LZ1--made only three flights, subsequently being broken up when she proved underpowered and almost uncontrollable. However, the lessons learned in this first attempt were used in the construction of her sister ship, the LZ2, in 1905. Interestingly enough, the indefatigable Count von Zeppel in, his personal fortune nearly gone due to his obsession with airship development, received permission from the State of Wurtenrg to finance the LZ2 through a lottery.
5. See Deeson, 37 and Botting, 40.
   NOTE: DELAG got its start with respect to fields when several German cities, eager for airship service, offered hangars and fields. These early cities were: Frankfurt, Baden Baden, Dusseldorf, Hamburg, Potsdam, Gotha, Leipzig, and Dresden.
6. See Deeson, 38 and Botting, 42.
   NOTE: The exact passenger numbers are given as 10,197. This represents four years of deluxe airship passenger operation which, according to Bottling, were flown without so much as a bruise being inflicted on any (perhaps a somewhat extravagant claim). Nonetheless, it's significant there were no serious passenger injuries despite the relative newness of this transport medium. Its unlikely passenger aircraft could make a similar claim.
7. See Deeson, 53-55 and Basil Coilier, The Airship: History, (New York, NY: G. P. Putnam's Sons, 1974), 74.
8. See Deeson, 56 and Coilier, 74.
   NOTE: The Kaiser's extreme reluctance to commence an aerial bombardment of London was due to the blood relationship between the royal houses of Germany and England. Indeed, all the royal houses of Europe were related to one another. For example, the Kaiser and the Tsar, cousins, maintained a personal correspondence throughout World War I, addressing each other as "Willy and Nicky".
9. Deeson, 61-64.
10. See Deeson, 64 and Botting, 73. 11. Deeson, 64-71.
    NOTE: Beatty attributed the German High Seas Fleet's ability to successfully break off the engagement before significant damage was done and subsequent successful evasion of the British search for it to the German Zeppelins. Deeson provides the following interesting information:
    “Shortly after the battle [Beatty] said: 'The enemy still has the monopoly of the best air scouting in good weather, when one Zeppel in can do as much as five or six cruisers.” Coming from a British admiral who commanded the battle cruisers at the Battle of Jutland, this is an amazing tribute.
12. Deeson, 71.
13. See Deeson, 76 and Robert Jackson, Airships: A Popular History, (Garden City, NY: Doubleday & Company, 1973), 179.
14. Deeson, 77.

NOTE: Eventually both were turned over to Allied nations as reparations under the Versailles Treaty. Lake Konstanz was given to the Italians, (who dismantled her in 1928), while Nordstern went to France (who dismantled her in 1926).

15. See Deeson, 78 and Henry Beaubois, Airships: Yesterday, Today, and Tomorrow, (New York, NY: Two Continents Publishing Group, 1976), 185.

16. See Deeson, 87; 126 and Beaubois, 195.

NOTE: The actual cause of the Hindenburg's fiery crash has been the subject of speculation for a half century. Of all the theories advanced, that of a chance electrostatic discharge-igniting hydrogen seeping from a leak near the tail has enjoyed the widest acceptance. However, this conflicts with the testimony of crewmen working in that area who say they heard what appeared to be a muffled explosion just before the fire. This would appear to support a sabotage theory. Regard/less, we're unlikely to every know what actually caused the crash. I believe it's far more important to remember the following:

1. The Hindenburg, originally designed to use helium, was inflated with hydrogen because the US, the world's only helium supplier, had embargoed sale of this gas to Germany.

2. Prior to the crash, DELAG had safely operated commercial dirigibles since 1910 (except for the World War I hiatus). This involved transporting tens of thousands of passengers over several mi II ion mi les. Those killed on the Hindenburg were the only commercial passengers ever killed in an airship accident.

3. In a properly designed airship, hydrogen is no danger. The Hindenburg was the penultimate airship--so well designed she even had a smoking room (a first). In fourteen months of operation, no problems were encountered.

17. Deeson, 88-102.

NOTE: Part of the reason Great Britain bowed out of the airship market was the ambivalent attitude the succession of postwar governments displayed towards passenger airships. Saddled with immense war debts, the British saw little value in an airship industry. It's likely their wartime experiences with Zeppel in raids may also have played in this sentiment. However, the British had their airship enthusiasts just like other industrialized nations and, in response to their incessant importunities, approved construction of two airships in order to explore their potential for trade and commerce. These airships were the R100 and R101.

The R100 was built by a Vickers subsidiary under contract to the government and was completed on schedule and without any cost overruns. It eventually completed a successful trans-Atlantic voyage, proving 10 mph faster than her sister ship, the R101.

The R101 was built by the government-owned Cardington plant, which had been taken over from Short Brothers. The R101 was supervised by government bureaucrats, eventually being completed late and over budget. Determined to prove the government-built airship was the equal of the privately- builtR100, the R101 was launched on her maiden voyage to India on 4 October 1930 without a Certificate of

Airworthiness. This was a purely political move prompted by the desire of the new Viceroy of India, Brigadier General

Lord Thompson, to travel to his new post aboard her. Despite unsatisfactory flights conducted the previous summer, a "decision" was made to conduct the airworthiness trials en route to India. Disaster overtook the R101 the next day over France when the airship crashed into a hill near Beauvais. Of the 54 people aboard, only 6 survived; Lord Thompson was not one of them.

This disaster nailed the lid on the airship's coffin where Britain was concerned. The

successful R100 was subsequently sold for scrap.
18. See Deeson, 103 and Guy Hartcup, The Achievement of the Airship, (North Pomfret, VT: David and Charles, lnc.1974), 157.
19. See Deeson, 105-107 and Hartcup, 219-224.
20. Deeson, 107-110.
21. Ibid, 113-120.
22. See Deeson, 121 and Lord Ventry and Eugene M. Kolesnik, Airship Saga, (Link House, West Street, Poole, Dorset, U. K.: Blandford Press, 1982), 166.
23. Deeson, 121. 24. Ibid, 123.
25. "Lighter-Than-Air Systems," AEROSPACE AMERICA, vol 24, no 12, December 1986, p. 84.
26. R. P. Largess, "Reviving the Naval Airship," NAVAL FORCES vol XI, No 1 (1990): 13.
27. David Brinkman, "Sentinels in the Sky," JANE'S DEFENCE WEEKLY vo I 15, no 3 (19 Jan 91): 89.
28. Douglas H. Robinson, Giants in the Sky, (Seattle, WA: University of Washington Press, 1973), xvi.
29. Deeson, 126.
30. William J. White, Airships for the Future, (New York, NY: Sterling Publishing Co., 1978), 156.
31. Deeson, 126.
32. Robinson, xvi i.
33. Hartcup, 108.
34. White, 152.
35. Ibid, 23.
36. Hartcup, 180.
37. Ibid, 28.
38. Ibid, 27-28.
39. White, 78.
40. Robinson, 226.
41. White, 78, 154.
    NOTE: Given the agitation level of today's animal activists, this probably would not be a useful material in any event.
42. Robinson, (App A: "The 161 Rigid Airships Builtand Flown, 1897-1940: LZs 127 & 129), 339-340
43. Deeson, 20.
44. Beaubois, 185.
45. I bid, 195.
46. White, 82.
47. Ibid, 84.
48. William Garvey, "Rebirth of the BI imp," Popular Mechanics, vol 168, no 8, August 1991, p. 32.
    NOTE: The rocket-propelled anchor is a backup mooring system which will be used by Eric Raymond to moor his experimental solar sky ship in the event of bad weather or mishap. Incidentally, the solar sky ship is a 100 foot long, 18 foot diameter, rigid airship which will be powered by a 5hp electric engine driving a 16 foot propellor. He expects it to achieve a daytime cruising speed of 60mph and, after dark, to be capable of 40mph running on battery

current stored during the daytime.

49. Joseph F. Vittek, Jr (Ed.), Proceedings of the Interagency Workshop on Lighter-Than-Air Vehicles, M.I.T. FIight Transportation--Laboratory, FTL Report R75-2 (January, 1975)--[Citing the NASA Advanced Technologies Transport Study], 237.
    NOTE: The specific reference to the NASA study asserts transport aircraft could achieve up 30 percent weight reductions with composite materials. However, the baseline aircraft is the standard fixed-wing variety, which inevitably uses heavier materials as a function of the aerodynamic stresses it is subjected to at high velocity. From an airship point of view, the lower stresses experienced (due to lower velocities) would argue for even greater use of composites. The 30 percent weight reduction cited in the text is, therefore, probably much lower than would be achievable with a rigid airship. The reader is referred to the entire article (pp 223-241) for a full treatment of the potential composite materials have for airships.
50. Vittek, 226.
51. USAF Airlift Master Plan, [Hereafter cited as AMP] (Scott , AFB, IL: HQ MAC/XPPB [29 September, 1983]), Table A-2, p A- 10.
    NOTE: The AMP states the C-5 can carry a 121 ton payload up to 1650 NM (p 11-4); however, the referenced table shows its long-range (2500 NM) payload capability as being only 68.9-tons. Obviously, the higher figure is the ideal, representing the total deadweight the transporter's Lift can get off the ground. To maximize the Lift, the C-5 (indeed, any transporter) would have to carry small, dense cubes, which stack easily and use every bit of available space.
    Realistically, cargoes simply do not come in uniformly dense, cubic shapes--for example, vehicles, helicopters, tanks, mail, rations, etc. In other words, the bulky, low-density cargoes consume airlift volume, which could carry denser items, causing payloads to be lower than the ideal. Since the AMP uses a 68.9-ton notional payload for long-range transport, this is considered a more reasonable load.
52. Murray Hammick, "Lost in the Pipeline," INTERNATIONAL DEFENSE REVIEW (9/1991): 998.
53. Jeffrey Record, U.S. STRATEGIC AIRLIFT: REQUIREMENTS and CAPABILITIES, National Security Paper: 2, (Cambridge, Mass and Washington, D.C.: Institute for Foreign Policy Analysis, Inc., [January, 1986]): 8-9.
54. Michael L. McDaniel, "Offensive Uses Of the Naval Airship," U.S. NAVAL INSTITUTE PROCEEDINGS vol 116, no 2 (February, 1990): 90.
55. See AMP, 11-8, 9 and "Draft C-17 Validation," HQ MAC, Scott AFB, IL, 1983 (as cited by Lt Col Charles E. Miller, USAF, in Airlift Doctrine, 1988, p 418, note 88).
    NOTE: The Direct Delivery capability described in the AMP and Airlift Doctrine envisions inter/intratheater operations from MOBs directly to FOLs. The C-17 will supposedly have this capability. Given its escalating cost projections (it's already projected to cost more than the C-5) it's difficult to envision a CINC being more willing to risk a C-17 in a FOL than a C-5 (which does not operate into FOLs). Therefore, it's reasonable to assume we will continue to rely on C-130s for the foreseeable future, which necessarily means we will have to transload strategic jet airlifter cargoes onto C-130s (or surface transport) at theater MOBs for onward movement to FOLs. This is the same system we use today.
56. Lieutenant Colonel John A. Skorupa (USAF), Airlift Operations in Hostile Environments, (Maxwell AFB, AL: 1989),8.

NOTE: A viable airship transporter with the same range as the Graf Zeppel in or the Hindenburg would enable us to have the desired Direct Delivery capability. This system could operate either from the CONUS or within the theater itself.

57. See Garvey, 32 and "Airship Ideal for Cruise Missile Defense," ARMED FORCES JOURNAL INTERNATIONAL (September, 1991): 50.
58. Colonel Gilbbert S. Harper (USA), "Army Logistics in 2010,"ARMY LOGISTICIAN (September-October 1991): 20.
59. US Superintendent of Documents, Hearings Before the Subcommitteeon Science, Technology, and Space: First Session on Propelled Lighter-Than-Air Vehicles,27 February and1 March Ser No 96-6, [Hereafter cited as "Hearings"] (Washington, DC: US Government Printing Office, 1979), p 149
60. Hammick, 998.
61. Hearings, 105.
62. See Largess, 12 and Ramon Lopez, "Airship Awaits MilitaryUplift," INTERAVIA AEROSPACE REVIEW vol 46, (September 1991): 39.
63. See David Brinkman, "Airship Ideal for Cruise Missile Defense", 50 and "Second Age of the Airship?" JANE'S DEFENCE WEEKLY vol 15, no 2 (12 Jan 91): 50-51.
64. See Garvey, 31 and Brinkman, "Sentinels in the Sky", 89.
65. H.B. Pratt, Commercial Airships, (London: Thomas Nelson and Sons, Ltd, 1920), 87.
66. Brooks, 52-54.

    NOTE: The discussion in Appendix 3, "Manufacture of Rigid Airships," demonstrates our estimates may not be too far off. He estimates the production costs (in 1972 dollars) of the Hindenburg would be $9-10 mi II ion. His figures are a straight buying-power comparison between 1936 and 1972 and do not include the costs for research and development and tooling up for mass production. Brook makes some interesting observations on the "Learning Curve" associated with production of new types of equipment (it was first observed in rifle mass production) and discusses how it was found to be equally valid in the aerospace industry. Apparently, doubting production numbers results in a 20 percent reduction in man-hours per unit required to produce the entire run. He attributes this to "working the bugs out", fine-tuning the production line, and the corporation's recouping its initial investment.

    The implications for airship production, especially today, are that the more airships produced, the lower the cost. This will be especially true as modern production technology reduces the construction man-hours; for example, the Hindenburg required 1,780,000 direct construction man-hours to build, using early twentieth century production technology.
67. Robinson, the Sky. Appendix A, "The 161 Rigid Airships Built and Flown,1897-1940", 330-343.

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