

Modern Airships: A Possible Solution for Rapid Force Projection of Army Forces

**A Monograph
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Abstract

MODERN AIRSHIPS: A Possible Solution for Rapid Force Projection of Army Forces
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Current U.S. strategic lift assets do not meet the Army's deployment needs in today's dynamic global environment. The Army transformation deployment objectives call for a deploying brigade task force in 96 hours, one division in 120 hours, and five divisions in 30 days. This monograph examines the role modern airships can fulfill in the deployment process.

The deployment process involves four phases: pre-deployment activities; movement to and activities at port of embarkation; movement to port of debarkation; and Joint Reception, Staging, Onward Movement, and Integration. This process is labor intensive and time consuming, especially so when deploying heavy forces. This process is also very reliant on Aerial Ports of Debarkation (APOD) and Sea Ports of Debarkation (SPOD). This reliance makes JRSOI sites in a theater somewhat predictable and thus a target for the enemy. Current OSD belief is that a lighter and more lethal fighting force could complete the deployment process faster than current heavy forces. Operation Iraqi Freedom, however, demonstrated heavy forces are still needed to defeat the enemy. Airships represent a new way of quickly deploying Army forces into a theater of operation.

Modern airships by design are capable of short-take off and landings (STOL), and vertical take-off and landings (VTOL). This VTOL capability enables the airship to land practically anywhere, independent of most infrastructure support. This ability would allow deploying heavy forces to be picked up at their home-station and transported directly to a location directed by the Combatant Commander, bypassing the labor intensive and time consuming portions of the deployment process. The challenge facing DoD is determining if this type of transport is feasible and acceptable for military use.

DoD has already sponsored two studies on two very different airship designs, thus demonstrating DoD is interested in the airship heavy transport concept. This monograph highlights some of the findings from those studies and looks at historically proven uses of airships and some contemporary uses as well. Contemporary transports, the deployment process, and the associated challenges for deployments are also discussed. Together this information is used to assess feasibility and acceptability of airships as heavy transports. This monograph concludes with a positive assessment for the airship and recommendations for how DoD should proceed toward the use of airships in the not too distant future.

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INTRODUCTION

THE PROBLEM

The period 1992 to 2000 saw reduction in both the Army size and units deployed overseas. The Clinton Administration “envisioned a smaller, highly capable, and flexible force countering regional aggressors anywhere in the world. These forces required a robust transportation system to move them quickly.¹ This transportation system cost \$20 billion dollars from 1998-2002, representing about seven percent of the overall military procurement for that period.² Items purchased included new C-17 transport jets and more sealift ships like the Large Medium Speed Roll-on/Roll-off (LMSR) vessel. Even with these new lift assets; the Army still has difficulty today meeting its transformation deployment objectives: a Brigade Task Force (BCT) in 96 hours, one Division in 120 hours, and five Divisions in 30 days.³ Consequently, the Army still needs a transportation asset that enables it to meet the deployment objectives.

Transporting forces is only one critical requirement of the deployment process. Other critical requirements include air and sea ports of debarkation (APOD/SPOD) able to receive and stage forces; ground lines of communication (GLOC) for onward movement of those forces to where the combatant commander needs them; and an adequate defense to secure APOD/SPOD/GLOC from attack by an adversary. Even when these critical requirements exist, as in South Korea, everyday civilian, commerce, and military traffic competes with U.S. forces for accessibility. Together these critical requirements create the steady flow necessary to deploy forces and their sustainment packages quickly from the U.S. into an area of operation (AO). A

¹ Congressional Budget Office (CBO), *Moving U.S. Forces: Options for Strategic Mobility* (Washington D.C.: CBO, 1997), Preface 1 (hereafter cited as CBO).

² Ibid, 1.

³ Information Paper, *Army Prepositioned Stocks (APS)-3/Army Prepositioning Afloat (APA)* (Washington D.C.: Pentagon, HQDA, DALO-FPP, 2001), 2 (hereafter cited as APS Info).

lift asset that can divorce itself from these critical requirements could help to ensure an uninterrupted flow of Army forces, and allow the Army to meet its deployment objectives.

The number of airplanes and ships the Transportation Command (TRANSCOM) has at its disposal is irrelevant without suitable APOD/SPOD/GLOC infrastructure and the ability to prevent their denial. The Air Mobility Command (AMC) Strategic Plan 2002 (STRATPLAN 2002) recognizes this fact. The plan states, “the chief limiting factor on deployment operations is usually not the number of available aircraft or crews but is instead the capability of the en route or destination infrastructure to accommodate the ground operations of air lifters and air re-fuelers.”⁴ The Army’s recent Afghanistan experience highlights the difficulties of moving forces, supplies, and Humanitarian Assistance (HA) into a landlocked and austere AO present. A lift asset that can bypass damaged or non-existent ports and road networks could help to establish a reliable flow of military forces and HA into these types of locations.

The Clinton Administration’s decision to increase the number of strategic lift planes and ships failed to recognize that increasing lift assets does not increase the number of suitable APOD/SPOD/GLOC infrastructures. Instead, an increase in lift assets only serves to increase the need for en route and destination support. Reducing the U.S. dependency on APOD/SPOD infrastructure would enable the deploying forces to enter the military theater at a greater number of places. That alone would make U.S. plans less predictable and in turn complicate the enemy’s response. America’s adversaries currently can use theater ballistic missiles (TBM), man-portable-air-defense systems (MANPADS), Special Operating Forces (SOF), and in some cases, diesel-electric submarines to deny APOD/SPOD/GLOC support required for the Joint Reception Staging Onward Movement and Integration (JRSOI) of forces into an AO. A lift asset that needs

⁴ Air Mobility Command (AMC), *Air Mobility Strategic Plan 2002* (Scott Air Force Base: AMC, 2001), Vol. 1, Section 2, Paragraph 9 (hereafter cited as AMC).

no APOD/SPOD/GLOC support, can deliver forces when and where the combatant commander requires without JRSOI.

AMC envisions future airlift divorcing itself from APOD infrastructure support to avoid enemy efforts to cripple those facilities. Modern helium filled airships capable of vertical take-offs and landings (VTOL) may require little or no support and represent a way to avoid the effects of such attacks. Figure 1 illustrates how an airship as part of the deployment process could provide point-to-point delivery of forces to the combatant commander. Modern airship designers like Advanced Technologies Group (ATG) assert they can construct an airship with this required capability.

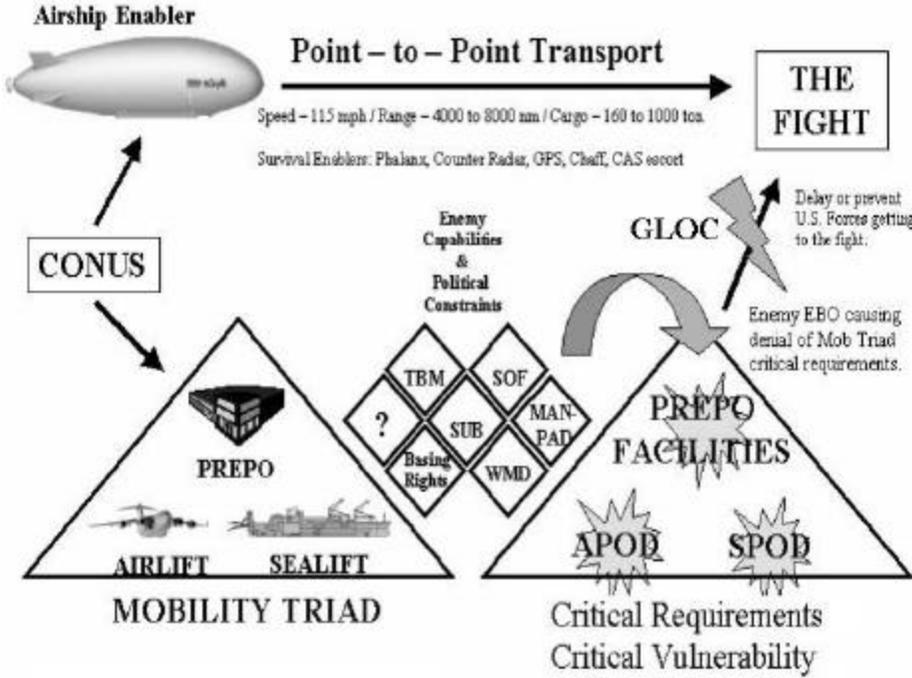


Figure 1: Conceptual illustration of a modern airship in the deployment process.

THE SOLUTION

Airships represent a means to overcome threats to port and road network infrastructures and to meet the AMC vision of future strategic airlift divorced from those facilities and networks. Airships employ lighter-than-air (LTA) gas for lift while engines, rudders, and stabilizing fins, attached to the envelope, propel and steer the vehicle. Airships can land in the following modes: commercial take-off and landing (CTOL), short take-off and landing (STOL), or vertical take-off and landing (VTOL). An airship's VTOL ability is what makes it an attractive option for inserting forces into locations normally devoid of APOD/SPOD/ GLOC support. The challenge facing airship development is the creation of commercial markets necessary for financial viability. Without these markets it is highly unlikely the military will ever consider using airships as part of the mobility triad.

Currently DoD is not interested in procuring its own airships. Instead, DoD prefers that the private sector develop airships with strategic lift capabilities and then enroll them in the CRAF program. Emerging airship designs are capable of transporting up to 1,100 tons of equipment and supplies (equivalent to 7 x C-5 or 13 x C-17 loads) and up to 900 passengers. These vehicles have a multitude of commercial uses and may give DoD what it wants. Some Russian airship designers even feel it is possible to operate an airship using nuclear power.⁵ Mitigating airship vulnerabilities to weather, small arms fires, and missiles has sparked research incorporating into the airship design such things as Doppler radar, GPS, Kevlar fabrics, and electronic jamming devices. These survivability enablers together with heavy lift capabilities could possibly make airships an accepted means of transport for future commercial use and military operations.

⁵ Henry Beaubois, *Airships: Yesterday, Today, and Tomorrow* (New York: Two Continents, 1973), 194 (hereafter cited as Beaubois).

AIRSHIPS AND THE STRATEGIC MOBILITY TRIAD

Strategic Airlift, Strategic Sealift, and Army Pre-positioned Stocks (APS) are the elements of the Strategic Mobility Triad (refer back to figure 1). Each capability has its own advantages, disadvantages, and vulnerabilities. Airlift is the fastest of the three, but costs the most and moves the least amount cargo. Additionally, airlift needs extensive APOE/APOD infrastructure support. Airlift is also highly vulnerable to anti-aircraft fire, MANPADS, and weather. Sealift is the slowest of the three, but costs the least and moves the most cargo. Additionally, sealift needs extensive SPOE/SPOD infrastructure support. Sealift is also vulnerable to mines, submarines, and weather. Both airlift and sealift are dependent on JRSOI activities to receive and flow forces from the APOD/SPOD over GLOCs to where the combatant commander directs. Augmenting both military airlift and sealift are two commercial programs: the Civil Reserve Air Fleet (CRAF) and the Voluntary Intermodal Sealift Agreement/Voluntary Tanker Agreement (VISA/VTA).

“Under CRAF and VISA/VTA, commercial companies agree to make planes and ships available to the military during wartime”.⁶ These aircraft and ships face the same dangers as their military counterparts during deployments and rely on JRSOI as well. Two additional vulnerabilities affecting CRAF/VISA/VTA are bankruptcies and strikes. When these happen, reliance on CRAF/ VISA/VTA can adversely affect the military’s ability to deploy. Airship availability through CRAF, DoD’s preference, would be affected by these bankruptcies or strikes as well – a good reason why the military might want to reconsider the merits of procuring and owning their own airship fleet.

Untouched by either bankruptcies or strikes is APS, the last element of the triad. APS combines the advantages of both airlift and sealift (speed and quantity) by storing equipment

⁶ CBO, Summary, 1.

where it is most likely needed. However, the decision to store equipment in certain parts of the world requires planners to predict where the next major conflict will arise. Currently planners have determined that the areas posing the greatest threat are Korea, South-West Asia, and Europe. APS on ships are also available to reinforce land-based stocks or to respond to a conflict where stocks are not stored. APS while not directly threatened by MANPADS or maritime type weapons (except for APS afloat), make a very attractive target for TBM, SOF, or terrorists. Troops falling in on APS sites normally arrive by aircraft, and as such face APOD vulnerabilities. APS also presents a training challenge. Equipment normally stored in APS is older and lacks the communication and digital upgrade soldiers are currently training on back at home-station.⁷ When this is the case, valuable time is lost re-training or waiting for upgrades to the equipment. Airships capable of transporting units in their entirety (company/battalion sized elements) from home-station to point of use may eliminate the need for some or all APS stocks, thereby minimizing time lost re-training or upgrading equipment.

The addition of airships into the mobility triad's airlift inventory may reduce the amount of time necessary to deploy forces from the U.S. to a theater of operation. VTOL, large cargo capacity and speed enable a modern airship to deliver heavy, medium, or light forces in company to battalion size elements to practically anywhere the combatant commander directs. Contemporary airlift and sealift can only provide comparable service when APOD/SPOD facilities are available, in both use and locale. Modeling scenarios for Korea found that seventeen SkyCat 1000 airships (equivalent lift capacity of a LMSR-plus) could very well deliver the SBCT (14,600 tons of equipment and 3,000+ soldiers) from Fort Lewis within 90 hours.⁸ The Korea modeling scenario also concluded airships could perform the deployment for one-third the fuel

⁷ Dr. Derek Povah, *What Do You Know About APS-3* [article on-line] (Fort Lee, VA: Army Logistician, 2000, accessed 14 Aug 2002); available from <http://www.almc.army.mil/alog/issues/JulAug00/ms541.htm>; Internet, (hereafter cited as Povah).

expense of a C-5 aircraft. The C-5 was the only aircraft evaluated for this scenario because it is the only airframe comparable to the airship in cargo capacity. Airships offer additional economies. Airships do not require KC-135 tanker support to maintain an air bridge. Airships can deliver SBCT elements directly to an assembly area bypassing JRSOI activities. Finally, airships able to transport company and battalion sized units in their entirety may reduce the need for APS sites and their associated logistical footprint. These findings, along with others (see Appendix B) present a compelling argument for the use of airships as heavy transporters.

Adopting airships as a part of the mobility triad would be a significant change in military thinking. To make that change airships must demonstrate they are safe, durable, and cost/time efficient modes of transport viable for both commercial and military use. Demonstrating the feasibility of airships entails assessing several criteria. Some of the criteria are strictly military while others address the commercial and political needs for adoption. The first criterion is safety because most people know about the Hindenburg disaster and judge the airship unsafe. The next criterion is marketability because DoD must be convinced of the viability and utility of airships before it will be willing to spend millions of dollars on their use. Speed is another criterion because airships must travel fast enough to be of use to the commercial world and meet the Army deployment objectives. Cost is always an issue and therefore, is a criterion for airships because they must be cost effective in comparison to other modes of airlift. Another criterion is AMC's requirement for future airlift to divorce itself from APOD support, a capability that enhances throughput of forces into an area of operation. The final criterion assessed is vulnerability because most people view airships as delicate vehicles. The assessment of these criteria should reveal how feasible and acceptable airships are for military operations and to a lesser degree commercial uses.

⁸ *SkyCat 1000 Engineering Study*, Final Report (prepared by Camber Corporation and SkyCat Technologies Inc., received CD ROM from CJCS J-4 via mail 23 October 2003), 186-191 (hereafter cited as SkyCat Study).

In assessing airship potential, it is helpful to look at historical and contemporary accounts of airships in both a commercial and military capacity. Airship history, as well as current experiences, helps to establish airship technology as proven and tested. History of the airship also provides a base, in tandem with projected airship capabilities, with which to compare contemporary lift assets of the mobility triad. Comparison of these varied lift assets will reveal airship superiority in some areas and not in others. It is, however, not necessary for the airship to demonstrate superiority in every dimension to prove its worth. Airships must instead achieve acceptable overall ratings, and in the end significantly improve the Army's deployment process.

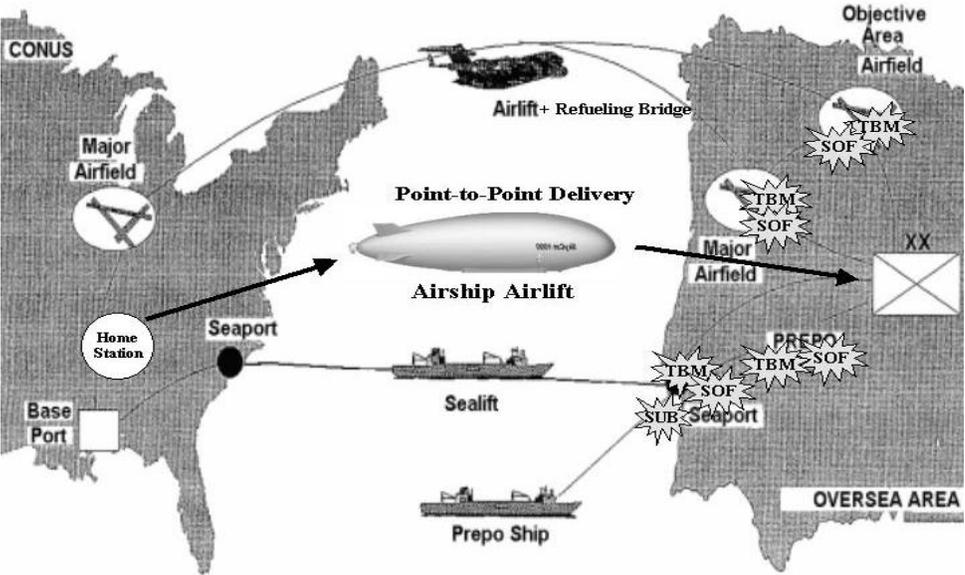


Figure 2: CRAF airship and the deployment process

AIRSHIPS – A PROVEN TECHNOLOGY IN WAR AND PEACE

AIRSHIPS IN WAR

Very few people are familiar with the significant role airships played during both world wars, the Cold War, and the early days of trans-Atlantic flight. This history is important because it demonstrates the versatility of the airship and sets some modern performance goals for newer airship design. Airships are seasoned veterans of both World Wars and the Cold War. Airships have been used for reconnaissance, bombing, long distance re-supply, convoy escort, anti-submarine warfare (ASW), air-sea rescue, mine spotting, and airborne early warning radar stations. Airship performance in these roles was astounding.⁹

- WW I: 400 European airships logged 83,360 flying hours over 2.6 million miles.
- WW I: German airship flew 4,200 miles in 95 hours to deliver emergency supplies to German troops in Africa.
- WW I: German airships completed 336 bombing raids over Europe.
- WW I: Fastest German airship attained speeds up to 75 mph; highest altitude attained – 20,000 to 25,000 feet.
- WW II: U.S. airships completed 55,900 missions for 550,000 flying hours.
- WW II: 168 U.S. airships over the Atlantic and Mediterranean escorted 89,000 ships without a single merchant ship loss from enemy surface action. Only one airship was lost to enemy action.
- WW II: Two U.S. airships flew 3,100 and 3,500 miles in 50 and 62 hours respectively while traveling between the U.S. and north Africa.
- Cold War: U.S. airship remained on-station for 264 hours (11 days) patrolling 9,500 miles over the Atlantic and Caribbean before needing replenishment.

Airship success, however, came with a price. Enemy airplanes and anti-aircraft fire as well as severe weather destroyed nearly half of Germany's WW I airship fleet. Hurricane level winds off the U.S. east coast in 1933 caused the worst U.S. airship crash. Seventy-three of seventy-six

crewmembers, including the commander of the U.S. Naval Air Service, Admiral William A. Moffett lost their lives. These losses, however, were small in comparison to other losses among merchant ships in the Atlantic and bombers over Europe during WW II.

Modern airship makers must highlight airship past performance if they are to convince military decision makers of the potential of modern airships. Modern airship makers must also address the vulnerabilities demonstrated by earlier airships and what their plan is to mitigate or eliminate them in the context of the modern battlefield. If what airships of old did during war is any indication, modern and future airships may indeed represent a viable means of transport.

AIRSHIP COMMERCIAL USES

In the 1920's and 30's, the airship was the 'Concorde' of its time.¹⁰ After the Great War, many airships ferried passengers across the Atlantic regularly. Within Germany, airships transported over 34,000 passengers and flew over 100,000 miles.¹¹ One German airship in particular stands above the rest, the Graf Zeppelin.

The Graf Zeppelin was comparable in size to today's CL160 design, but the Graf Zeppelin's speed, 70 mph, and range, 6,500 nm, were significantly greater than the CL160's. The Graf carried a crew of 44 and up to 20 passengers, who were treated to service comparable to what first class passengers on ocean going cruise ships get today (cabins, fine dining, wash rooms, etc).¹² The Graf began service in the latter part of 1928 and made 144 Atlantic crossings carrying 2,880 total passengers. Between August and September 1929, the Graf circumnavigated the world, 31,000 miles, in 12 days, 12 hours, and 20 minutes. The Graf also completed the first

⁹ Beaubois, 92, 103, 101-105, 179, 184, 194.

¹⁰ Center for Army Analysis, *CargoLifter Aerial Transport System* (Fort Belvoir: CAA, 2001), 66 (hereafter cited as CAA Study).

¹¹ Rick Archbold, *Hindenburg: An Illustrated History* (Toronto: Madison Press Books), 35.

¹² Beaubois, 184.

aerial survey of the Arctic in 1937.¹³ The Graf saw nearly ten years of continuous service before it was retired to a hangar for preservation.¹⁴ The Graf's performance record provides a benchmark for emerging modern airship companies to model.

Currently airship companies predominately provide advertising and photography services. The airship is used as a flying billboard or camera platform over sporting events. However, in 2001, Germany's Federal Air Traffic Office certified Zeppelin Luftschifftechnik's latest airship to carry 19 passengers.¹⁵ The airship completed 1,000 hours of test flights and a 2,200-mile tour of northern Germany the previous year.¹⁶ Zeppelin plans to charge around \$275 per seat for one-hour sightseeing trips.¹⁷ While tourism is one market area, another emerging one is the transport of heavy freight.

The increasing cost of fuel and high demand for moving heavy freight quickly is taxing the limits of jet transport capability. This is especially true when destinations have limited APOD infrastructure support. Laying pipelines or building dams in remote areas requires expensive GLOC or APOD infrastructure development. Airships capable of lifting large sections of pipe, heavy turbines, construction supplies/equipment, and people can easily transport those items straight to the construction site without disturbing the environmentally sensitive areas in between, and can eliminate the costly construction of GLOCs and/or APODs. Airships capable of moving heavy freight and people long distances represent a lift asset that could appeal to the military.

Two promising airship designs come from CargoLifter AG and SkyCat Technologies (a subsidiary of Advanced Technology Group (ATG)). The CargoLifter airship carries 176 tons of

¹³ Ibid.

¹⁴ Ibid.

¹⁵ "Zeppelin Airships Are Cleared to Fly Again," Ananova, 27 April 2001, [magazine on-line] (Ananova Ltd., 2001, accessed 12 March 2003); available from <http://www.ananova.com/news/story>; Internet.

¹⁶ Ibid.

¹⁷ Ibid.

cargo at a speed of 52 mph for a distance of 5,200 nm.¹⁸ The SkyCat airship carries 1,100 tons of cargo or 900 personnel at a speed of 115 mph for a distance of 4,000 nm.¹⁹ The SkyCat airship can double its range if cargo capacity is reduced by half. These capabilities caught the attention of the DoD and resulted in detailed studies on both.

The Joint Staff director of Logistics (J-4) sponsored a study of the SkyCat and the Center for Army Analysis (CAA), with guidance from the Army Deputy Chief of Staff for Logistics (DCSLOG), conducted the study on the CargoLifter. Since completion of these studies, CargoLifter became insolvent and could not complete its design development. SkyCat, however, is continuing development of its airship design and is incorporating J-4 recommendations for mitigating airship vulnerabilities, and improvements to the payload module to better accommodate military cargo. DoD remains interested in the SkyCat airship design, but it is not willing to initiate procurement proceedings for it. DoD is content, for the moment, to continue procuring C-17s and LMSRs as well as the re-conditioning of the entire C-5 fleet. Although this collection of new and venerable lift assets are capable of moving military forces, as demonstrated by the war in Iraq, they are unable to meet the Army's transformation deployment objectives. Understanding the advantages and disadvantages of current lift assets within the mobility triad will help determine where and how a fleet of airships can best augment the deployment process to meeting the Army's deployment objectives.

¹⁸ CAA Study, 10.

¹⁹ SkyCat Study, 1.

THE MOBILITY TRIAD

To improve the Army's deployment profile it is necessary to do more than simply make existing transportations modes better. To demonstrate this it is necessary to identify the important aspects of the existing transportation modes in the deployment equation. Found within the Mobility Triad, these modes include APS, airlift, and sealift.

APS

APS possesses two advantages to the deployment process are: pre-positioned equipment and supplies strategically located around the world (see table 1) ready for deploying personnel to fall-in on, and reduced need for inter-theater lift. APS disadvantages are: pre-positioned stocks are relatively fixed, except for those aboard ships, and require intra-theater lift for movement; and pre-positioned stocks are normally older and require component up-grades and soldier re-training before the equipment is available for use. Pre-positioned stocks, both ashore and afloat, also present a significant target of opportunity for an enemy.²⁰ The loss of an APS-Ashore site or APS-Afloat vessel to TBM, SOF, or submarines represents a major loss of combat power in the neighborhood of battalion to brigade sized task forces and/or their associated combat service support equipment and supplies. Another point to consider is the reality that future area of operations may not be near an APS-Ashore site or accessible by APS-Afloat vessels.

The deployment profile for units currently deploying into SWA, validate requirements to 're-training' and to bring components with which to upgrade stored vehicles. Many of the vehicles recently pulled out of APS-5 or the APS sets from Europe are the same vehicles the Army used to defeat Saddam Hussein's forces eleven years ago.²¹ Because Iraqi ports are

²⁰ Povah, 3.

²¹ "Old Gear Greets Gulf Soldiers," *Kansas City Star*, 16 February 2003, sec. A, p. 18.

shallow, APS-3 vessels could not use them, thus demonstrating that pre-positioned stocks will not always be available where needed. Airships, as currently under design, could potentially mitigate these problems.

APS	Bde Sets	Operational Project Stocks	Sustainment Stocks	Other	Location
APS-1	None	12	Yes	None	CONUS
APS-2	2x1 (3)	7	Ammunition	155mm FA Bn, Stocks for Allies	Norway, Italy, Netherlands, Luxembourg, Italy, Israel
APS-3	2x2, 1x1	4	Yes	CSS units	Diego Garcia, Guam, Saipan
APS-4	2x1	14	Yes	4 Hospitals, Ammo/Equip Stocks for Allies	Korea, Japan, Hawaii
APS-5	2x1 (2)	6	Yes	2 Hospitals, Division Base	Kuwait, Qatar, Bahrain

Table 1: Army Pre-positioned Stocks worldwide ²²

An airship designed to carry any type of Army equipment, in combination with other airships, could transport heavy, medium, and light BCTs in their entirety (personnel, equipment, and Unit Basic Loads (UBL)). For example, one SkyCat 1000 airship with its 1,100-ton cargo capacity can transport company plus sized elements. Modeling scenarios indicate it would take seventeen SkyCat 1000 airships to transport the new SBCT from Fort Lewis to Korea in one lift. Another illustration of this is the realization that just thirteen SkyCat 1000 airships have the combined carrying capacity of one APS-3 LMSR, which carry battalion-plus sized task forces. Furthermore, the airship fleet transporting the SBCT from Fort Lewis to Korea can do it in one-fifth the time it takes an APS-3 LMSR. Finally, airships with their STOL/VTOL ability are not

restricted by APOD infrastructure limitations, whereas shallow draft channels or competition for berthing with commerce ships, in this case, might restrict a LMSR. In this Korea scenario, the airships delivered the SBCT to a location outside of Pusan known as 'Rigger Drop Zone'. The maintenance on the ground (MOG) allowed five airships at a time to land and discharge cargo and troops.²³ This type of performance by airships present a unique opportunity for reducing reliance on APS, time wasted 're-training' or up-grading APS equipment, and allows more strategic maneuverability and operational mobility for the combatant commander. Reducing reliance on APS makes the Army less vulnerable at those sites and less predictable. While airships could eliminate the need for APS-Ashore, the APS-Afloat fleet, because of its mobility and large cargo carrying capacity would probably remain a part of the Mobility Triad.

AIRLIFT

Airlift advantages to the deployment process are: speedy delivery of troops, equipment, and supplies; the ability to transport forces inland when APODs are available; and the ability to conduct aerial delivery of forces and equipment (airdrop). Airlift disadvantages to the deployment process are: high dependency upon APOD infrastructure support; small cargo carrying capacity in comparison to the amount of fuel consumed to move cargo; and high vulnerability to weather, mechanical failures, and anti-aircraft artillery/missiles. Vulnerability to anti-aircraft fire is a special concern because it can result in a total loss of an aircraft, its crew, and its cargo.

Current strategic airlift uses a variety of military and CRAF aircraft to move cargo and personnel (see Appendix A for specific aircraft data). Airlift is desirable because it is fast and can deliver forces where ships or ground transports cannot. Unfortunately, this ability is diminished

²² Command and General Staff College, *Support Operations Officer Course – APS Brief*, Fort Leavenworth, 18 April 2002, slide 5.

²³ SkyCat Study, 185-191.

by the fact that airlift cannot deliver large quantities of oversized equipment and supplies when compared to ships and airships.

The SkyCat Korea modeling scenario determined it would take 188 C-5 sorties over one hundred hours to delivery the SBCT to Korea, thereby failing to achieve the Army's deployment objective of ninety-six hours.²⁴ Using C-5s for this mission also proved to be two-thirds more expensive in regards to fuel expense and air-tanker support. Additionally, of the total DoD wartime requirement for lift, airlift only accounts for five percent (sealift has the rest).²⁵ This translates approximately to a 54.7 to 67.0 million tons/mile/day (MT/M/D) airlift requirement. Of that requirement, airlift can only move approximately 45 MT/M/D with current available assets (military and CRAF).²⁶ One solution to reduce the shortfall and improve the Army deployment timeline is on-going research into the Boeing Pelican ULTRA Heavy Lifter, a large fixed winged aircraft which uses Wing-In-Ground-Effect (WIGE) to allow it to transport 1,400 tons of cargo (see Appendix A for specifics). Another solution is the re-engineering of engines for the entire C-5 fleet. The venerable C-5, the oldest of the airlifters, is plagued with engine problems resulting in a mission capability rate (MC) of 59%, significantly less than the wartime MC requirement of 75%.²⁷ Improving the C-5's MC rate could help airlift meet its airlift mission requirements. Until these solutions come to fruition, however, strategic airlift will continue to fail to meet the Army and DoD deployment requirements.

The challenges faced by airlift in the deployment process are compounded by the call from AMC and the Army for a STOL/VTOL aircraft for future inter-theater airlift. STOL/VTOL capabilities divorce airlift assets from APOD infrastructure support and reduces the associated

²⁴ Ibid.

²⁵ MMIRRG Information Brief, Strategic Sealift [brief on-line] (Military Sealift Command: 1997, accessed 15 October 2002); available from http://www.navres.navy.mil/navresfor/navsurf/staff_codes/N14/powerpoint/sealift; Internet. Slide 4 (hereafter cited as Sealift).

²⁶ AMC, vol. II, sec. 2.3, p. 1.

²⁷ Ibid, 2.

vulnerabilities to threats at those sites. The C-17 is the only airframe in the inter-theater lift inventory capable of using STOL austere airfields. STOL capability is only one aspect of using an austere airfield; the other aspect is the ability of that airfield to handle the gross weight of the aircraft. In the C-17's case, the aircraft may be too heavy for most STOL missions.

A recent Government Account Office (GAO) report found that many of the airfields previously deemed useable for the C-17 cannot actually support a C-17's wartime weight. The report found only about 1,400 of those airfields could possibly be used and of those only, three would likely be used in a major regional contingency scenario.²⁸ Until the Air Force validates which austere airfields the C-17 can use (or develop a C-17 variant with VTOL capability), the C-17 remains dependent on developed APODs and is subject to the associated vulnerabilities. Airships are the only vehicles capable of both STOL/VTOL and due to their LTA characteristics, do not crush runways, austere or developed. Runway weight is also a problem for the Boeing Pelican.

The proposed Boeing Pelican with its total gross weight, with cargo, exceeding 3,000 tons will crush most if not all of today's runways – it is just too big.²⁹ Runways already suffer stress damage from fully loaded C-5 and 747 aircraft (weighing in at only 400 tons), and as a result, many APODs publish weight restrictions for those types of aircraft. Inability to use APODs because of these restrictions does not help AMC in meeting DoD's MT/M/D objective for airlift. Larger aircraft, like the Pelican, with massive carrying capacity and greater speed than the airships, while sounding attractive, are not feasible because they damage APOD runways and surrounding infrastructure. Bigger is not always better.

²⁸ United States General Accounting Office, *Military Airlift: Comparison of C-5 and C-17 Airfield Availability* [on-line] (GAO/NSIAD-94-225, 1994, accessed 03 December 2002); available from <http://www.fas.org/man/gao/gao94225.htm>; Internet (hereafter cited as GAO).

²⁹ Bill Sweetman, "MONSTER AT 20 FT.," *Popular Science*, 27 January 2003, [magazine – online, accessed 03 Feb 2002]; available from <http://www.popsci.com/popsci/aviation>; Internet.

Finally, bigger aircraft heavily dependent upon APOD infrastructure support present inviting and highly valuable targets to an adversary. As with the loss of an LMSR, the loss of a Pelican size or even C-5 and 747 sized aircraft to MANPADS results in loss of combat power both in equipment and in personnel. Torpedoed ships generally take time to sink, thus allowing people to escape. Aircraft hit by missiles, sufficient small arms, or larger caliber rounds generally crash and burn resulting in a total loss of cargo and passengers. Aircraft crashes of that magnitude also have demoralizing effect on the force. Airships are helium filled. If struck by missiles and or anti-aircraft fire, the airship sinks slowly to the ground over a period hours, and lands, thereby, allowing equipment and cargo to discharge safely for use another day.³⁰

Augmenting the airlift element of the mobility triad with airships can very well serve to improve that element's ability to meet the DoD's MT/M/D lift requirement, lower costs associated with fuel, and reduce air-tanker bridge requirements. Additionally, Airships like the SkyCat 1000 can provide the STOL/VTOL capabilities AMC and the Army are asking for, although not necessarily in the form of a 'sexy' looking jet transport. Finally, airships present a unique opportunity to provide an air vehicle to the military that will not crash when hit by enemy fire, but instead land and allow cargo and personnel a chance to offload.

SEALIFT

In contrast to airlift, sealift provides large cargo carrying capacity at a much lower cost per ton than airlift. Sealift can contribute to pre-positioning by providing mobile storage. Unfortunately, sealift is slow, vulnerable to weather, mechanical failures, and subject to interdiction by enemy submarines or mines. It cannot provide point-to-point delivery of forces because pier or lighterage is needed for off loading cargo. Current strategic sealift predominantly consists of LMSRs, container ships, and Fast Sealift Ships (FSS). These ships as well as others

³⁰ SkyCat Study, 116.

provide inter-theater transport for 95% of all deploying cargo during the deployment process. Smaller boats like the Logistics Support Vessel (LSV) and Landing Craft Utility (LCU) constitute the Army's watercraft fleet. These vessels provide the majority of intra-theater lift, although they have some limited inter-theater capabilities (see Appendix A for specific ship and boat data).³¹ Together these vessels provide a robust, yet slow, transportation asset for the Mobility Triad.

Transit times from the U.S. to locations in SWA or the Pacific are dependent upon a variety of factors. These factors include weather, speed of the vessel, mechanical serviceability, and waterway restrictions; e.g., canal dimensions. When conditions are ideal, a LMSR steaming at 24 knots theoretically can cover 10,000 nm in 17 days, while a FSS steaming at 33 knots can do it in 13. Conditions, however, are rarely ideal which leads to average transit times in the neighborhood of 17 days for the FSS and 21 to 30 days for the LMSR. Transiting an ocean is only the first part of the deployment process for sealift. The other part is finding a suitable port capable of berthing, tending, and offloading these very large vessels at the destination.

Every nation with a coast does not necessarily have SPODs capable of handling aircraft carrier size ships with drafts of 34-35 feet. This is very evident now in southern Iraq where LMSRs are unable to use ports because the shallow channels only accommodating ships with a 30-foot draft. Even when suitable SPODs do exist, there is a limit to how many ships can offload at one time. Ships normally require at least one day to offload cargo when cranes and material handling equipment (MHE) are available, longer when not. If ships arrive at a theater SPOD and have to wait for offload, they wait offshore and make inviting targets for submarines or mines. When suitable SPODs are not available, the next option is the employment of Joint-Logistics-Over-The-Shore (JLOTS).

³¹ Global Security, Large Medium Speed Roll-on/Roll-off Ships – Specifications [on-line] (accessed 10 October 2002; available from <http://www.globalsecurity.org/military/systems/ships/lmsr.htm>; Internet (hereafter cited as Global).

JLOTS is resource and labor intensive, weather dependent, and requires suitable beaches for operation. Just as with the SPOD, JLOTS can handle only a limited number of ships at a time and waiting ships make nice targets. The historical and doctrinal use of SPODs or beaches for JLOTS makes them a critical requirement and vulnerability for any U.S. deployment. The SPOD/JLOTS sites in an area of operation are somewhat predictable and subject to attack by submarine, mines, SOF, and TBM.

A single LMSR lost in a Kilo submarine attack or destroyed by any other means represents a significant loss of combat power for the combatant commander (an armored or mechanized battalion sized task force or 30 days of division sustainment stocks).³² SPOD dependency as with APOD dependency makes highly valuable LMSRs or FSSs vulnerable to attack. Former Soviet Union Kilo class diesel/electric submarines are available on the world arms market. The Kilo class submarine is virtually undetectable when operating under battery power. Thus, there is a potentially serious threat to military shipping.³³ One possible answer to overcome the submarine threat is the introduction of High Speed Vessels (HSV).

Strategic planners would like to see ships that can travel at speeds between 40 to 70 knots, carry 500 to 12,000 tons of cargo, and cover distances between 1,200 to 35,000 nm before refueling.³⁴ The fastest cargo vessel MSC operates at this time is the FSS and its maximum speed is only 33 knots. Currently several 300-500 ton cargo capable vessels do exist with un-refueled ranges of 1000-1200 nm. DoD currently leases the WestPac Express High Speed Vessel (HSV) (see Appendix A) from Australia and the Marines are testing it in daily operations between Okinawa and Japan. The Marines are very positive about this vessel and estimate its use will

³² APS Info, 2.

³³ David Lague, "We All Live For Another Submarine," *Far Eastern Economic Review*, 15 Aug 2002 [on-line] (accessed 8 Aug 2002); available from <http://ebird.dtic.mil/Aug2002/e20020808we.htm>; Internet (hereafter cited as Submarine).

³⁴ Global, HSV.

significantly reduced the number of C-17 sorties required to transport troops and equipment between Okinawa and Japan/Korea/Guam.³⁵

The HSV, like most other ships, will be subject to attack while in port. However, unlike other ships, it will probably be immune to submarine attacks due to its speed and disposition on the water's surface. Ship-to-ship missiles and aircraft attacks will still pose a threat as well as severe weather conditions. The WestPac HSV, while attractive, falls short of what strategic planners want. Additionally, the WestPac is very expensive to operate because it uses a large amount of fuel – an aspect that may make the vessel economically unacceptable.

Transportation planners envision a HSV superior to the WestPac. The conceptual HSV has a range of 3,000 nm, carries 3,000 tons of cargo (up to 15 M1A1s), and cruises at speeds of 50 knots. There are currently blueprints for LMSR type vessels capable of 40 knots and carrying 10,000 tons of cargo. The expected cost for these ships is estimated at \$1.7 billion (for four ships). However, funding and construction contract issues have prevented transforming blueprints into actual vessels.³⁶

Large fast ships will undeniably improve the ability of sealift to transit long distances quickly, but they do not eliminate the need for suitable SPODs or JLOTS locations. No single airship will ever replace what a LMSR or FSS can carry. However, a fleet of airships could very well carry a combined load comparable to a LMSR or FSS. The difference is the airship fleet is not dependent on available or suitable SPOD/JLOTS locations for offloading. Additionally, the speed of the airships allows them to complete several sorties before a LMSR crosses the ocean. For example, assume it takes one LMSR to move the SBCT from Fort Lewis to Korea over a period of 21 days. Airships, according to the SkyCat modeling scenario, take two days to deliver the SBCT to Korea, and then two days to return to Fort Lewis. Theoretically, this airship fleet

³⁵ Ibid.

³⁶ Ibid.

could complete five sorties to Korea, delivering the equivalent of five LMSR loads. This capability is very advantageous when deploying to areas devoid of SPOD or APOD infrastructure support. Point-to-point delivery is something that neither airplanes nor ships can fully accomplish, no matter how big or fast because they require APOD/SPOD infrastructure support. Turkey's resistance to allow the U.S. to use its APODs/SPODs for flowing forces into northern Iraq demonstrates this point.

In summary, lift assets in the current Mobility Triad can use a new transport enabler; that enabler is the airship. Current airlift and sealift advantages in speed and cargo carrying capacity are mitigated by their inability to provide point-to-point delivery. When APOD/SPOD infrastructures are unavailable or denied by the enemy, the current airlift and sealift modes of transport cannot support the combatant commander. Examples throughout the war in Iraq demonstrate this point. AMC and the Army also recognize this shortfall and are looking for a lift asset capable of delivering forces where the combatant commander directs, independent, if need be, of APOD/SPOD/GLOC support. Furthermore, the constant reliance on these facilities makes U.S. deployments into a theater of operation predictable. Predictability leads to the enemy targeting the likely ports and ground transportation routes. Modern helium filled airships with STOL/VTOL capability; large cargo capacities, minimal infrastructure support requirements, and durability may present the military a way to avoid enemy interdiction and denial. Airships are a proven and tested technology and could provide a unique capability in the deployment process.

A MODERN AIRSHIP

History has shown how versatile airships can be and modern deployment challenges have highlighted the limitations of current modes of transport. Modern technology is providing new ways of making airships suitable for commercial and military use again. Airship designers like CargoLifter and Advanced Technologies Group (ATG) are two companies trying to create a modern airship. Unfortunately, CargoLifter experienced funding problems and became insolvent. ATG, however, continues work on its family of modern airships – the SkyCat series. This series of airships, especially the SkyCat 1000, has captured the interest of DoD, which sponsored a detailed engineering study of the airship (completed April 2001). This airship and its smaller siblings represent an enabler that can overcome the deployment limitations of airplanes and ships and provide a unique capability in the deployment process.

SKYCAT 1000

The SkyCat comes in three models named by their cargo size in tons: SkyCat 20, 200, and 1000. An easier way to remember these models is to label them as small, medium, and extra-large. Current fabric technology, however, has forced the SkyCat engineering team to admit its 1000 model is not currently feasible. In its place, they believe they can construct, using fabric technology available now, an airship with a 550-ton payload (model 500, large size).³⁷ In the not so distant future, the engineering team feels the fabric technology will exist to permit construction of the SkyCat 1000.

A SkyCat airship derives its ability to fly from a combination of a lighter than air gas (helium) and aerodynamic lift generated by the hull design.³⁸ An Air Cushion Landing System

³⁷ SkyCat Study, 153.

³⁸ World SkyCat Ltd., World SkyCat Catalogue (Oxford: World SkyCat Ltd., 2002), 3 (hereafter cited as SkyCat Catalogue).

(ACLS) allows the airship to conduct STOL/VTOL from most surfaces including water.³⁹ This STOL/VTOL capability allows the airship to divorce itself from most of the APOD infrastructure support, the very capability AMC demands for future airlift. In July 2000 a prototype, dubbed ‘the SkyKitten’ successfully demonstrated STOL/VTOL capability.⁴⁰

The SkyKitten success established a rough timeline for subsequent construction and design development of the SkyCat airships, starting with the SkyCat 20 in 2002, SkyCat 200 in 2003, and the SkyCat 1000 in 2005.⁴¹ According to a recent news release, “CargoLifter and ATG signed a letter of intent” in September 2002 providing for joint cooperation in the construction of ATG’s AT-10 airship and subsequent construction of a SkyCat 20 prototype. This joint venture is pending the outcome of CargoLifter’s chapter 11 filing in Germany. Work on the AT-10 and SkyCat 20 should begin around mid-2003.⁴² Of the four SkyCat models, the 500 and 1000 show the most potential for strategic inter-theater airlift, while the smaller models show potential for intra-theater airlift.

DESIGN AND CAPABILITIES

SkyCat airships, as with all modern airships, use non-flammable helium as its lifting gas. Static and dynamic lift enables the SkyCats to conduct STOL/VTOL. The helium accounts for 80% static lift and aerodynamic design creates 20% dynamic lift – older airships were 100% static lift.⁴³ The neutral buoyancy created by the helium gives the SkyCat a heaviness value (a non-dimensional measure of the relation between the mass of an object and the mass of the air that object displaces), of 20% as compared to a B-747’s heaviness value of 8,500%.⁴⁴ In other

³⁹ SkyCat Study, 16.

⁴⁰ Ibid, 8.

⁴¹ Ibid.

⁴² Airship News, CargoLifter and ATG To Join Forces [on-line] (Airship and Blimp Resource web- page, 2002, accessed 11 March 2003); available from <http://hotairship.com/news/>; Internet. CL was unable to secure a government loan of 40 million Euro to help its development of the CL-160 airship.

⁴³ SkyCat Study, 11.

⁴⁴ Ibid, 10.

words, this means the SkyCat can deliver maximum weight payloads to any APOD, if used, without crushing runways – something C-5s, B-747, and the Boeing Pelican design cannot do.

The payload module design calls for Kevlar composite materials and the ability to carry payloads ranging from 20 to 1,100 tons, depending on SkyCat model. The commercial payload module variant is a long rectangular multi-level box (265 feet long by 44 feet wide by 27 feet high) capable of holding up to 195 “Twenty Foot Equivalent Unit” (TEU) containers.⁴⁵ SkyCat 1000 propulsion calls for six 13,000 horsepower turbo-prop engines ‘with a specific fuel consumption of 0.38 pounds per horsepower hour’.⁴⁶ The SkyCat 1000 maximum speed and range is approximately 105 knots for 4000nm. Reducing the payload to around 550 tons enables the airship to double its range.

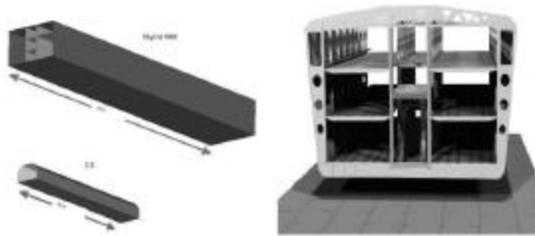


Figure 3: SkyCat 1000 payload module

Construction of the SkyCat envelope uses “heat-bonded, high-tensile laminated fabric, incorporating a Mylar film providing the gas barrier.”⁴⁷ Hull design and Kevlar laminated fabrics allow the airship to survive numerous small arms and larger caliber hits, to include MANPADS.⁴⁸ Weather remains the biggest threat, but enablers like Doppler radar and GPS to keep the airship

⁴⁵ Ibid, 9.

⁴⁶ Ibid, 16

⁴⁷ SkyCat Catalogue, 6.

crew aware of weather conditions mitigate even that. Finally, the before mentioned ACLS allows SkyCat airships to land without the assistance of a ground crew or the need for a mooring mast at the point of debarkation. Water, however, is required for ballast; to maintain the airships neutral buoyancy after cargo offloads. Venting helium is one way to overcome a shortage of water, but necessitates replacing the helium for future operations.

SkyCat airships are not the blind and ticking time bombs that their hydrogen predecessors were in the early years of the 20th century. Airship designers are more aware of what went wrong with airships in the past and what is required for airships in the future. Modern technologies such as Kevlar, GPS, and Doppler radar make the use of an airship quite attractive and safe. The SkyCat family of airships exemplify what modern technology and safety engineering can do to make a modern airship suitable for commercial and military use.

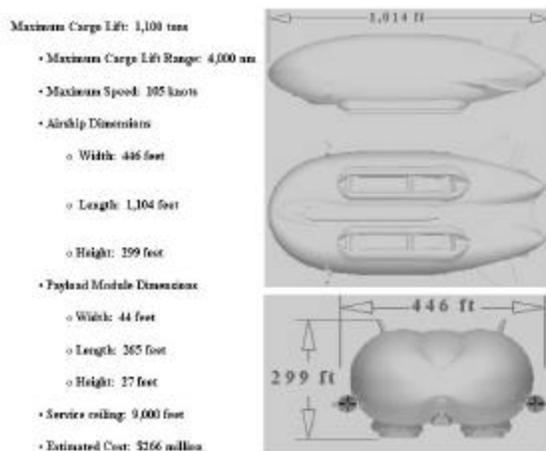


Figure 4: SkyCat 1000 Airship

⁴⁸ SkyCat Study, 118-124.

COMMERCIAL MARKETS

World SkyCat Ltd. maintains an on-line catalogue highlighting the commercial markets their airships can serve. The following bullet statements come directly from this publication:⁴⁹

- **SkyPatrol:** *Surveillance/Border Control*
- **SkyLift:** *Emergency Relief*
- **FireCat:** *Fire-fighting*
- **SkyCruise:** *Luxury Tourism*
- **SkyShuttle:** *Mass Passenger Transport*
- **SkyFerry:** *Passenger Car Transport*
- **SkyYacht:** *Executive SkyCat*
- **SkyCom:** *Telecommunications*
- **SkyScreen:** *Advertising*
- **SkyFreight:** *Heavy-lift Cargo*
- **SkyLine:** *Pipeline Transport*
- **SkyGas:** *Natural Gas Transport*

This list of airship services demonstrates how versatile airships can be (see Appendix E for a more detail description). ATG and its subsidiary companies were wise not to limit themselves to moving only heavy freight, something CargoLifter did and which may explain why they became insolvent. The question now is whether ATG and its SkyCat airship designs can generate enough interest and funding to allow them to remain solvent and produce the airships. A promising note for ATG is the successful trials of its AT-10 advertising airship and its subsequent sale and delivery to China.⁵⁰

⁴⁹ SkyCat Catalogue, 9-20.

⁵⁰ Alan Johnson, *Airship Maker in Bid to Take Rivals' Berlin Facility* [magazine on-line] (Business Weekly, 2002, accessed 20 February 2003); available from <http://www.businessweekly.co.uk/news>; Internet.

MILITARY MARKETS

The SkyCat on-line catalog briefly touches on some military requirements such as patrolling, surveillance, and telecommunications. Historical uses of airships in both world wars and the cold war validate the applicability of airships in those advertised roles. Recently, a 135 foot helium filled airship normally used to cover sporting events, the U.K. A60, was outfitted with “optical and electro-optical surveillance systems and ground penetrating radar to identify minefield areas and to detect individual mines” in support of U.N. demining operations in Kosovo.⁵¹ The A60, or Mineseeker as it was dubbed, performed outstandingly. Statistics showed 80% of an area classified as mined was actually empty of mines, but would have taken trained deminers days to verify.⁵² The Mineseeker could do the same work in a matter of seconds (100m² of mined area per second vice 40m² per day using trained deminers).⁵³ The faster suspected minefields are determined free of mines, the quicker the land is returned to locals to farm or develop. The return of land greatly facilitates the rebuilding of a nation – something the U.S. is looking to do in both Afghanistan and Iraq. The Mineseeker airship is definitely an enabler in that endeavor.

While the Mineseeker airship is one example of a successful modern military/humanitarian application, the SkyCat 1000 Engineering Study sponsored by CJCS, J-4 office was interested in what a large airship could provide in heavy military transport. The study used several modeling scenarios, scenarios that moved forces from various locations in the U.S. to locations in Korea, SWA, and Afghanistan. The findings showed SkyCat 1000 airships numbering anywhere from 1 to 17 ships could move BCTs / ACRs faster and deliver them to tactical assembly areas independent of APOD infrastructure support. Not only were the SkyCats

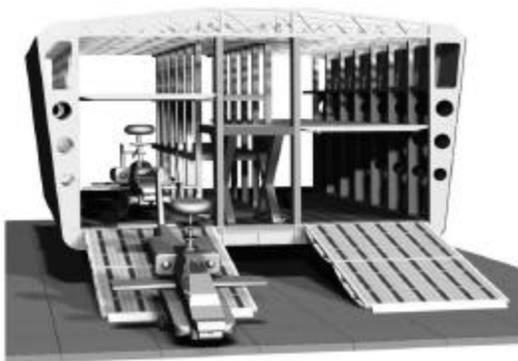
⁵¹ Mineseeker, *Mine Detection System, United Kingdom* [on-line] (Defence Industries – Air Force, United Kingdom, 2001, accessed 06 January 2003); available from <http://www.airforce-technology.com>; Internet (hereafter cited as Mineseeker).

⁵² Ibid.

⁵³ Ibid.

faster, but they were also one-third as expensive to operate when compared to C-5s (see Appendix C). Deployments of smaller units, battalion or less, showed SkyCats taking longer than C-5s. However, C-5s had to use APODs while the SkyCats could deliver the battalion-sized unit directly where needed or at least closer than the nearest APOD. While these modeling results are promising, they can only be achieved by modifying the existing commercial payload modules planned for by SkyCat.

The Engineering study looked at a half-a-dozen military modifications to ease loading and off-loading; width, height, and weight of vehicles; and the inclusion of passenger carrying modules. The final modification selected (referred to as Mil-C, see figure 5) included ramps for RO/RO operations, Variable Mezzanine Decks (VMD) to adjust for height of cargo, and a Wider Payload Module (WPM) to accommodate dual rows of the widest pieces of equipment in the Army inventory.⁵⁴ Using the Mil-C payload module, the modeling scenario determined 17 SkyCat 1000 airships could deliver one SBCT from Fort Lewis to Korea within 89 hours – meeting the deployment objective set by the Army for one BCT.⁵⁵ Another very important modification strengthened the floor to accommodate the M1A2 tank.



Configuration	Baseline (MI-A)	Var-Height Mezzanine (MI-B)	4-ft Wider Cargo Bay (MI-C)
# of SkyCat Flights	24	21	17
Delivery Time for IBCT	92h 33m	90h 57m	88h 49m
Cost / Ton-Mile			
- Fuel	\$0.07	\$0.06	\$0.05
- Wet Lease	\$0.45	\$0.39	\$0.32

Figure 5: Mil-C modification and SBCT deployment timelines

⁵⁴ SkyCat Study, 48-54.

⁵⁵ Ibid, 53.

The baseline SkyCat 1000 floor strengths are designed to handle only 200 pounds per square foot (ppsf) – the M1A2 and heavily loaded wheeled vehicles require 500 ppsf.⁵⁶ The study looked at both strengthening the entire main deck to 500 ppsf or only portions of it. Using the Army’s heavy ACR as a baseline, the study found only approximately 11% of the total floor space needed strengthening in excess of 200 ppsf to support the deployment of the heavy ACR. The results of their analysis indicate that 85% of the floor layout needs to be rated for 300 ppsf and 15% rated for 500 ppsf (see figure 6 for a sample load plan of various ACR equipment).⁵⁷ The floor strengthening and Mil-C Configuration are modifications SkyCat engineers will use for future design work in making the SkyCat acceptable for military use.⁵⁸

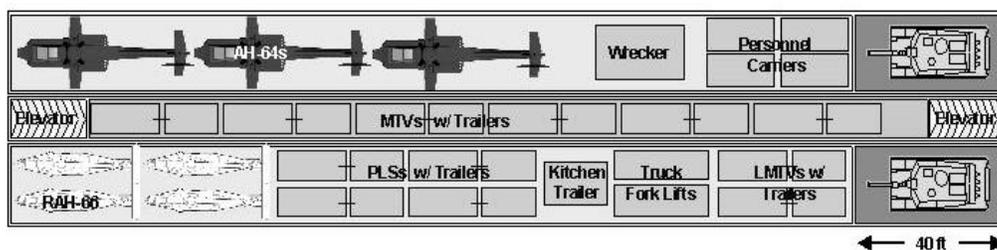


Figure 6: Sample load plan of ACR equipment on strengthened main deck

SkyCat Technologies willingness to include military modifications in the final designs of their airships signals their interest in obtaining military contracts and indicates the likelihood these airships, when built, will be part of CRAF – something DoD prefers over the alternative of buying their own airship fleet. The introduction of these airships into CRAF will definitely enhance the mobility triad’s force and supply throughput. The point-to-point airship will help to reduce the threat of APODs/SPODs denial. If these airships truly perform as advertised, heavy airship transporters along with smaller auxiliary airships will play a role in future military operations.

⁵⁶ Ibid, 55-58.

⁵⁷ Ibid.

⁵⁸ Ibid, 53.

VULNERABILITIES

Although the SkyCat 1000 is not the hydrogen flammable accident-waiting-to-happen Hindenburg, it is still vulnerable to missiles and air defense artillery. Because the SkyCat 1000 will be a CRAF asset, it is unlikely to actually encounter MANPADS, SAMS, or HEIT rounds. Although CRAF aircraft avoid areas with those threats, the possibility does exist. Designers must ask not what does an adversary have, but what could an adversary do to ‘kill’ a SkyCat 1000 heavy transport. That is exactly what the SkyCat engineers did in the study.

The most likely threats to the airship included: 7.62mm, 12.7mm, 14.5mm armor piercing incendiary (API), 23mm API and high explosive incendiary tracer (HEIT) rounds, and MANPADS (Stinger, SA-7, 14, and 16).⁵⁹ The engineers looked at how these weapons threaten various components of the airship such as the propulsion, fuel, flight control, crew stations, cargo compartment, and the envelope and structure of the airship itself.⁶⁰ The analysis found the most vulnerable areas of the airship were the propulsion, the cargo compartment, the envelope, and crew stations.

The airship’s six 13,000-horse power engines generate significant heat signatures to attract MANPADS. Mitigating the heat signatures requires infrared (IR) signature reduction technology; technology baseline commercial variant airships normally do not have. The loss of one or two engines will degrade propulsion performance but not ‘kill’ the airship. Of more concern are the external fuels lines feeding those engines and the subsequent fires. Mitigating fuel line leaks and fires requires self-sealing technology; again something commercial baseline models do not currently employ. Internal fuel lines bathed in helium will not burn, only leak, but fuel loss can just as easily cut short a mission.

⁵⁹ Ibid, 117.

⁶⁰ Ibid, 119-121.

The cargo compartment, while not likely to attract MANPADS, is vulnerable to fires and explosions sparked by API and HEIT rounds striking hazardous cargo. Mitigating these effects are the water ballast tanks that rounds must pass through before entering the interior of the cargo compartment. SkyCat engineers are confident the water will slow projectiles sufficiently to prevent fires and explosions. The use of Kevlar armor is also another option, but the more armor used, the less cargo carried. Another mitigation tool is the installation of fire extinguishers or a sprinkler system.

The envelop of the SkyCat 1000 presents a massive target for gunners. However, one must imagine how much damage is required to sink an aircraft carrier and then translate that to an airship of comparable size, which the SkyCat 1000 is. The SkyCat team determined the envelope could sustain hundreds of thousands of pinpricks from small arms fire and still operate for hours before repair. Of greater concern is an elongated tear created by a missile or large round fired at the proper angle. Pinpricks in the envelope vent helium slowly, which allows the airship to operate for a period before landing to conduct repairs. A massive 'tear' in the envelope could create rapid helium venting and a rapid descent or catastrophic crash (see Appendix D for venting rates).

Another vulnerable spot on the airship are the pilot positions. There are two separate pilot positions on the airship, each capable of operating the airship. The pilot stations are located sufficiently far away from the engines to avoid secondary damage from MANPADS aimed at the engines. Additionally, baseline commercial designs do not include 'ballistic' protection below and on the sides of the station. If the crew is killed or the pilot stations disabled the mission must end, therefore it is imperative to protect these areas.

The vulnerability of airships is a major military concern. Losing one airship would be comparable to losing one LMSR to a submarine – a significant loss of combat power or supplies.

Even so, despite its size the airship has advantages over other transports if attacked in transit. Unlike airplanes and ships, the airship is unlikely to explode and it has the ability to land anywhere, including water. Additionally, large airships will not be used recklessly so doctrine will be written to show how best to avoid unreasonable risks. It is fair to say actions will be taken to prevent attack and destruction of any airship the size of the SkyCat 1000.

LIMITATIONS

Although airships are most vulnerable to air defense weapons, terrain and weather, while not vulnerabilities, can limit airship operations. Terrain plays an important role in identifying suitable landing/take off locations for the SkyCat. The SkyCat does not require an airfield infrastructure for its VTOL/STOL operations, but it does need a large ‘landing/takeoff zone’ clear of obstacles such as telephone poles, electrical wires, tall trees, etc. According to the study, “a VTOL zone is a 1,500-ft. circle, and can accommodate SkyCat takeoffs with up to about 630 tons of cargo and normal fuel load”.⁶¹ At weights closer to the SkyCats maximum cargo carrying ability, the runway dimensions are significantly larger, 4,500 feet long by 3,000 feet wide for STOL and 10,000 feet long by 4,000 feet wide for commercial takeoff and landing (CTOL) (see Appendix C CTOL/STOL/VTOL size requirements). The landing zone is wide because the SkyCat has to maneuver to counter crosswinds. Weather is the other limiting factor in airship operations. Table 2 displays these limitations (see Appendix C).⁶² Modern forecasting technologies will allow airlift planners to plan around weather limiting airship operations, primarily severe wind. Weather will remain a constant factor in the planning of airship missions until technology is found that can further mitigate its effects.

Parameter	Flight Limit	Ground Ops Limit	Ground Safe Limit	Notes
Headwind	90 kts	60 kts	50 kts	Ground limits apply to low-friction surfaces
Crosswind	45 kts	15 kts	10 kts	Crosswind above limits requires vehicle to be turned
Precipitation	none	none	none	Rain ONLY, (see below for freezing rain or ice, sleet, snow)
Snow Accumulation	N/A	2 ft	2 ft	Excess snow may be removed by high-speed taxi
Icing	none	N/A	N/A	Heaters, boots, and shakers handle severe icing in flight
Sea State	N/A	3	5	Limits are to keep cargo bay dry
Visibility	0/0	.5 miles	marshellers must be visible	Numbers are for IFR (all aircraft certified for IFR)
Ceiling	200 ft	N/A	N/A	May be 0/0 for military fields with PAR capability

Table 2: Operational limitations

In summary, the SkyCat family of airships, particularly the 1000 model represents a fresh look at the use of airships in both the commercial and military arenas. The Engineering study indicates that DoD is interested in a modern airship as a heavy transport vehicle. The airship’s ability to deliver forces without the need of an APOD also addresses the AMC objective for future airlift. Finally, ATG and its subsidiary company, SkyCat Technologies, have shown they are not limiting the role of the SkyCat airship to just that of a heavy transporter, thereby avoiding the fate of their nearest competitor, CargoLifter. The challenge now facing the SkyCat airship is proving it is feasible and acceptable for military heavy transport missions.

⁶¹ Ibid, 37.

⁶² Ibid, 19.

AIRSHIP ASSESSMENT

Assessing airship feasibility and acceptability is necessary for determining the practicality of airships in a contemporary environment. Forming the basis of the assessment is various criteria such as cost, safety, speed, and survivability. Advocating that airships replace current lift assets is not the intent here, but rather coming to the conclusion that airships can complement existing heavy transports.

FEASIBILITY

For the purpose of this monograph, airship feasibility hinges on two criteria: can it be built, and can it be marketed commercially. Both SkyCat and CargoLifter studies concluded they could build, operate, and maintain their airships with technology available today, with one notable exception. The exception, mentioned previously, was the inability to build the 1000 model using current fabric technology.⁶³

The second part of the feasibility question, and the more critical, is the commercial marketability of these airships. Eighty-five years ago airships were the “Concorde” of the skies transporting thousands of people and tons of cargo across the Atlantic.⁶⁴ Airplanes, however, quickly proved faster and cheaper than airships, and the introduction of the DC-3 airliner in 1937 ended the airship era. Today, however, the cost effectiveness of these two modes of air transport is switching again. Increasing aviation fuel prices, growing numbers of air travelers, and the desire to transport bulk freight quickly (and in some cases to remote areas) make airships an attractive alternative. The re-discovered potential in airships has generated interest from the private and military markets.

⁶³ SkyCat Study, 153; and CAA Study, 58.

⁶⁴ CAA Study, 66.

The DoD, while interested in the airship transport capabilities, has stated it has no desire to spend money for airship procurement, operations, and personnel training. According to both studies, DoD envisions the commercial sector purchasing, owning, and operating these airships and enrolling them in CRAF.⁶⁵ Both airship companies launched marketing campaigns for their products, but their significantly different marketing approaches resulted in CargoLifter becoming insolvent while the SkyCat prospered. One reason for SkyCat's success over CargoLifter might be the fact SkyCat always considered the military as a potential market area while CargoLifter only looked at moving oversized freight.

CargoLifter declared itself insolvent and filed for Chapter 11 in late 2002 after it failed to convince the German government and investors of the CL160 airship's potential. A large part of this failure is related to the fact CargoLifter was focused on a niche market area – the Big Ugly Freight (BUF) market. They based their entire strategic business plan around the CL160 capturing 15% or more of this market, a market filled with fixed-winged competitors. ATG and SkyCat Technologies looked at a myriad of market areas, and are now capturing the interest of investors; an interest demonstrated by China's purchase of their AT-10 advertising airship. Two other advertised roles warrant further discussion: pipeline transport and humanitarian assistance.

SkyCat Technologies claims their 1000 model could transport whole sections of pipe, (160-320 feet in length) eliminating the current requirement to cut the pipe into several pieces for transport and then welding those pieces back together at the site. The company advertises in its brochure that three 1000 models could transport pipe and unload pipe at the site exactly where it is needed. The company uses a pipeline from Lake Baikal, Russia to China as its example. SkyCat estimated 3,000 km of pipe could be laid in two years, apparently a significantly shorter time and at lower cost than current methods. SkyCat airship pipeline transport and laying present a means for military logisticians to quickly emplace fuel and water pipelines in regions where

⁶⁵ SkyCat Study, 6; and CAA Study, 44.

extended supply lines make transport of fuel and potable water a challenge. Finally, the emerging oil and natural gas reserves in the Caspian Sea area require extension pipelines to transport the fuel to ports around the region. The SkyCat 1000 or 500 model could significantly reduce the amount time required to construct these pipelines and, thus, make that oil available much sooner than expected. If these claims and the others made by SkyCat can actually be delivered as advertised, chances of SkyCat airships becoming a new means of commercial transport are good.

In a Humanitarian Assistance (HA) role, SkyCat airships of all sizes can bring immediate aid directly to those affected by a natural or manmade disaster. Not only can the airship bring relief supplies, equipment, and personnel, but it could also evacuate hundreds of persons directly from the affected area to a relief site. SkyCat estimates one of its 20 models “can do the job of eight MI8 helicopters at 10% of the effective cost”, and that its larger models can deliver cargo at significantly lower cost than comparable aircraft.⁶⁶ In the modern age of nation building and routine humanitarian assistance missions, the SkyCat airships represent a faster means of providing immediate support to those who need it most. The U.N. World Food Program has validated the potential of these airships by endorsing the airship, especially the SkyCat 200, and citing its ability to deliver large quantities of food.

Whether or not airships can actually perform as advertised is yet to be seen. Successful application of airship technology as seen in the Minseeker and the ATG advertising airship demonstrate marketability feasibility of these air vehicles. SkyCat modeling scenarios also demonstrate feasibility of their larger airships as heavy transporters. Acceptance of these larger airships as heavy transporters is something airship companies must garner from the commercial and military sectors if they hope to market the airship.

⁶⁶ SkyCat Catalogue, 10.

ACCEPTABILITY

Airship acceptability hinges on three criteria: safety, speed, and cost. Most people when asked about airship safety immediately think of the Hindenburg. The burning image of the Hindenburg in 1937 over Lakehurst New Jersey and the accompanying emotional radio commentary capturing the event, unjustly branded airships as a very risky means of transportation. Overshadowed by the horrendous image of the Hindenburg engulfed in flames are the following facts: up to that fateful event, the Hindenburg had already made 63 successful Atlantic crossings, 63 of the 97 persons on board survived, and the Hindenburg used highly flammable hydrogen instead of non-flammable helium. Airship historians estimated over 13,000 people traveled safely between the U.S. and Europe by airship before the Hindenburg accident. As mentioned earlier, the Graf Zeppelin airship set the standard for airship safety and performance back in the 1930s and is regarded as a benchmark for safety and performance for airships even today.⁶⁷

While commercially operated airships had relatively good safety records, wartime airships were notoriously dangerous because hydrogen did not mix well with bullets. The German Army and Navy airship fleets suffered fifty and seventy-two percent losses respectively. Many of those losses were from hostile fire, primarily aircraft. Hydrogen being the primary lifting gas during the war was highly flammable and contributed immensely to the total destruction of airships. There were, however, exceptions to the rule. One French airship had its lifting envelope riddled with hundreds of small arms rounds and still was able to return to base for repairs.⁶⁸ Enemy action aside, weather also caused numerous losses.

Forecasting weather in the days of the airship was not a scientific process. Just like sea captains, airship captains relied on their experience to 'sense' weather changes, and many times,

⁶⁷ Beubois, 194.

they were wrong or surprised by ‘mother nature’. The worst U.S. accident occurred in 1933 when the airship Akron was struck by hurricane force winds off the coast of New Jersey and forced into the ocean, killing 73 of 76 crew members, including the U.S. Naval Air Service commander, ADM William A. Moffett.⁶⁹ Surprisingly this accident, not losses from hostile actions in WW II, caused the greatest loss of life among U.S. airship crews. Although airships are subject to weather and enemy action, so are airplanes.

Because all airships, both heavier and lighter than air, are subject to loss from weather and hostile action, a safety standard of acceptability is needed. Looking at non-combat related accidents only, the period of 1908 to 1940 saw 270 airplane crashes resulting in the loss of 1,859 lives as compared to eight airship crashes with 313 lives lost.⁷⁰ The raw numbers suggest airplanes were less costly in terms of lives lost per crash (7 lives per airplane crash as compared to 39 lives per airship crash), but it must be remembered that airships, like large airliners of today, were the only flying craft capable of carrying large numbers of passengers/crew, hence the higher loss rates. Extrapolating out the airship lost/lives lost data, the following comparison is sobering. Considering airship usage was highest from 1910 to 1940 (a 30 year period), it is fair to say the last thirty years (2003-1973) represent the highest usage of modern airliners. Looking at the ten worst airplane accidents during this 30-year period (9/11 excluded); 3,563 persons have died in accidents involving seven Boeing 747s, two DC-10s, one L1011, and one Airbus.⁷¹ The worst of these accidents involved a collision between two B-747s and resulted in the loss of 583 lives (291 lives lost per airplane), nearly twice the number of lives lost in all airship crashes combined.⁷² These facts alone should create a ‘Hindenburg’ type stereotype for airplanes, but they have not and people continue to fly jet airliners with little concern about their safety. Lastly, passenger

⁶⁸ Ibid, 90.

⁶⁹ Ibid, 204.

⁷⁰ Airplane Crash Data, [data on-line] (accessed 15 November 2002 and 25 January 2003) available from <http://www.planecrashinfo.com> and <http://www.nts.gov/aviation/stats.htm>; Internet.

⁷¹ Ibid.

survival rates involved in airship crashes as compared to airplanes during the 1908-1940 period were around twenty-eight percent for airships and fifteen percent for airplanes. Survival rates now for airplane crashes are practically zero, unless the crash occurs during take-off or landing. Airships experiencing mechanical failures while in flight will remain aloft until the crew either fixes the problem or vents helium in order to land the airship. Airplanes experiencing major mechanical failures while in flight usually end up crashing. These facts taken as a whole should cause air travelers to pause and think about which mode is really the safest, especially now that non-flammable helium has replaced hydrogen. An airship built today using available technology to mitigate risks and enhance safety is by far a safer way of travel when compared to airplanes.

Although most travelers and transportation businesses are concerned about safety, they are even more concerned about time and costs associated with traveling from one place to the other. There are currently two speeds of travel for inter-theater movement: fast on airplanes, and slow on ships. The airship provides a medium speed capability that fills the gap between slow sealift and fast airlift. The speed of transport, however, is not a simple issue of transport speed. It also includes time to load and unload and movement to the final destination. Two scenarios addressed by the SkyCat study help illustrate this point (see Appendix C for detailed information). The first scenario called for the SBCT to deploy to Korea from Fort Lewis, a distance in excess of 4,000 nm. It took 188 sorties of C-5 aircraft 102 hours to deliver the SBCT. Seventeen SkyCat 1000s delivered the SBCT in less than 90 hours to an assembly area, bypassing the APOD the C-5s had to use. The other scenario involved moving an aviation battalion from Diego Garcia to a location in Afghanistan, a distance of 2,900 nm. While both C-17 and SkyCat 1000 aircraft accomplished the mission, the SkyCat took twice as long as the C-17s. The value of this analysis is the realization that in some cases airships, because of their range and cargo carrying ability, will be faster (normally over longer distances) than fixed winged transports.

⁷² Ibid.

While shorter missions would be best served by quicker fixed-winged assets with the ability to complete two or three sorties in the time it takes the airship to accomplish one.

The primary reason airships ceased to be the preferred choice for travel in the earlier part of the 20th century was due to the introduction of faster and more available airliners such as the DC-3. People wanted to get where they were going faster, and as the global community grew closer through economic dependencies, the need to get to places faster grew. Airships with current non-nuclear technology can only achieve a speed of 115 mph, and as such will not replace airliners transporting passengers around the world. If, however, future technology allows for nuclear powered airships, as the Russians once contemplated, the possibility of airships replacing airliners is more plausible.⁷³ In the absence of nuclear power, fuel cost may become the criteria that make airships more desirable than airplanes.

Both airship studies used fuel costs as a measure to determine the effectiveness of airships and current strategic lift assets (military and CRAF). Refer to appendix B for the specific details of the scenario used to determine cost savings. In short, the studies found that airships could move forces, equipment, and supplies for one-third the cost of conventional aircraft. The cost savings varied depending on the airship operations. VTOL operations are more expensive because helium gas must be vented to make vertical landings and subsequently replaced. STOL does not require any venting because water provides the ballast. Airships may avoid other costs. For example, APOE/APOD user fees may be avoided because airships can pick up forces at their home-station and deliver them precisely where they are needed in a theater of operation. This type of point-to-point transportation also reduces the requirement for secondary transportation normally associated with fixed wing transport. Finally, the greater range of an airship reduces the need for air refueling. For example, a SkyCat 1000 can transport 1,100 tons of cargo 4,000 nm or

⁷³ Beaubois, 210.

500 tons of cargo 8,000 nm before refueling. Consequently, as fuel cost continues to rise, the use of airships may prove more cost effective than using traditional fixed winged transports.

The final cost factor is the cost of purchasing a SkyCat 1000. If DoD changed its position and chose to purchase the SkyCat, the cost per unit is \$266 million each. If a single SkyCat 1000 carried as much as thirteen C-17s, which cost \$236 million each, the airship could save the military approximately \$3.1 billion in procurement. Additional costs savings would come from needing fewer crews and reducing the operating costs for the C-17 fleet. Consequently, if DoD did opt to purchase SkyCat 1000 airships, the \$3.1 billion would be sufficient for a fleet of twelve airships (roughly the cargo capacity of one LMSR).

In summary, the Engineering study, safety standards of performance, cost savings, and proven uses (historical and contemporary) demonstrate that modern airships can be feasible and acceptable for use as a heavy transport aircraft. The obstacle facing airship designers is overcoming the 'Hindenburg' stereotype. Establishing a safety standard of performance and highlighting airship performance may be one way of changing that stereotype. Finally, the significant cost savings in relation to quantity of cargo transported needs to be heavily advertised. Businesses and the military are always looking for ways to save money and the airship definitely could help in that endeavor. Airships like the SkyCat will not replace commercial or military transport planes. However, they can join the mix of aircraft and reduce the overall cost of air transport.

CONCLUSION AND RECOMMENDATIONS

CONCLUSION

Modern airships like the types under development at SkyCat Technologies do represent a transportation enabler capable of increasing the mobility options of the U.S. military, particularly the Army. Historically airships have proved their worth as commercial transporters and as weapons of war during both world wars and the outset of the Cold War. Modern technology such as Doppler radar, Kevlar fabrics, and the use of non-flammable LTA gases such as helium now mitigate the majority of vulnerabilities and dangers early airships experienced. While weather conditions will continue to challenge airship operations, one must recognize that weather effects any and all types of air, sea, and ground transport, airship or not. What airships do provide that neither current strategic air or sea transport can, in the truest sense, is point-to-point delivery of persons and cargo. Coining a term currently used in the field of logistics, Just-In-Time (JIT), airships could very well make JIT a reality by providing forces and supplies when and where the combatant commanders needs them on or near the battlefield.

The SkyCat airship catalogue, in part, demonstrates the seriousness of their marketing campaign. The sale of their AT-10 advertising airship to China further demonstrates worldwide interest in airships and could very well signal the beginning of their reemergence in the market place. Other examples of this include Zeppelin's introduction and current use of a tourism airship capable of transporting nineteen passengers. The use of the U.K. A60 airship in a 'Minesweeper' role with huge success in Kosovo has sparked development of even larger 'Minesweeper' airships for use in other areas requiring minefield identification and clearing. Finally, the United Nations endorsement of SkyCat's 200 series airship design for future humanitarian assistance missions underscores the myriad of tasks airships are capable of doing, both commercially and militarily.

Consequently, the question of marketability is no longer a question – commercial markets worldwide are interested in airships.

The various modeling scenarios used in the SkyCat Engineering Study sponsored by the CJCS J-4 have also answered the question of cost savings and meeting the Army deployment timeline objectives. Airships operating at one-third the cost of C-17, C-5, and B-747 aircraft theoretically were shown to be able to deliver the Army's SBCT from the U.S. to places like Korea and SWA within the desired 96-hour window. Not only were airships shown to operate at lower cost, but the actual cost of building an airship the size of the SkyCat 1000 was also shown more cost effective than building an equivalent number of C-17s required to move 1,100 tons of cargo in a single lift – the lift capability of one SkyCat 1000. Furthermore, the \$3.1 billion in procurement dollars not spent on C-17s replaced by one SkyCat 1000 can be used to build up to twelve of those airships, a carrying capacity in all total similar to that of one LMSR. Finally, the airship heavy transport is the only airlift vehicle currently capable of VTOL, consequently allowing it to meet AMC's guidance of future airlift divorcing itself from APOD infrastructure support. The question now is no longer marketability, safety, or cost effectiveness, but rather will Congress recognize the value of these airships and take the necessary measures to ensure continued interest and subsequent capital investment?

It interesting to note that historically Congress has reluctantly approved funding for strategic lift out of the fear that if it was easy for the U.S. to go anywhere in the world they would, and then the U.S. would find itself in the role of the world policeman.⁷⁴ Whether the U.S. policy makers like it or not, the role of the world policeman was forced upon them by the collapse of the Soviet Union, global economic reliance, failed nation state crisis's, and the emergence of rogue nation states sponsoring international and regional terrorism – terrorism that struck the U.S.

⁷⁴ Global, LMSR, Senator Richard B. Russell 1967 cancellation of the FDL ship.

soil on September 11, 2001. U.S. policymakers must look in the mirror now and recall that they had a chance to improve the strategic lift nearly 35 years ago and they failed to do so.

RECOMMENDATION

In the quest to transform the Army, the SECDEF must look at more than just creating a lighter and more lethal force. Operation Iraqi Freedom (OIF) demonstrated once again that heavy armored forces are needed to defeat an enemy. OIF also demonstrated how difficult it is to transport heavy forces and how easy it is to deny critical APOD/SPOD facilities. The SkyCat airship is an aircraft that could provide the transport capability to rapidly deploy heavy forces into an area of operation without relying on APOD/SPOD facilities. For example, airships could quite easily have delivered heavy forces into northern Iraq. The DoD, by sponsoring airship studies, has already demonstrated it is interested in what these aircraft can do. However, waiting for the private sector to manufacture large airships and then enroll them in CRAF is a bit shortsighted. The DoD should allocate funding for the construction of a SkyCat 500 or 1000 prototype for the purpose of finding out if these airships can actually perform as modeling indicates. If in fact they do perform as expected, DoD should at least procure enough airships (approximately 17 SkyCat 1000) to deploy the SBCT in a single lift from CONUS to any area of operation in the world. Maintaining and crewing of these airships can be outsourced to ATG or other airship companies who provides these services. Contingent upon these airships performing as expected, further studies should be initiated into other uses for airships such as: minesweeping, SLOC/GLOC surveillance and security, and as JLOTS lighterage. Failure to capitalize on this emerging capability will only serve to make deployment of heavy forces a continuing challenge.

BIBLIOGRAPHY

- Addington, Larry H. *The Patterns of War since the Eighteenth Century*. 2nd Ed Indianapolis: Indiana University Press, 1994.
- Advanced Technologies Group. *SkyCat™ Series*. 2002. Accessed 9 September 2002. Internet Available from http://www.airship.com/prod/skycat_data.htm.
- Air Force Doctrine Document 2-6.1, Airlift Operations. 13 November 1999. OPR: HQ AFDC/DR.
- Air Force. *Operation and Maintenance, Active Forces Budget Activity*. Internet. Available from <http://public.scott.af.mil/hqamc/om/budget.doc>; accessed 15 Oct 02.
- Air Mobility Command (AMC) Strategic Plan 2002*. Internet. Available from <https://amc.scott.af.mil/xp/xpx/STRATPLAN2002/stratpln.htm>; accessed 15 Oct 02.
- Airplane Crash Data. Internet. Available from <http://www.planecrashinfo.com> and <http://www.nts.gov/aviation/stats.htm>; Internet.
- Austin, Sara and Colin Beavan. "Helium High." *Civilization* Vol. 7, Issue 4, (Aug/Sep 2000).
- Ananova. Zeppelin Airships Are Cleared to Fly Again [article on-line]. United Kingdom, 2001, accessed 12 March 2003; available from <http://www.ananova.com/news/story/sm.html>; Internet.
- Beaubois, Henry, *Airships: Yesterday, Today, and Tomorrow*. New York: Two Continents Publishing Group, 1976.
- Boeing. Preliminary Information – 747-400ER. [on-line]. Everett, WA: Boeing, 2002, accessed 3 December 2002; available from <http://www.boeing.com/commerical/747family/technical.html>; Internet.
- "Old Gear Greets Gulf Soldiers." *Kansas City Star*, 16 February 2003, sec. A, p. 18.
- Center for Army Analysis. CargoLifter Aerial Transport System. Fort Belvoir: Center for Army Analysis, 2001.
- Charters – Special Assignment Airlift Missions (SAAM'S), Joint Chiefs of Staff Exercises (JCSE), and Contingencies for the Transportation Working Capital Fund (TWCF), and Non-TWCF Aircraft*. Internet. Available from <https://public.scott.af.mil/hqamc/fm/saam.doc>; accessed 05 Oct 02.
- Coleman, Arthur J. *United States Transportation Command (TRANSCOM) Transportation Working Capital Fund (TWCF) Budget Narrative Analysis: FY02 President's Budget (PB) Submission*. TRANSCOM, 2001.
- The Congress of the United States Congressional Budget Office. *Moving U.S. Forces: Options for Strategic Mobility*. Washington D.C.: Congressional Budget Office, 1997.

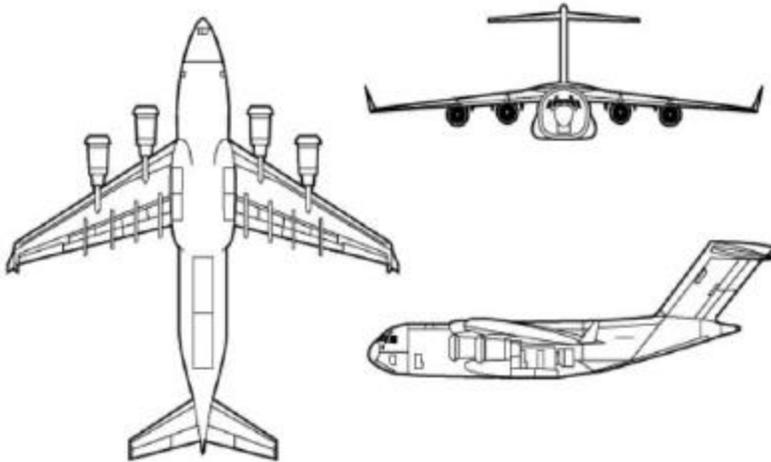
- Drew, Dennis and Donald Snow. *Making Strategy: An Introduction to National Security Processes and Problems*. Maxwell Air Force Base: Air Univ Press, 1988.
- Dryden, George M. "The C-17 Transport – Joint Before Its Time." *Joint Forces Quarterly*, Summer 1996, 67-73.
- Federation of American Scientists, *C-5 and C-17*. Military Analysis Network, 2000. Accessed 21 August 2002. Internet. Available from <http://www.fas.org/man/dod-101/sys/ac/c-5.htm>
- Fellows, James A., Michael H. Harner, Jennifer L. Pickett, and Michael F. Welch. 1996. *Airlift 2025: Getting There First With the Most*. Internet. Available from <http://www.au.af.mil/au/2025/volume2/chap04/v2c4-1.htm>; accessed 4 September 2002.
- Headquarters, Department of the Air force. *Airfield Suitability and Restrictions Report (ASRR)*. Washington D.C.: Government Printing Office, 1998.
- Headquarters, Department of the Army. *Field Manual (FM) 3-0. Operations*. Washington D.C.: Government Printing Office, 1994.
- _____. *Field Manual (FM) 55-9. Unit Air Movement Planning*. Washington D.C.: Government Printing Office, 1994.
- _____. *Field Manual (FM) 100-16. Army Operational Support*. Washington D.C.: Government Printing Office, 1995.
- _____. *Field Manual (FM) 100-17. Mobilization, Deployment, Redeployment, Demobilization*. Washington D.C.: Government Printing Office, 1992.
- _____. *Field Manual (FM) 100-17-1. Army Pre-Positioned Afloat Operations*. Washington D.C.: Government Printing Office, 1996.
- _____. *Field Manual (FM) 100-19. Domestic Support Operations*. Washington D.C.: Government Printing Office, 1993.
- _____. *Field Manual (FM) 100-23. Peace Operations*. Washington D.C.: Government Printing Office, 1994.
- Johnson, Alan. "Airship Maker in Bid to Take Rivals' Berlin Facility." *Business Weekly*, 18 June 2002, 30.
- Headquarters, Joint Chiefs of Staff. *Joint Publication 4-01.8. Joint Tactics, Techniques, and Procedures for Joint Reception, Staging, Onward Movement, and Integration*. Washington D.C.: Government Printing Office, 2000.
- Kloetzer, Sabine., and Roth, Monique. *Airships – The Flying Giants* [book on-line]. Sabine Kloetzer and Monique Roth, 2001, accessed 05 September 2002; available from http://www.sabinerin.de/werke/airships/table_of_contents.html
- Lague, David. *We All Live for Another Submarine* [magazine on-line] Hong Kong: Far Eastern Economic Review, 2002, accessed 20 August 2002; available from <http://ebird.dtic.mil/Aug2002> ; Internet.

- Military Traffic Management Command (MTMC). *Port Handling Billing Rates – FY 2002*. Internet. Available from www.mtmc.army.mil/CONTENT/2023/portRatesfy02.pdf; accessed 05 Oct 02.
- Mineseeker Foundation. *Concept Approval for UNMIK MACC Mineseeker Airship Operations in KFOR AOR*, Shropshire: Mineseeker Foundation, 2001.
- Mobilization Budget Estimates*. Internet. Available from <http://www.dtic.mil/comptroller/fy2003budget/pdfs>; accessed 05 Oct 02.
- Navy Reserve Forces. *MMIRRG Information Brief – Strategic Sealift* [brief on-line]. Navy Reserve Forces, 1997, accessed 15 October 2002; available from http://www.navres.navy.mil/navresfor/navsurf/staff__codes/N1/N14/powerpoint/sealift; Internet.
- Povah, Derek Dr. *What Do You Know About APS-3* [article on-line] Fort Lee, VA: Army Logistician, 2000, accessed 14 Aug 2002; available from <http://www.almc.army.mil/alog/issues/JulAug00/ms541.htm>; Internet.
- Quested, Tony. “Airship Company Fights to Keep IP in Britain.” *Business Weekly*, 13 September 2002, 24.
- Richards, Kim. APS Information Paper. Pentagon: Headquarters Army Deputy Chief of Staff for Logistics, 2001.
- SkyCat 1000 Engineering Study, Final Report. 10 April 2002. Camber Corporation and SkyCat Technologies Inc.
- SkyCat™ Series. Accessed 04 August 2002. Internet available from <http://www.skycattech.com/skycat20>.
- Sweetman, Bill. “Monster at 20 FT.” *Popular Science*, 27 January 2003, 43-66.
- TRANSCOM. *TRANSCOM Handbook 24-2*. 1998. Internet Available from <http://www.globalsecurity.org/military/systems/aircraft>; accessed 15 Oct 02.
- World SkyCat Advertising Brochure. 15 September 2002. World SkyCat Ltd., Wytham Abbey, Wytham, Oxford, UK.
- Wilson, Jim. “Return of the Battle Blimps,” *Popular Mechanics*, 2002. Accessed 05 August 2002. Internet. Available from <http://popularmechanics.com/science/military/2002/3/>.
- United States General Accounting Office. *Military Airlift: Comparison of C-5 and C-17 Airfield Availability*. Washington D.C.: General Accounting Office, 1994.

APPENDIX A: STRATEGIC LIFT CHARACTERISTICS AND CAPABILITIES

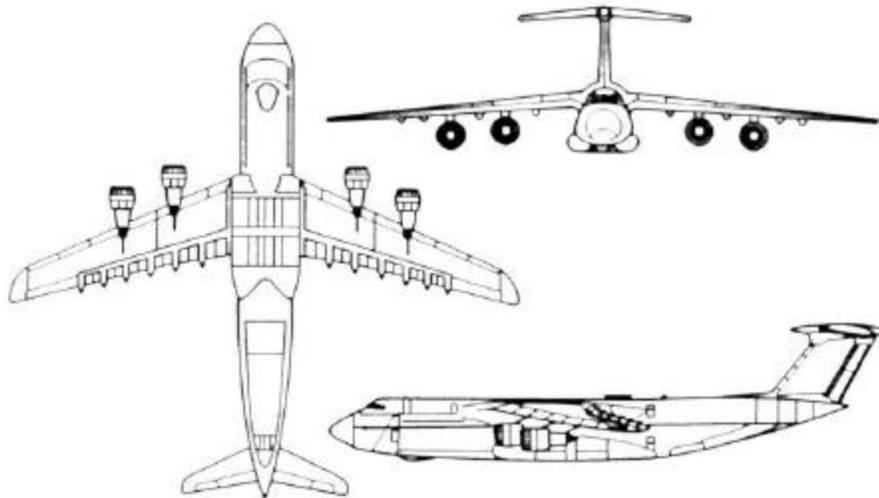
C-17 Globemaster

- Maximum Cargo Lift: 170,900 lbs
- Maximum Cargo Lift Range: 3,500 NM
- Max Speed: 500 mph
- Dimensions
 - Wingspan: 170 feet 9 inches (51.81 meters)
 - Length: 173 feet 11 inches (53.04 meters)
 - Height: 55 feet 1 inch (16.79 meters)
- Service ceiling: 45,000 feet at cruising speed (13,716 meters)
- Requires APOE/APOD infrastructure support, however it can operate at austere airfields with short runways (2,900 feet).
- Inventory: 120 airframes Cost: \$236.7 Million (FY 98 dollars)



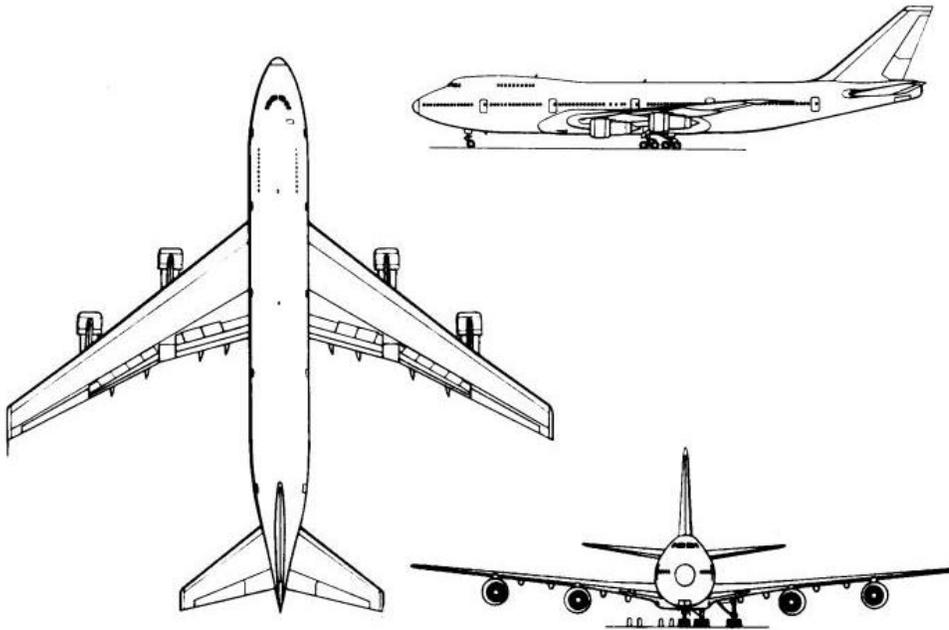
C-5 Galaxy

- Maximum Cargo Lift: 291,900 lbs
- Maximum Cargo Lift Range: 2,960 NM
- Max Speed: 541 mph
- Dimensions
 - Wingspan: 222 feet 9 inches (67.9 meters)
 - Length: 247 feet 10 inches (75.3 meters)
 - Height: 65 feet 1 inch (19.8 meters)
- Service ceiling: 34,000 feet at cruising speed (13,716 meters)
- Requires APOE/APOD infrastructure support, especially maintenance facilities. Needs at least a 11,000 foot runway for maximum weight loads for takeoff.
- Inventory: 126 (active and reserve component).
- Cost: \$179 Million (FY 98 dollars)



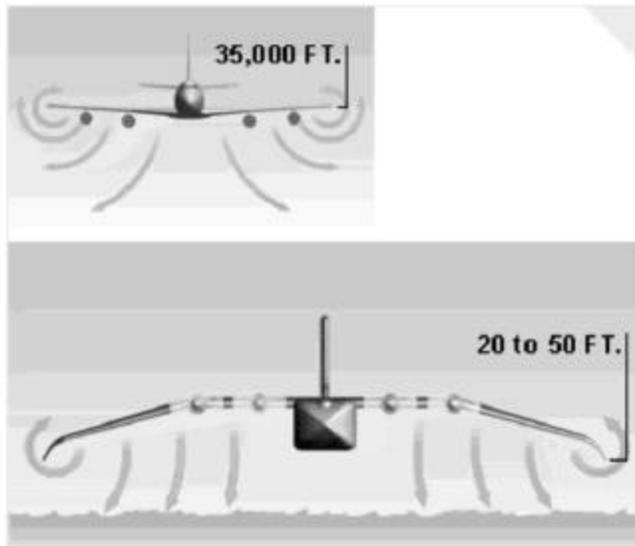
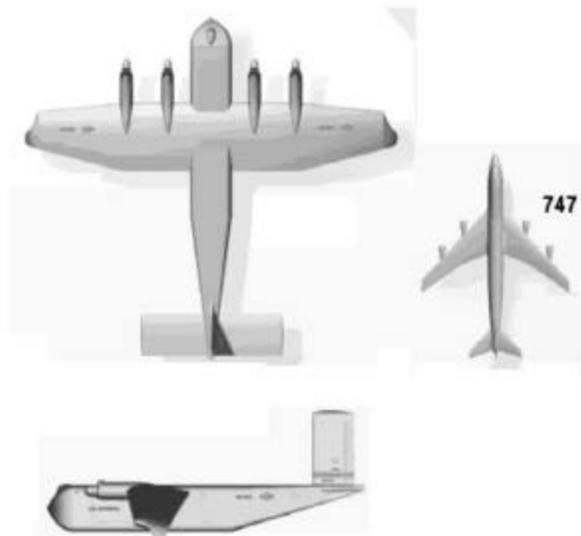
Boeing 747-400 ER

- Maximum Cargo Lift: 248,600 lbs
- Maximum Cargo Lift Range: 4,970 NM
- Max Speed: 560 mph
- Dimensions
 - Wingspan: 211 feet 5 inches (64.4 meters)
 - Length: 231 feet 10 inches (70.7 meters)
 - Height: 63 feet 8 inch (19.4 meters)
- Service ceiling: 34,000 feet at cruising speed (13,716 meters)
- Requires APOE/APOD infrastructure support, especially maintenance facilities. Needs at least a 11,000 foot runway for maximum weight load takeoffs.
- Inventory: Determined by what level of call-up and availability of aircraft.



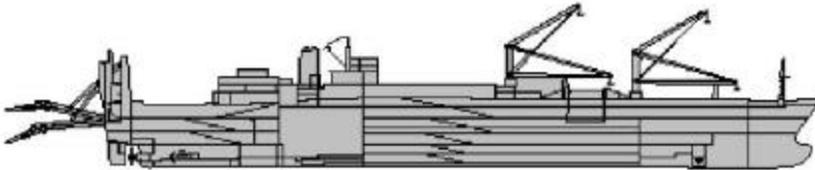
Boeing Pelican Wing-In-Ground (WIG) Effect (Design Only)

- Maximum Cargo Lift: 1,400 tons
- Maximum Cargo Lift Range:
 - Over water: 10,000 NM
 - Over land: 6,500 NM
- Max Speed: 300 mph
- Dimensions
 - Wingspan: 500 feet
 - Length: 400 feet
- Service ceiling:
 - Over water: 50 feet.
 - Over land: 20,000 feet
- Require a very large APOE/APOD infrastructure support and a very long runway in excess of 10,000 feet when carrying maximum payload – may crush runway.
- Inventory: None – in design exploration phase.



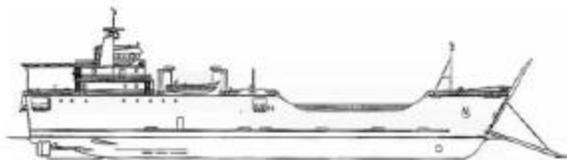
Large Medium Speed Roll-on / Roll-off Ship (LMSR) – Watson Class

- Maximum Cargo Lift: 26,000,000 lbs (equivalent to 152 C-17 or 89 C-5 sorties)
- Maximum Cargo Lift Range: 13,800 NM
- Max Speed (with cargo): 24 knots
- Dimensions:
 - Length (overall): 905 feet.
 - Draft (loaded): 37 feet.
 - Deck area: 395,000 square feet (88 M1A1/54 BFV/900 other vehicles).
- Inventory: 8 vessels in APS-3, 11 additional vessels in the SURGE program.



Logistics Support Vessel (LSV) – Besson Class

- Maximum Cargo Lift: 4,000,000 lbs (equivalent to 24 C-17 or 14 C-5 sorties)
- Maximum Cargo Lift Range: 6,500 NM
- Max Speed (with cargo): 11.5 knots
- Dimensions:
 - Length (overall): 273 feet.
 - Draft (loaded): 12 feet.
 - Deck area: 10,500 square feet (21 to 24 M1 main battle tanks or 25 [50 double-stacked] 20-foot ISO containers).
- Inventory: 6



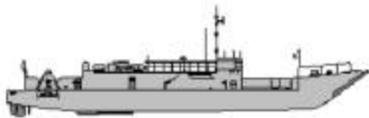
Landing Craft Utility 2000 series

- Maximum Cargo Lift: 700,000 lbs (equivalent to 5 C-17 or 3 C-5 sorties)
- Maximum Cargo Lift Range: 6,500 NM
- Max Speed (with cargo): 10 knots
- Dimensions:
 - Length (overall): 174 feet.
 - Draft (loaded): 9 feet.
 - Deck area: 2,500 square feet (5 M1 main battle tanks or 12 [24 double-stacked] 20-foot ISO containers).
- Inventory: 34



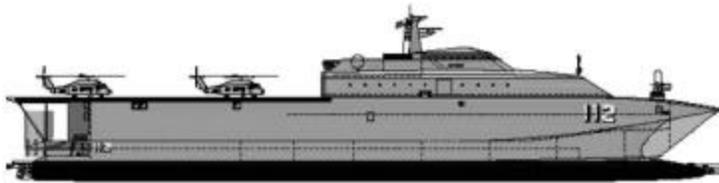
LCU 1600 series

- Maximum Cargo Lift: 368,000 lbs (equivalent to 2 C-17 or 1.5 C-5 sorties)
- Maximum Cargo Lift Range: 1,100 NM
- Max Speed (with cargo): 11 knots
- Dimensions:
 - Length (overall): 135 feet.
 - Draft (loaded): 7 feet.
 - Deck area: 1,785 square feet (3 M1 main battle tanks or 400 troops).



High Speed Vessel (HSV) (Prototype Only)

- Maximum Cargo Lift: 300-500 tons and 900-1,200 troops
- Maximum Cargo Lift Range: 500-1,200 NM
- Max Speed (with cargo): 37 knots
- Dimensions:
 - Length (overall): 331 feet.
 - Draft (loaded): 12.5 feet.
 - Deck area: 33,000 square feet (Ten 40 ton trucks).
- Inventory: N/A – items is experimental and under lease



APPENDIX B: MEASURES OF EFFECTIVENESS

The following measures of effectiveness come directly from the SkyCat Engineering Study.

Parameter	SkyCat 1000 ¹		C-17 ²
	STOL	VTOL	
<i>Number of Aircraft</i>	2	2	9
<i>Number of Flights</i>	2	2	18
<i>Airspeed (outbound)</i>	100 kt	105 kt	490 kt
<i>Transit Time (outbound) ³</i>	25.4 hr	24.1 hr	5.0 hr
<i>Battalion Delivery Time ⁴</i>	26.6 hr	25.5 hr	29.0 hr
<i>Flight Hours for Fleet</i>	103.2 hr	108.6 hr	219.2 hr
<i>Total Fuel Burned</i>	1.69 Mlb	1.58 Mlb	4.70 Mlb
<i>Total Helium Released</i>	0	12.9 M-ft ³	N/A
<i>Cost per Ton-Mile ⁵</i>	\$0.67	\$1.62	\$1.86

¹ SkyCat MOG = 2, overflight of Pakistan at night only

² C-17 MOG = 5, overflight of Pakistan in day or night

³ based on 5 kt avg. headwind (worst case scenario)

⁴ time from takeoff of first flight to landing of last flight in Pakistan

⁵ cost of expendables only (Fuel @ \$2.75/gal, Helium @ \$0.05/cu. ft)

Table B - 1: Airship transport mission from DGAR to Pakistan⁷⁵

Measure of Effectiveness	Light ACR		Heavy ACR	
	SkyCat	C-5	SkyCat	C-5
<i># of Aircraft</i>	18	61	38	68
<i># of Flights Required</i>	18	241	38	408
<i>Cruise Speed</i>	90 kt	490 kt	80 - 90 kt	490 kt
<i>Crossing Time (outbound)</i>	66.5 hr	14.5 hr	66.5 - 74 hr	14.5 hr
<i>Total Delivery Time</i>	4.7 days	20.0 days	7.4 days	33.4 days
<i>Total Fleet Flight Hours</i>	3,049 hr	6,507 hr	6,743 hr	11,016 hr
<i>Total Fuel Burned</i>	29.3 Mlb	152.6 Mlb	64.4 Mlb	258.3 Mlb
<i>Fuel Cost per Ton-Mile</i>	\$0.05	\$0.25	\$0.04	\$0.16

Table B - 2: Airship transport mission from CONUS to SWA

⁷⁵ SkyCat Study, 198.

When this study was completed the Interim Brigade Combat Team (IBCT) had not yet been renamed the Strkyer Brigade Combat Team (SBCT), hence the discrepancy between the chart and the table B-3 title.

Measure of Effectiveness	SkyCat 1000	C-5
# of Aircraft	17	63
# of Flights Required	17	188
Cruise Speed	105 kt	490 kt
Crossing Time	43.4 hr	10.3 hr <i>(incl. refuel)</i>
MOG	5	16
IBCT Delivery Time	90.3 hr	102.6 hr
Total Flight Hours for Fleet	1,514 hr	3,791 hr
Total Fuel Burned	24.9 Milb	88.9 Milb
Fuel Cost per Ton-Mile	\$0.05	\$0.18

Table B - 3: Airship transport mission from CONUS to Korea⁷⁶

Commercial Comparison Tonnage Fort Lewis to Kimhae AB							
Aircraft	Total Payload Capacity in Tons	Payload Moved in Tons @ 80% Load Factor	Sorties Required	Total Cost per Sortie	Total Cost for Sorties Required	ATM @ \$1.57 per Gallon Fuel Cost (FedEx)	ATM @ \$1.90 per Gallon Fuel Cost (Government)
MD-11F	101	809	11	\$84,888	\$933,565	\$0.23	\$0.25
747-400F	102	817	11	\$111,456	\$1,226,016	\$0.30	\$0.33
SC 1000	1100	880	1	\$360,836	\$360,835	\$0.09	\$0.10

Commercial Comparison Based Equal Number of Sorties				
Aircraft	Number of Sorties	Payload Moved in Tons	Total Cost	Cost per ATM (Available Ton Mile)
MD-11	124	10,019	\$10,466,817	\$0.23
747-400F	124	10,118	\$13,820,544	\$0.30
SC 1000	124	108,907	\$45,896,741	\$0.09

Table B - 4: Airship cost comparison with CRAF⁷⁷

⁷⁶ Ibid, 191.

⁷⁷ Ibid, 28.

<i>COST METRICS</i>		<i>SKYCAT 1000</i>		<i>ANNUAL BUDGET</i>		
Type of Lease Agreement - Estimates Only				Day	Month	Year
Dry Lease per -				\$92,182	\$2,803,880	\$33,646,564
Wet Lease per -				\$122,746	\$3,733,506	\$44,802,075
ACM Lease per Hour @105 Kts TAS						\$9,036
Purchase - Estimate Only						Total
Acquisition Price						\$266,094,000
Annual Interest Rate						5.51%
Period (Yrs)						20.00
Monthly Payment						\$1,859,409
Annual Payment						\$22,312,908
Annual Operating Budget (Aircraft Owned)			Based on TAS / Knots			
Load Factor	80.00%	Speed (Kts)	105	85	70	
Payload Capacity in Tons	1,100					
Annual Flight Time	Hours		5,370	5,534	5,664	
Total Cost (No Depreciation)			\$45,896,741	\$43,574,031	\$41,993,314	
- Per Hour			\$8,547	\$7,874	\$7,414	
- Per Nautical Mile			\$81	\$93	\$106	
- Per ATM (Ton Mile)			\$0.09	\$0.11	\$0.12	
Direct Cost			\$17,377,002	\$15,054,292	\$13,473,575	
Fixed Cost with 10% Book Depreciation			\$55,129,139	\$55,129,139	\$55,129,139	
Total Cost			\$72,506,141	\$70,183,491	\$68,602,714	
- Per Hour			\$13,502	\$12,682	\$12,112	
- Per Nautical Mile			\$129	\$149	\$173	
- Per ATM (Ton Mile)			\$0.15	\$0.17	\$0.20	
Total Cost (No Depreciation)			\$45,896,741	\$43,574,031	\$41,993,314	
Market Depreciation Average 4% per Year			\$10,643,760	\$10,643,760	\$10,643,760	
Total Cost (Market Depreciation)			\$56,540,501	\$54,217,791	\$52,637,074	
- Per Hour			\$10,529	\$9,797	\$9,294	
- Per Nautical Mile			\$100	\$115	\$133	
- Per ATM (Ton Mile)			\$0.11	\$0.13	\$0.15	
Annual Operating Budget (Dry Lease)			Based on TAS / Knots			
Load Factor	80.00%	Speed (Kts)	105	85	70	
Payload Capacity in Tons	1,100					
Annual Flight Time	Hours		5,370	5,534	5,664	
Total Cost			\$33,646,564	\$33,646,564	\$33,646,564	
- Per Hour			\$6,266	\$6,080	\$5,941	
- Per Nautical Mile			\$60	\$72	\$85	
- Per ATM (Ton Mile)			\$0.07	\$0.08	\$0.10	
Annual Operating Budget (Wet Lease)			Based on TAS / Knots			
Load Factor	80.00%	Speed (Kts)	105	85	70	
Payload Capacity in Tons	1,100					
Annual Flight Time	Hours		5,370	5,534	5,664	
Total Cost			\$44,802,075	\$44,802,075	\$44,802,075	
- Per Hour			\$8,343	\$8,096	\$7,910	
- Per Nautical Mile			\$79	\$95	\$113	
- Per ATM (Ton Mile)			\$0.09	\$0.11	\$0.13	

Table B - 5: Cost metrics for the SkyCat 1000⁷⁸

⁷⁸ Ibid, 176.

APPENDIX C: MODELING SCENARIOS FOR THE AIRSHIP

Scenario 1: Strategic Airlift of an Interim Brigade Combat Team From Ft. Lewis, Washington to Korea⁷⁹

To better illustrate the various elements of SkyCat military operations, three military airlift scenarios have been developed. In the first scenario, an Interim Brigade Combat Team (IBCT) is to be deployed from Fort Lewis, Washington to southeastern Korea. The goal is to deliver the entire IBCT as quickly as possible.

The general route is shown in Figure C-1. The great circle distance of 4,556 NM is almost entirely over water, but cuts across the center of the Alaska Peninsula, the southern tip of the Kamchatka Peninsula, and the northern tip of Japan's Hokkaido Island.

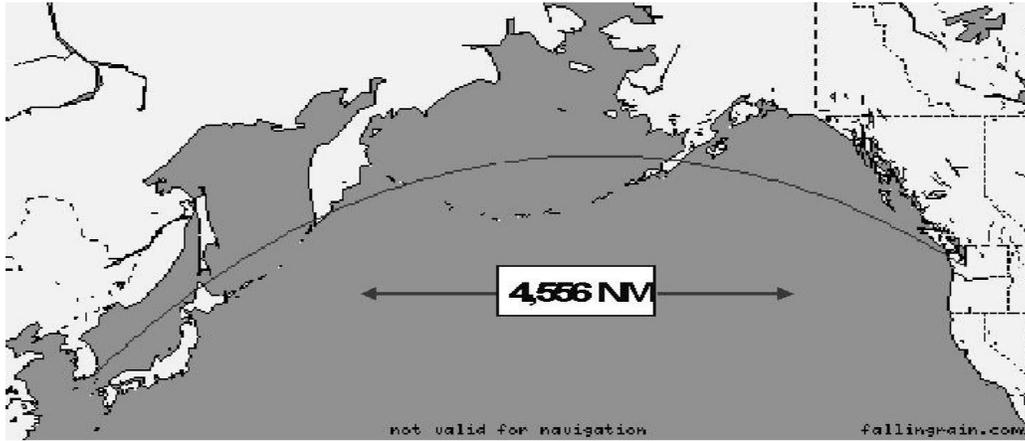


Figure C - 1: Airship transport of SBCT to Korea

The scenario begins with a certain number of empty SkyCats on the ground in standby mode at the edge of Rogers Drop Zone (DZ) in Fort Lewis (Figure 1.1.C-12). This number of SkyCats is the "maximum on ground" (MOG), which is initially a free parameter in the analysis. The military modifications to the SkyCat cargo bays have been completed, and the loading and flight crews are present and ready. Sufficient water ballast is on board to maintain a positive weight-on-ground condition. The fuel tanks are not necessarily full, but sufficient fuel for all flights is at hand. Ground support equipment includes tanker trucks or hydrants for transferring fuel and water to and from the SkyCats. All IBCT equipment and personnel have been assembled and prepared for transport in close proximity to the DZ.

The destination site is the Rigger DZ, about 14 statute miles to the northwest of Kimhae International Airport in South Korea (Figure 1.1.C-13). The drop zone and its approach routes have already been secured against ground or air attack. Fuel for SkyCat return flights has been pre-positioned near the off-loading area, and water for ballast is available from the nearby Naktong River. Ground support equipment includes tanker trucks for transferring fuel and water ballast. Off-loaded IBCT equipment and personnel move away from the area quickly, and their subsequent activities are not tracked in this analysis.

After unloading, SkyCats take on fuel and ballast at Rigger DZ, then return immediately to Fort Lewis. Upon arrival, they are assigned to other missions or returned to commercial

⁷⁹ SkyCat Study, 187-192.

service. The scenario ends when the last SkyCat return flight comes to rest on the ground at Fort Lewis.

An IBCT (as defined by Mr. Larry Guderjohn, DAMO-SSW, in an information paper on 26 November 2001) contains 1,367 pieces of equipment and 3,566 soldiers. Total equipment weight is 12,574 tons. In addition, there is a follow-on sustainment Combat Service Support Company (CSSC), consisting of 195 tons of equipment (predominantly oversized and outsized) and 297 soldiers. This analysis does not include the estimated 195 tons per day of bulk cargo needed to sustain the IBCT during its deployment.

IBCT personnel and their “carry on” baggage are carried on the upper decks of the SkyCat cargo bay according to the passenger planning factors shown in Figure 1.1.C-10. Adding personnel raises the total weight transported to 14,198 tons, about 11% more than for the equipment alone.

For the Mil-C configuration, the average payload per SkyCat flight is 835 tons, well below the commercial maximum of 1,100 tons. In fact, most flights must add ballast before departure, to keep from becoming buoyant, as fuel is burned en route.

For an optimistic case of 0-kt average headwind and a pessimistic case of 10-kt average headwind, SkyCat requires 700,000 to 780,000-lb of fuel to cruise between Fort Lewis and South Korea. Adding this to the “fixed” fuel allocations for taxi, takeoff, etc. listed in Table 2.2-1, the total fuel needed for the outbound flight is 799,200 to 879,200-lb. Since the tank capacity is 992,000-lb, SkyCat can make the complete flight unrefueled.

Mission time for each SkyCat flight is the interval from the beginning of cargo loading at Fort Lewis, through the delivery of the cargo to Korea, to when the return flight is on the ground at Fort Lewis again. The average time to load or unload a SkyCat is taken to be 11 hours (Figure 1.1.C-14) (unloading times are similar). A taxi time of 35 minutes at either end of the mission is based on the parking area being about 10,000 ft from the landing/takeoff area and ground speed being about 5 kt (plus 15 minutes to operate the cargo bay doors and move ground personnel). “Fixed” times for takeoff, landing, etc. are taken from Table 2.2-2. The average cruise times are 45^h 34^m outbound and 41^h 25^m return. These are calculated based on 105 kt airspeed and average wind conditions. Random sampling of wind data (reported more fully in Section 3.1.D) suggests that SkyCats flying near 5,000 ft altitude will encounter an average headwind of about 5 kt on the way to South Korea and an average tailwind of 5 kt on the return flight.

Based on these inputs, a computer simulation was built (using Microsoft Excel software) to determine how long it takes to deliver an IBCT to the Korean theater using SkyCat transport. A free parameter in the simulation is the maximum on ground (MOG) at either the departure or destination takeoff and landing zone. The simulation begins with a number of SkyCats equal to the MOG on the ground at Fort Lewis ready to be loaded. When loading is complete, they take off in staggered sequence, so that no more than one SkyCat is in motion on the ground at once. After their departure, the next group of SkyCats lands immediately at Fort Lewis (in staggered sequence), and their loading begins. This process continues until all 17 SkyCats have been loaded and sent on their way. At the Korean end, only one SkyCat at a time is allowed to be landing, taxiing or taking off, and the maximum number allowed on the ground at one time is equal to the MOG. This last restriction in fact forces some SkyCats to “loiter” before landing while waiting for a parking place. A similar set of rules is applied to the return flights.

This analysis is based on 17 separate SkyCats being available for service. The rationale for this ground rule is the pressing need for speed: the Army goal for IBCT deployment is 96 hours. Since a single SkyCat round trip takes at least 90 hours, this goal cannot be met unless each SkyCat flies only once.

It is useful to compare these SkyCat results with what would be obtained by transporting an IBCT with C-5 aircraft, as shown in Figure C-4. A top level loading analysis, similar to the one described for SkyCats above, suggests about 162 C-5 flights would be needed to carry the IBCT equipment. Normally, the soldiers would travel separately in CRAF passenger aircraft, but

if they were to travel by military transport, an additional 26 C-5 flights would be needed, bringing the total to 188. MOG for the C-5's, particularly at the Korea end, is unknown, but a generous value of 16 is used to compare with SkyCat's adopted value of 5. To obtain a scenario deployment time approaching 96 hours, at least 63 separate C-5 aircraft, each flying three round trips, are needed. Although they fly nearly five times faster, the total number of flight hours put on the C-5 fleet is more than double the SkyCat flight hours. A cost comparison between SkyCats and C-5's is difficult because of the different ways in which costs are accounted. "Operating cost" of a C-5, for example, does not include amortization of its purchase price, labor costs of flight and ground personnel, insurance, or profit. The "wet lease" cost of a SkyCat, on the other hand, includes all those things. Perhaps the fairest "apples-to-apples" comparison can be made between the costs of fuel burned to complete the scenario. On that basis, the SkyCat is less expensive than the C-5 option by more than a factor of three. (Note: fuel costs for both SkyCats and C-5 based on \$0.90 per gallon.)

Refer to Appendix B for the graphic depiction of this fuel cost and other comparison data.

Scenario 2: Strategic Airlift of an Armored Cavalry Regiment (ACR) from Ft. Campbell, Kentucky to Saudi Arabia⁸⁰

The second strategic airlift scenario considered is the transport of an Armored Cavalry Regiment (ACR) from its home in Fort Campbell, Kentucky to Al Kharj AB near Riyadh, Saudi Arabia. Two versions of an ACR have been considered. A "light" ACR is intended for advance reconnaissance, defense, and light offense only and includes little actual armor. Its transportation requirements resemble those of the IBCT discussed above. A "heavy" ACR is a much more formidable force, with over 500 tracked vehicles, including M1A1 tanks. The basic route is shown in Figure C-5. There appear to be suitable SkyCat takeoff and landing areas at both ends. To minimize flight over land (where permissions must be obtained and guerilla attacks with small arms are more likely), the SkyCats fly across the Atlantic Ocean to the Strait of Gibraltar, and then along the Mediterranean Sea.

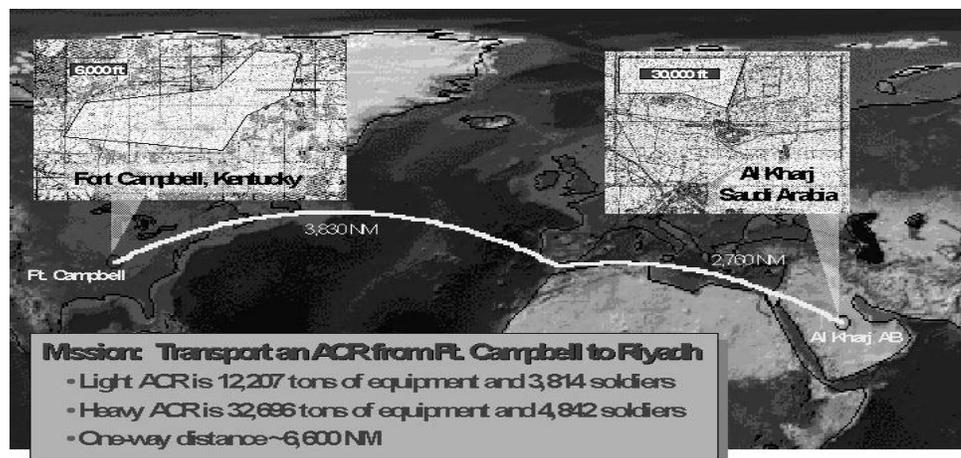


Figure C - 2: Airship transport of ACR to SWA

⁸⁰ Ibid, 192-195.

An important new feature of this scenario, compared to the IBCT, is the much longer distance that the SkyCats must fly. SkyCats can still cover this distance unrefueled, but only by flying slowly on the outbound leg (80 to 90 kt, instead of 105 kt). Fortunately, the prevailing winds help in this direction.

In average or better wind conditions, SkyCat is just able to complete the entire outbound trip without needing additional ballast. If the wind is adverse, however, it may need to stop once on the ocean. On average, the outbound flight time is 66.5 hours, or just under three days. On the return flight, the prevailing winds are headwinds, so airspeed must be even slower (75 kt airspeed) if a refueling stop is to be avoided. The typical return cruise time is 100 hours. Two stops on the ocean for ballast are required *en route*.

Alternatively, if the SkyCats choose to make a fuel stop along the way, faster flights are possible. Seven hours can be saved on the outbound leg, and over 30 hours on the return flight. Airlift requirements for this scenario are shown in Figure C-7. With the basic “Mil-A” configuration (middle side decks removed), 19 SkyCat flights are needed for the light ACR, or 51 for the heavy ACR. The light ACR packs quite efficiently, so there is only a little improvement from adjusting the upper deck height or widening the cargo bay (Mil-B or Mil-C modifications).

In contrast, the heavy ACR does benefit from lowering the upper decks in the Mil-B configuration, since it includes many taller vehicles. In fact, the loading is so efficient in the Mil-B and Mil-C configurations that heavy ACR loads approach the SkyCat weight limit. Some of these flights exceed 950 tons, and must be flown at the reduced airspeed of 80-kt if a refueling stop is to be avoided. For comparison, the numbers of C-5 flights required, as listed in the *Deployment Planning Guide* (MTMCTEA Pamphlet 700-5), are also shown in the figure. Figure C-8 shows the other scenario results, based on the SkyCat Mil-C configuration and timeline analyses similar to those described for the IBCT scenario above. Again, jet fuel was projected at \$0.90 per gallon. MOG=5 was used for both SkyCats and C-5’s.

Refer to Appendix B for the graphic depiction of this fuel cost and other comparison data.

Scenario 3: Intra-Theater Airlift of a Helicopter Battalion from Diego Garcia to Pakistan⁸¹

This scenario was developed to explore SkyCat’s effectiveness in a stressing, austere base environment where water ballast to replace off-loaded cargo is not available. The mission is to transport a helicopter battalion from Diego Garcia to the Pakistan border with Afghanistan. (Note: the destination could have been placed inside southern Afghanistan without changing any essential features of the analysis.)

The ground rules specify no fuel or ballast available at the forward takeoff and landing zone (Figure C-9). Lack of fuel is not a constraint, since SkyCat can carry more than enough for the round trip. Ballast would not constrain the scenario either, except for the additional ground rule of a short field in Pakistan, which favors landing as light as possible. The impact of not having ballast will be seen to depend on whether the takeoff and landing zone is STOL (4,500 ft) or VTOL (1,500 ft).

An additional scenario complication is the possibility of over flying rebel groups in western Pakistan. The relatively low flight altitude makes SkyCat susceptible to small arms or MANPADS attack, especially in the mountains. It is therefore specified that SkyCat over flight of Pakistan occur during hours of darkness only. The entire attack helicopter battalion, including its personnel and gear, can be loaded into two SkyCat flights.

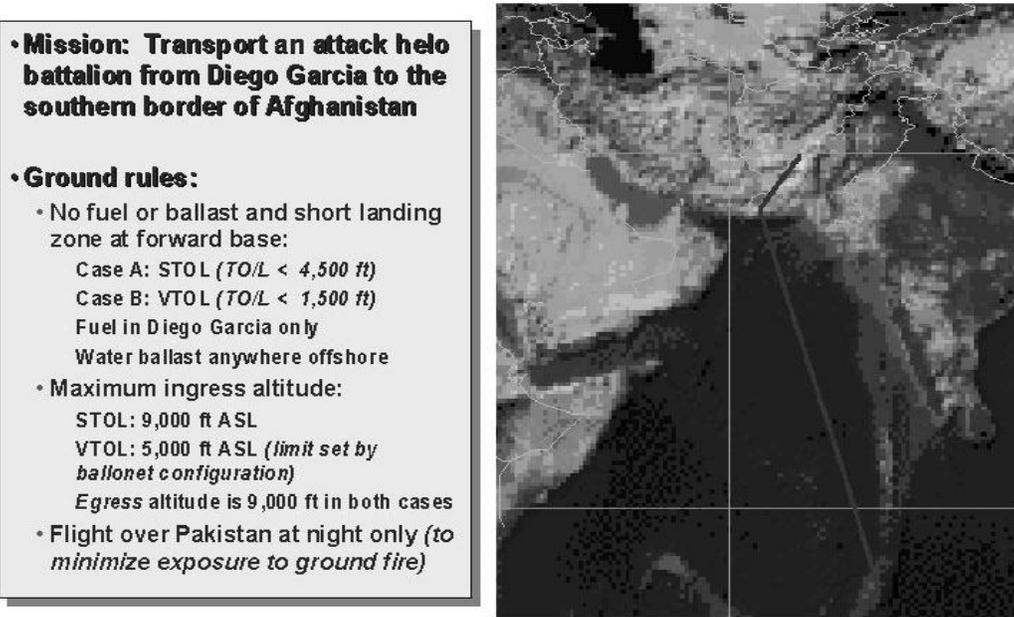


Figure C - 3: Airship transport from DGAR to Afghanistan

The scenario timelines for the STOL and VTOL cases are shown in Figure C-11. In both cases, the departure time from Diego Garcia is chosen so that the Pakistan coast is reached after dark. Landing occurs before dawn, and unloading is complete around noon. The SkyCats then wait on the ground until nightfall, so that egress is also accomplished after dark. A full tank of fuel is more than adequate to carry the SkyCats to the forward base and back without refueling. But ballast must be carefully planned to cover the 215 tons of cargo off-loaded from each SkyCat as well as the fuel burned getting to the forward base and back to the Indian Ocean (where the SkyCats land and take on additional water). In the STOL scenario, the initial takeoff weight is quite heavy (near 20%), so that no helium needs to be vented. The heaviness has dropped to 11% by the time the forward base is reached, permitting a landing within the STOL distance of 4,500-ft. After the cargo is unloaded, heaviness is down to below 3%, so a STOL takeoff is easy. For the VTOL scenario, the initial ballast load must be lighter so that a vertical landing can be made. The lighter flight weight does mean that the SkyCats can fly about 5 kt faster, cutting an hour off the delivery time. Helium is vented as cargo is unloaded, and the vertical takeoff is made at near zero heaviness. Additional helium is vented in flight on the way to the ocean, to compensate for fuel burned. The slow flight out is done to minimize the fuel used, and thus minimize the amount of helium that needs to be vented.

Helium venting in the VTOL case has the unfortunate effect of forcing the SkyCats into their 5,000 ft ceiling configuration during ingress. They can still clear the mountain passes to reach their destination, as shown in Figure C-12, but the low ceiling does make them more vulnerable to ground fire. The situation improves for egress, when SkyCats in both cases can be in their 9,000 ft ceiling configurations.

Summary results for this scenario are shown in Figure C-13, which also compares SkyCats to C-17's. Each of the two SkyCats is flown once, compared to two flights each for nine

⁸¹ Ibid, 196-198.

C-17's. The transit time for each C-17 is much shorter than for the SkyCats, of course, but the total battalion delivery time is actually a little longer, even under the ground rule of MOG=5 for the C-17's. Because the C-17's burn up almost three times as much fuel as the SkyCats, the cost per ton-mile is nearly three times higher than the SkyCat STOL scenario. The cost of helium for the SkyCat VTOL scenario is obviously a serious consideration, however, adding almost a dollar to the cost per ton-mile. Even so, it is still less expensive to use SkyCats than C-17's.

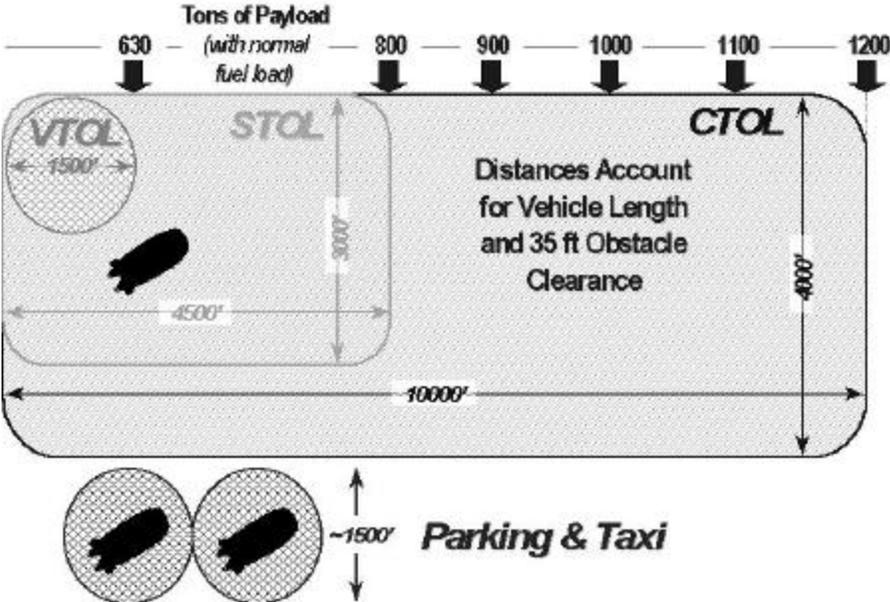


Figure C - 4: Takeoff and landing zone size requirements⁸²

⁸² Ibid 37.

APPENDIX D: SMALL ARMS/MANPADS DAMAGE VENT RATES

Study 4: Leakage of Helium from Holes in the Envelope⁸³

Calculations were made to determine the helium loss rates as a function of hole size, taking into account the expected maximum pressure differential between the top and bottom of envelope. The values considered for this pressure differential were 79.2 and 36 psf, and the damage selected was that which the envelope would incur from approximately 300 penetrations by 23mm API projectiles (1.33 ft²), 10,000 penetrations by 7.62mm API projectiles (4.9 ft²), and a severe level of damage from a MANPADS detonation 1.5 feet from the surface of the envelope (9 ft² of damage). The damage mechanism from the MANPADS is modeled as that of conical fragment trajectories emanating from the detonation point. Figure E-5 shows the leakage rate, expressed in percentage of helium loss per hour. Representative leakage rates ranged from 1.8% per hour for the smallest amount of damage considered to 12.1% per hour for a severe damage level, both for maximum pressure delta of 39 psf, considered to be most representative of typical conditions. Assuming the airship remains buoyant with only 25% of helium present, a hit from a MANPADS will cause the airship to land within four hours of the strike and make repairs.

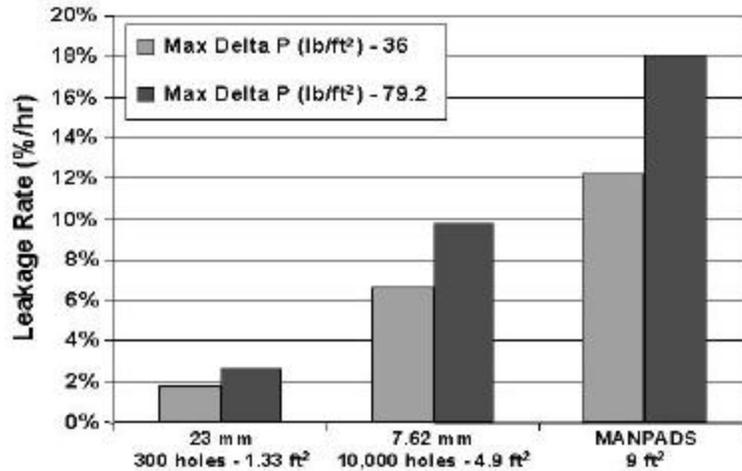


Figure D - 1: Airship venting rates

⁸³ SkyCat Study, 221.

APPENDIX E: SKYCAT COMMERCIAL MARKET AREAS

- **“SkyPatrol: *Surveillance/Border Control*.** A SkyCat 20 offers ideal solutions to the vital need for a high-endurance, low-cost and versatile airborne platform for missions like border control, counter-drug operations, coastguard search and rescue, harbor traffic monitoring and police surveillance – as well as civil uses like surveillance of pipelines.⁸⁴
 - Hush and stealth: Extremely quiet propulsion system and small radar signature.
 - Long Endurance: Seven days over a 4,000 nm patrol route.
 - Surveillance payload: Can carry up to 20 tons of surveillance equipment.
 - Low vulnerability: Virtually impervious to small arms and mortar fire.
 - Interdiction: Able to land practically anywhere, including water.
- **SkyLift: *Emergency Relief*.** The SkyCat provides the ideal vehicle for emergency operations, disaster relief and humanitarian aid. With only minor interior modifications, the same vehicle is deployable interchangeably in the full range of relief missions, from combating natural disasters to the control of bush and forest wildfires.⁸⁵
 - Point-to-point operations: SkyCats with their STOL/VTOL ability can bring relief workers, equipment, and supplies directly to the effected areas of a disaster.
 - Endorsements: U.N. World Food Program, the world’s largest aid logistics agency, calls the SkyCat 200 an optimum relief vehicle due to its large carrying capacity and STOL/VTOL capabilities.
- **FireCat: *Fire-fighting*.** The SkyCat 20 and 200 models offer a uniquely flexible, rapid and high-volume solution to the problem of fighting wildfires in bush, forests, farm estates, and residential areas.⁸⁶
 - Capacity and efficiency: SkyCat 20 and 200 models can lift, transport, and disperse 20-220 tons of water (4,000 to 44,000 gallons) more efficiently and cost effectively than conventional water-bombers.
 - Water scoup ability: SkyCats configured for firefighting can take water on board direct from the sea, lakes, or reservoirs.

⁸⁴ SkyCat Catalogue, 9.

⁸⁵ Ibid, 10.

⁸⁶ Ibid, 11.

- **SkyCruise:** *Luxury Tourism.* With spacious cabins, gentle cruising speed and autonomous all-terrain operation, the SkyCruiser offers a uniquely attractive tourist vehicle.⁸⁷
 - Capacity: A SkyCat 20 can carry up to 120 economy-class passengers or 70 first-class passengers.
 - Low cost: Estimate charging passengers \$35 per hour.
 - The experience: SkyCruisers can land alongside sea going cruise liners and pick-up/drop-off passengers for deep inland tours over areas otherwise inaccessible.
- **SkyShuttle:** *Mass Passenger Transport.* The SkyCat 200 offers a highly economical mass passenger transport vehicle for short-haul routes for up to 900 passengers at a cost per passenger/km of under \$0.10 (U.S.).⁸⁸
 - Spacious room: Space enough for recreation, dining or sleeping for passengers.
 - Low cost: Capital cost per seat of the SkyShuttle is \$120,000, compared with \$365-380,000 for the largest Airbus or Boeing passenger aircraft.
- **SkyFerry:** *Passenger Car Transport.* A SkyCat 200 could carry 420 first class passengers on the lower deck and up to 42 cars on the upper deck.⁸⁹
 - RO/RO ability to quickly load/off load cars.
 - Point-to-point service.
 - Low costs (\$15/100km for pedestrian passengers and \$25/100km for passenger and car) and quicker turn-around times over existing ferries.
- **SkyYacht:** *Executive SkyCat.* The SkyCat 20 offers a strikingly original as well as uniquely versatile vehicle to fulfill a function as a luxury Executive aircraft, both for the personal use of the owner and for the transport and entertainment of guests, invited dignitaries, and business associates.⁹⁰
- **SkyCom:** *Telecommunications.* A SkyCat 20, operating on station at 10,000 feet and equipped with advanced digital beam-forming antenna equipment, can provide a rapidly-

⁸⁷ Ibid, 12.

⁸⁸ Ibid, 13.

⁸⁹ Ibid, 14.

⁹⁰ Ibid, 15.

deployed and highly cost-effective low-altitude telecommunications platform for broadband, broadcast and 3G mobile wireless networks.⁹¹

- **SkyScreen:** *Advertising.* With its unique payload capacity, the SkyCat 20 can be fitted with large display screens and offer a revolutionary new, high-impact approach to the traditional role of airships in outdoor advertising as a truly unique flying billboard.⁹²
- **SkyFreight:** *Heavy-lift Cargo.* The ideal vehicle for the heavy-lift freight role is the SkyCat 200. With a payload capability of 220 tons this offers a uniquely low-cost, flexible addition to transportation/logistical resources of many key regions of the world.⁹³
 - Inland freight: 6,000 km range allows the SkyCat 200 to quickly transport fresh produce from deep in the interior of a nation to the port or terminal, bypassing lengthy and slow overland routes.
 - Export freight: For those products where air freight is too costly and sea transport too slow – perishable fresh produce can be transported directly from the source to the market place.
 - Low cost: Transports items at a cost of \$0.20 per ton/km.
- **SkyLine:** *Pipeline Transport.* Able to operate fully autonomously in the remotest regions of the world, the SkyCat 1000 offers a uniquely cost-effective and flexible heavy equipment transporter for the oil and gas industry, and specifically for the delivery of up to twelve 320 foot sections of pipeline directly to the trench site in one lift.⁹⁴
- **SkyGas:** *Natural Gas Transport.* A SkyCat 1500, an extended variant of the SkyCat 1000 and a payload of 1,500 tons, offers a profitable and environmentally benevolent means of transporting natural gas in gaseous form from well-head to user terminal.⁹⁵

⁹¹ Ibid, 16.

⁹² Ibid, 17.

⁹³ Ibid, 18.

⁹⁴ Ibid, 19.

⁹⁵ Ibid, 20.