HYBRID AIRSHIPS IN JOINT LOGISTICS OVER THE SHORE (JLOTS)

A thesis presented to the Faculty of the U.S. Army
Command and General Staff College in partial
fulfillment of the requirements for the
degree

MASTER OF MILITARY ART AND SCIENCE
General Studies

by

SAMUEL W. MORGAN III, MAJ, USA
B.S., Widener University, Chester, Pennsylvania, 2000

Fort Leavenworth, Kansas
2013-01

REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**			
1. REPORT DATE *(DD-MM-YYYY)* 14-06-2013	**2. REPORT TYPE** Master's Thesis		**3. DATES COVERED** *(From - To)* AUGUST 2012 – JUNE 2013
4. TITLE AND SUBTITLE Hybrid Airships in Joint Logistics Over The Shore (JLOTS)			**5a. CONTRACT NUMBER**
			5b. GRANT NUMBER
			5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) Major Samuel W. Morgan III			**5d. PROJECT NUMBER**
			5e. TASK NUMBER
			5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Command and General Staff College ATTN: ATZL-SWD-GD Fort Leavenworth, KS 66027-2301			**8. PERFORMING ORG REPORT NUMBER**
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)			**10. SPONSOR/MONITOR'S ACRONYM(S)**
			11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for Public Release; Distribution is Unlimited			
13. SUPPLEMENTARY NOTES			

14. ABSTRACT

Logistics Over-the-Shore (LOTS) is the capability to discharge a vessel offshore or in-stream and deliver its cargo to land where it is marshaled for onward movement. Army LOTS operations handle cargo multiple times before delivery to the marshalling area and then usually move the onward equipment over long distances to the tactical assembly area or point of need. This thesis examined whether Hybrid Airships can economically increase the throughput of LOTS in Sea State 3 or higher and provide a more responsive, flexible solution than existing LOTS capabilities. The study compared throughput and cost benefits of proposed Hybrid Airships against watercraft. The thesis examined the feasibility, responsiveness, integration, and survivability of airships used in LOTS. The results determined that some Hybrid Airships have the capacity to increase the throughput over watercraft and ground movements to a tactical assembly area. Although it was challenging to determine costs, the thesis determined that deploying Hybrid Airships to a theater is less cost effective than watercraft, but Hybrid Airships have the potential to cost less during employment in LOTS. Finally, the study showed that airships are a feasible solution in LOTS, increase responsiveness, should be integrated with a jointly manned crew, and that the aircraft are surprisingly survivable

15. SUBJECT TERMS

LOTS, JLOTS, Hybrid Airship, Dirigible, LEMV, SkyCat, Aeros, Aeroscrane, Pelican, WALRUS, HULA, Lighterage, Watercraft, Seabasing, Deployment, Force Projection, Anti-Access, Distribution

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. PHONE NUMBER** *(include area code)*
(U)	(U)	(U)	(U)	152	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

MASTER OF MILITARY ART AND SCIENCE

THESIS APPROVAL PAGE

Name of Candidate: MAJ Samuel W. Morgan III

Thesis Title: Hybrid Airships in Joint Logistics Over The Shore (JLOTS)

Approved by:

____, Thesis Committee Chair
Eric M. Morrison, Ph.D.

____, Member
Michael E. Weaver, M.A.

____, Member
Gerald J. Leonard, M.S.

Accepted this 14th day of June 2013 by:

____, Director, Graduate Degree Programs
Robert F. Baumann, Ph.D.

ABSTRACT

HYBRID AIRSHIPS IN JOINT LOGISTICS OVER THE SHORE (JLOTS), by Major Samuel W. Morgan III, 152 pages.

Logistics Over-the-Shore (LOTS) is the capability to discharge a vessel offshore or in-stream and deliver its cargo to land where it is marshaled for onward movement. Army LOTS operations handle cargo multiple times before delivery to the marshalling area and then usually move the onward equipment over long distances to the tactical assembly area or point of need. This thesis examined whether Hybrid Airships can economically increase the throughput of LOTS in Sea State 3 or higher and provide a more responsive, flexible solution than existing LOTS capabilities. The study compared throughput and cost benefits of proposed Hybrid Airships against watercraft. The thesis examined the feasibility, responsiveness, integration, and survivability of airships used in LOTS. The results determined that some Hybrid Airships have the capacity to increase the throughput over watercraft and ground movements to a tactical assembly area. Although it was challenging to determine costs, the thesis determined that deploying Hybrid Airships to a theater is less cost effective than watercraft, but Hybrid Airships have the potential to cost less during employment in LOTS. Finally, the study showed that airships are a feasible solution in LOTS, increase responsiveness, should be integrated with a jointly manned crew, and that the aircraft are surprisingly survivable.

ACKNOWLEDGMENTS

First and foremost, all thanks are owed to the Lord our God. Through Him I have been blessed and given undeserving grace.

To my family: my wife, Noelle, my boys Samuel, Ezekiel, and Nathaniel. Thank you for your support and patience over the past year. A special thanks to Nathaniel that sat on my lap many nights and pecked at the key board when I was not looking.

A debt of gratitude is owed to my advisors, Dr. Eric M. Morrison, Mr. Michael E. Weaver, and Mr. Gerald J. Leonard. Their feedback and patience during this thesis was invaluable.

Additionally, special thanks are extended to my small group and instructors Mr. Thomas Meara, Mr. Leo Verhaeg, Mr. Kenneth Szmed, and Dr. Gary Bjorge. You often were my sounding board and an encouraged me to press on. MAJ Luis Garcia shared my enthusiasm for the potential of Hybrid Airships and often shared new articles that related to this project.

TABLE OF CONTENTS

Page

MASTER OF MILITARY ART AND SCIENCE THESIS APPROVAL PAGE iii

ABSTRACT iv

ACKNOWLEDGMENTS v

TABLE OF CONTENTS vi

ACRONYMS ix

ILLUSTRATIONS xii

TABLES xiv

CHAPTER 1 INTRODUCTION 1

Background 3
Sea Lines of Communication 3
Logistics Over-the-Shore (LOTS) 5
Brief History of 20th to 21st Century Airships 7
Assumptions 16
Scope and Delimitations 17
Significance of the Study 18

CHAPTER 2 LITERATURE REVIEW 22

Watercraft Limitations in LOTS Operations 22
Equipment Capabilities and Processes 25
Airship Military Applications 30
Airships in LOTS Operations 30
Hybrid Airships in Intratheater Operations 33
Hybrid Airships Versus Sea Basing 34
Hybrid Airships in Intertheater Lift 38
Point of Need Concept of Operations 40

CHAPTER 3 RESEARCH METHODOLOGY 49

Movement Requirement 50
Comparative Trip Analysis 51
Method 1 52
Method 2 52

Method 3 52
Method 4 53
Method 5 53
Comparative Throughput Analysis 54
Determining Fleet Size 56
Cost Comparison of Airship Fleet to Watercraft Fleet 56
Feasibility, Responsiveness, Integration, and Survivability 57

CHAPTER 4 ANALYSIS 58

Comparative Trip Analysis Results 58
How Trip Analysis Compared to Other Research 62
Comparative Throughput Analysis Results 63
Mooring and Casting Off Affects on Throughput 66
Loading and Offloading Affects on Throughput 69
Distances Affect on Throughput 71
Results for Determining Fleet Size 74
Results for Cost Comparison of Airlift Fleet to Watercraft Fleet 75
Deployment Cost 75
JLOTS Employment Costs 75
Other Costs Considerations 77
Feasibility, Responsiveness, Integration, and Survivability 80
Feasibility 81
Environment 81
Sea State 2 and Worse 82
Mooring and Loading 83
Landing Zones 86
Responsiveness 89
Deployment 89
Point of Need Delivery 93
Integration 94
Survivability 96

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS 100

Conclusions 100
Recommendations 101
Suggestions for Further Research 103

APPENDIX A CAPABILITIES-BASED ASSESSMENT FINDINGS 106

APPENDIX B STRYKER BRIGADE COMBAT TEAM MOVEMENT REQUIREMENTS 107

APPENDIX C THROUGHPUT CALCULATIONS FOR SHIP TO SHORE 112

APPENDIX D DISCHARGE PLANNING FACTORS 113

APPENDIX E THROUGHPUT CALCULATIONS FOR GROUND............................117

APPENDIX F VARIANCE CAUSED BY PLANNING FACTORS.............................121

APPENDIX G COST ESTIMATES...124

APPENDIX H HYBRID AIRSHIP DESIGNS 128

BIBLIOGRAPHY...130

ACRONYMS

ARC	Ames Research Center
ASD(R&E)	Assistant Secretary of Defense for Research and Engineering
CBO	Congressional Budget Office
CF	Causeway Ferry
COSH	Control-of-Static Heaviness
CRADA	Cooperative Research and Development Agreement
CSNP	Causeway Section, Non-powered
CSP	Causeway Section, Powered
DARPA	Defense Advanced Research Projects Agency
DOTMLPF	Doctrine, Organization, Training, Material, Leadership and Education, Personnel, and Facilities
ELCAS	Elevated Causeway System
FSS	Fast Sealift Ship
GLOC	Ground Lines-of-Communication
HA	Hybrid Airship
ICODES	Integrated Computerized Deployment System
ISB	Intermediate Staging Base
JFACC	Join Force Air Component Command
JFAST	Joint Flow and Analysis System for Transportation
JHSV	Joint High Speed Vessel
JTF-PO	Joint Task Force – Port Opening
LARC-C	Lighter, Amphibious Re-supply Cargo (LARC-V)
LCAC	Landing Craft, Air Cushion

LCU	Landing Craft, Utility 1600 or 2000
LEMV	Long Endurance Multi-intelligence Vehicle
LHS	Load Handling System
LMSR	Large, Medium Speed Roll-on/Roll-Off Ship
LOC	Lines of Communication
LSV	Logistics Support Vessel
MEB	Marine Expeditionary Brigade
MHE	Material Handling Equipment
MLW	Mean-Low-Water
MOG	Maximum On Ground
MSC	Military Sealift Command
NASA	National Aeronautics and Space Administration
NEW	Net Explosive Weight
OPDS	Offshore Petroleum Discharge System
OSMIS	Operating and Support Management Information System
PLS	Palletized Load System
POND	Point-of-Need Delivery
RIBS	Rapidly Installed Breakwater System
RORO	Roll On/Roll Off; referred to ships with a ramp that rolling stock can drive on and off
RRDF	Roll-on/Roll-off Discharge Facilities
RTCH	Rough Terrain Container Handler
SBCT	Stryker Brigade Combat Team
SDDC-TEA	Surface Deployment and Distribution Command Transportation Engineering Agency

SLOC	Sea Lines of Communication
SLWT	Side Loadable Warping Tug
STOL	Shot Take-Off and Landing
STON	Short Tons
TAA	Tactical Assembly Area
T-ACS	Auxiliary Crane Ships
TPFDD	Time Phased Force and Deployment Data
USAF	United States Air Force
USMC	United States Marine Corps
USN	United States Navy
USNS	United States Navy Ship
USTRANSCOM	United States Transportation Command
VMOSC	Visibility and Management of Operating and. Support Costs Management Information System
VSTOL	Vertical Short Take-Off and Landing
VTOL	Vertical Take-Off and Landing

ILLUSTRATIONS

Page

Figure 1. Hybrid Airships Decrease Steps and Simplify the LOTS Process 7

Figure 2. Aereon III at Mercer County Airport in NJ, 1966 10

Figure 3. Aereon 26 or "The Deltoid Pumpkin Seed" Take-off from FAA Test Center in NJ, March 1971..11

Figure 4. PA-97: Multiple Helicopter Heavy Lift System, July 1, 1986 12

Figure 5. Lockheed Martin P-971 Hybrid Airship Demonstrator..................................13

Figure 6. Aerocrane...32

Figure 7. Vignette Transportation Network 55

Figure 8. Required Trips Made by Individual Lift Assets Based on Weight Carrying Capacity...60

Figure 9. Required Trips Made by Individual Lift Assets Based on Available Square Footage in Cargo Area..60

Figure 10. Required Trips Made by Individual Lift Assets Based on JFAST Simulation...61

Figure 11. Required Trips Made by Individual Lift Assets Based on Author's Manual Estimate 61

Figure 12. Required Trips Made by Individual Lift Assets Based on ICODE's Estimate 62

Figure 13. Approximate Size and Sustainment Requirements for Ground Units 63

Figure 14. Container and Rolling Stock Throughput by Individual Lift Asset from Offshore Anchorages to TAA, 259 Kilometers Inland by Air or 326 Kilometers Inland by Ground 65

Figure 15. Rolling Stock Throughput by Individual Lift Asset from Offshore Anchorages to TAA, 259 Kilometers Inland by Air or 326 Kilometers Inland by Ground..65

Figure 16. Container Throughput by Individual Lift Asset from Offshore Anchorages to TAA, 259 Kilometers Inland by Air or 326 Kilometers Inland by Ground 66

Figure 17. Throughput by With Standardized Mooring and Casting Off Planning Factors....67

Figure 18. Throughput by With Standardized Mooring and Casting Off Planning Factors for Rolling Stock Only....68

Figure 19. Throughput by With Standardized Mooring and Casting Of Planning Factors for Containers Only....68

Figure 20. Throughput without Loading and Offloading Planning Factors....70

Figure 21. Throughput without Loading and Offloading Planning Factors for Rolling Stock Only....70

Figure 22. Throughput without Loading and Offloading Planning Factors for Rolling Stock Only....71

Figure 23. Throughput of Airships Flown from ISB to TAA versus JLOTS at 5 Kilometers Offshore....73

Figure 24. Throughput of Airships Fleets versus Traditional Operation with One LSV and Eight LCU-2000....74

Figure 25. USS *Los Angeles* (ZR-3) Moored to USS *Patoka* (AO-9), off Panama during Fleet Problem XII, February 1931....86

Figure 26. Blimp Makes Carrier Landing, October 24, 1944....86

Figure 27. Hybrid Airships Save Time and Are More Responsive in Deployment Timeline....92

TABLES

Page

Table 1. Trips Per Lift Asset 59

Table 2. Changes to Delivery Time Based on Distance 73

Table 3. Cost Versus Throughput 77

Table 4. SkyCat Operating Limits in Weather Conditions 83

Table 5. Comparison of Airship Dimensions to Fixed Wing Aircraft 89

Table 6. Summary of Army Watercraft Capability Gap Analysis (2008) 106

Table 7. Prime Movers and Towed Equipment Unions Used Scenario 107

Table 8. Movement Requirements for Self Propelled Equipment Transported by LCU-2000 in Scenario 109

Table 9. Rolling Stock Movement Requirements for Towed Equipment Transported by LCU-2000 in Scenario 110

Table 10. Movement requirements for secondary loaded equipment that contributed to the overall weight in all scenarios, but did not affect the total square footage 111

Table 11. Calculated Loading/Offloading Planning Factors 114

Table 12. Cycle Times for RORO Discharge 115

Table 13. Cycle Times for Container Discharge 116

Table 14. Ground Movements 119

Table 15. Throughput for Container Ground Movements 120

Table 16. Variance for Rolling Stock and Containers, Caused by Mooring and Casting Off Planning Factors 121

Table 17. Variance for Rolling Stock, Caused by Mooring and Casting Off Planning Factors 122

Table 18. Variance for Containers, Caused by Mooring and Casting Off Planning Factors 123

Table 19. US Army Watercraft Operational Costs 125
Table 20. US Navy and Joint Watercraft Operational Costs 125
Table 21. Estimated Airship Operational Costs...126
Table 22. Estimated Operational Costs for PLS Medium Truck Company...................126
Table 23. Deployment Costs...127
Table 24. Hybrid Airship Designs 128

CHAPTER 1

INTRODUCTION

> U.S. Army planners are not shy about admitting that they don't know where or when the next fight will be. But until now, they have been less forthcoming about a related problem: How they'll move troops and material to the next conflict.
>
> — Paul McLeary, *Defense News*

Logistics Over-the-Shore (LOTS) is the capability to discharge a vessel off shore or in-stream and deliver its cargo to land where it is marshaled for onward movement. Generally, throughput increases when cargo is handled less. Time distance factors and carrying capacities also affect throughput significantly. Army LOTS operations handle cargo multiple times before delivery to the marshalling area and then usually onward move the equipment over long distances to the tactical assembly area or point of need. Exacerbating the slow movement of assets is the U.S. Army watercraft capability gap that cannot satisfactorily meet Combatant Commanders' timelines to move combat ready maneuver units, move combat ready maneuver units from a Sea Base, move intact operationally ready maneuver forces, nor support sustainment requirements rapidly, table 6.[1]

The purpose of this thesis was to determine whether Hybrid Airships could increase the throughput of LOTS in Sea State 3 or higher. In order to answer this question, the research analyzed the efficiency of Hybrid Airships by determining how many trips a Hybrid Airship performs compared to watercraft, what is the comparative throughput of each lift asset over time, and how large would an Hybrid Airship fleet be to have better throughput than Army and Navy watercraft. Several factors affect the size of the fleet. The research studied the capacities of existing watercraft versus a range of proposed Hybrid Airship designs, in order to determine throughputs of each mode.

A second question that this research answered is whether a fleet of Hybrid Airships can be more cost effective than watercraft. Finding an answer was determined by an analysis of operating costs, purchase prices, and maintenance costs. This analysis considered the costs associated with Doctrine, Organization, Training, Material, Leadership and Education, Personnel, and Facilities (DOTMLPF) for a Hybrid Airship program versus the Army's watercraft program.

The final question assessed whether Hybrid Airships are a feasible and effective solution that can provide a more responsive and flexible solution than existing LOTS equipment? The criteria for this question was determined by several other questions. What environmental conditions can Hybrid Airships operate in and can they operate in Sea State 3 or worse? Are airships feasible in LOTS and how would equipment transfer to the airship? How would Hybrid Airships be effectively employed if used in LOTS? How can airships be used in a non-permissive environment and are they survivable?

The next few sections are dedicated to describing how lines of communication fit into a strategic framework and how LOTS can mitigate a sea terminal's limitations and vulnerabilities. Although LOTS is a critical capability, it is also a complicated operation with limitations. An exhaustive explanation of LOTS will help the reader grasp the advantage of Hybrid Airships over watercraft in these operations. Advancements in materials and airship technology have made Hybrid Airships a feasible solution for mobility.

Background

Since antiquity the ability to sustain and project forces determined the duration and operational reach of military campaigns. Food, water, and fodder were the fuel that fed maneuver forces throughout most of history. Armies survived by living off the land or pillaging. However, like locusts consuming entire crops, armies continuously moved and devoured everything in their path. Alternatively, armies based their campaigns on the harvest periods or developed supply trains with supporting magazines and depots. The route that connected operations to a source of supply became known as Lines-of-Communication (LOC).

Increasing the length of a LOC makes an army more vulnerable to isolation and defeat. Extended distances make a LOC susceptible to external obstacles and delays, such as weather or enemy interdiction. Classical mechanics dictates that the delivery times for supplies and forces will increase as distances grow and if the average velocity is slower. If delivery takes too long, there is less lead time to allow the system to be responsive.

Sea Lines of Communication

Alexander the Great of Macedon recognized that he could shorten his ground-LOC by linking it to an intermediate sea-LOC that connected to his supply base. He used merchant fleets to sail provisions along the coast parallel to his army's march. The ground-LOC ran perpendicular to the coast and the army did not have to carry as much. "He also made extensive use of ships to carry fodder, since large merchant ships could carry about 400 tons, while a pack horse carrying only 200 pounds would eat 20 pounds of fodder daily, thus consuming its own load in ten days."[2] His strategy allowed the army to march 11,250 miles to the river Beas in India over eight years.[3] Millennia later, the United States also relies on sea-LOCs to supply and project forces across the globe.

These vital lines of communication are connected at a node called a terminal or port where loading and unloading takes place. Seaports and river ports are chosen based on their characteristics to support offload and onward movement of equipment, personnel, and supplies. Planners determine if there are enough berths with the right mix of material handling equipment (MHE) to offload the amount of material stowed on the ship. MHE might be gantry style cranes for offloading containers or smaller cranes for lifting rolling stock and break bulk cargo. Stevedores are the operators who use the material handling equipment for downloading the vessels. The size and composition of the stevedore force, labor laws, labor unions, competing commercial shipping, backhaul, and even lighting are all factors that determine how many hours per day the material handling equipment can be used.

Ports are also selected based on available temporary storage and onward movement. Some cargo requires large covered or refrigerated warehouse space, whereas other cargo, like rolling stock and containers need a large marshalling yard. Onward movement typically relies on rail or trucking over the ground-LOC. The amount of cargo that the ground-LOCs move away from a port is affected by temporary storage at the rail or trucking terminals, material handling, personnel, rail or truck availability, commercial movements, backhaul, and the size of the road or rail network. While the different parts of a port's infrastructure affect the amount of cargo that flows from a ship to onward movement, none of it matters if the ship cannot approach the port or berth along a pier or quay.

Piers and quays may be unusable for particular ships because of pier length, a narrow berth, or the water depth is too shallow. Draft and beam are terms used to assess accessibility. Draft is the distance between the waterline and the bottom of a ship's hull or keel. This measurement determines the minimum depth of water that a ship can safely navigate. The beam is the measure of a ship at its widest point.

Even if a country has deepwater ports, the ports are not always accessible during an operation. The obvious cause is that the enemy or friendly actions can easily deny access by blocking channels that lead to the harbor and damage the piers or material handling equipment. Poor maintenance can allow silt to build up in channels, which makes the water shallower or channel too narrow. Natural disasters can degrade ports like Haiti's Port au Prince during a 2010 earthquake. Extreme tidal variances can limit how long a vessel can be in a harbor or channel. Host nations may not want the port competing with their commercial shipping for space and material handling or may limit the type or amount of hazardous cargo in their port. As an example, the ammunition's Net Explosive Weight carried in ship may prevent the vessel from berthing. To mitigate the lack of a fixed-port facility or the amount of cargo that a port can support, combatant commanders must use Logistics Over-the-Shore (LOTS) or change the plan.

Logistics Over-the-Shore (LOTS)

LOTS is the capability to discharge cargo and equipment from ships while off shore or in-stream without berthing at a port or fixed facility. Throughout this paper the author will use LOTS and JLOTS interchangeably. JLOTS is simply Joint Logistics Over-the-Shore, in which more than one service is involved in the operation. Almost every LOTS operation that the U.S. Army is involved with is Joint by nature.

JLOTS operations rely on smaller vessels to ferry equipment between the ship and a pier. These smaller watercraft have flat bottoms and shallow drafts that allow the craft to land on beaches with a suitable gradient. In most LOTS there is a lot of auxiliary equipment that helps transition cargo from the ship to the smaller vessel. These may include large vessels with cranes to trans-load containers or floating causeways for the rolling stock to drive across onto the small vessel.

The Normandy landings in WWII form an image for many when they imagine LOTS. During the D-Day invasion Mulberry harbors were created as artificial harbors with breakwaters and piers to offload ships off the Normandy beaches because the Allies had not captured a French port on the northern coast. These were intended to "bridge the gap between beach operations and the capture and rehabilitation of ports."[4] More than 290,000 long tons of supplies and 71,000 vehicles were delivered across the beaches during a 25-day period.[5]

Other historical LOTS operations were conducted in Korea, Lebanon, Vietnam Somalia, and Operation Iraqi Freedom. In more recent history Haiti was devastated by an earthquake in January 2010. Port-au-Prince was damaged and ships could not access ports with cranes, material handling equipment, and storage facilities. The U.S. responded with Operation Unified Response. Trish Larson and Mike Neuhardt wrote an article about the USNS 1st LT Jack Lummus, one of many U.S. ships that provided aid during the operation. The Lummus was loaded with critical pallets of relief supplies from USAID, bottles of propane for temporary cooking stoves, dump trucks, bull dozers, generators, water purification units, building materials, medical supplies, Marines, and Navy lighterage. Upon arriving in Haiti, the ship had to anchor three miles off shore because of the port's damage and vessel's deep draft. Although offshore, Lummus's important cargo and equipment was offloaded using lighterage.[6]

While nothing should be taken away from the historical significance of LOTS operations, the question remains whether LOTS can be done more efficiently and effectively. Hybrid Airships may be an alternate solution. Hybrid Airships could replace traditional LOTS watercraft and not only deliver to the beach, but deliver cargo and equipment further inland to reduce ground transportation requirements, figure 1.

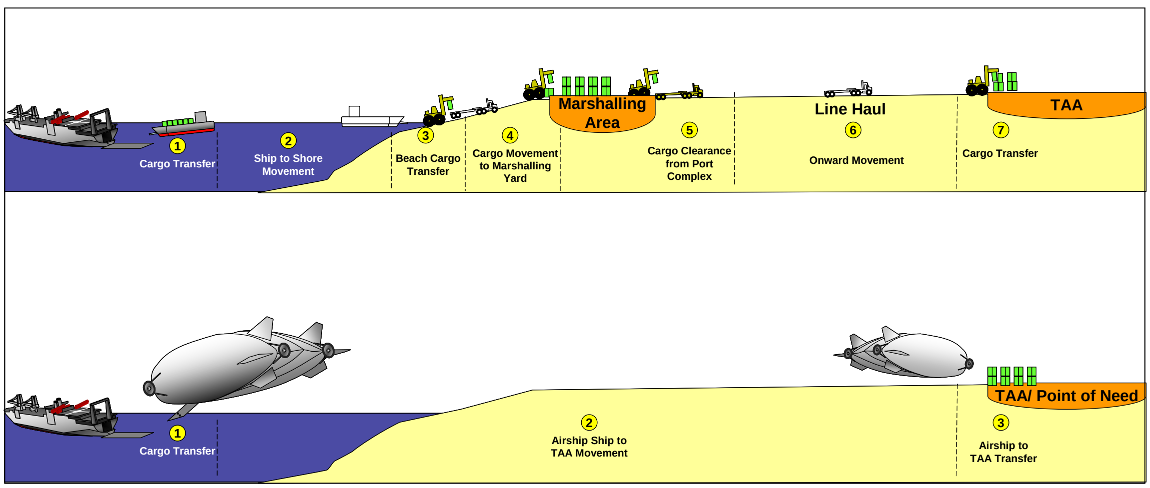

Figure 1. Hybrid Airships Decrease Steps and Simplify the LOTS Process

Source: Created by author.

Brief History of 20th to 21st Century Airships

> Afghanistan operations, recent Haitian relief efforts and fiscal realities point to the need for an improve ability to both effectively and efficiently conduct intratheater delivery. Hybrid Airships will provide the Joint Forces Commander a complementary capability to existing theater delivery capabilities that will ensure the adequate distribution of intratheater cargo and personnel, to the point of need, while minimizing risk and costs.[7]

Hybrid Airships offer the potential to increase the efficiency and effectiveness of LOTS and other transportation requirements. They combine various characteristics to produce lift that include buoyant gases, dynamic lift from the aerodynamic shape, and vectored propulsion. The advantage is that they are heavier than air while on the ground and do not need ballast.

On the other hand, traditional airships or dirigibles depend exclusively on buoyant gases for lift and are considered lighter than air. Because dirigibles are lighter than air, the aircraft depend on ballast like sand or water to stay on the ground. The ballast is released to gain elevation and then the lifting gas is vented off for descent. Dirigibles were widely used before 1940 until their cousin the airplane, outpaced them in speed and capacity.

The range of airship tasks varies throughout history and includes commercial passenger flight, reconnaissance, antisubmarine warfare, bombing, aircraft carrier, exploration, advertising, and heavy lifting. The idea to use an airship for supplies dates back to 1916. After returning to Germany from a prisoner exchange, a former Chief Medical Officer suggested that an airship be used to deliver badly needed medical supplies to East Africa.[8] Germany increased the size of the L.59 Zeppelin by almost 100 feet in order to increase the gas volume.[9] The increase was based on an estimated requirement to carry 16 tons of cargo across 4,350 miles up to four and half days without refueling.[10] In November 1917, the L.59 airship launched with three tons of medical supplies and twelve tons of weapons and ammunition from Bulgaria to Africa.[11] The airship had a number of difficulties enroute, and was recalled while close to its destination because the few German survivors were caught between British and Portuguese forces.[12]

Post World War I enjoyed a short lived golden era that provided luxury passengers services until the infamous Hindenburg crash in 1937. Passenger travel ceased but airships still had a place in aerial reconnaissance and patrolling especially for submarine spotting. Even these roles slipped away toward the end of the 1950s with the advent of nuclear submarines that could outrun airships.[13] The surviving applications in the United States were limited to scientific study and commercial advertising. Only a few enthusiasts considered freighter applications.

The Union of Soviet Socialist Republics was one of those enthusiasts. They studied aerostatics and began work in 1962 on the LL-1, a small pressure-airship.[14] The LL-1 was built for forestry and used for lifting timber, fire-watching, and firefighting, but the freighter airships were also a consideration.[15] The Soviets also considered freighter airships and began work on an 18 million cubic foot super airship intended to carry up to 500 passengers at 150 mph.[16]

An unlikely enthusiast that considered freighter applications included an American Presbyterian minister, Monroe Drew. In 1958, he proposed a fleet of large airships that could be used to carry food, Bibles, and trade goods to undeveloped countries.[17] However, his proposed airships were not ordinary dirigibles; the aircraft resembled modern hybrid airships. Drew formed a company called the Aereon Corporation. The company began work on trilobe and delta wing shaped airships that did not have to be lighter than air, figure 2 and figure 3. The airships were intended to carry 200-ton payloads.[18] Although the first prototype crashed in 1966, a few small scale test airships were constructed and eventually there was some success in the early 1970s.[19] During the early 2000s, the company worked on concepts for small multi-functional unmanned aerial vehicles and larger heavy-lift Hybrid Airships.

Figure 2. Aereon III at Mercer County Airport in NJ, 1966

Source: Aereon Corporation, "Aereon III," http://www.aereon.com/pages/aereon3.html (accessed May 1, 2013).

Figure 3. Aereon 26 or “The Deltoid Pumpkin Seed”
Take-off from FAA Test Center in NJ, March 1971

Source: Aereon Corporation, “Aereon 26,” http://www.aereon.com/pages/aereon26.html (accessed May 1, 2013).

Another Hybrid Airship design was the experimental Piasecki PA-97 Helistat, figure 4. This design combined four H-34J helicopters with a blimp in an attempt to create a heavy-lift vehicle for forestry work.[20] Unfortunately, the aircraft crashed after completing a test on July 1, 1986. Vibrations caused one helicopter to break free and the aircraft destabilized, resulting in one pilot dying and three others being injured.[21]

Figure 4. PA-97: Multiple Helicopter Heavy Lift System, July 1, 1986

Source: Piasecki Aircraft Corporation, "PA-97: Multiple Helicopter Heavy Lift System," http://www.piasecki.com/heavylift_pa97.php# (accessed May 2, 2013).

A more successful Hybrid Airship was the Sky Kitten prototype. This aircraft was built by Advanced Technologies Group SkyCat a company in the United Kingdom. The airship was a proof of principle for the lifting body and air cushion landing system that would be used in the company's planned SkyCat series of airships capable of lifting 20-ton, 200-ton, and 1,000-ton loads.[22] The Joint Chiefs of Staff J4, Lieutenant General Mike McDuffy, witnessed the SkyKitten flight in 2000.[23]

Presumably this prompted fiscal year 2001 funding for the Joint Chief of Staff "SkyCat 1000 Engineering Study," followed by fiscal years 2002 and 2003 funding for the US Navy NAVAIR Hybrid study.[24] The United States Navy initiated the Hybrid Ultra Large Aircraft (HULA) project in May 2003 that aimed to develop an airship that could lift 500-ton loads.[25]

In 2005, Congress approved Defense Advanced Research Projects Agency's (DARPA) Walrus project. The objective was to create a Hybrid Airship that could carry up to a 1,000-ton payload up to 12,000 nautical miles in less than seven days.[26] Christopher Bolkom's report to Congress described how these airships would be ideal for strategic airlift missions that deliver a "brigade directly from 'fort to the fight.'"[27]

A contract was awarded to Lockheed Martin for $2.9 million and Aeros Aeronautical Systems Corp for $3.2 million to conduct and develop an operational design vehicle during phase one of the project.[28] During phase two, DARPA selected one of the contractors to refine the design requirements, potential military utility, develop technologies, perform risk reduction, and a flight demonstration for a scaled down version of the vehicle.[29] Lockheed Martin built the P-971 that flew on January 31, 2006, figure 5.[30] The Walrus project was cancelled during the fiscal year 2006 appropriations. Interest in Hybrid Airships did not wither despite funding cuts.

Figure 5. Lockheed Martin P-971 Hybrid Airship Demonstrator

Source: "The P-791 Hybrid Air Vehicle by Lockheed Martin," http://i270.photobucket. com/albums/jj103/GreginSD/Avionics/P791-0.jpg# (accessed April 16, 2013).

The United States Transportation Command (USTRANSCOM) has continued to research Hybrid Airships for humanitarian assistance, disaster relief, and combat support. In 2010 the USTRANSCOM's Office of Research and Technology Applications posted a request for collaborators to work on a Cooperative Research and Development Agreement (CRADA). The CRADA is intended for industry and academia to collaborate with USTRANSCOM on Hybrid Airship development, integration, operations, and economic feasibility. The white paper submissions to USTRANSCOM were not available for this research project. However, the notes page of a 2011 USTRANSCOM brief titled "Department of Defense and Hybrid Airship Development" shows that USTRANSCOM and Lockheed Martin are coordinating on a CRADA studying the capabilities, limitations, risks, and costs of Hybrid Airships for a Haiti disaster relief scenario and a combat support scenario in Afghanistan. Lockheed Martin's experience in the earlier Walrus project makes them very knowledgeable about Hybrid Airships.

In addition to the ongoing CRADA, USTRANSCOM completed a modeling and simulation assessment for time savings in a humanitarian assistance or disaster relief situation. The organization also worked on a business case analysis to assess whether there was any value to building a prototype for demonstration. A third paper titled "Hybrid Airship Universal Logistics Demonstrator (HAULD)" stated that the Lightweight Endurance Multi-intelligence Vehicle (LEMV) could be leveraged for determining the feasibility of a logistics variant. These papers were not available for this research.

The LEMV is a Hybrid Airship designed for high altitude surveillance. The advantage of this aircraft over unmanned drones and manned surveillance aircraft is the ability to linger over an area for days without refueling or landing. The United States Space and Missile Defense Command posted a statement of objectives for the LEMV that entailed engineering, designing, developing, constructing, testing, operating, and maintaining and an unmanned, un-tethered Hybrid Airship to be used in high altitude surveillance.[31] Northrop Grumman received a $517 million contract in 2010 to build the LEMV and have it ready for testing 18 months later.[32]

Northrop Grumman subcontracted the LEMV's airframe to Hybrid Air Vehicles Ltd. from the United Kingdom and the aircraft flew August 7, 2012. In October 2012 the Government Accounting Office reported that the aircraft was 10 months behind schedule and overweight, which reduced its operational altitude.[33] In mid-February 2013, announcements stated that the military cancelled the LEMV program due to resource constraints and technical and performance challenges.[34] This left the Aeros Corporation with the only active contract for Hybrid Airship developments in the United States for fiscal year 2013.

The Aeros Corporation continued developing its technologies even after funding was cut for the Walrus project. Conventional airship designs require ballast, typically water or sand, carried onboard to maintain neutral buoyancy on the ground. The pilot gradually releases the ballast to gain altitude and then the buoyant gas vented to descend. The same physics apply to a SCUBA diver's buoyancy compensator device. However, like the SCUBA diver's lungs, gas has to be vented during ascent which compensates for expansion to prevent the lungs or balloonets from popping. Most Hybrid Airships depend on aerodynamic lift and vectored propulsion for lift to overcome these challenges. Aeros tackled the problem differently in its Pelican project by adding a third method to the aerodynamic and propulsion lift capabilities.

The Pelican controls buoyancy by distributing helium gas between a lifting gas cell and a pressurized fiber-composite cell while preventing any of the gas to escape like traditional airships. This system allows the airship to stay neutrally buoyant at any altitude despite consuming fuel which acts as a ballast. The advantage of this system over other Hybrid Airships is that the airship can land and take-off vertically and can be heavier than air when the payload is offloaded on the ground.[35]

The Department of Defense's Rapid Reaction Technology Office collaborated with the NASA Ames Research Center (NASA/ARC) and Air Force Research Lab in sponsoring the Pelican project. The aircraft's most recent success was completion of the prototype and first ground-handling test within its hangar in January 2013 and outdoor flight tests are expected later in 2013.[36] In February 2013, NASA/ARC solicited a modification and 10 month extension to the sole source contract with Aeros that will add another $5 million to the existing contract so that the company can further test and demonstrate the Rigid Aeroshell Variable Buoyancy (RAVB) airship design.[37]

Assumptions

The most important assumption is that Hybrid Airships can either land in the water to moor to a Roll-on, Roll-off Discharge Facility (RRDF), more directly to the ship with a ramp, or land directly on a ship. This ensures that rolling stock can be loaded onto the airship. The second part to this assumption is that the airship has some way to load and unload containers.

This paper assumes that airship designs will be constructed with pull through Roll On Roll Off (RORO) capabilities. This is a significant lesson learned from lighterage like the U.S. Army's LCU-2000 that has a single bow ramp. A single ramp cause unnecessary delays during loading or offloading. This design is especially impractical for vehicles pulling trailers.

A second assumption is that the loading decks will have an expedient tie down and release for vehicles parked inside. The analysis assumes that airships will require stow plans in order to evenly distribute weight. This also assumes that the deck of the Hybrid Airship can support the pounds per square foot of the heaviest vehicles in the SBCT. Finally, when loaded the airship will likely weigh-out rather than cube-out because weight limitations are likely to be more of constraint than the size of the cargo hold.

Scope and Delimitations

The scope of this research is limited to airships used to transfer equipment and cargo from vessels anchored offshore and delivered inland to the Caucuses region. A Stryker Brigade Combat Team (SBCT) and its containers will be used as the requirements that need to be delivered from ships anchored offshore in vicinity of a damaged fixed port or beach in the Black Sea. All supporting units and headquarters external to the SBCT will be excluded from the ship to shore movement analysis. The analysis will deliver the SBCT directly to its Tactical Assembly Area (TAA) deeper inland, somewhere up to 259 kilometers straight-line distance away from the anchored ships.

Significance of the Study

During a Senior Leader Seminar at the National Defense University, General Ray Odierno, the Army Chief of Staff briefed senior leaders on how the Army is progressing in modernization efforts to get troops to the next fight.[38] These comments followed the annual Unified Quest war game exercise that is the Army Chief of Staff's annual Title 10 Future Study Plan. During the exercise U.S. forces were tasked to land in a foreign country, but were faced with a struggle to land troops and supplies while fighting off a committed enemy.[39] General Odierno shared with the Senior Leader Seminar that "Joint Logistics Over-the-Shore capability is limited, and Joint Future Theater Lift is a capability that is still well off into the future."[40]

The proposed Joint Future Theater Lift is a heavy lift vertical takeoff and landing (VTOL) platform using advanced tilt-rotor systems.[41] The closest relative in any of the Department of Defenses inventory is the V22 Osprey. Vertical lift is very expensive; an individual MV-22 costs an estimated $74 million to purchase and $11,500 to operate per hour.[42]

An even more expensive heavy lift version will be challenging to support since requirements for economic solutions to government are becoming more important as the United States Government (USG) seeks to comply with the "2011 Budget Control Act's requirement to reduce future expenditures by approximately $487 billion over the next decade or $259 billion over the next five years."[43] The USG plans to make U.S. forces smaller and leaner, but still requires these forces to stay rapidly deployable, expeditionary, agile, and flexible. Hybrid Airships may provide a more economic and environmentally friendly solution to transportation and JLOTS.

[1]U.S. Army Combined Arms Support Command (CASCOM), *Army Watercraft Master Plan, Fleet Strategy* (Fort Eustis, VA: Government Printing Office, March 2008), 3.

[2]Julian Thompson, *Lifeblood of War*, *Logistics in Armed Conflict* (Great Britain: Biddles, 1998), 15.

[3]Ibid., 16.

[4]Benjamin King, Richard Biggs, and Eric Criner, *Spearhead of Logistics, A History of the U.S. Army Transportation Corps* (Fort Eustis, VA: Government Printing Office, 1994), 225.

[5]Ibid., 226.

[6]Trish Larson and Mike Neuhardt, "Lummus and JLOTS Lift Hearts in Haiti," *Sealift*, *U.S. Navy's Military Sealift Command* (March 2010), http://www.msc.navy.mil (accessed September 23 2012).

[7]U.S. Transportation Command, "Department of Defense and Hybrid Airship Development" (PowerPoint presentation, presented by Earl Wyatt, August 25, 2011).

[8]Basil Collier, *The Airship*, *A History* (New York: G. P. Putnam's Sons, 1975), 135.

[9]Ibid., 136.

[10]Ibid.

[11]Ibid., 138.

[12]Ibid., 139.

[13]Gordon J. Vaeth, *They Sailed The Skies* (Annapolis, MD: Navy Institute Press, 2005), 131.

[14]Collier, 224.

[15]Ibid., 226.

[16]Ibid., 234.

[17]Ibid., 227.

[18]Ibid., 228.

[19]Ibid.

[20]Steve Huett, "The Art of Possible, Hybrid Airship History" (PowerPoint presentation by NAVAIR Research and Engineering, March 2010), http://paxpartnership.org/Knowledgebase/Attach/11%20Hybrid%20History%2029MARCH%20Optimized.pdf (accessed May 2, 2013), 7.

[21]Best of Discovery, "Piasecki PA97 Helistat Accident Crash–helicopter helium blimp hybrid air vehicle heavy lift," http://www.youtube.com/watch?v=_7jENWKgMPY (accessed May 3, 2013).

[22]AerospaceTechnology.com, "Advanced Technologies Group SkyCat, United Kingdom," http://www.aerospace-technology.com/projects/skycat/ (accessed May 2, 2013).

[23]Huett, "The Art of Possible, Hybrid Airship History," 9.

[24]Ibid., 10.

[25]Christopher Bolkcom, *Potential Military Use of Airships and Aerostats*, (Washington, DC: Congressional Research Service, 2004), 3.

[26]Defense Industry Daily staff, "Walrus/HULA Heavy-Lift Blimps Rise, Fall…Rise?" *Defense Industry Daily*, October 23, 2012, http://www.defense industrydaily.com/ (accessed September 23, 2012).

[27]Ibid., 4.

[28]"Lockheed Martin, Aeros Aeronautical Systems Win Walrus Work," *Defense Daily* 227, no. 42 (August 2005), http://search.proquest.com/docview/234096269?accountid=28992 (accessed May 3, 2013).

[29]Mike Hanlon, "The Walrus: the US Army contemplates building an aircraft the size of a football field" *Gizmag*, September 5, 2005, http://www.gizmag.com/go/4538/ (accessed October 15, 2012).

[30]Michael A. Dornheim, "Skunks Working," *Aviation Week & Space Technology* 164, no. 6 (200): 24-25.

[31]Marie Tornai, "Draft Statement of Objectives (SOO) for the Long Endurance Multi-INT Vehicle LEMV, Solicitation Number: W91260-LEMV," FedBizOpps.gov, April 22, 2009, https://www.fbo.gov/?s=opportunity&mode=form&tab=core&id=8a9576adda671991e001a322c98a6a44&_cview=1 (accessed May 1, 2013).

[32]Noel McKeegan, "Northrop Grumman to build football field-sized Hybrid Airship," *Gizmag*, June 16, 2010, http://www.gizmag.com/hybrid-airship-us-army/15432/ (accessed September 9, 2012).

[33]Bill Carey, "U.S. Army Cancels LEMV Surveillance Airship," *AINonline*, February 22, 2013, http://www.ainonline.com/aviation-news/ain-defense-perspective/2013-02-22/us-army-cancels-lemv-surveillance-airship (accessed May 3, 2013).

[34]Spencer Ackerman, "Army Kills the Military's Last Remaining Giant Spy Blimp," *Wired*, February 14, 2013, http://www.wired.com/dangerroom/2013/02/spy-blimp-deflates/ (accessed May 3, 2013).

[35]Bill Sweetman, "Up Ship Airship with a difference nears flight test" *Aviation Week* (October 15, 2012): 46.

[36]PRWeb, "Aeros CEO Igor Pasternak Announces Successful Completion of the First Movement Test of the Aeroscraft Vehicle," January 9, 2013, "http://www.prweb.com/releases/igorpasternak2/01/prweb10309799.htm (accessed November 22, 2012).

[37]Michael J. Hutnik, "A--RAVB Demonstrator, Solicitation: NNA08BC43C" FedBizzOpps.gov, February 4, 2013, https://www.fbo.gov/index?s=opportunity&mode=form&id=5941115e43d3a56b245dc2b36c9bcfa8&tab=core&tabmode=list&= (accessed May 3, 2013).

[38]Paul McLeary, "U.S. Army Leaders Ponder How To Get Troops To Next Fight," *DefenseNews.com*, September 18, 2012, http://www.defensenews.com/article/20120918/DEFREG02/309180006/U-S-Army-Leaders-Ponder-How-Get-Troops-Next-Fight (accessed September 19, 2012).

[39]Ibid.

[40]Ibid.

[41]Kate Brannen, "DoD Sheds Light on Joint Future Theater Lift," *Air Force Times*, July 15, 2012, http://www.airforcetimes.com (accessed September 23, 2012).

[42]Eric Braganca, "The V-22 Osprey: From Troubled Past to Viable and Flexible Option." *JFQ* 66 (July 2012), http://www.ndu.edu/press/v-22-osprey.html (accessed November 12, 2012).

[43]U.S. Department of Defense, *Defense Budget Priorities and Choices* (Washington, DC: Government Printing Office, January 2012), 1.

CHAPTER 2

LITERATURE REVIEW

> While I was the Commander of the Military Sealift Command, I lived in fear that someone would tell me we needed to offload an MSC ship in-stream.
>
> ― Vice Admiral James B. Perkins III

This thesis will explore Hybrid Airships in order to evaluate whether these aircraft can economically increase the throughput of LOTS in Sea State 3 or higher. This chapter opens with information published on watercraft limitations in LOTS, equipment capabilities, and processes. The chapter then transitions to airships and describes previous works written about their utility in cargo movements. This chapter will not discuss Hybrid Airships used as communications or intelligence, surveillance, and reconnaissance platforms.

Watercraft Limitations in LOTS Operations

While LOTS is a niche capability that can mitigate inaccessible fixed ports, these operations are limited by the physical environment, equipment capabilities, and the process. The U.S. Department of Defense Joint Publication 4-01.6 *Joint Logistics Over-the-Shore (JLOTS)* and U.S. Department of Army ATTP 4-15 *Army Water Transport Operations* thoroughly discuss the environmental factors that affect site selection. These factors include tide and tidal range, surf, weather, beach gradients, sand bars, bottom and beach surfaces, soil type, anchorages, and topographic features.[1]

The Inchon landing in Korea during 1950 is the most impressive example of amphibious operations constrained by the tide, tidal range, and topographical features. By August 4, 1950 the Eighth U.S. Army and Republic of Korea established the Pusan perimeter at the southern tip of the Korean peninsula. The advancing North Korean's extended stretched their lines of communication hundreds of mile toward the north. "General MacArthur never waivered in his belief that a sweep by sea around the enemy's flank was the most practical way to end the war."[2] General Douglas MacArthur decided on Inchon in favor of its proximity to Seoul, but the Navy and Marines favored Kunsan because Inchon did not have suitable beaches and it was difficult to navigate.

Inchon's tides varied from 31.2 feet at flood to minus 0.5 at ebb and had 16 foot sea walls.[3] There was a small window on September 15, 1950 and a window a month later when the tides were deep enough and the conditions right for an Inchon landing. The approach was difficult because of 3-8 knot channel currents.[4] An even bigger constraint was that the tides were high enough 45 minutes after sunrise and left the landing party exposed on mud flats until the second high tide 37 minutes after sunset.[5] Despite these challenges, the landing was a success and allowed a Naval Beach group and Marine Shore Party Battalion to unload 4,000 tons of supplies the next day and subsequent supplies delivered to Inchon directly from the United States.[6]

Weather and the effects of the sea play an important part in planning and selecting landing sites. Planners incorporate meteorological teams into LOTS to provide onsite 24-hour forecasts.[7] Heavy surf can damage or swamp lighterage if the watercraft is hit broadside.[8] The coxswain pilots the vessel perpendicular to the breakers while compensating for currents that usually run parallel to the beach.[9] Adding to the challenge are steady surface winds or gusts that can approach from any direction.

The Pierson-Moskowitz sea spectrum is a table that provides a concise sequential listing of wind speed and Sea States.[10] The table synthesizes this raw data into a number scale used for judging whether landing operations are feasible. The surf zone is predicted by the breaker period or how frequently waves will break, the type of breaker, breaker angle to the shore, underwater topography, beach gradient, and surf damage. “RRDF can be safely operated through Sea State 2”[11] on the scale and becomes the limiting Sea State for LOTS, although other lighterage can operate in worst conditions. This equates to one and half foot to three foot waves depending how often they are breaking and wind speeds from five to twelve knots.[12] The Beaufort scale is an alternate table for determining Sea States based on a measurable wind temperature and more subjective, but observable wave behavior.[13]

Other environmental factors are beach gradients and composition. A beach’s gradient or slope is expressed as a ratio of depth to horizontal distance.[14] The problem is that gradients can rarely be determined from charts and they change often due to currents, surf, and heavy storms. The ideal beach for landing craft operations has deep water close to the shore with a firm bottom of hard packed sand and gravel.[15] There should be minimal tide variation and a moderate to gentle (1:15 to 1:60) underwater beach gradient without any underwater obstructions, current or surf.[16] Soft mud, silt, or fine, loose sand bottoms are undesirable because they can foul a vessel’s engine coolant system and disembarking vehicles may sink and get stuck.[17] The opposite concerns are underwater obstacles, rocks, and coral that can puncture a vessel’s hull or break its propulsion system.

Finally the topography and water depths affect navigation for lighterage and anchorages for the vessel being discharged. Deceptively open areas of sea may constrain lighterage to subsurface paths directed by hidden sandbars, reefs, and channels. This may affect the amount of lighterage that can operate in an area or create underwater chokepoints that do not allow lighterage to pass simultaneously. Also large vessels require a certain diameter for anchoring offshore or in-stream to allow the ship to swing freely around its anchorage. Subsequently this affects the distance lighterage may have to travel to the ship and the number of ships that can stage or offload at any given time.

Putting all these variables into perspective, only certain beaches around the world are accessible by Navy and Army watercraft. Further, this limited accessibility does not account for the affects weather conditions may have throughout the year. The Inchon landings in 1950 had to be executed in the fall before the winter storms. Assuming conditions are met that allow a LOTS operation, the second limitation is the watercraft throughput capacity.

Equipment Capabilities and Processes

Throughput is the rate that an amount of material can be delivered within a given period of time.[18] Typically this is measured by how many containers, wheeled vehicles, tracked vehicles, break bulk cargo, and bulk liquid cargo that can pass through a port or beach daily.[19] Rather than measuring pieces moved, alternative units of measure may be tonnage or square feet and even personnel in rare cases. The five parts to LOTS operations that impact the throughput rate of an overall operation from end to end are similar to normal terminal operations at a fixed port described earlier in chapter 1, but also include movement of cargo between the ship and the shore. The elements of LOTS are ship cargo transfer, cargo movement from ship to shore, beach cargo transfer, cargo movement to marshalling yards, and cargo clearance from a port complex.[20] Whichever of these has the least throughput capability represents the throughput of the entire operation and efficiency is achievable only if cargo flows steadily.

Ship cargo transfer rates depend on the type of cargo being moved. Container discharge rate is determined by crane cycle times or how fast onboard cranes or auxiliary crane ships (T-ACS) can lift off and lower containers onto lighterage, how many cranes are in use, the proficiency of the crane operators, and if there are enough crews for shift work. Typical planning factors for a single crane's cycle time is 7:29 minutes for a single container, two cranes working simultaneously have a cycle time of 10:36 for two containers, and three cranes have a cycle time of 16:42 minutes for three cranes.[21] However, T-ACS container discharge is hampered by sea conditions on the windward side and operates in winds up to 13 knots.[22] Ocean swells that cause the ship to roll five degrees or more will stop operations too because the containers start to swing uncontrollably like a pendulum.[23]

Discharging rolling stock can be done by crane, but most is driven off the ship onto a RORO Discharge Facility (RRDF) moored alongside the ship. The RRDF serves as a staging area and platform for vehicles to drive onto lighterage. The Navy system forms a 65 by 182 foot platform whereas the Army RRDF is configurable to different shapes and dimensions.[24] In Sea State 0-2, RRDF systems are moored to a non-self sustaining ship. In Sea State 0-2 RRDF systems are moored to a self-sustaining ship. The RRDF can be safely operated through Sea State 2. The current limitation to install and operate the system is 4 knots.[25] As a planning factor it usually takes roughly nine minutes for an Army watercraft to approach and moor to an RRDF. Depending on the type of lighterage being loaded, it takes different amounts of time to load and cast-off and clear

(C&C) an RRDF. As an example, planning factors for Landing Craft Utility 2000 (LCU-2000) loads wheeled vehicles up to an hour and 33 minutes and can C&C in four minutes, whereas the Logistics Support Vessel (LSV) takes up to five hours and 50 minutes to load wheeled vehicles and seven minutes to C&C.[26]

Once cargo is loaded onto lighterage the second step of LOTS is the cargo movement from ship to shore. This is the part of LOTS that depends on the lighterage capabilities as a function of the quantity on hand and the vessel's speed and carrying capacity. The LSV is considered the workhorse of Army watercraft[27] and can carry up to 50 containers or 24 M1 Abrams tanks[28] while traveling at 12 knots fully loaded.[29] As a rule of thumb the optimal operation will plan around the most productive watercraft and then other lighters are loaded while the more productive vessel is away from the RRDF.[30] Later in chapter four a more detailed analysis will be given of the various types of lighterage as part of a comparative study. However it is worth mentioning that in the past the Army tried a variety of amphibious craft that could travel over the beach. These included wheeled watercraft and hovercraft designed to eliminate the third step of a LOTS operation and move directly to the fourth step.

The third step in a LOTS operation is beach cargo transfer. This is the point where cargo is disembarked from lighterage and onto transportation at the pier or beach. In the absence of a fixed facility pier with functioning material handling equipment, the Navy may be tasked to install a modular Elevated Causeway System (ELCAS) that forms a temporary pier. Installation includes a crane that is used to lift containers and break bulk cargo from watercraft. The ELCAS can extend up to 3,000 feet from the beach into the sea, provided that the deck is 20 feet above MLW to survive high storm tides.[31] Installation is completed in 10 days if weather is less than Sea State 3.[32]

The system is exceptionally survivable in heavy storms with up to 75 knot winds and nine foot waves; but cargo operations are limited to conditions at Sea State 2 or better.[33] Throughput is dependent on crane cycle times. Also, the ELCAS has an interoperability limitation with offloading cargo from LSVs. Vehicles can be lifted off vessels using the ELCAS, but it is not the ideal method of discharge.

A preferred method to discharge vehicles is driving them off the watercraft directly onto the beach. If the beach gradient limits beaching, then they can be offloaded onto a floating causeway called the trident pier. Vehicle throughput is not normally a limitation in this step of LOTS. The only other factor that may affect discharge is how firm the beach is that the vehicles have to drive across. This leads to the fourth step.

The fourth step of LOTS is the cargo movement to marshalling yards. Generally vehicles will not limit throughput, but container and break bulk cargo throughput will be limited by how many support vehicles and material handling equipment are on hand. The limiting factor is usually how much space is available to separately marshal, offload, and document the cargo. As an example, the author estimated that the equipment in an Armor Brigade Combat Team takes up more than 292,429 ft^2 when parked side by side without any access lanes or separation between equipment. The final step of LOTS is cargo clearance, but is not discussed because it shares the same limitations as fixed ports that were discussed in chapter one describing sea-LOCs.

The discussion of limitations and throughput communicates how LOTS is very challenging, dangerous, and sensitive to weather. To mitigate these risks, LOTS are normally rehearsed during small scale exercises roughly twice a year. Of course, these exercises are very expensive. Consequently a large scale operation is rare, but in 2008 the Pacific Strike Joint Logistics Over-the-Shore (JLOTS) exercise delivered a full SBCT to a beach near Marine Corps Base Camp Pendleton, California with follow-on movement to the National Training Center. In total, the exercise cost $20 million over a one month period[34] that included a week of transferring over 1,500 vehicles and containers across the shore.[35] This is hardly an efficient method if time is critical during force projection.

Amphibious craft and hovercraft are a consideration for improving throughput. The Army discontinued these efforts, but the Navy still uses the Landing Craft, Air Cushion (LCAC). The advantage of hovercraft is their speed. Decreased cargo handling and reduced friction between the craft and the ground or water contribute to a hovercraft's rapid cargo delivery. The trade off is high fuel consumption and cost. Conceptually vertical short take-off and landing (VSTOL) or rotary wing aircraft are used for the same reasons, but both sacrifice fuel consumption and they have limited carrying capacities.

It is conceptually feasible that reducing steps and reducing the number of units or lift requirements will likely increase throughput and shorten delivery times or allow more distant deliveries. Hybrid Airships share some of the characteristics of a hovercraft, but can also travel over larger obstacles and across longer distances. Technological advances in Hybrid Airships could be the material solution to achieve this end state, as depicted in figure 1.

Airship Military Applications

There is very little written about using any kind of airship during LOTS operations, however there was some research applicable to supporting the United States Navy and United States Marine Corps with Hybrid Airships in lieu of "Sea Basing" and as "Sea Base Connectors." In Charles Newbegin's School of Advanced Military Studies monograph for the U.S. Command and General Staff College, he made a brief recommendation to study the use of airships in applications like minesweeping, surveillance and security for lines of communication, and as lighterage in JLOTS.[36]

Despite limited discussions on LOTS applications, there was considerable research on the efficiency, cost, and effectiveness of using Hybrid Airships for intratheater and intertheater lift. Common in all literature was that Hybrid Airships are an intermediary solution for lift and cost between traditional aircraft and surface movements. Another common theme was that Hybrid Airships can operate independent of infrastructure and are survivable against enemy. Overall, the literature viewed Hybrid Airships optimistically.

Airships in LOTS Operations

The only work available specifically for LOTS was written by John Hauser in 1976 as part of his Master of Military Art and Science thesis for the U.S. Army Command and General Staff College. His thesis investigated the feasibility of using an Aerocrane in LOTS operations and the advantage of using this aircraft as lighterage over Army lighterage during that era.

The Aerocrane was a hybrid aircraft concept that combined balloon and helicopter technology.[37] It was basically a spherical balloon with four wings tipped with propellers oriented to make the entire sphere and wings spin as a single unit like the blades of a helicopter, figure 6. The technical potential of the aircraft was considered feasible by the U.S. Army Air Mobility Research and Development Laboratory, U.S. Navy Air Systems Command, U.S. Navy Air Development Command, and the U.S. the Civil Programs Division of the Aerospace Corporation under the sponsorship of the Department of Agriculture Forest Service. The hybrid was projected to lift single containers or pieces of equipment that weighed up to 50-tons. The Aerocrane was rated to travel at speeds of 42 mph and cost $4.1 million per unit in 1976.[38]

Hauser did a comparative analysis of Aerocrane's ability to move containers relative to equipment capabilities modeled in the U.S. Army's Trans Hydro Study 1975-1985 that included the TH-X Lighterage Air Cushion Vehicle-30, TH-B 60 ton wheeled amphibian, and the conceptual Heavy Lift Helicopter. He concluded that the Aerocrane shared the best responsiveness as the Heavy Lift Helicopter at moving containers and the Aerocrane was the most cost effective of all four lighterage that were compared. The Aerocrane study differed from this thesis because it focused on a Lift On/Lift Off (LOLO) capability and it was limited to individual pieces of equipment rather than a larger payload with various types of equipment.

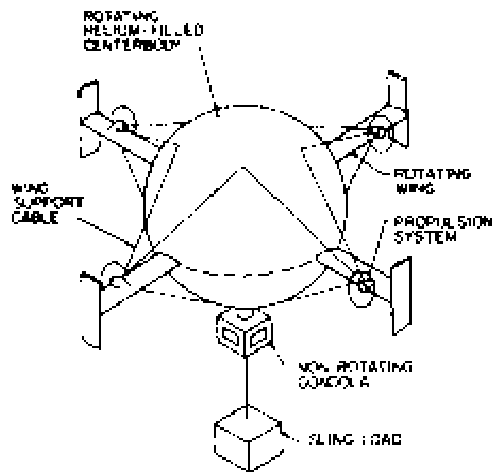

Figure 6. Aerocrane

Source: Igor Pasternak, “A review of airship structural research and development” *Progress in Aerospace Sciences* 45, no. 4-5 (May-July 2009), http://www.sciencedirect.com/science/article/pii/S0376042109000153 (accessed May 2, 2013).

An opposing view was written by Dan Beakey six years after Hauser’s thesis. In Beakey’s monograph he defended the necessity of LOTS and offered recommendations for future procurements of LOTS equipment. He described the advent of containerization in the 1950s, its evolution, and the problems with discharging them from vessels anchored offshore. The problem with offshore discharge is that fewer ships were being constructed with onboard cranes and depended on more economical pier side cranes. Beakey wrote that planners wrestled with this problem, “Ideas actually tested even included heavy-lift helicopters and lighter-than-air balloons used in logging operations. These tests proved entertaining and novel but were not very effective in moving a large number of containers from ship to shore. Extreme sensitivity to weather and sea conditions was the main disadvantage which led to the ultimate rejection of these schemes as practical and economical solutions.”[39]

Hybrid Airships in Intratheater Operations

USAF Major Philip W. Lynch wrote a research paper to examine the potential of Hybrid Airships for intra-theater lift. He performed a quantitative analysis to determine the most effective use of Hybrid Airships mixed with conventional aircraft and vessels. MAJ Lynch used an “excursion from a base scenario” methodology that demonstrated how Hybrid Airships could have been used to transport humanitarian assistance and disaster relief to Haiti during Operation Unified Response.[40] He constrained the movement requirement to 200 short tons per day from Charleston, South Carolina and Jacksonville, Florida to Haiti. The analysis covered movements between ports.

Lynch’s thesis concluded that Hybrid Airships could augment airlift and sealift to fill capability gaps in intra-theater distances of 2,500 nautical miles. He estimated that a fleet of five Hybrid Airships flying at speeds of 80 knots and altitudes below 10,000 feet with payloads of 40 to 50 tons could reduce delivery times for sealift movements. The real usefulness of Hybrid Airships is during the first few days of an operation while ships are still being readied, loaded, and sailed to destination.[41] An airship with 12 hours notification to launch would have a two to three day lead over the ships arriving.

Lynch’s thesis concluded that Hybrid Airships can “be used to effectively and efficiently augment USTRANSCOM’s current airlift and sealift capability. For medium-range distances approximately 2,500 nautical miles one way, as many as five HA (each capable of lifting 40 to 50 tons) can help reduce or minimize total cargo movement time.”[42] Based on 2011 operating costs, he demonstrated that Hybrid Airships would be cheaper than C-17s and sealift if operating expenses were kept below $3,000 per hour.

This thesis differs from Lynch's cost benefit analysis in a few areas. First, he focused on a homogenous load of like items rather than vehicles in a Stryker Brigade Combat Team with different dimensions and weights. Also the distance that the lift assets travelled in Lynch's thesis was much further and ranged 2,500 nautical miles. Another difference is that Lynch excluded ground movements in the comparison and focused on movements from port to port. The final difference between this thesis and Lynch's is that he included fixed wing aircraft in his comparison.

Hybrid Airships versus Sea Basing

Sea Basing is a concept to transition land based infrastructure to the sea in order to provide more responsive force projection and reduce overseas bases. The concept was revisited by the Congressional Budget Office (CBO) to study the cost of Sea Basing a US Marine Corps Marine Expeditionary Brigade. In the course of their study the office assessed four courses of action that varied from rotary wing, heavy lift airships, to traditional amphibious lighterage.

The CBO's results estimated that 46 Hybrid Airships would be required to transport a complete Marine Expeditionary Brigade in a single lift from a forward base 2,000 nautical miles away in lieu of a Sea Base, 110 nautical miles away. The airship fleet would cost between $12 billion to $18 billion.[43] The Hybrid Airships used throughout the study had a 500-ton lift capacity. Comparatively it would cost $31 billion to $39 billion to use larger aviation ships and heavy lift helicopters bigger than the CH-53K to establish a Sea Base.[44] Another course of action called for 14 ships, an oiler, two high speed vessels, and new air cushioned vehicles that would cost $15 billion to $22 billion for the entire package to be Sea Based.[45] The final course of action was to use the existing amphibious task force and spend $2 billion to add three ships as an added capability for sustainment at sea.[46]

Another part of the CBO study explored sustainment alternatives. For the airship course of action, the analysis concluded that eight Hybrid Airships purchased for $5 billion to $7 billion would be required to support a Marine Expeditionary Brigade and a light Army brigade or 1,000-tons per day from an advance base 2,000 nautical miles away.[47] However, the study concluded that the airship was less tactically responsive compared to other sustainment options using ships because of the 2,000 nautical mile distances used in the assessment.[48] On the other hand, 40 airships could strategically deploy a force from the United States more than a week faster than the current Maritime Prepositioning Force and more than two weeks faster than an Army heavy brigade deployed by sea.[49]

The CBO study also examined its courses of action in a forcible entry application. The study recognized that less developed parts of the world may not have adequate facilities, the local nations may not being willing to provide access, or an adversary may deny the facilities through attack or threat of an attack.[50] In light of these challenges, the study identified characteristics that were desired for a Sea Basing solution. These included the ability to deliver combat ready units directly to their area of operation through forcible entry, the ability to support the forces for extended periods, and the ability to withdraw ground forces from an area of operation.[51]

The final part of the CBO study examined the effectiveness of Sea Basing alternatives that included Hybrid Airships. The measures of effectiveness included sensitivity to access limitations, geographic reach, strategic responsiveness, and the capability to sustain a ground force.[52] The study assessed airship operations as sensitive to airspace restrictions due to increased transit times and visibility over conventional aircraft. However, airships are survivable against anti-aircraft threats despite how easy they are to track and shoot.[53] Another problem was that the airship landing zone for 40 airships to land simultaneously required more than four square miles that may not be easily defended from ground attack during offload.[54] The airships had an advantage over delivery by surface ship and watercraft that were compared because they could reach 90 percent of the world's land with ground elevations up to 5,000 feet above sea level.[55]

The CBO study assessed strategic responsiveness by the ability to deliver a force to where it is needed in an allotted time. More specifically the study examined "the time required to get the force into position to commence operations," size of the force that could be moved within the time frame, and the type of force.[56] The study estimated that the airships "could deliver a MEB-sized force in about seven days if the MEB" were ready to load in less than 48 hours.[57] This demonstrated that an airship fleet could be one of the most strategically responsive capabilities, second to forward deployed Marine expeditionary units and airdropped airborne brigades. However, an airship fleet would be less tactically responsive if operating from long distances than compared to a Sea Base 100 to 200 nautical miles away from the area of operations.[58] This same challenge at long distances for tactical responsiveness makes sustainment of ground forces just as challenging from these distances. It would take an airship a day to reach ground units 2,000 nautical miles away requesting special cargo requests.[59]

The difference between the CBO study and this thesis is that the CBO study focused on airships flying long distances. This thesis is more concerned with the airship flying to the equipment that is afloat and at even shorter distances than a Sea Base 100 to 200 nautical miles away. However, it did steer this thesis into examining whether Hybrid Airships could replace LOTS all together if the Hybrid Airship flew from an intermediate staging base.

While an overall comparison of Hybrid Airships to Sea Basing was helpful, a comparison of individual Sea Base Connectors was more applicable to this thesis. Justin A. Dowd wrote a thesis on the cost benefits and a capability analysis of surface and air Sea Base Connectors, which included a 500-ton Hybrid Ultra-large Hybrid Airship (HULA) in his study. He concluded that the HULA showed the greatest potential to deliver "payloads to or across the beach" when compared to MV-22 Osprey tilt rotor aircraft, CH-53 Super Stallion rotary wing aircraft, Hybrid Very-Large Aircraft (HVLA), Landing Craft Air Cushion (LCAC) hovercraft, Landing Craft Utility Replacement (LCU-R) vessel, and conceptual Ultra Heavy-Lift Amphibious Connector (UHAC).[60] The Joint High Speed Vessel (JHSV) performed better than the HULA, but depended on port facilities and could not deliver directly to a beach or over the beach.[61]

Although Dowd's thesis did not compare all the same lighterage as this thesis, both theses compared the JHSV, LCAC, and a 500-ton Hybrid Airship. His comparison focused heavily on the cost comparison and provided a good framework for comparing Sea Connectors by the "tons per hour" and "cost per hour" and how to create a baseline across data from different fiscal years. Another insight from Dowd's thesis is that operation and sustainment costs constitute 80% of the total life-cycle cost in most systems, which lead him to focus only on this aspect of the comparison. He assumed this cost encompassed all the "direct and indirect costs incurred in using the delivered system that included the cost of personnel, equipment, maintenance, supplies, software, and services associated with operating, modifying, maintaining, supplying, training, and supporting the defense system."[62]

Hybrid Airships in Intertheater Lift

Strategic intertheater lift is the final area that has been researched for using Hybrid Airships as a force projection and sustainment platform. In Charles Newbegin's 2003 monograph he proposed that modern airships could be used as a possible solution for rapid force projection. He also recommended further study in using Hybrid Airships for lighterage in JLOTS.

Newbegin assessed airships feasibility in intertheater lift based on whether the aircraft could be built and they could be marketed commercially. He concluded that the technology at the time could build, operate, and maintain airships except for the largest airships capable of lifting 1,000-tons. This larger aircraft could not be built yet because fabric technology still had not been developed to support this size. This challenge was substantiated in an Air Force Journal for Logistics article that described the strength differences between rigid and non-rigid airship envelopes and the issues with larger variants.[63] The marketability of airships has been demonstrated in advertising, but use in heavy transport was yet to be determined. This assessment for heavy transport is still true in 2013, although there has been commercial interest in using hybrid airships for arctic resupply and to replace "ice road trucking" in Alaska and Canada.[64]

Newbegin's monograph also evaluated the acceptability of intertheater lift based on safety, speed, and cost. He described how the use of helium and advancements in weather detection increased the safety of airships over their historical past. Throughout his thesis, he cited a Department of Defense engineering study of the SkyCat 1000 airship sponsored by the Combined Joint Chiefs of Staff J-4 in fiscal year 2001.[65] The SkyCat 1000 study demonstrated that airships are survivable against enemy interdiction.

In terms of speed, the study demonstrated that a fleet of 17 SkyCat airships with 1,100 short tons lift capability could transport a Stryker Brigade Combat Team from Fort Lewis to Korea in a single lift. This fleet could complete the move in a fifth of the time it took a Large, Medium Speed Roll-on/Roll-off (LMSR) ship based out of Diego Garcia in Guam, Saipan to deliver the same requirement.[66] His thesis showed that 13 SkyCat 1000 airships have the same lift capacity of a single LMSR that can carry a battalion sized task force.[67] When compared to C5 fixed wing aircraft, the airships could deliver an SBCT to the TAA faster because they bypassed APODS, but the airships also took twice as long as a C-17.[68] Modern Hybrid Airships are expected to travel at speeds up to 115 miles per hour,[69] which is a significant advancement over historical dirigibles.

Newbegin's assessment of cost was based on fuel costs for operation and purchase cost. The shortfall with this measure of effectiveness for cost was that it did not account for the many other cost factors that cover the entire spectrum of Doctrine, Organization, Training, Material, Leadership and Education, Personnel, and Facilities (DOTMLPF) that are considered in the Joint Capabilities Integration Development System (JCIDS) process. Fuel costs and purchase costs do address some "Material" costs, but excludes research development and testing, maintenance, and other life cycle costs. He did acknowledge "Facilities" related savings from Hybrid Airships independence from infrastructure and secondary transportation costs that other modes have. On the

“Personnel” side, he acknowledged that fewer crews would be needed over fixed wing aircraft.

Overall, Newbegin’s thesis stated that Hybrid Airships can deliver equipment at “one-third the cost of conventional aircraft.”[70] He estimated that a single SkyCat 1000 could save $3.1 billion in procurement over the equivalent lift capability for 13 C-17 fixed wing aircraft.[71] This cost savings would be enough to purchase a fleet of 12 SkyCat 1000 that would have the near equivalent carrying capacity of an LMSR ship.[72]

Point of Need Concept of Operations

The National Defense Authorization Acts in fiscal year 2010 and 2012 requested that the Assistant Secretary of Defense for Research and Engineering (ASD(R&E)) to develop a “concept of operations for how rigid-hull, variable-buoyancy (RAVB) hybrid air vehicle technology might be employed in future platforms.”[73] This is the same Hybrid Airship developed by the Aeros Aeronautical Systems Corporation for the Pelican project. The ASD(R&E) replied with an operational concept study that reported the feasibility and a methodology to use a RAVB “to augment existing logistic systems” and other “operational and logistics considerations.”[74] These other considerations included basing, airspace, and environmental factors. Like Newbegin’s thesis, the report concluded that operational costs for Hybrid Airship will fall between fixed wing aircraft and sealift modes of transportation.

The ASD(R&E) report document identified shortfalls with existing modes of transportation that result in long delivery times and excessive costs, which cannot deliver directly a point-of-need in a theater of operation.[75] The combatant commanders require a point-of-need delivery (POND) “capability to rapidly deploy war fighting and sustainment forces from the Continental United States to their theater of operations" and "intra-theater requirements to deliver within several days a read-to-employ, task-organized brigade size element to or from a PON, independent of receptive infrastructure."[76] Hybrid Airships could fill this capability gap in intertheater and intratheater transportation because they can carry larger payloads than fixed wing aircraft and at speeds greater than sealift, while bypassing intermediate staging bases, defensive areas, obstacles, and enemy threats.[77]

The report discussed environmental factors that included visibility, wind, snow, ice, and lightening. All of these factors could be mitigated, but the wind was the most influential on Hybrid Airships. Significant wind forces are expected on the ground and airships operating ceiling at a 5,000 to 9,000 foot ceiling are exposed to dynamic wind patterns.[78] Also, airships are more affected by headwinds than faster moving fixing wing aircraft.[79]

Another operational constraint is hostile fire. The report pointed out that neither Hybrid Airships nor conventional cargo aircraft are likely to fly into areas with sophisticated air defense systems, but that the Hybrid Airships were more likely to encounter hostile fire due to its large visual signature and low operational altitudes.[80] Like many other airship studies, the report explained that holes from bullets and fragmentation do not have catastrophic affects on airships, unless they caused large tears. Technical constraints were briefly mentioned as obstacles for buoyancy control, docking techniques, cargo transfer techniques, material development, and propulsion. Some of these are being addressed through the Pelican project.

A significant limitation described in the report involved basing and landing zones for hybrid airships. Although capable of operating independent of infrastructure, airships will need home bases for maintenance and storage that require enormous hangars.[81] Another issue explained is the amount of space that Hybrid Airships take up for take-off and landing. This could be a problem if they operate from traditional airfields and affect the maximum on ground (MOG), reduce the number of other aircraft on the parking apron, and congest the runway.[82] VTOL Hybrid Airships like those being developed in the Pelican project will reduce some of these limitations by creating a smaller footprint. However, loading and offloading times would have to be consistent with aircraft in the range of 2.25 hours and 3.25 hours if fueling was performed during loading and offloading.[83] The report explained that in situations where the Hybrid Airship landed in an austere environment without MHE, hand offloading, winch operations, organic MHE carried with the aircraft, and onboard crane systems will be likely requirements. Another unique capability is that Hybrid Airships have the ability to land and operate on water, which will make operations at sea ports feasible.[84]

Finally the ASD(R&E) study explained a POND Experimentation Campaign conducted by U.S. European Command, U.S. AFRICOM, and U.S. Transportation Command in 2010. The POND experiment involved a requirements workshop, capability solutions workshop, and table top experiment. The results from the experiment were validated by the ASD(R&E) in the spring and summer of 2012.

The requirements workshop concluded that the combatant commands required a capability to deliver a ready-to-employ, task organized unit up to brigade sized within 3-5 days to a point-of-need without relying on any infrastructure for reception.[85] The capabilities in the current deployment process were identified and then modeled in the table top experiment to identify solutions to fill the capability gap. “The experiment determined that the only platform that had the capability to meet the requirements…was a hybrid airship capable of lifting at least 200 short tons.”[86] The experiment estimated that a Navy Mobile Construction Battalion could be deployed 2,500 miles away to a point-of-need in four days with Hybrid Airships rather than the 30 days it took to deploy the same unit to Haiti in 2010.[87]

The POND experiment showed that airships can reduce the cost of deployment. As an example, a RAND Corporation study was cited that concluded an 80 percent fuel savings using airships over C-17s to perform like missions and cost $0.22 per ton-mile, whereas the C-17 cost $1.20 per ton-mile. An Air Force Global Mobility Exercise 10 also was cited for its determination that a combination of Hybrid Airships, C-17s, and surface vessels would result in billions of dollars in fuel savings over a 30 days deployment.[88] The POND experiment closed with proposed uses that included mobile medical facilities, mobile command posts, firefighting, operational and tactical movements for combat units across the battlefield, avoiding anti-access defenses, and other applications.[89]

While there have been numerous studies on the usefulness of Hybrid Airships, none have adequately explained how airships could support JLOTS. Some have acknowledged the usefulness of direct delivery from fort to foxhole, but none have adequately addressed the details of how to execute airship operations. The next chapter will discuss the research methods that will be used in this thesis.

[1]U.S. Department of the Army, Army Tactics, Techniques, and Procedures (ATTP) 4-15, *Army Water Transport Operations* (Washington, DC: Government Printing Office, February 2011).

[2]T. R. Fehrenbach, *This Kind of War, The Classic Korean War History* (New York: Macmillian, 1994).

[3]Roy E. Appleman, *South to the Naktong, North to the Yalu* (Washington, DC: U.S. Government Printing Office, 1961), 499.

[4]Todd S. Zwolensky, "Logistics Over The Shore: A Review of Operation Chromite, Operation Bluebat, and Its Relevance to Today" (Master's Thesis, Command and General Staff College, Ft. Leavenworth, KS, 2007), 12.

[5]Appleman, 499.

[6]Zwolensky, 16.

[7]U.S. Joint Chiefs of Staff, Joint Publication 4-01.6, *Joint Logistics Over-the-Shore (JLOTS)* (Washington, DC: Government Printing Office, August 2005), G-1.

[8]Ibid., G-3.

[9]Ibid.

[10]Ibid., G-1.

[11]U.S. Department Army, Technical Manual (TM) 55-2200-001-12, *Operators Manual for Modular Causeway System (MCS) Roll-On/Roll-Off Discharge Facility (RRDF) RRDF-1 NSN 1945-01-473-2282* (Washington, DC: Government Printing Office, May 2002), 02-001.

[12]U.S. Joint Chiefs of Staff, Joint Publication 4-01.6, G-2.

[13]U.S. Department of the Army, ATTP 4-15, 7-11.

[14]Ibid., 7-2.

[15]Ibid., 7-3.

[16]Ibid.

[17]Ibid., 7-3.

[18]Michael Agnes, and David B. Guralnik, ed., *Webster's New World College Dictionary,* 4th ed. (Cleveland: Wiley Publishing Inc., 2008) s.v. "throughput."

[19]U.S. Joint Chiefs of Staff, Joint Publication 4-01.6, III-2.

[20]Ibid.

[21]Ibid., A-4.

[22]Ibid., VI-9.

[23]Ibid.

[24]Ibid., IV-6.

[25]Ibid., G-3.

[26]Ibid., A-5.

[27]U.S. Army Combined Arms Support Command (CASCOM), 1-6.

[28]U.S. Joint Chiefs of Staff, Joint Publication 4-01.6, A-5.

[29]Ibid., B-2.

[30]Ibid., A-9.

[31]Ibid., IV-2.

[32]Ibid.

[33]Ibid.

[34]Richard A. Pacquette, "Expeditionary Logistics in Its Truest Form," *Army Logistician* (March-April 2009): 22.

[35]Brian F. Coleman and Mark MacCarley, "The 8th Theater Sustainment Command Leads the Way During Operation Pacific Strike 2008," *Army Logistician* (March-April 2009): 28.

[36]Charles Newbegin, "Modern Airships: A Possible Solution for Rapid Force Projection of Army Force" (Monograph, School of Advanced Military Studies, Ft. Leavenworth, KS, 2003), 45.

[37]John Hauser, "Aerocrane in LOTS Operations" (Master's Thesis, Command and General Staff College, Ft. Leavenworth, KS, 1976), 20.

[38]Ibid., 26.

[39]Dan J. Beakey, “Logistics Over The Shore, Do We Need It?” (National Security Affairs Monograph Series 82-6, National Defense University, Ft. Lesley J. McNair, Washington, DC, 1983), 8.

[40]Philip W. Lynch, “Hybrid Airships: Intratheater Operations Cost-Benefit Analysis” (Master’s thesis, AFIT/IMO/ENS/11-08, School of Engineering and Management, Air Force Institute of Technology, Wright-Patterson AFB OH, June 2011), 2.

[41]Ibid,. 51.

[42]Ibid., 62.

[43]Congressional Budget Office (CBO), *Sea Basing and Alternatives for Deploying and Sustaining Ground Combat Forces* (Washington, DC: Government Printing Office, 2007), XI.

[44]Ibid.

[45]Ibid., X.

[46]Ibid., XI.

[47]Ibid., 19.

[48]Ibid., 31.

[49]Ibid., 30.

[50]Ibid., 2.

[51]Ibid.

[52]Ibid., 23.

[53]Ibid., 26.

[54]Ibid.

[55]Ibid., 27.

[56]Ibid., 29.

[57]Ibid., 30.

[58]Ibid., 31.

[59]Ibid., 32.

[60]Justin Dowd, “Cost Benefit and Capability Analysis of Seabase Connectors” (Thesis, Naval Postgraduate School, Monterey, CA, September 2009), 53.

[61]Ibid., 51.

[62]Systems Engineering and Analysis-6 Cohort, “Seabasing and Joint Expeditionary Logistics” (Master’s thesis, Naval Postgraduate School, Monterey, California, December 2004), cited by Dowd, 21.

[63]Walter O. Gordon, Chuck Holland, and Karen S. Wilhelm, “Back to the Future: Airships and the Revolution in Strategic Airlift,” *Air Force Journal of Logistics* 29, no. 3 (2005): 46-56.

[64]Barry E. Prentice, “There is a global need for airships,” Buoyant Aircraft Systems International (BASI), November 8, 2012, http://www.buoyantaircraft.com/there-is-a-global-need-for-airships/ (accessed May 9, 2013).

[65]Huett, “The Art of Possible, Hybrid Airship History,” 10.

[66]Newbegin, 14.

[67]Ibid.

[68]Ibid., 40.

[69]Ibid., 41.

[70]Ibid.

[71]Ibid., 42.

[72]Ibid.

[73]U.S. Department of Defense, *Hybrid Airships Operational Concepts*, Prepared by Office of the Assistant Secretary of Defense for Research and Engineering, Rapid Reaction Technology Office, 5.

[74]Ibid.

[75]Ibid., 12.

[76]Ibid.

[77]Ibid., 13.

[78]Ibid., 14.

[79]Ibid.

[80]Ibid., 15.

[81]Ibid., 19.

[82]Ibid., 18.

[83]Ibid., 17.

[84]Ibid., 20.

[85]Ibid., 21.

[86]Ibid., 22.

[87]Ibid., 23.

[88]Ibid.

[89]Ibid.

CHAPTER 3

RESEARCH METHODOLOGY

This chapter was organized to show the research steps used to evaluate whether Hybrid Airships can economically increase the throughput of LOTS in Sea State 3 or higher and provide a more responsive, flexible solution than existing capabilities. While describing the research methodology, several principles of sustainment from joint doctrine were loosely used to explain how the method applied to movement of forces with Hybrid Airships. The author used joint terminology over U.S. Army principles of sustainment because the intended audience is all military Services.

A comparative analysis of lift capabilities for both current watercraft and proposed Hybrid Airships was essential to determining the number of trips each individual lift asset travelled to move a common movement requirement. This helped assess Hybrid Airships using the “economy” principle of sustainment by comparing which assets met the mission requirement in the most efficient way possible. While efficiency is important, it will always be trumped by effectiveness.[1]

Throughput was then compared to determine which lift assets were most effective. These results were then used to determine the minimum size of a Hybrid Airship fleet and to determine the cost effectiveness of Hybrid Airships over watercraft. Throughput results then guided the analysis to determine the minimum fleet size of Hybrid Airships. This may be considered the “attainability” principle of sustainment because it identified the minimum service required to execute operations.[2]

The second research question was aimed at determining whether Hybrid Airships were more cost effective than watercraft. This evaluated the “sustainability” principle because a more cost effective capability maintains the necessary level of support, while freeing up financial resources that can be diverted to increase other capabilities or extending economic operational reach.[3] Finally, the principle of “responsiveness” was used as an all encompassing method to determine if Hybrid Airships are a feasible capability that can provide the right support at the right time and place. The principles of “flexibility,” “simplicity,” “integration,” and “survivability” were included in the third research question. The following sections describe the procedures in more detail.

Movement Requirement

Throughout this study a movement requirement was used to compare various Hybrid Airships and JLOTS watercraft. Since the Stryker Brigade Combat Team is likely to be one of the earliest brigades deployed by sea in an expeditionary role, the research used this brigade’s rolling stock and an estimated 200 containers as the movement requirement. The data was gathered from an MTOE with effective dates of July 16, 2012 and August 17, 2012 accessed through the U.S. Army Force Management Support Agency “s Force Management System Website. The unit’s mission statement says that the unit is 100 percent mobile so the equipment in table 10 was assumed to have been secondary loaded onto all of the vehicles. However, these secondary loads were excluded from the gross vehicle weights, in order to simplify the cargo lists the author built into the databases used for this thesis. Time did not permit for an analysis of how many trips it would take to move an Infantry Brigade Combat Team or Heavy Brigade Combat Team.

The analysis assumed that trailers were coupled with a prime mover and driven onto the lighterage during loading and driven off during offload. These movement requirements are listed in table 7. An exception was made for rolling stock transported by the LCU-2000 because the vessel was constructed with only a bow ramp that made it too time consuming for the prime movers to back on with a trailer. In this case, the prime movers and trailers are listed separately in table 8 and table 9, in order to account for the additional loading time to lift the trailers onto the LCU-2000 by an LMSR's shipboard crane.

Comparative Trip Analysis

To begin this research, individual watercraft and Hybrid Airships were researched to perform a comparative case study. The research assessed how many trips each lift asset had to complete in order to discharge the brigade's equipment. To ensure the data's integrity, the author compared the results of five methods for determining lifts.

The first two methods were simple calculations using the amount of weight and usable square footage each piece of equipment could move in a single lift divided by the total requirement for either weight or square footage. This appeared to be the method used in other airship research. Most of the airships discovered in the research were design proposals, so not all of the estimated capabilities were available for analysis, particularly the size of the cargo areas. However, many manufacturers suggested that the cargo area is scalable to the requirement and size of the airship. The author used a planning factor of 6.47 tons to represent one twenty foot equivalent unit (TEU)[4] for container capabilities and used the known dimensions of containers to estimate the overall square footage, but not necessarily the actual length and width of cargo holds. This factor was determined by the mean content weight for general cargo listed in Field Manual 55-15.[5] The author considered determining the average square footage per ton of equipment in the SBCT as an alternate technique, but time did not permit for this level analysis.

The third method used JFAST, the fourth method used a spread sheet to manually stow equipment for each trip based off lengths and widths, and the fifth method used stow plans from ICODES. The first two methods that depended strictly on weight or square footage are acceptable for homogenous movement requirements with identical dimensions, but for a requirement with diverse rolling stock and actual stow plan is the preferred method of analysis.

Method 1

$$Quantity_{(Deliveries)} = \frac{\sum \text{Re}\,quirements_{(Rolling\ Stock +\ Secondary\ Loads\ Tonnage)}}{Capacity_{(Vessel\ Tonnage)}} + \frac{\sum \text{Re}\,quirements_{(Container\ Tonnage)}}{Capacity_{(Vessel\ Tonnage)}}$$

Method 2

$$Quantity_{(Deliveries)} = \frac{\sum \text{Re}\,quirements_{(Rolling\ Stock\ ft^2)}}{Capacity_{(C\arg o\ Hold\ ft^2)}} + \frac{\sum \text{Re}\,quirements_{(Container\ ft^2)}}{Capacity_{(C\arg o\ Hold\ ft^2)}}$$

Method 3

The third method relied on JFAST to simulate how many sailings each vessel made. The requirements were generated by creating a notional Time Phased Force and Deployment Data (TPFDD) with level 4 data from table 7. A single vessel in the JFAST fleet was assigned to the notional TPFDD and then its lift characteristics were manipulated to reflect the square footage capabilities of the researched lighterage or airship. The load factors in this analysis were set to 90 percent target fill with 25 percent minimum load. The author varied these target fills and minimum loads without any significant change to the number of lifts that were modeled. At the most these changes might increase or decrease the number of lifts by one trip.

Method 4

The fourth method determined the lift capabilities by manually stowing equipment. The author created a spreadsheet that used the length, width, and weight of individual equipment to optimize the number and mix of equipment within the confines of the length and width of the lighterage's cargo area. A problem with this method is that there can be variance between models if the user is not consistent with which equipment they select for the next load or which equipment they load for maximum efficiency per lift. The final concern with this technique is that it does not account for center balance and distribution of weight in the cargo area. Not accounting for these two factors decreased the number of lifts the transportation mode must carry.

Method 5

The USTRANSCOM Integrated Computerized Deployment System (ICODES) stow planning tool was the fifth method used to analyze loading capabilities. This tool provided the most realistic and accurate of all five methods for determining how many trips each lift asset required to discharge an entire SBCT. Factors used in an ICODES load plan include allowable pounds per square foot on the loaded deck, the path cargo must make through the vessel, trim and stability conditions, exclusion areas, bulkheads, decks, holds, and spacing between equipment.

The ICODE master vessel library included the LSV, LCU-2000, LCU-1600, and LCAC characteristics. The author designed a sample airship in the ICODES conveyance creator, but the system did not allow the user to load the design into the aircraft for automatic stow planning. While the SBCT could have been manually stowed with ICODES without the auto load planner, this work was too time consuming to complete for this thesis. The other four methods provided a heuristic analysis to compare against the analysis completed with all five methods for the Army watercraft.

Comparative Throughput Analysis

In this analysis a vignette was created to compare the throughput of the entire distribution network from where the ship was discharged to the tactical assembly area as depicted in figure 1. This comparison assessed whether the cruising speeds of airships and decreased cargo handling requirements were more advantageous than slower moving watercraft with higher carrying capacities that relied on ground movements to deliver cargo to final destination. In order to understand the results of the initial findings the planning factors for mooring and casting off, loading and offloading, and the affects of distance were given separate analysis.

The vignette background was a fictional requirement to deploy a Stryker Brigade Combat Team from Fort Carson to the Georgia, Armenia, Azerbaijan, Turkey region as a flexible deterrent option to prevent a notional Ahurastanian enemy from further cross border violations in Azerbaijan, figure 7. A tactical assembly area was established in vicinity of Georgia's capital, Tbilisi. Insurgents damaged critical infrastructure in Western Georgia, 10 days prior to the decision to deploy the SBCT. Damage to the Mikha Tskhakaya airport, near the port of Poti, prevented C-17 and commercial airframes from landing other than C-130s. The Tbilisi Soganlug airport, near the port of Batumi, was so severe that aircraft cannot land or takeoff. The estimated time of repair for these airfields was five months.

The majority of the brigade's equipment was loaded on two LMSR ships and one container ship. The commander's critical items and sensitive items were flown on two C-

17s to Tbilisi international airport. The brigade's personnel flew to Tbilisi. However, a large contingent had to fly on intratheater aircraft to Mikha Tskhakaya airfield near the port of Poti in order to marry up with their equipment and then convoy 202 miles to their tactical assembly area established near the city of Tbilisi. Due to draft and beam restrictions in the ports of Poti and Batumi, a port opening sustainment brigade deployed with a JLOTS force module and a PLS medium truck company. The vignette then eliminated the truck company and intra-theater air requirements to account for airships delivering equipment directly to Tbilisi, 161 miles away by straight line distance.

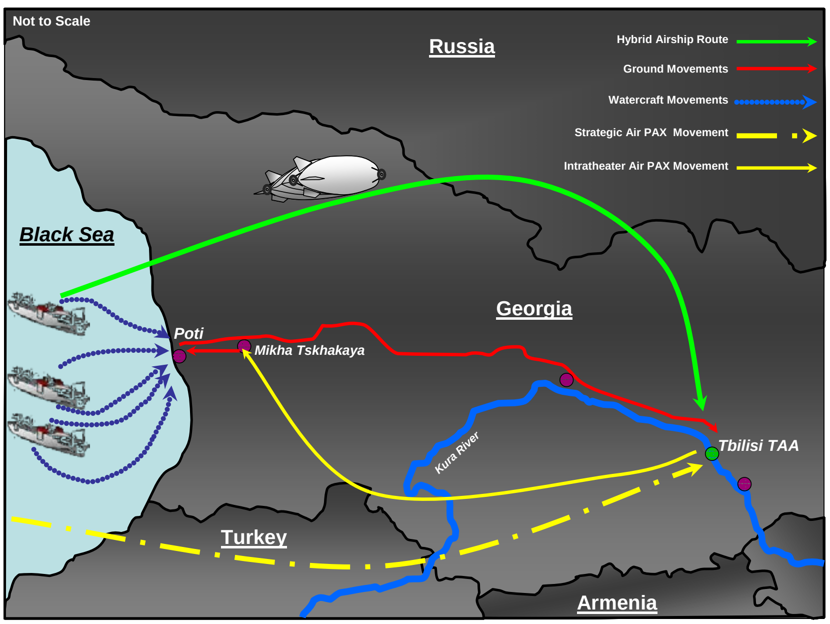

Figure 7. Vignette Transportation Network

Source: Created by author.

Determining Fleet Size

To determine the minimum size of an airship fleet, the analysis modeled the throughput of an LSV detachment, a heavy boat company, and four RRDFs working together, and the onward movement to the tactical assembly area by ground. This throughput established the benchmark to determine the minimum size of a comparable airship fleet. In total one LSV and eight LCU-2000s were used in an ICODES stow plan with a 1:3 ratio of LSV to LCU-2000 mix. This ensured all three ships were offloaded simultaneously over 24 hour operations. Daily maintenance, refueling, and crew rest were not accounted for, in order to represent the best case scenario in the analysis.

Cost Comparison of Airship Fleet to Watercraft Fleet

After the airship fleet sizes were determined, a cost comparison was made for lighterage used in current LOTS. This analysis was broken into two phases. First the author examined how much it cost to deploy a hybrid fleet versus a traditional JLOTS capability. Second, the analysis examined the cost to deliver equipment from the LOTS site to tactical assembly area. For watercraft movements this required an analysis of ground movements. The goal was to determine operational costs per hour for each system or cost to deliver a ton over a mile.

The research looked for pre-existing data in other studies and the Operating and Sustainment data in government databases. Additional costs were considered that might be associated with Doctrine, Organization, Training, Material, Leadership and Education, Personnel, and Facilities (DOTMLPF) for a Heavy-Lift Airship program versus the Army’s watercraft program. There were limitations in finding data for airships because most are still in development and difficult to compare existing equipment.

Feasibility, Responsiveness, Integration, and Survivability

Finally, the research studied previous works, articles, and reports related to Hybrid Airships to determine if they are feasible in JLOTS and can provide a more responsive and adaptive solution than existing LOTS capabilities? More specifically the affects of weather, Sea State conditions, mooring and loading challenges, and landing zone requirements were assessed for feasibility and the principle "flexibility." Deployment timelines and point of need delivery were evaluated for "responsiveness," "flexibility," "simplicity," and effectiveness. The principle "integration" required a discussion on which organization is best suited for employing Hybrid Airships and providing command and control. Enemy threats determined the "survivability" of Hybrid Airships. The research also considered elements of DOTMLPF where it was applicable to the discussion. The advantage of this is to could feed ideas for a Functional Solutions Analysis if hybrid aircraft were pursued as a material solution to the US Army watercraft capability gap.

---

[1]U.S. Army Command and General Staff College, Student Text (ST) 4-1, *Sustainment in the Theater of War* (Leavenworth, KS: Government Printing Office, June 2012), 1-8.

[2]U.S. Joint Chiefs of Staff, Joint Publication 4-0, *Doctrine for Logistics Support of Joint Operations Logistics Over-the-Shore (JLOTS)* (Washington, DC: Government Printing Office, August 2005), xvi.

[3]Ibid., III-4.

[4]U.S. Department of the Army, Field Manual (FM) 55-15, *Transportation Reference Data* (Washington, DC: Government Printing Office, October 1997), G-3.

[5]Ibid.

CHAPTER 4

ANALYSIS

This chapter presents, explains, analyzes, and interprets the evidence produced by the methodology in the previous chapter to determine if Hybrid Airships can economically increase the throughput of LOTS in Sea State 3 or higher.

Comparative Trip Analysis Results

Large airships with proposed 200 short ton carrying capacities or higher, fared well compared to the watercraft used in JLOTS. The medium airship showed more capacity than Navy's LCAC and LCU-1600 lighterage. On the other hand, the small airship had the least capability of all the lift assets compared. The results of this comparison are captured in table 1. The fewer trips a lift asset travelled, the better.

The lighterage with the highest capacity to carry weight did not necessarily correspond to the lighterage that carries more square footage. Figure 8 through figure 12 illustrate this trend. As an example, the LSV had the best carrying capacity based on its ability to carry up to 2,000 tons of material, but it had less capacity than the JHSV, 1K ton Walrus project, and 500-ton Walrus project that carry more square footage.

Ideally all of the lift assets could have been compared using load plans in ICODES. However, ICODES was limited to using pre-existing vessels and aircraft for its auto-loading function. The best alternative was to use the highest number from one of the other four methods analyzed. For the remainder of the research, data bolded and underlined in table 1 is used to analyze throughput.

Table 1. Trips Per Lift Asset

Number of Trips for One Type of Lift Asset based on either its weight capability, square footage capability, JFAST analysis, manual stow plan analysis, or stow plans created in ICODES					
	Trips based on:				
Asset	**Weight**	**SF**	**JFAST**	**Manual Stow**	**ICODES**
JHSV w/o containers	15	14	22	+	**12**
Walrus 1K ton Airship	12	11	12	**17**	*
Walrus 500-ton Airship	23	20	24	**25**	*
LSV Watercraft	6	23	31	34	**32**
CSP+3 Watercraft	37	35	**41**	+	*
JHSV Watercraft w/ containers	18	17	28	+	*****46**
Large Airship 200-ton	56	51	**61**	+	*
LCU2000 Watercraft	33	62	76	80	**123**
Medium Airship 80-ton	139	126	**150**	+	*
LCAC w/o containers	169	100	134	+	****187**
LCU1600 Watercraft	64	64	90	+	**276**
Small Airship 40-ton	276	251	**301**	+	*
**Cannot be modeled in ICODES*					
***This quantity only represents the rolling stock because JP 4-01.6, page IV-13, stated that lift-on/lift-off operations are discouraged because of the LCAC's aluminum hull; an additional lift asset is required to move the containers*					
****This quantity is inflated because of the multiple turns the JHSV must make to move containers; realistically the JHSV would be dedicated exclusively to rolling stock; an additional lift asset is required to move the containers*					
+unrealistic to manually stow plan all lift assets when the JFAST modeling tool provided relatively close results with other lift assets					
-bold, underlined numbers represent those used for further calculations throughout the thesis					

Source: Created by author.

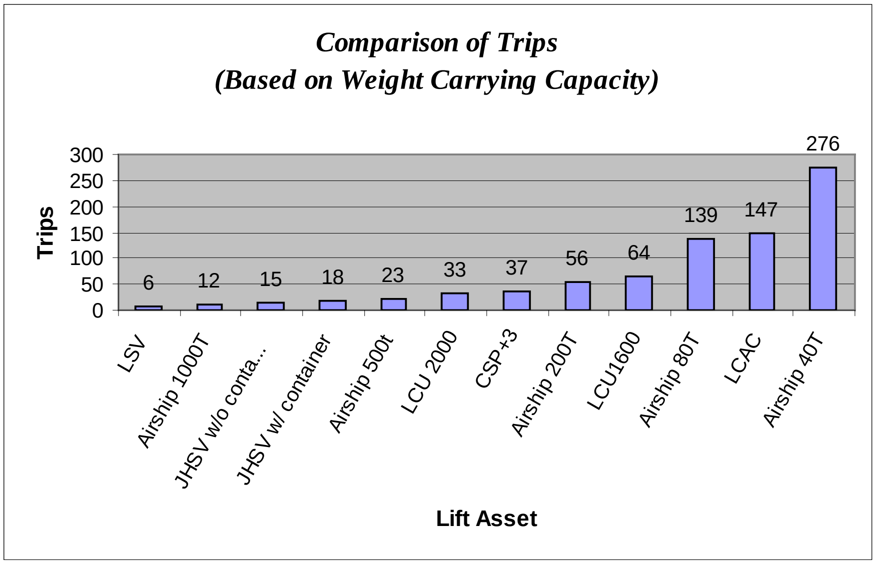

Figure 8. Required Trips Made by Individual Lift Assets Based on Weight Carrying Capacity

Source: Created by author.

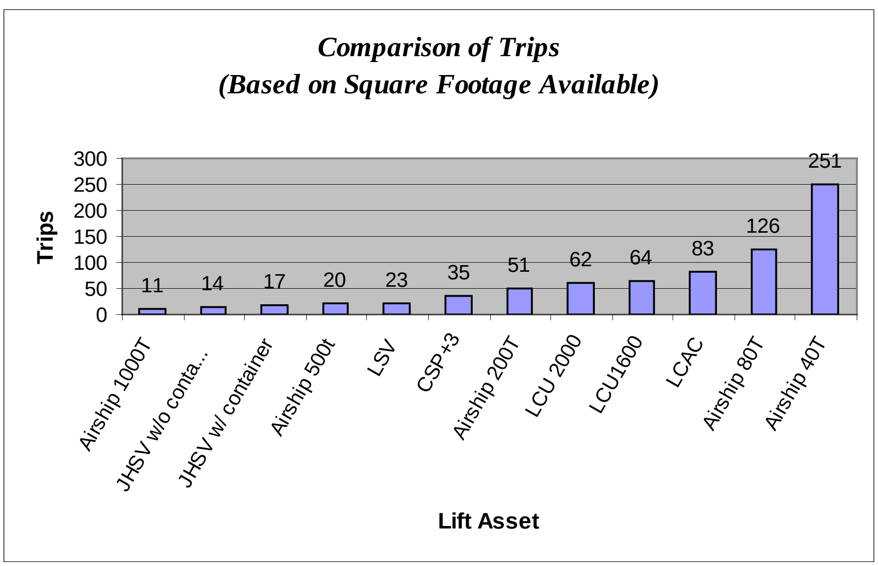

Figure 9. Required Trips Made by Individual Lift Assets Based on Available Square Footage in Cargo Area

Source: Created by author.

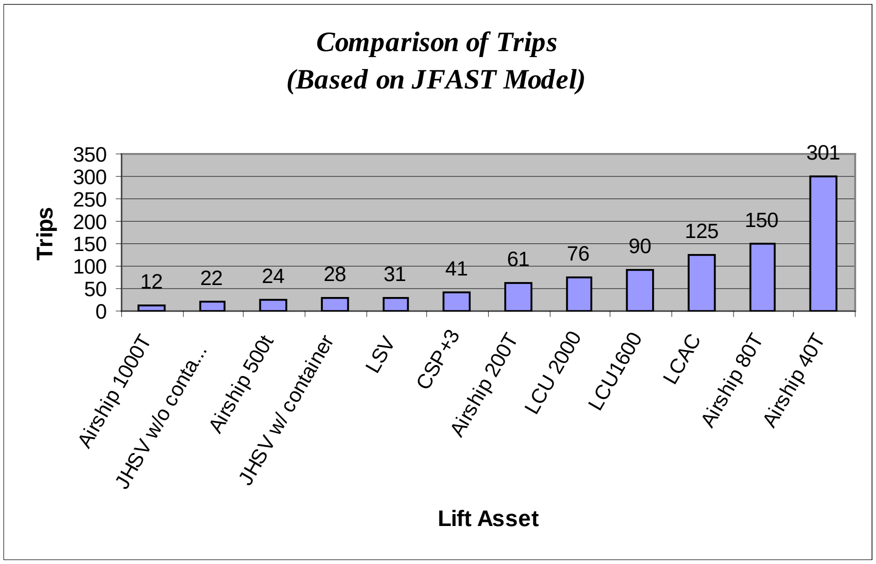

Figure 10. Required Trips Made by Individual Lift Assets Based on JFAST Simulation

Source: Created by author.

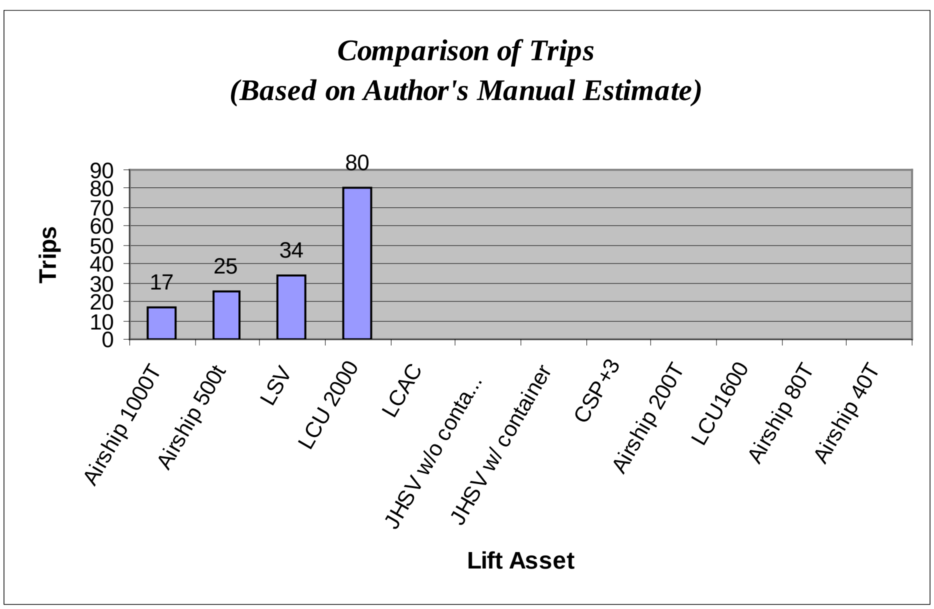

Figure 11. Required Trips Made by Individual Lift Assets Based on Author's Manual Estimate

Source: Created by author.

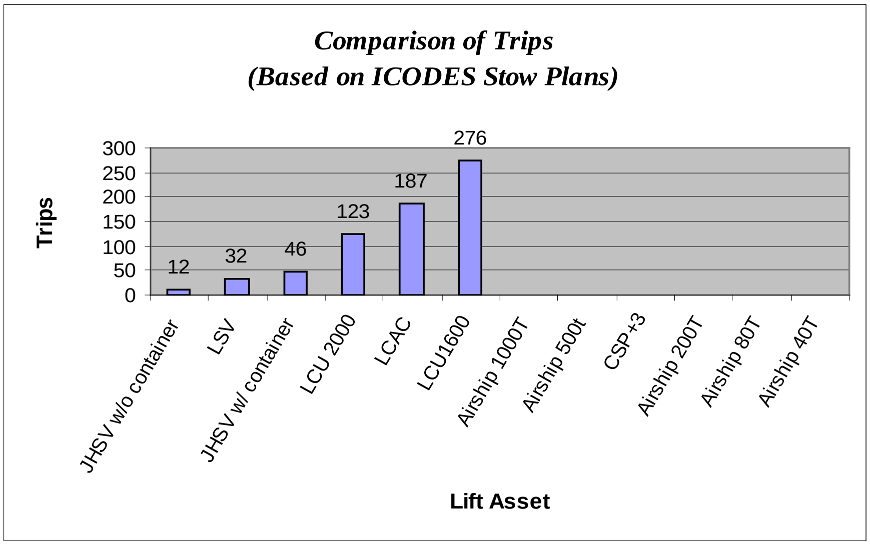

Figure 12. Required Trips Made by Individual Lift Assets Based on ICODE's Estimate

Source: Created by author.

How Trip Analysis Compared to Other Research

The Congressional Budget Office's study of "Sea Basing and Alternatives for Deploying and Sustaining Ground Combat Forces," estimated 46 Hybrid Airships were needed to deploy a Marine Expeditionary Brigade and an Army light infantry brigade. Based on the ratio of vehicles used for each unit in from the study, figure 13, a Stryker Brigade Combat Team would require 23 airships. The problem is that the Congressional Budget Office study did not specify the size of the airships. Based on the analysis in this thesis it is likely that the study used airships with a 500-ton lifting capacity. This falls within the results this thesis found using JFAST and manual stow plans.

In the SkyCat study referenced in Newbegin's monograph, the study had 17 airships moving the entire Stryker Brigade Combat Team. The study was based on airships with the capacity to lift 1,000 short tons. These were the identical results this thesis calculated in the manual stow plans.

Approximate Size and Sustainment Requirements for Ground Units

Force	Personnel	Number of Vehicles	Weight of Vehicles (Tons)	Sustainment Requirement (Tons/day) Surge Intensity	Sustained Intensity
Sea-Based MEB (Ground-combat element)	5,000	1,300	13,000	734	470
Army Light BCT	3,200	500	2,200	272	217
Army Stryker BCT	3,500	900	9,300	338	280
Army Heavy BCT	3,800	1,400	25,000	613	344

Source: Congressional Budget Office based on data from the U.S. Army and U.S. Marine Corps.

Notes: MEB = Marine expeditionary brigade; BCT = brigade combat team.

Figure 13. Approximate Size and Sustainment Requirements for Ground Units

Source: Congressional Budget Office, *Sea Basing and Alternatives for Deploying and Sustaining Ground Combat Forces* (Washington, DC: Government Printing Office, 2007), 14.

Comparative Throughput Analysis Results

Large airships on the scale explored by DARPA's Walrus program have better throughput than most individual lighterage used in LOTS operations established five kilometers offshore. The only exceptions with better throughput were the Joint High Speed Vessel and Causeway Ferry. The large airship with a 200-ton payload had better throughput than the LCU-2000, LCAC, and smaller airships. However, these results are speculative based on a number of factors that will be described.

The faster flight time for airships helps compensate for those with lower carrying capacities, but not enough to exceed the combined throughput of watercraft and supporting ground movements. The throughput results did not align with the carrying capacity analysis from the previous section. There was an expectation that the airships might outperform some of the watercraft due to their faster speeds; this was observed with the large airships that ranged from 200 to 1,000-ton payloads, figure 14.

The most surprising result was that vessels and airships with smaller carrying capacities could perform better than similar capabilities travelling at the same speed or even faster, figure 14. As examples, the 500-ton airship payload had better throughput than the 1,000-ton airship payload and the 40-ton airship payload had better throughput than the 80-ton airship payload. Even more shocking was that the Causeway Ferry that travels slower than all the compared watercraft and airships had better throughput than the LSV, 1,000-ton airship, and 500-ton airship that have larger cargo holds.

These unexpected results drove the analysis to find the root cause. The throughputs were isolated by rolling stock and container movements in figure 15 and figure 16 respectively. The isolated rolling stock and container throughputs showed different results for which lighterage had better throughput. The factors that differ between each figure are the planning factors used, table 11. After some experimentation with the calculations, the author discovered that loading, offloading, mooring, and cast off rates dramatically affected the performance of all vessels and airships because of the multiple turns they made. These factors would have less an impact if lift assets had fewer deliveries.

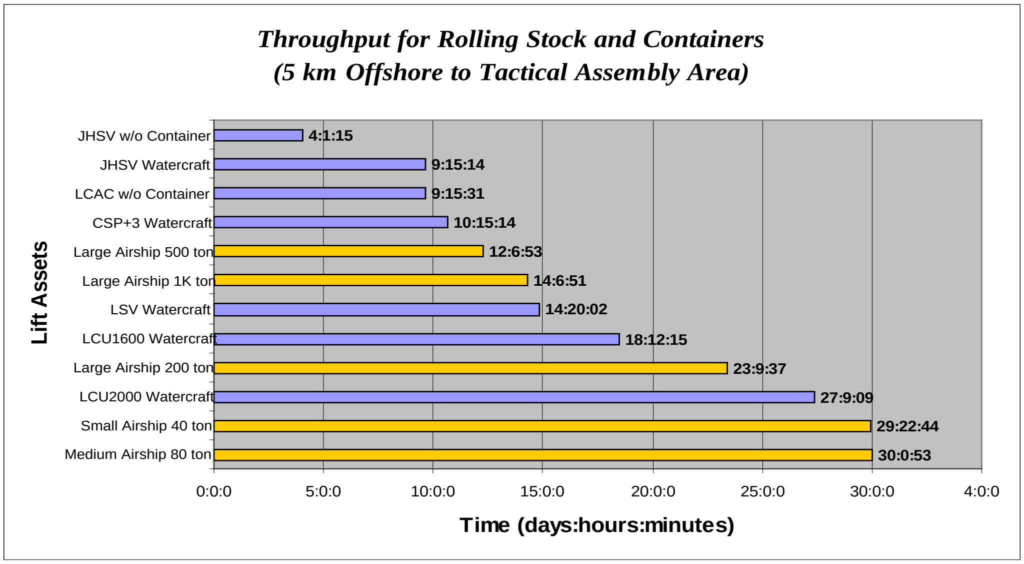

Figure 14. Container and Rolling Stock Throughput by Individual Lift Asset from Offshore Anchorages to TAA, 259 Kilometers Inland by Air or 326 Kilometers Inland by Ground

Source: Created by author.

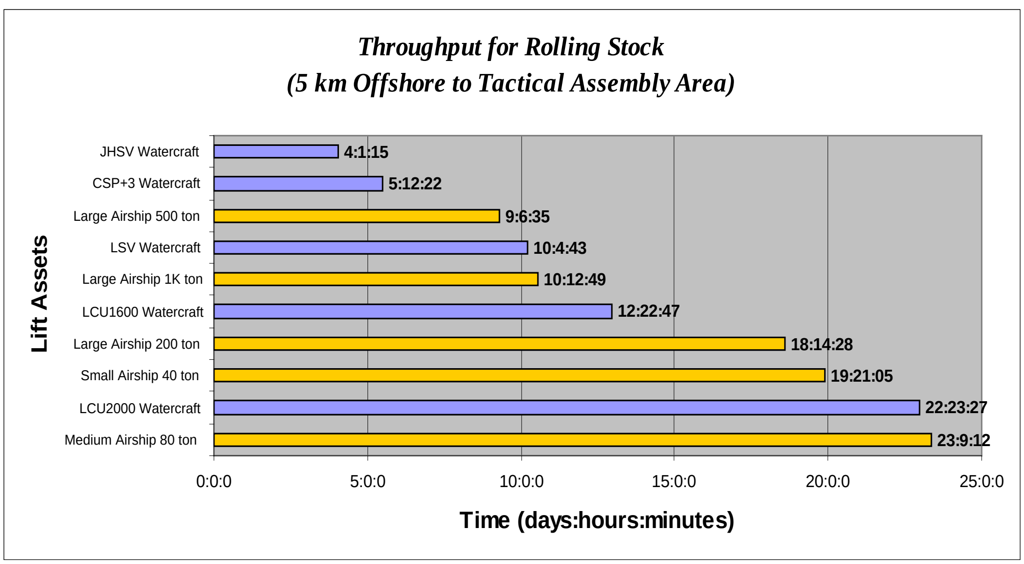

Figure 15. Rolling Stock Throughput by Individual Lift Asset from Offshore Anchorages to TAA, 259 Kilometers Inland by Air or 326 Kilometers Inland by Ground

Source: Created by author.

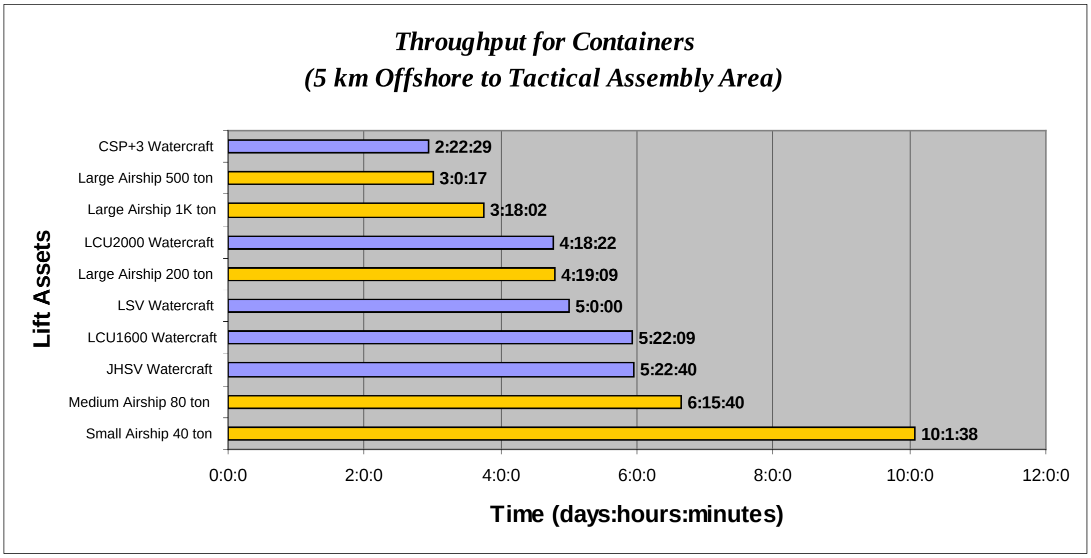

Figure 16. Container Throughput by Individual Lift Asset from Offshore Anchorages to TAA, 259 Kilometers Inland by Air or 326 Kilometers Inland by Ground

Source: Created by author.

Mooring and Casting Off Affects on Throughput

The results of the research lead the author to question how much of an effect the planning factors for mooring and casting off affected throughput. Answering this was critical because LSV's planning factors were used for the airships and the JHSV that did not have any planning data available. Factoring out these values across all lift assets, figure 17 through figure 19 illustrate that throughput can change due to how long it takes to moor or cast off. Vertically striped "blue" and "white" bars represent throughput for select lighterage that performed better than other lighterage as a result of excluding mooring and casting off planning factors.

This was a significant finding for airships designed for JLOTS. If the nature of this concept causes the airship to take more time to approach and depart a ship, then it could offset any advantages identified in the previous section. Table 16 through table 18, illustrate how much variance is caused by factoring out mooring and cast off planning factors.

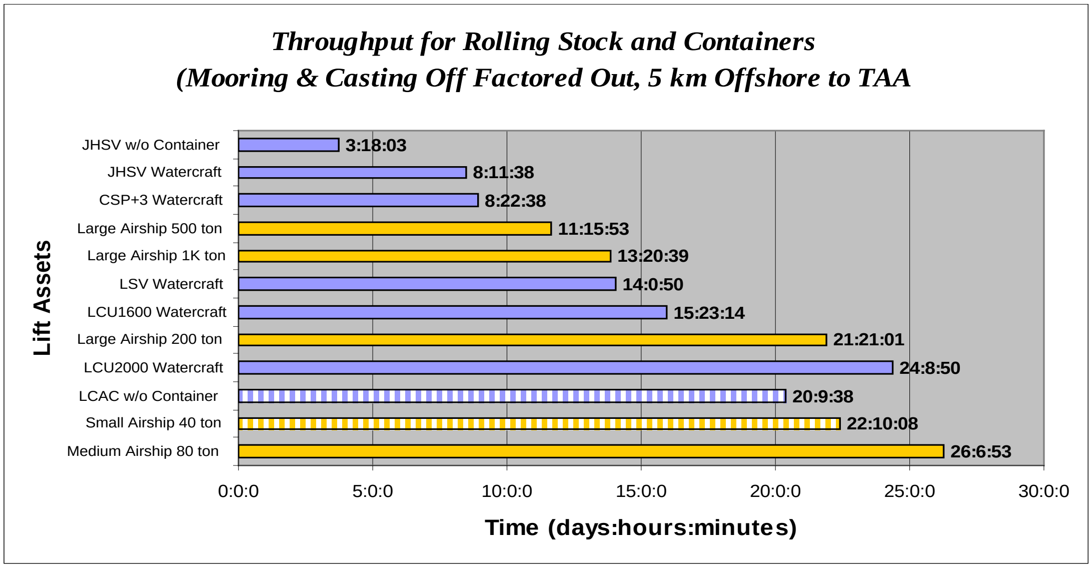

Figure 17. Throughput by With Standardized Mooring and Casting Off Planning Factors

Source: Created by author.

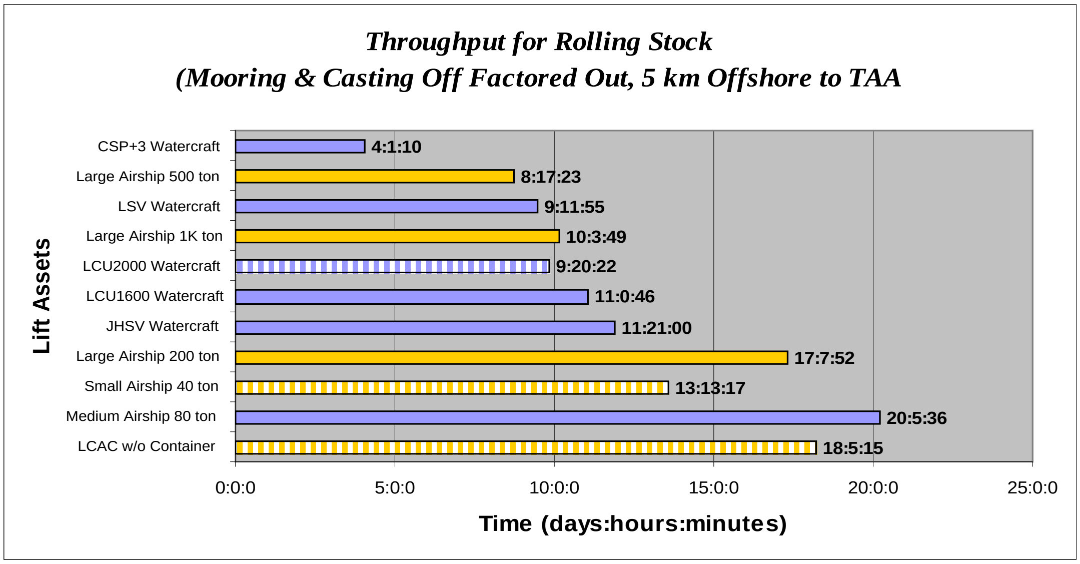

Figure 18. Throughput by With Standardized Mooring and Casting Off Planning Factors for Rolling Stock Only

Source: Created by author.

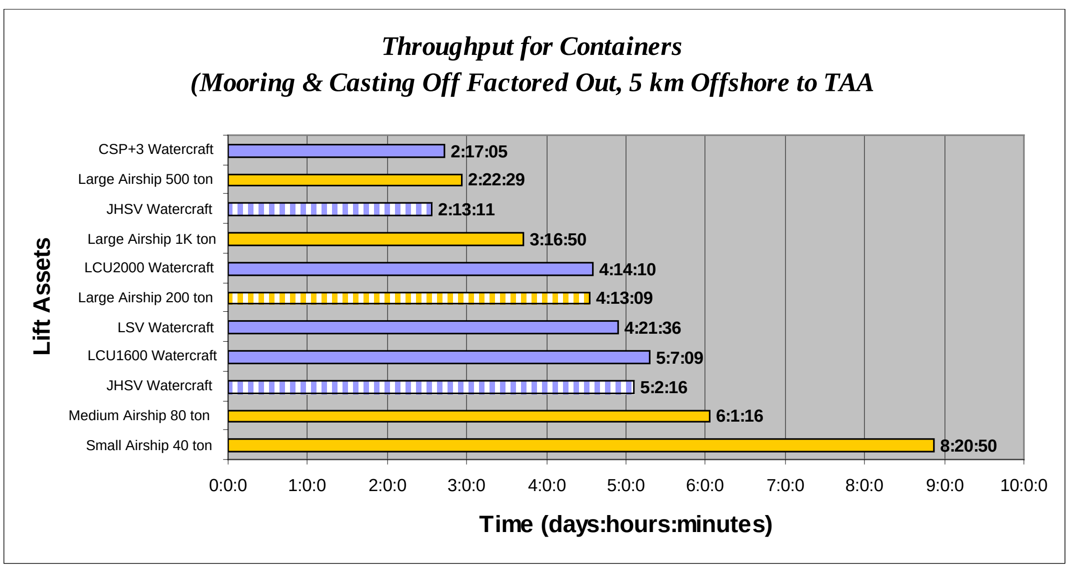

Figure 19. Throughput by With Standardized Mooring and Casting Off Planning Factors for Containers Only

Source: Created by author.

Loading and Offloading Affects on Throughput

Discovering throughput's vulnerability to mooring and casting off planning factors that measure in one to two minutes, drove further analysis of the affects of loading and offloading that span even longer times. Again JHSV and airships did not have any planning data available so these were derived from data on existing watercraft, table 12 and table 13. Factoring out these values across all lift assets, figure 20 through figure 22, illustrate that throughput can change due to how long it takes to load and offload equipment. The diagonally striped bars represent throughput for select lighterage that performed better than other lighterage as a result of excluding loading and offloading planning factors.

This was a significant finding for airships designed for JLOTS. If the nature of this concept causes the airship to take more time to approach and depart a ship, then it could offset any advantages identified in the previous section. Table 16 through table 18 illustrate how much variance is caused by factoring out mooring and cast off planning factors.

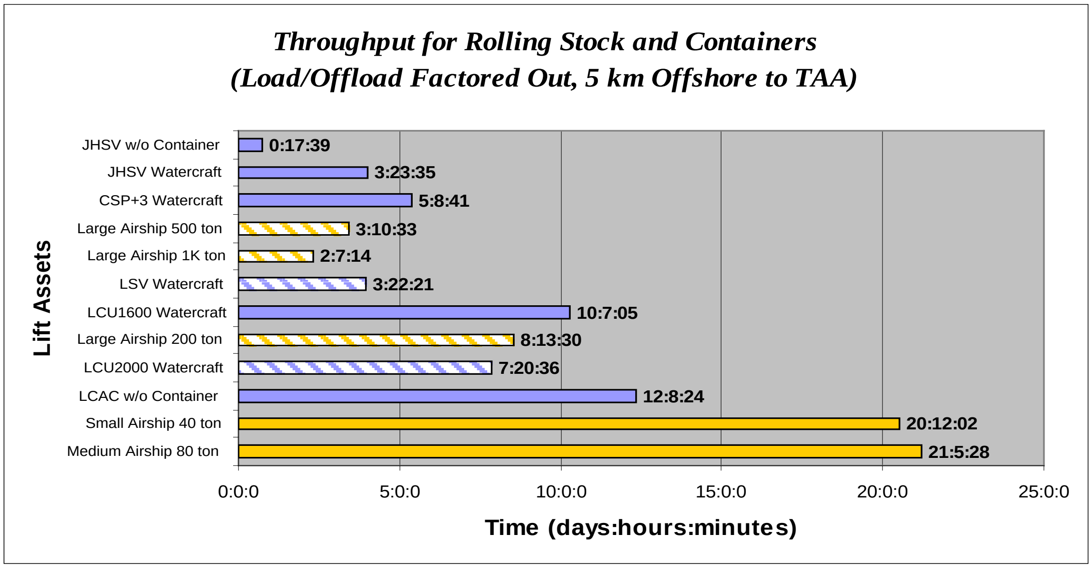

Figure 20. Throughput without Loading and Offloading Planning Factors

Source: Created by author.

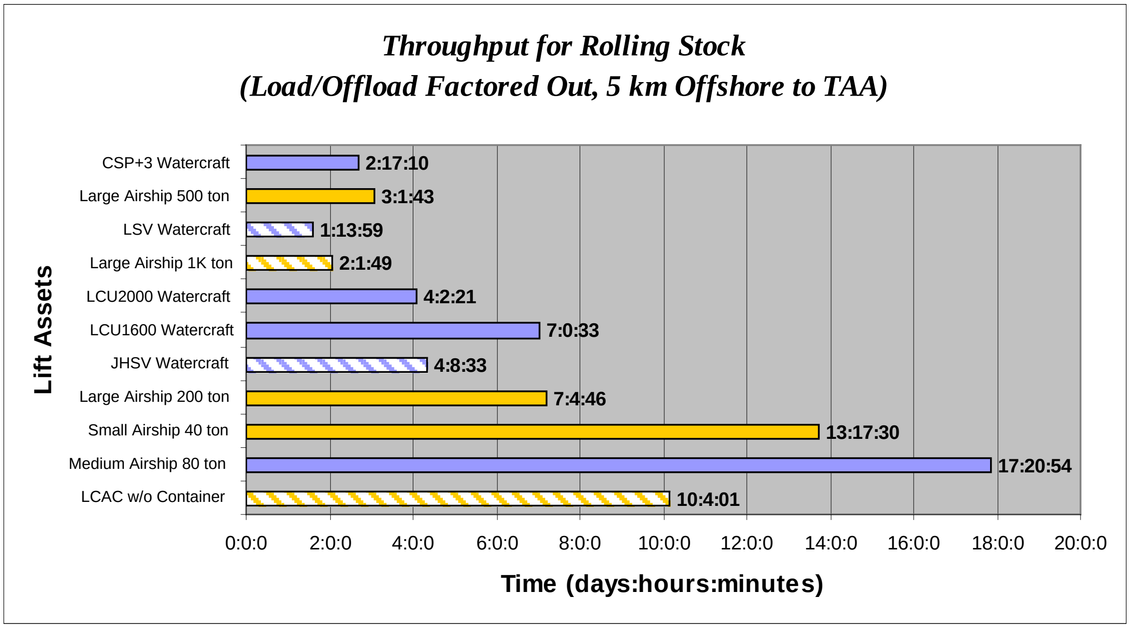

Figure 21. Throughput without Loading and Offloading Planning Factors for Rolling Stock Only

Source: Created by author.

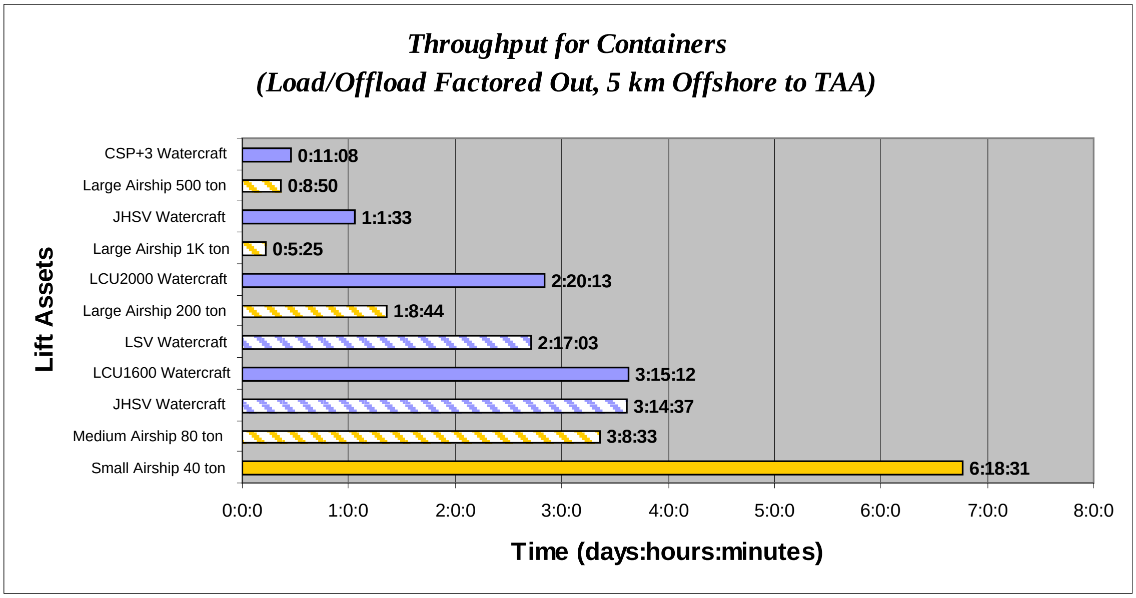

Figure 22. Throughput without Loading and Offloading Planning Factors for Rolling Stock Only

Source: Created by author.

Distances Affect on Throughput

Distance is another factor that affected the cycle time for lighterage between the ship and delivery location, table 2. In short distances between one to five kilometers offshore there were small differences in the throughput for airships. On the other hand LCAC, LSV, CSP+3, had significant decreases in throughput.

The distance was increased to 43.3 kilometers or 25 nautical miles which was considered "operating over the horizon" in the Congressional Budget Office Study "Sea Basing and Alternatives for Deploying and Sustaining Ground Forces." There was an obvious increase in throughput for all of the lighterage that was compared. However, the airships had the smallest increase. This implied that airships had better performance as distance increased. This finding was substantiated by the decreased performance when the distance was varied from five kilometers to one kilometer.

This stimulated a question of whether an individual airship's increased performance over distance could eliminate the necessity of LOTS all together. In this case, the distance for airships was increased to 2,671 kilometers which reflected an Intermediate Staging Base at Abano, Italy to the Tactical Assembly Area at Tbilisi, Republic of Georgia. These results were compared to the results of the time it took an LMSR to sail 1,707 nautical miles from Abano to the LOTS operation five kilometers offshore, time to complete the LOTS with traditional lighterage, and the time for onward movement over ground. The results show that airships cannot increase throughput enough to eliminate LOTS all together, figure 23. However, this analysis only reflects the capabilities of individual watercraft and airships and begs the question, "how large does an airship fleet need to be?" If the Hybrid Airship fleet were built large enough it may be capable of eliminating LOTS all together if the entire brigade was moved in a single lift.

Table 2. Changes to Delivery Time Based on Distance

Throughput Rolling Stock & Containers	5km (d:hr:min)	1km (d:hr:min)	43.3km (d:hr:min)	Increase/Decrease 5 km to 1km +/-(d:hr:min)	Increase/Decrease 5 km to 43.3 km +/-(d:hr:min)
JHSV w/o Container	4:1:15	4:1:05	4:14:48	**+0:0:10**	**+0:13:33**
JHSV	9:15:14	9:15:14	11:20:16	**+0:0:00**	**+2:5:02**
LCAC w/o Container	1:9:15:31	1:26:14:22	2:4:11:21	**+16:22:51**	**+1:25:19:50**
CSP+3	10:15:14	9:17:37	19:6:15	**+0:21:37**	**+8:15:01**
Large Airship 500-ton	12:6:53	12:7:09	12:18:11	**-0:0:16**	**+0:11:18**
Large Airship 1K ton	14:6:51	14:7:01	14:14:23	**-0:0:10**	**+0:7:32**
LSV Watercraft	14:20:02	14:8:46	19:7:58	**+0:11:16**	**+4:11:56**
LCU-1600 Watercraft	18:12:15	18:12:15	57:9:45	**+0:0:00**	**+38:21:30**
Large Airship 200-ton	23:9:37	23:10:16	24:13:52	**-0:0:39**	**+1:4:15**
LCU-2000 Watercraft	27:9:09	27:9:09	44:0:11	**+0:0:00**	**+17:15:02**
Small Airship 40-ton	29:22:44	29:23:56	31:2:48	**-0:1:12**	**+2:4:04**
Medium Airship 80-ton	30:0:53	30:2:30	31:23:00	**-0:1:37**	**+2:22:07**
			Averages:	**+1:12:58**	**+8:20:35**

Source: Created by author.

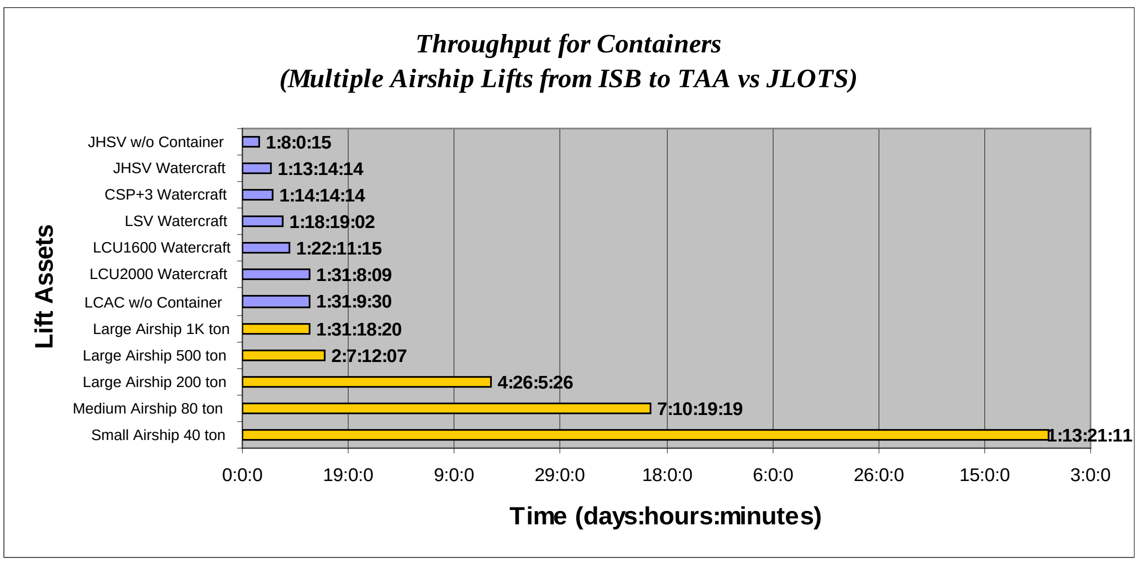

Figure 23. Throughput of Airships Flown from ISB to TAA versus JLOTS at 5 Kilometers Offshore

Source: Created by author.

Results for Determining Fleet Size

It took eight days, one hour, and 49 minutes for an LSV and eight LCU-2000 watercraft to simultaneously offload three LMSRs and onward move the Stryker Brigade Combat Team to the tactical assembly. This established the benchmark for airship fleets. Figure 24 shows that four 1,000-ton, four 500-ton, seven 200-ton, eight 80-ton, or eight 40-ton airships can have better throughput than a traditional LOTS operation. In a later sub-section titled "Deployment," it will be apparent that this two to three day throughput window can deliver an SBCT before traditional JLOTS equipment can complete a deployment and establish a fully operational site.

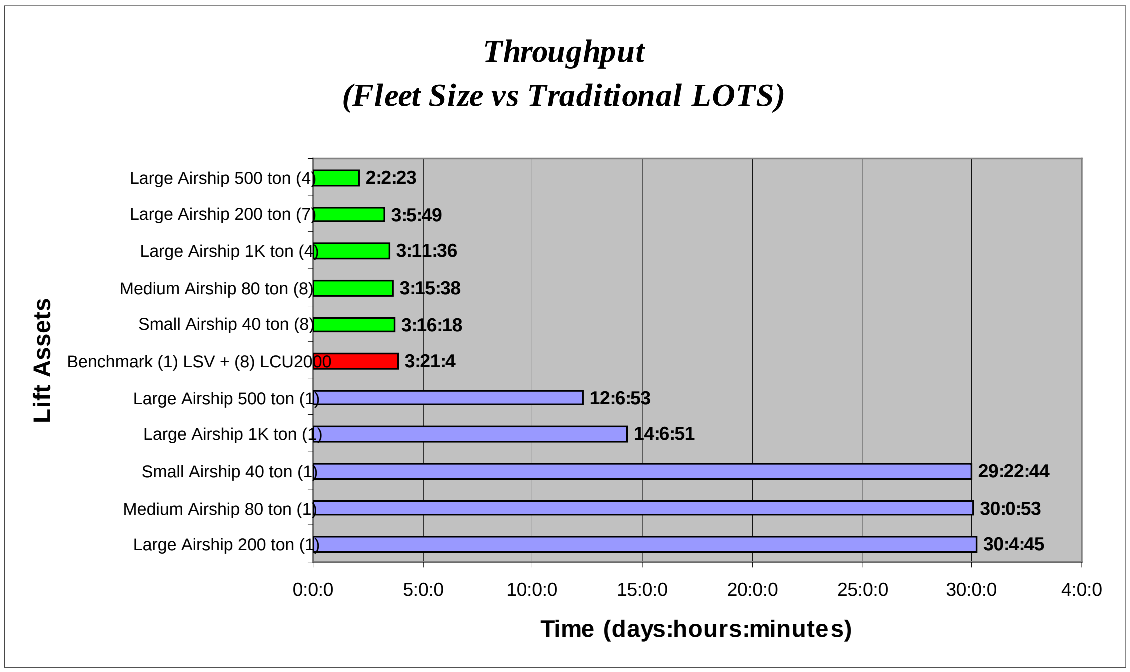

Figure 24. Throughput of Airships Fleets versus Traditional Operation with One LSV and Eight LCU-2000

Source: Created by author.

Results for Cost Comparison of Airlift Fleet to Watercraft Fleet

The results of the research demonstrated that Hybrid Airships may not be as cost effective as watercraft during deployment to the LOTS location. However, the employment costs in JLOTS implied that there could be savings using Hybrid Airships to deliver equipment from the LOTS location to a tactical assembly area. There was not enough time to confirm either of these assertions because of the amount of detail required for the analysis.

Deployment Cost

Deployment costs were determined from the distance and time to fly hybrid airships into theater and the cost to deliver or self-deploy Army lighterage, table 23. The problem with this analysis was that the shipping costs were limited to the fuel consumption of the shipping vessels, whereas the Hybrid Airship cost of $0.22 per ton mile[1] assumed operation and sustainment costs like crew pay, maintenance, and fuel. Another problem is that loading costs onto the ships and activation costs for prepositioned equipment were not calculated. Another consideration is that Hybrid Airships may depend on RRDFs to transfer equipment and would incur some of the same shipping costs considered for traditional LOTS. If Hybrid Airships self-deploy and transfer equipment and containers without auxiliary LOTS equipment, the aircraft may add another significant cost savings and will reduce crew requirements.

JLOTS Employment Costs

Table 3 attempted to compare the throughput and cost of Hybrid Airships to watercraft and subsequent ground movements. The results in the table show that watercraft cost less in their employment, however there are many factors that were excluded in the ground costs that could make the watercraft more expensive to employ than Hybrid Airships. Calculations for employing Hybrid Airships used $0.22 per ton mile operation and sustainment costs to deliver the SBCT from the LOTS site to a tactical assembly area. Watercraft costs were based on the cost for watercraft movements per hour of operation and then combined with the cost for a PLS medium truck company to delivery 200 containers. Examples missing from the analysis include material handling costs, the cost for the SBCT to convoy to the tactical assembly area, and the myriad of other supporting units involved in a LOTS operation. While this thesis did not calculate the total cost for a traditional LOTS operation, there was a JLOTS exercise that gave some insight into the magnitude of these operations and why Hybrid Airships would simplify the process and likely reduce costs.

A 2008 JLOTS exercise called “Pacific Strike 2008” cost $20 million to deploy 3d Brigade, 25th Infantry Division from Hawaii to NTC.[2] The movement entailed offloading onto Red Beach[3] near Camp Pendleton in a JLOTS operation and then onward moving the equipment 180 miles to Fort Irwin, California.[4] In total the exercise moved 200,000 gallons of fresh water and 1,500 vehicles and containers from ship to shore.[5] An operation this scale involved more than 2,700 personnel and cost $2.5 million in life support and maintenance.[6] The throughput for the operation was roughly 298 vehicles and containers per day.[7]

Table 3. Cost Versus Throughput

Lift Asset	Deploy	Transfer/ Receive		Onward Move		Total Cost of Operation
	Deployment Costs	Throughput w/o ground movement	Cost for Lighterage	Ground Movement (Containers)	MHE/ Ground Movement (SBCT)	
Medium Airship 80-ton	$779,328.00	30:0:53	$424,776	NA	NA	**1,204,104**
Small Airship 40-ton	$389,664.00	29:22:44	$426,192	NA	NA	**815,856**
LCU2000 Watercraft	$495,649	27:9:09	$213,166	$168,995	Not Calculated	**877,810**
Large Airship 200-ton	$1,704,780.00	23:9:37	$431,856	NA	NA	**2,136,636**
LCU1600 Watercraft	Unavailable	18:12:15	Unavailable	$168,995	Unavailable	Unavailable
LSV Watercraft	$148,933	14:20:02	$351,159	$168,995	Not Calculated	**>669,087**
Large Airship 1K ton	$4,870,800.00	14:6:51	$601,766	NA	NA	**5,472,566**
Large Airship 500-ton	$2,435,400.00	12:6:53	$442,475	NA	NA	**2,877,875**
CSP+3 Watercraft and RRDF	$490,242	10:15:14	$64,229	$168,995	Not Calculated	**?669,087**
LCAC w/o Container	Not Calculated	9:15:31	$975,018	$168,995	Not Calculated	**>1,144,013**
JHSV Watercraft	Not Calculated	9:15:14	$372,048	$168,995	Not Calculated	**>541,043**
JHSV w/o Container	Not Calculated	4:1:15	$97,056	$168,995	Not Calculated	**>266,051**
(1)LSV + (8)LCU2000+ (4)RRDF	$1,540,355	3:21:4	$173,433	$168,995	Not Calculated	**>1,882,783**
	Excludes: -cost to activate prepo -cost to load lighterage -Ship maintenance -crew costs	Excludes: -auxiliary crane ship to transfer containers -C2 vessels -tugs -ELCAS assembly		Excludes: -MHE cost per hour -convoy costs to TAA		

Source: Created by author. Derived from data in Appendix G.

Other Costs Considerations

The operations and support costs available for this research focused on fuel and maintenance, but there are other considerations for comparing watercraft and airships that are important for discussion. The DOTMLPF construct helped frame some of these costs. Doctrine, Organization, Leadership and Education, Training was not addressed in any of the research that was reviewed and not defined in a way that could be associated with costs.

In terms of "Material" there are costs related to procurement and the research and development testing and evaluation (RDT&E) and then separate costs associated with procurement. Various RDT&E projects have been funded over the past several years on heavy lift and high and low altitude surveillance Hybrid Airships. The problem is that most fell behind schedule and incurred unforeseen costs, which resulted in disapproval for future funding. As examples, both the US Air Force's Blue Devil 2 and US Army's LEMV programs will not be funded next year, although $60 million was already spent on the Blue Devil[8] and $356.2 million on the LEMV.[9] This was the fate of DARPA's Walrus project that went unfunded in 2006 after $3.2 million was awarded to Aeros Corporation and $2.9 million awarded Lockheed Martin to construct scaled down demonstrator Hybrid Airships for heavy lift.[10] NASA and ASD(R&E) sponsored the Pelican project[11] for $42.2 million and the aircraft is scheduled to perform a flight demonstration in 2013.

The second part of "Material" is the actual cost of procurement. Unfortunately, the procurement cost for various airship sizes is uncertain. The Congressional Budget Office estimated a cost of $4.8 billion for 14 airships in a 2006 study and then $12 billion to $18 billion for 46 airships in a 2008 study.[12] Averaging the cost all three of these estimates for and accounting for an inflation factor, a single airship may cost $360 million per system in the fiscal year 2012 market. Compared to traditional Army watercraft this is extremely high. The LSV costs $26.7 million[13] and LCU-2000 costs $5 million.[14] On the other hand, the Joint High Speed Vessel's contract for 10 vessels cost $3.5 billion[15] or roughly $350 million each, a comparable figure to the cost of an airship.

The "Personnel" attribute of DOTMLPF is where airships could be potentially more affordable. In the vignette, the reduction in wheeled vehicle crews for the PLS Medium Truck Company would save more than 108 personnel that would not require entitlements for deployment and would not face confrontation with the enemy. The airship's crew compared to the watercraft is another elusive number. There was no research on how large the crews should be. The author speculates that the crew sizes might be around five personnel and could mirror a fixed wing cargo aircraft or an LCAC crew. A pilot, co-pilot, deck engineer, load master, and engineer seemed like a realistic requirement. This is a much smaller crew than compared to water craft that have 32 personnel onboard an LSV, 13 personnel onboard an LCU2000, 16 personnel operating a Causeway Ferry, and 41 on a JHSV. This excludes all the other craft such as the four RRDFs planned in the vignette that each have a 31 person crew, 33 personnel operating a Floating Causeway, and countless other personnel operating tugs, material handling equipment on the beach, floating cranes, equipment processing, and life support. It was mentioned earlier that more than 2,700 were involved in the 2008 Pacific Strike JLOTS exercise.[16] Airships could eliminate the need or at least draw down the requirement for so many people.

The research found that a Department of Defense report titled "Hybrid Airships Operational Concept" did discuss the "Facilities" part of DOTMLPF. The report's discussion did not talk specific costs, but identified issues and concerns that should be considered as cost considerations. The first of these is a requirement for Hybrid Airships to be compatible with current material handling equipment used at sea ports, airfields, and by ground forces. A second concern is that although airships can operate without much infrastructure, there would be a hangar requirement for home basing maintenance. This will be an enormous cost based on the extreme sizes Hybrid Airships must be built in order to provide the lift promised. As an example, a two ton lifting airship that has similar dimensions as the LEMV will be 180 feet long by 75 feet wide and is roughly the length of a C-17. Scale that size up to a 1,000-ton airship and the dimensions increase to 1,000 feet long by 450 feet wide, and very high.

The DoD report identified eleven hangars in the entire world capable of holding large airships. Although the locations were not discussed, the operational range of airships would likely require new construction at various locations in order to support power projection where most needed and minimize refueling enroute. An alternative solution may be to self deploy the airships with a self-sustaining fuel bladder to increase the operational range and then offload the bladder on the beach near the JLOTS location.

Feasibility, Responsiveness, Integration, and Survivability

The re-occurring theme for anything written about Hybrid Airships is that they have incredible potential as a joint enabler for force projection and sustainment. In 2010 the US Africa Command, US European Command, and US Transportation Command participated in a Point of Need Delivery (POND) Experimentation Campaign. In the experiment, both Combatant Commands required “a capability to deliver within 3-5 days a ready-to-employ, task-organized element up to brigade-sized or equivalent, to or from a point-of-need, independent of receptive infrastructure.”[17] The participant’s finding was that current lift platforms cannot meet the requirements used in the experiment and that only a Hybrid Airship capable of lifting 200-tons or more had the capability.[18]

Feasibility

Environment

Wind has the biggest impact on Hybrid Airships because the immense size and shape increases the sail affect. This translates to increased fuel consumption and decreases the operational range and speed. However, modern radar and weather analysis could help the airships avoid weather systems or go to ground early. The assumption is that airships would fly under the same conditions as rotary wing aircraft.

Other environmental concerns are snow, ice, visibility, and lightning strikes, but this is no different than rotary and fixed wing aircraft. Also there are methods to mitigate all of these issues. Sea salt is a concern for airships in JLOTS, but may be less of a problem than rotary wing aircraft that have a stronger downwash.

Altitude does affect airships. As the aircraft rises, the lifting gases expand and can risk bursting the envelope containing the gas. All of the Hybrid Airship designs used for heavy lift will operate at altitudes below 10,000 feet mean sea level. As altitude increases temperatures change, but the affects of temperature on airships was not researched. Another question that was not answered is how much of the earth is below 10,000 feet. However, a study by the Congressional Budget Office showed that "10 percent of the world's land area would not be accessible to airships if airships were limited to flying in areas with ground elevations no greater than 5,000 feet above sea level."[19] This is significant in some areas like Asia where the majority of the largest mountains project. For example, the report indicated that "40 percent of Iran's land area and almost half its population are at elevations greater than 5,000 feet above sea level.[20] Of course, another perspective is that airships can reach at least 90 percent of the globe and watercraft can only access 70 percent of the earth's surface.

Sea State 2 and Worse

It is conceivable that Hybrid Airships can operate in Sea State 3 or higher, but they are susceptible to the affects of weather. In order to operate in conditions worse than Sea State 2, waves must be taller than three feet and winds stronger than 12.66 knots based on the Pierson-Moskowitz sea scale. Table 4 shows that some airship can operate with crosswinds up to 15 knots, but overcome these by turning into the wind. A Russian manufacturer suggests their airship can fly in winds up to 25 meters per second or 48.5 knots.[21] If the airship can moor or land on a ship being offloaded, this might eliminate the affects of waves larger than three feet that risk lighterage colliding with the ship. On the other hand, wind would have an affect on mooring which will be discussed in the next section.

Table 4. SkyCat Operating Limits in Weather Conditions

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 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	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 held with PAR capability*

Source: Charles Newbegin, "Modern Airships: A Possible Solution for Rapid Force Projection of Army Force" (Monograph, School of Advanced Military Studies, Ft. Leavenworth, KS, 2003), 34.

<u>Mooring and Loading</u>

In the past dirigibles had been moored to ships at sea, figure 25. In 1928 the USS Los Angeles landed on the USS Saratoga for reasons unknown.[22] Later the tanker, USS Patoka, was converted to an airship tender and used during the US Navy's fleet exercise in the 1931. Supplies, mail, and fuel were transferred to the airships, but there is nothing written about the procedures used for the transfer. Photos from the 1940s and early 1950s show K-Class blimps landing and taking off from carriers called "jeep carriers."[23] Unfortunately, there is no data on how long it took to moor dirigible to a ship or how it was performed.

Dirigibles relied on releasable ballast to stay grounded and required mooring masts to keep from floating away in a breeze. These masts allowed the dirigible to be anchored, but allowed the tail to sway freely in the wind to prevent damage in higher winds that would damage the dirigible if hit broadside. Hybrid Airships differ in that they are heavier than air and do not require a mooring mast or ballast. However, turning into the wind like the dirigible moored to a mast will reduce the airships cross section and increase its operational limits.

The problem is how Hybrid Airships will moor to ships during loading at sea and transfer cargo from the ship to the airship. The only thing written about was discussed in the literature review where the Aerocrane was researched as a sling load option for containers. This method eliminates the need to moor, but consumes fuel while at a hover. The airship is most vulnerable to wind while trying to stay stationary over the ship. A similar method may be to develop an elevator system that lowers and raises a platform for rolling stock to drive onto, but this has the same issues as the sling load. A third technique may be to have a large flatrack device that vehicles and containers are loaded onto and then the airship winches up to its belly like the retired Skyhook helicopter. The additional problem with this technique is that the flatracks would require deck space on the ship.

Alternative methods may be to move directly to the ship, an RRDF, or the US Navy's proposed Mobile Landing Platform ship. Most of the Hybrid Airship manufacturers stated that their aircraft can land in the water. This might allow the airship to transfer equipment from the ship to the airship the same as traditional lighterage. One issue will be managing the center balance of the airship during loading to prevent it from listing or pitching too much. This could be overcome by the vectored propulsion, but then consumes more fuel. Also the ramp will have to be long enough to extend past the nose of the aircraft and keep the airship a safe distance from the ship.

A proposed method for mooring is with a pivoting loading ramp or a turntable on the platform being offloaded in order to allow the airship's tail to swing freely in the wind. The nose of the airship and its loading ramp might be moored to the stern ramp on an LMSR to allow the airship to align with the ship as it swings around an anchor point.

The third alternative is to land the airship onto the ship or a Mobile Landing Platform ship. The size of the airship might degrade this ability and the ships would have to be modified to create a landing platform. The advantage of landing directly on the ship is that the Hybrid Airship could suck itself to the deck and the airship and ship could move as a single unit. Moving as a single unit is probably the safest method to load the airship.

Loading containers is even more challenging. One method is to develop a self loading device that is compatible with ISO containers and runs on some sort of track or a roller system like on a CH-47 or fixed wing cargo aircraft. Alternatives are the flatrack and sling load techniques discussed earlier or to use MHE to drive onto the airship and drop containers. The problem with MHE is that they will require a lot of overhead clearance once inside the airship.

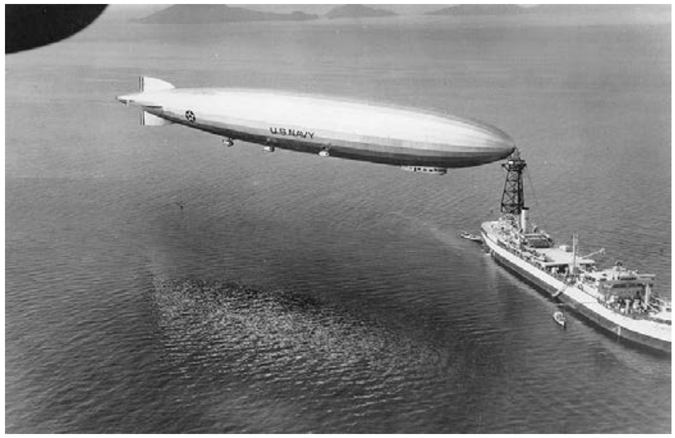

Figure 25. USS *Los Angeles* (ZR-3) Moored to USS *Patoka* (AO-9), off Panama during Fleet Problem XII, February 1931

Source: U.S. Naval Historical Center Photograph, "Photo #: NH 63069," http://www.history.navy.mil/photos/sh-usn/usnsh-p/ao9-d.htm (accessed December 12, 2012).

Figure 26. Blimp Makes Carrier Landing, October 24, 1944

Source: U.S. Navy Photo, "Blimp Makes Carrier Landing," posted by Christopher Eger, "Warship Wednesday, February 13" (February 13, 2013), http://laststandonzombieisland.com/2013/02/13/warship-wednesday-febuary-13/ (accessed April 11, 2013).

Landing Zones

Hybrid Airships are expected to land in open unimproved areas that vary from snow, desert, and water. There was not any data on how rough the terrain could be or the maximum slope a Hybrid Airship can operate on. If the loading and off loading ramps were long enough it may be feasible to load and offload while at a hover only a few feet off the ground and over any uneven terrain. The problem is that this hover will consume fuel as the vectored propulsion counters any ground wind.

A bigger issue is the amount of space that a Hybrid Airship requires. As an example, the Walrus 1,000-ton airships would have been around the length of a Nimitz-class aircraft carrier and longer than a Watson class LMSR. Table 5 compares the airship dimensions to fixed wing aircraft. Hybrid Airships that rely heavily on their aerodynamic shape for lift; have more of a short take off landing (STOL) characteristic. This implies a certain amount of ground space to get the aircraft up to speed. One paper suggested that the dimensions for STOL would be 4,500 feet long by 3,000 feet wide.[24] For comparison a C5 requires an 11,000 foot runway and a C-17 requires a 2,900 foot runway. Although an airfield is not required, it is expected that Hybrid Airships might be complemented by fixed wing aircraft and have to operate from airfields. Airships would have to clear runways and loading areas without impacting fixed wing operations.

A Congressional Research Analysis report referred to an analysis by Boeing that assessed 80,000 square miles of the planet for feasible landing zones of 3,500 feet or longer.[25] The results determined that only one percent of the areas in the assessment could support these dimensions. It is assumed the report was only referring to land masses. The same report identified 50 percent of the area was capable of 1,000 foot landing zones.[26]

One solution for the takeoff and clearing requirements is vertical take-off and landing (VTOL). Relying on lift from vectored propulsion rather than aerodynamics will decrease lifting capacity and consume more fuel. On the other hand, the advantage is a smaller operating radius. To minimize the lift from vectored propulsion, the Aeros Corporation is currently working on the Pelican project to design a rigid variable buoyancy air vehicle. The overall concept is to compress the helium used for buoyant lift and make the aircraft heavier than air by taking on outside air. Then the helium is released back into lifting cells and normal air expelled from the hull to gain elevation. This technology is sometime referred to as Control of Static Heaviness (COSH). The VTOL space requirements would be a 1,500 foot radius for the largest SkyCat Hybrid Airship,[27] one and a half times the length of the airship. This equates to a little more than the length of a football field for small airships.

All of these space issues translate to the maximum on ground (MOG). This term is used at airfields to describe how many aircraft can fit on an apron and the number of aircraft that can be serviced by material handling equipment at any given time. Airships will have the same planning considerations when selecting landing zones and it could be a limiting factor in some areas and require staggered landings and take-offs. The "Hybrid Airships Operational Concepts" report concluded that air ships in the 200-ton to 500-ton range provided the best balance of moving large volumes of equipment and ground mobility at the point of need delivery.[28]

Table 5. Comparison of Airship Dimensions to Fixed Wing Aircraft

Airships					
Hull Volume (cu ft)	**185,000**	**1,000,000**	**3,000,000**	**35,000,000**	**67,000,000**
Payload (tons)	2	15	50	500	1,000
Length	180’	250’	370’	830’	1,000’
Width	75’	150’	185’	365’	450’
Fixed Wing Aircraft					
Fixed Wing	**C-130**	**C-17**	**C-5**		
Payload (tons)	15	80	125		
Length	97’	174’	247’		
Width	132’	165’	222’		

Source: U.S. Department of Defense, *Hybrid Airships Operational Concepts* (Prepared by Office of the Assistant Secretary of Defense for Research and Engineering, Rapid Reaction Technology Office, 2012), 18.

Responsiveness

Deployment

An earlier section titled “Comparative Throughput Analysis Results,” established that the larger hybrid airships will deliver equipment to a TAA faster than most ground movements and lighterage used in LOTS operations. This reflected the throughput from the JLOTS site to TAA. A more impressive finding was that Hybrid Airships can deploy to the JLOTS site significantly faster than traditional LOTS in the vignette, figure 27.

Notional Hybrid Airships could be home-based at Lakehurst Naval Air Station and transit to Eurasia via Bedford, United Kingdom where both locations have large hangars that were used for large dirigibles in the past. The stop would allow time for the Hybrid Airship to refuel. JFAST modeling estimated 34 hours to fly both legs at 100 knots, in winds common during the May timeframe.

A separate JFAST model showed that it may take the equivalent time to deploy the initial elements of a JLOTS operation and an additional nine days and 12 hours for it to be fully functional. The throughput results from earlier sections, figure 14, showed that an individual Hybrid Airship with 500-ton lift capacity could deliver the entire SBCT only three days after a JLOTS operation was fully operational in figure 27. Results for a fleet of four 500-ton Hybrid Airships, figure 24, would actually deliver the SBCT seven days and four hours sooner than a traditional JLOTS operation becoming fully operational.

The modeling for the traditional JLOTS relied on two RRDF sets and 10 LCU-2000s in prepositioned in Kuwait. The analysis assumed the LCU-2000 deployed aboard a heavy lift flow-on flow-off ship and the RRDF on a container roll-on roll-off ship. An additional two RRDF deployed from Virginia aboard a second container roll-on-roll-off and an LSV detachment self deployed from a notional exercise it was participating at in Italy. The model also assumed that the Hybrid Airships operated independent of any RRDFs and moored directly to the vessel using one of the methods described in the earlier “Mooring and Loading” section. On the other hand, if Hybrid Airships do need RRDFs for loading equipment, the JLOTS operation will be established along the same timeline as traditional operations.

Hybrid Airships decreased the required lead time to decide on their employment. This makes them very flexible and responsive to changing situations. For example in the vignette, decision makers had four days lead time to decide to use traditional JLOTS equipment for vessel discharge before a later decision increased the overall delivery timeline. Such situation might arise if the ships sailing with the SBCT equipment were five or more days into the voyage when the ports suddenly were damaged. In this case, the timeline is already increased, but Hybrid Airships still have several more days before a decision was made for their employment.

These results are true for this particular vignette. Different results are likely if locations are changed or equipment is prepositioned closer than the locations used in this thesis. Nonetheless, a small fleet of Hybrid Airships do have the ability to deliver the SBCT to the TAA faster than a JLOTS operation can be established. This assertion includes the small and medium sized Hybrid Airships if employed as fleet sized in figure 24.

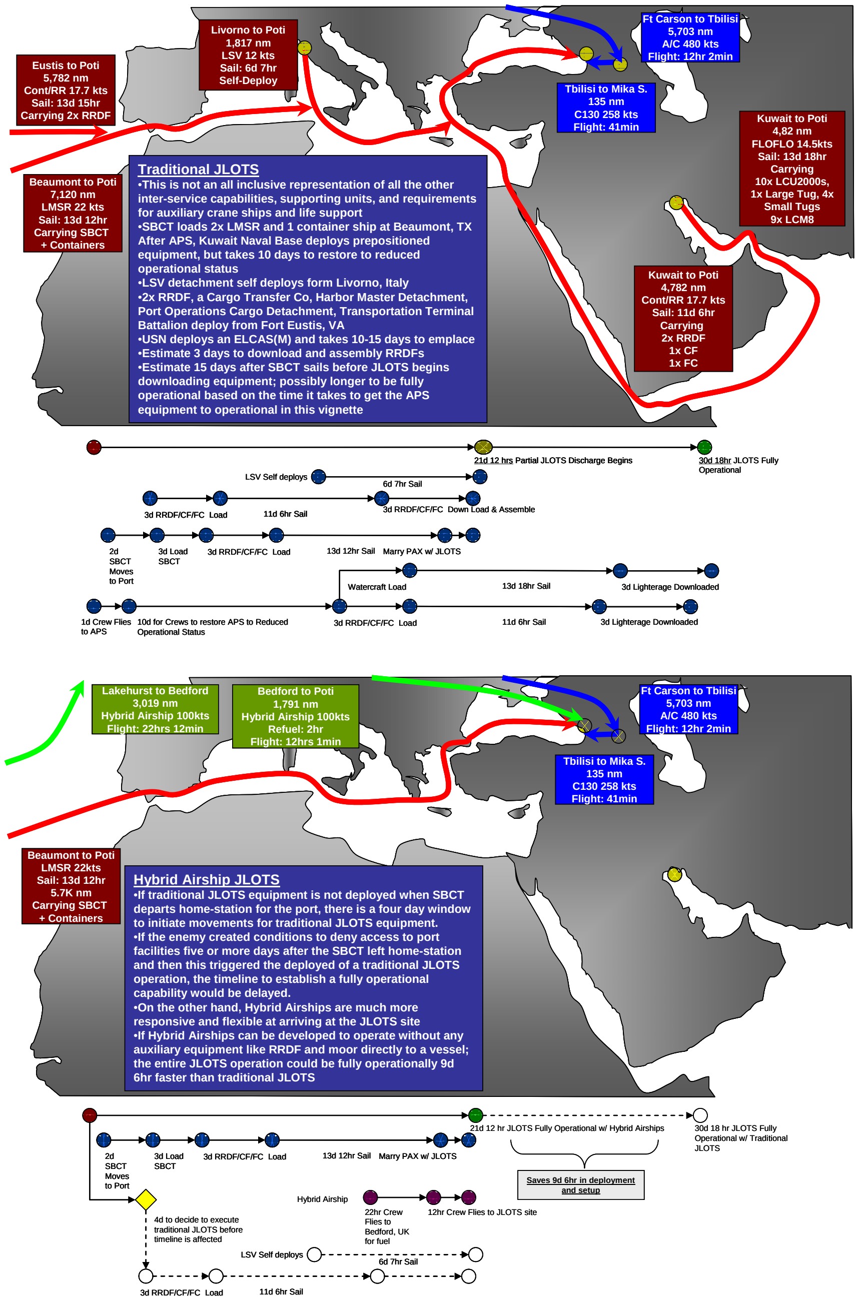

Figure 27. Hybrid Airships Save Time and Are More Responsive in Deployment Timeline

Source: Created by author.

Point of Need Delivery

The significant advantage of Hybrid Airships is the ability to deliver point to point without dependence on infrastructure, ability to bypass obstacles, and contested area. The imagination runs wild with how this could affect “Doctrine” in DOTMLPF. While it is true that airships can operate independent of airfields and sea ports, the reality is that these nodes are usually in vicinity of where forces need to be and these nodes have access to rail and road networks. The advantage is that if the enemy denies access to those facilities, the airship can still get near enough, land at the location, or bypass it all together. In terms of center of gravity, a critical capability to provide sustainment to an area can be independent of critical requirements for airfields and sea ports. Arguably there will still be a critical requirement for a large landing zone and air superiority.

This could increase options for targeting an enemy’s landing strip without any immediate concerns that friendly forces will have to use the same strip for air landing cargo or personnel. Hybrid Airships might be useful for building up combat power with the follow-on echelon at the airhead if the runway were too severely damaged for fixed wing to airland. Airships also could increase the quantity and size of wheeled vehicles used in an airborne forcible entry rather than what current heavy airdrop and airland capabilities provide. If airborne forces had to withdraw or air evacuate casualties the airships would likely require less lifts than rotary wing and fixed wing aircraft.

There has not been anything studied on airships used to transport personnel other than some ideas for luxury cruises and tourism. Conceivably the number of troops that could load an airship is immense. Airships might provide a capability to operationally maneuver light infantry brigades in fewer lifts than by ground or rotary wing and mass them where needed.

On account of all the other possible ways to employ a Hybrid Airship in addition to JLOTS, it raises questions about how the airship could be re-purposed. Who would have operational control in theater and which branch or service would be the lead operators. The next section will discuss some of these DOTMLPF "Organization" questions.

Integration

There was no research on which organizations would be best suited for operating and employing Hybrid Airships. The author advocates Hybrid Airships being identified as a joint mobility capability rather than an air mobility capability. Under this auspice, the airship can support all of the services in a JLOTS operation and then be re-purposed as a common user lift platform within theater or used for direct support to the ground component commander. Hybrid Airships should be treated as strategic assets in order to reposition them between theaters if other critical requirements emerge. Within theater, tactical control or operational control should be given to the Joint Force Air Component Command (JFACC). If assigned to a specific service, the service should not retain the airship as an organic force. The question is which service should be assigned the Hybrid Airships and its crew.

The US Navy has a vested interest in JLOTS and amphibious assaults. They have shown interest in a "sea-connector" that could support sea-basing. Traditional JLOTS is a maritime function and even the US Army LOTS community uses nautical language and culture. If Hybrid Airships were assigned to the US Navy there could be the added benefit of the airships servicing both the US Marine Corps and the US Army. The US Navy also has an aviation community that could easily transition their experience to airship operations. Secondly, the US Navy already has a history of using dirigibles and experience with integrating them with their fleets. Probably the best candidates for airships in JLOTS are the US Navy's Assault Craft Units. Assault Craft Units already perform this mission with LCACs and LCU-1600s. LCAC crews are particularly experienced at the nuances of center balance and loading a vehicle that can hover in place. It is assumed that the Hybrid Airships behave similar to LCACs, but at higher altitudes. Another assumption is that the US Marine Corps would prefer that the US Navy to continue providing the Corps ship to shore movement.

Previous studies related to inter-theater lift strategic mobility, implies the US Air Force's Air Mobility Command could be assigned Hybrid Airships. The US Air Force seems like a natural fit because of its aviation culture. Hybrid Airships could be managed as a strategic asset and then used in theater to support force flow and sustainment through the Air Mobility Division of the JFACC. Once in theater the aircraft could be re-purposed to support operational maneuvers as needed. The problem is the US Air Force has no experience at JLOTS, whereas the US Army and US Navy are experienced.

If Hybrid Airships replaced watercraft in JLOTS, US Army watercraft crews might transition to airship crews. Regardless of which service owned the airships, their personnel would have to be licensed on Hybrid Airships even if licensed on other airframes. Another consideration is that although watercraft are usually under the operational control of the theater opening sustainment brigade, Hybrid Airships probably need more of an aviation background that US Army aviation community could support more easily. As an example, the airships might be assigned to theater aviation brigades.

A more “hybrid” solution may be to create joint detachments, crewed and supported by each of the services. This sort of joint organization might be assigned to one of USTRANSCOM’s major subordinate commands. USTRANSCOM already has a Joint Task Force Port Opening (JTF-PO) process that complements the use of Hybrid Airships in JLOTS. The JTF-PO is an expeditionary capability that rapidly opens and establishes seaports or airports to support a Ground Component Commander’s requirement.

Survivability

Overall airships are more survivable than might be expected and no more susceptible to enemy defenses than rotary wing aircraft. The only exception is that they are very visible and make it obvious to the enemy where the landing zone is located. On one hand, this can also be used for deception. Visibility could also be advantageous at influencing a population favorably when humanitarian assistance is delivered by an enormous airship with a US flag on the side. Visibility can be mitigated by flying in darkness or limited visibility.

Airships will most likely face threats from small arms and MANPADS.[29] However, aircraft, air defense artillery, and “kamikaze” ultra-lights are other potential threats. Other than an envelope, airship’s share the same vulnerable areas as other aircraft such as the propulsion, cargo compartment, crew area, and flight controls. The difference is that the airship can often stay aloft and even adrift despite these areas being damaged, whereas normal aircraft usually crash disastrously.

Interestingly, small pin prick holes in the envelope have little effect on airships. The low pressure in their envelopes is only a little higher than the ambient air on the outside. In World War I German Zeppelins were immune to British anti-aircraft guns until incendiary rounds were used that ignited the hydrogen inside. In Newbegin's monograph he wrote that an elongated tear in the envelope can vent helium quickly and cause a rapid descent or catastrophic crash.[30]

The SkyCat study extensively explained the leakage rates affect on helium losses. Approximately 1.8 percent of the helium is lost in an hour if the envelope received by 300 projectiles 23 millimeter in diameter.[31] Increasing the damage to nine square feet that a MANPAD might create would result in a 12.1 percent lost in an hour.[32] The analysis concluded that the airship could stay afloat for four hours with only 25 percent of helium in the envelope.[33]

Hybrid Airships could be armed with weapons or reactive defenses to defeat enemy threats. Additionally it could be "hardened" with protective materials to minimize damage and equipped with self sealing technologies.[34] The problem with all of these solutions is that they add weight that diminishes the available payload.

---

[1]U.S. Department of Defense, *Hybrid Airships Operational Concepts*, 23.

[2]Pacquette, 22.

[3]Coleman and MacCarley, 26.

[4]Ibid., 27.

[5]Ibid., 28.

[6]Pacquette, 22.

[7]Coleman and MacCarley, 28.

[8]Dave Majumdar, "Blue Devil 2 Airship Expected to be Canceled," *AirForceTimes*, 28 March 2013, http://www.airforcetimes.com/article/20120318/NEWS/203180319/Blue-Devil-2-airship-expected-canceled (accessed May 1, 2013).

[9]Jen Hudson, "Army Deflates LEMV Airship; Cost And Schedule Cited," *InsideDefense.com*, February 13, 2013, http://insidedefense.com/201302132424647/Inside-Defense-General/Public-Articles/army-deflates-lemv-airship-cost-and-schedule-cited/menu-id-926.html (accessed May 1, 2013).

[10]Defense Industry Daily staff, "Walrus/HULA Heavy-Lift Blimps Rise."

[11]Office of the Assistant Secretary of Defense for Research and Engineering, Rapid Reaction Technology Office, *Lighter-Than-Air Vehicles* (Washington, DC: Government Printing Office, 2005), http://www.defenseinnovationmarketplace.mil/resources/Final_LTA_report.pdf (accessed May 1, 2013), 55.

[12]Congressional Budget Office, *Sea Basing and Alternatives for Deploying and Sustaining Ground Combat Forces*, XI.

[13]U.S. Army Force Management Support Agency, "LIN query V00426," https://fmsweb.fms.army.mil/protected/WebTAADS/Listing_LIN.asp?LIN=V00426&MACOM=P1&DOCNO=55530LP145&CCNUM=0109&PARNO=101 (accessed May 8, 2013).

[14]U.S. Army Force Management Support Agency, "LIN query L36989," https://fmsweb.fms.army.mil/protected/WebTAADS/Listing_LIN.asp?LIN=L36989&MACOM=X1&DOCNO=55829LX110&CCNUM=0107&PARNO=102 (accessed May 8, 2013).

[15]Austal News, "USNS Millinocket (JHSV 3) Christened," April 20, 2013, http://www.austal.com/us/media/media-releases/13-04-20/USNS-Millinocket-JHSV-3-Christened.aspx (accessed May 1, 2013).

[16]Pacquette, 20.

[17]Brian Meade and Michael McGuiness, "EUCOM-AFRICOM-TRANSCOM, Point-of-need Delivery (POND)" (EUCOM J8-C, PowerPoint Presentation, April 7, 2010), http://paxpartnership.org/Knowledgebase/Attach/6%20Mead%20POND%20brief%20to%20HAHC_Mar%2010.pdf (accessed May 8, 2013).

[18]U.S. Department of Defense, 21.

[19]Congressional Budget Office, 27.

[20]Ibid., 28.

[21]Airship GP, "Airships," http://airship-gp.com/index_htm_files/A-GP_008.pdf (accessed April 1, 2013), 6.

[22]Waring Hills, "First Airship to Land on Aircraft Carrier, 1928!" January 27, 2011, http://www.patriotspoint.org/news_events/first-airship-to-land-on-aircraft-carrier-1928/ (accessed March 10, 2013).

[23]Christopher Eger, "Warship Wednesday, February 13," February 13, 2013, http://laststandonzombieisland.com/2013/02/13/warship-wednesday-febuary-13/ (accessed April 10, 2013).

[24]Newbegin, 33.

[25]Christopher Bolkom, *Strategic Mobility Innovation: Options and Oversight Issues* (Washington, DC: Congressional Research Service April 2005), 26.

[26]Ibid.

[27]Newbegin, 33.

[28]U.S. Department of Defense, 18.

[29]Newbegin, 31.

[30]Ibid., 32.

[31]Ibid., D-1.

[32]Ibid.

[33]Ibid.

[34]Ibid., 31.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

> The emerging strategic environment in which our military institutions will have to operate suggests a number of similarities to the period between the great world wars of the first half of this century. During this timeframe, military institutions had to come to grips with enormous technological and tactical innovation during a period of minimal funding and low resource support.
>
> — Williamson Murray and Allan R. Millett

Conclusions

This thesis determined that some Hybrid Airships have the capacity to increase the throughput over ground movements and LOTS executed by some US Army and US Navy lighterage. As the distance increased offshore this throughput increased favorably for the Hybrid Airships, table 2. As an example, the 500-ton carrying airships saved more than two days over the LSV traveling one to five kilometers from the coast and at 46.3 kilometers the airship saved six more days. In the all distances explored, Joint High Speed Vessels performed better than both Hybrid Airships and other lighterage. Heavy-Lift Airships with the capacity to lift 500-tons were the best performers amongst the airships studied. However, none of these findings mattered unless they could be compared to a normal JLOTS with a mix of different watercraft.

None of the airships individually compared to the throughput of an LSV detachment and Heavy Watercraft Company, which exceeded the best airship's completion by eight and half days. The research determined the minimum size of various airship fleets to have better throughput than the mixed watercraft, figure 24. Some might argue that the size of either fleet could be increased in order have better throughput, but the watercraft was at the maximum capacity to offload three vessels simultaneously. While establishing a fleet size, the research assessed how cost effective these fleets were compared the watercraft fleet in the vignette.

The research demonstrated that Hybrid Airships are less cost effective as the procurement and operational costs for watercraft, but comparable to the Joint High Speed Vessel. Hybrid Airships were also more expensive to deploy in the vignette used for this thesis, but this may be attributed to additional costs not included with the watercraft deployment. However when considering end to end distribution, there may be a considerable cost savings using airships rather than LOTS operations and ground movements, but the details of this analysis could not be performed in time to complete this thesis. There was likely a huge cost savings in personnel in this scenario too, but it was not calculated. Also, costs associated with doctrinal changes, organizational changes, training, leadership and education, and facilities were not calculated.

Using Hybrid Airships in JLOTS is conceptually feasible, but they have not been studied or tested in enough depth to verify this application. There are technical issues that must be studied that will affect weight and how equipment is loaded onto the airship. Wind will be the other challenge facing an airship, but airships have the potential to operate on the lower spectrum of the Sea State 3 scale. This is a huge operational victory over traditional watercraft and could impact JLOTS operations not shutting down and waiting for the weather to clear over hours or days.

Recommendations

Seven 200-ton and four 500-ton lifting Hybrid Airships are the recommended quantities and sizes for supporting JLOTS operations. The airships should be jointly manned by a pilot, co-pilot, deck engineer, load master, and engineer. The aircraft will best serve as a joint mobility capability rather than a specific service. Each airship best serves as a detachment subordinate to USTRANSCOM and are OPCON'd to the Joint Force Air Component Command (JFACC) when deployed.

A separate recommendation is that US Army Military Surface Deployment and Distribution Command (SDDC) request a systems change to the Integrated Computerized Deployment System (ICODES) joint decision support system. The research could not use ICODE's "auto-load" function to stow plan the author's experimental drawings in the Single Load Planner. Only vessels and aircraft in the conveyance repository could use this feature. In the absence of this change, researchers are limited to less capable methods of estimating load plans on new and experimental mobility platforms. Until this change is made, the calculations in this thesis are speculative for lift assets that were stowed manually or with JFAST.

The final recommendation is to continue research in Hybrid Airship technologies and operational concept white papers. During this project, the LEMV was not approved for further funding. "This project was initially designed to support operational needs in Afghanistan in Spring 2012; it will not provide a capability in the timeframe required. Due to technical and performance challenges, and the limitations imposed by constrained resources, the Army has determined to discontinue the LEMV development effort."[1]

It is uncertain how USTRANSCOM will respond to this update considering the Hybrid Airship Universal Logistics Demonstrator paper said that the LEMV could be leveraged for determining the feasibility of a logistics Hybrid Airship. Unless commercial industry makes initiatives with Hybrid Airships, the United State's current financial situation and likely drawn down in Afghanistan will cause the nostalgia for airships to fade. However, organizational leaders of an earlier era faced these same conditions.

While Japan and Britain developed amphibious forces pre-World War II, only the United States developed a force capable of opposed landings.[2] Throughout most of the interwar period amphibious warfare was written about academically and could only be practiced in small-scale exercises because of commitments in the Banana Wars.[3] Nonetheless, these studies were serious and resulted in the *Tentative Manual for Landing Operations* being accepted as official doctrine in 1938 and then distributed as *Fleet Training Publication 167*.[4] Between 1934 and 1940 fleet landing exercises made refinements and formed the basic amphibious doctrine to be used in World War II.[5] While the amphibious debacle at Gallipoli during World War I tainted the opinion of many in the U.S. and other powers from attempting opposed landings, these exercises gave the U.S. maritime services an appreciation that it was possible.

As the U.S. enters its next interwar period in a few short years, we should consider the USMC’s history and not allow the military to excuse innovation because of resource constraints. Our focus should be on how to fight the next fight, refitting our organizations to fight that fight, and figuring out how to overcome anti-access conditions a determined enemy creates. It is likely that redundant capabilities across our services will be cut and we will have to fight more jointly than ever. Hybrid Airships must be a joint solution to our capability gaps.

Suggestions for Further Research

If Hybrid Airships are used in JLOTS they will require solutions for transferring equipment to the airship. Several approaches were suggested in Chapter 4. However, the technical feasibility and designs require an engineering study that is beyond the scope of this thesis. Another technical challenge to research is how mission specific, modular cargo holds could be exchanged between a universal airframe that could be used by all the services.

An additional application for Hybrid Airships may be the transport of liquids. The US Air Force has Aerial Bulk Fuel Delivery Systems that 3,000 gallon bags that can be loaded on C-130s and are some sometimes called "bladder birds." This is nothing more than a single truckload of fuel. Given the increased carrying capacity of Hybrid Airships which exceed the weight limits of a C-130, it seems feasible to employ airships with this same capability. This capability might deliver more fuel or water capacity than rotary wing sling loads that occasionally deliver these commodities to locations isolated from road access. Liquid logistical airships could also provide short term fuel distribution until an Inland Petroleum Distribution System is constructed or provide an expeditionary fuel distribution capability until an Offshore Petroleum Discharge System is installed.

Another suggestion for future research is how Hybrid Airships could be employed in airborne operations. An analysis of cycle time and productivity factors should be compared to fixed wing aircraft for personnel, equipment, and resupply. Other analysis should include time-space factors across the drop zone and determine if an airships slower speed would allow equipment and supplies to mass closer to the point of impact.

In 2009 Secretary Gates directed that Afghanistan would be diverted additional air assets to provide the "golden hour."[6] This is the desired window for delivering an injured soldier to the appropriate level of treatment. Air assets are the preferred method for evacuating casualties because of speed, but they are susceptible to weather and visibility. A recommended study is whether a Hybrid Airship could be outfitted as a small Early Entry Hospital Element similar to the USNS Mercy and USNS Comfort, but with the ability to go inland and provide level III treatment. Weather forecasts could trigger the airship to fly and position itself within reach of the "golden hour" for ground evacuation, while rotary wing are grounded during inclement weather. This platform would benefit disaster relief and Medical Civil Action Programs.

---

[1] David Szondy, "US Army cancels LEMV airship project," *Gizmag*, February 15, 2013, http://www.gizmag.com/lemv-airship-canceled/26274/ (accessed March 1, 2013).

[2] Ibid., 59.

[3] Benis M. Frank and Henry I. Shaw Jr. "Amphibious Doctrine in World War II," in *Victory and Occupation: History of the U.S. Marine Corps Operations in World War II*, Quantico, VA Historical Branch, US Marine Corps, 1968. Excerpt reprinted in US Army Command and General Staff College, H200 Book of Readings (Fort Leavenworth, KS: USACGSC, October 2012).

[4] Donald E. Gillum, "Gallipoli: Its Influence on Amphibious Doctrine," *Marine Corps Gazette* 51 (1967). Excerpt reprinted in US Army Command and General Staff College, H200 Book of Readings (Fort Leavenworth, KS: USACGSC, October 2012).

[5] Ibid., 203.

[6] Donna Miles, "'Golden hour' initiative pays off in Afghanistan," *U.S. Air Force News*, May 20, 2011, http://www.af.mil/news/story.asp?id=123256862 (accessed March 25, 2013).

APPENDIX A

CAPABILITIES-BASED ASSESSMENT FINDINGS

Table 6. Summary of Army Watercraft Capability Gap Analysis (2008)

ARMY WATERCRAFT TASKS (2015-2024 Modular Force Requirements	CBA	CRITICAL CAPABILITY GAP (Creating Red Assessment)
Close the Force	Amber to Red	Current Fleet not designed to **move combat ready maneuver units or move at speeds required** to meet COCOM swiftness goals.
Establish and Maintain Situational Awareness	Amber to Red	Current Fleet not fully equipped with interoperable, **Joint C4ISR capabilities** needed to maintain real-time situational awareness of the COP.
Provide BCOTM to Embarked Units	Amber to Red	Current Fleet not designed to **support maneuver or equipped to provide BCOTM** to embarked forces.
Operate in Open Ocean and Anti-Access Environment	Amber	**NONE** – Maintaining Current Fleet capabilities meets minimum requirement (amber assessment).
Provide Operational Maneuver for Combat Forces	Amber to Red	Current Fleet not designed to **move intact operationally-ready maneuver forces** to any access point in a manner that meets COCOM timelines.
Conduct Distributed Sustainment Operations	Green Amber Red	Current Fleet does not possess the **speed** to meet Modular Force requirements.
Support Terminal Operations	Green Amber Red	**NONE** – Maintaining Current Fleet capabilities meets minimum requirement (amber assessment)
Conduct Seabase Operations	Amber to Red	Current Fleet not designed to **support movement of combat ready maneuver untis from a seabase.**
Operate in Non-Contiguous, Uncertain Threat Environment	Amber to Red	Current Fleet not equipped to **identify threats and/or mount appropriate defensive and/or lethal response.**

Red-amber-green scale assessed how well current Army watercraft can achieve the required Future Modular Force capabilities between 2015-2014.

Source: U.S. Army Combined Arms Support Command (CASCOM), *Army Watercraft Master Plan, Fleet Strategy* (Fort Eustis, VA: Government Printing Office, March 2008), 3.

APPENDIX B

STRYKER BRIGADE COMBAT TEAM MOVEMENT REQUIREMENTS

Table 7. Prime Movers and Towed Equipment Unions Used Scenario

LIN	NSN	NOMENCLATURE	QTY OH	MODEL	Length (in)	Width (in)	Weight (lb)	SF (ft^2)
83852	2355014818576	ANTI-TANK GUIDED MISSILE VEH: (ATGM)	9	M1134	294	125	41,160	256
A93374	2355014376957	ARMORED SECURITY VEHICLE: WHEELED W/MOUNT (ASV)	6	M1117	237	101	29,560	167
C41314	2355014818573	COMMAND VARIANT VEH: (CV)	29	M1130	299	125	39,160	260
F86821	2355014818574	FIRE SUPPORT VEHICLE: (FSV)	17	M1131	297	123	38,160	254
H53576	2420015354061	HIGH MOBILITY ENGINEER EXCAVATOR (HMEE): TYPE I	6	JCB HMEE-1	407	96	26,300	272
J22626	2355014818575	INFANTRY CARRIER: VEHICLE (ICV)	44	M1126	294	123	38,640	252
J97621	2355014818570	ENGINEER SQUAD VEHICLE: (ESV)	12	M1132	304	118	40,000	250
M30567	2355014818580	MEDICAL EVACUATION VEHICLE: (MEV)	16	M1133	293	129	39,900	263
M53369	2355014818578	MORTAR CARRIER VEHICLE: (MCV)	20	M1129	290	127	40,100	256
M57720	2355014818577	MOBILE GUN SYSTEM: (MGS)	9	M1128	296	128	44,196	264
N96543	2355014818579	NUCLEAR BIO CHEM RECON VEH: (NBC RV)	3	M1135	297	132	38,041	273
R62673	2355014818572	RECONNAISSANCE VEH: (RV)	25	M1127	289	123	38,760	247
S25681	4940013338470	SHOP EQUIPMENT: CONTACT MAINTENANCE ORD/ENG TRUCK MOUNTING	17	CMTH	191	89	9,200	119
T07543	2320011467193	TRUCK UTILITY: S250 SHELTER CARRIER 4X4 W/E (HMMWV)	1	M1037	189	85	5,269	112
T07679	2320013469317	TRUCK UTILITY: HEAVY VARIANT HMMWV 4X4 10000 GVW W/E	41	M1097	191	93	5,600	124
T34704	2320015187330	TRUCK UTILITY: ECV ARMAMENT CARRIER W/IAP ARMOR READY M1151A1	8	M1151	194	86	8,053	116
T38844	2310011112274	TRUCK AMBULANCE: 4 LITTER ARMD 4X4 W/E (HMMWV)	18	M997	204	86	7,500	122
T41135	2320013601895	TRUCK CARGO: MTV W/E W/W and M1076 trailer	9	M1083 WWN	607	96	39,993	405
T41135	2320013601895	TRUCK CARGO: MTV W/E W/W	7	M1083 WWN	278	96	23,463	186
T41203	2320013543387	TRUCK CARGO: MTV W/MHE W/E	7	M1084	306	96	26,152	204
T41271	2320015303843	TRUCK VAN: EXPANSIBLE MTV W/E M1087A1	1	W/E M1087A1	337	96	28,685	225
T56383	2320015402017	TRUCK UTILITY EXPANDED CAPACITY ENHANCED 4X4: M1165A1	5	M1165A1	194	91	7,230	123
T58161	2320010970249	TRUCK TANK: FUEL SERVICING 2500 GALLON 8X8 HEAVY EXP MOB W/WINCH	4	M978 WWN	401	140	38,165	390
T61239	2320013554332	TRUCK TRACTOR: MTV W/E and M172 Semi Trailer	7	M1088	698	115	36,678	558
T61494	2320011077155	TRUCK UTILITY: CARGO/TROOP CARRIER 1-1/4 TON 4X4 W/E (HMMWV) and trailer LIN T30377	1	M998	338	96	8,140	226
T61494	2320011077155	TRUCK UTILITY: CARGO/TROOP CARRIER 1-1/4 TON 4X4 W/E (HMMWV) and M1101 trailer	123	M998	323	96	6,680	216
T61494	2320011077155	TRUCK UTILITY: CARGO/TROOP CARRIER 1-1/4 TON 4X4 W/E (HMMWV) and M1102 trailer	72	M998	323	96	6,680	216
T61494	2320011077155	TRUCK UTILITY: CARGO/TROOP CARRIER 1-1/4 TON 4X4 W/E (HMMWV)	2	M998	187	96	5,280	125
T61562	2320011077156	TRUCK UTILITY: CARGO/TROOP CARRIER 1-1/4 TON 4X4 W/E W/W (HMMWV)	2	M1038 WWN	186	108	5,200	140
T61630	2320014120143	TRUCK UTILITY: EXPANDED CAPACITY 4X4 W/E HMMWV M1113	69	M1113	191	98	6,380	130
T61704	2320013544530	TRUCK CARGO: MTV LWB W/E	6	M1085	352	96	23,762	235
T61908	2320013543386	TRUCK CARGO: MTV W/E and HOWITZER MEDIUM TOWED: M777	6	M1083	661	198	31,886	909
T61908	2320013543386	TRUCK CARGO: MTV W/E and W/DROPSIDES M1095	43	M1083	508	96	32,615	339
T61908	2320013543386	TRUCK CARGO: MTV W/E and trailer LIN D34883	1	M1083	476	96	28,066	318
T61908	2320013543386	TRUCK CARGO: MTV W/E and trailer LIN E02807	6	M1083	447	96	24,931	298
T61908	2320013543386	TRUCK CARGO: MTV W/E and trailer LIN P42194	1	M1083	443	96	32,710	296
T61908	2320013543386	TRUCK CARGO: MTV W/E and trailer LIN G17460	1	M1083	443	96	29,299	296
T61908	2320013543386	TRUCK CARGO: MTV W/E and trailer LIN G78306	1	M1083	443	96	29,206	296
T61908	2320013543386	TRUCK CARGO: MTV W/E and M149 Water buffalo	40	M1083	440	96	25,286	294
T61908	2320013543386	TRUCK CARGO: MTV W/E and trailer LIN G78374	1	M1083	425	96	25,646	284
T61908	2320013543386	TRUCK CARGO: MTV W/E and trailer LIN P63530	6	M1083	414	96	25,971	276
T61908	2320013543386	TRUCK CARGO: MTV W/E	8	M1083	278	96	22,486	186
T63093	2320010970248	TRUCK WRECKER: TACTICAL 8X8 HEAVY EXPANDED MOBILITY W/WINCH	17	M984 WWN	402	140	53,100	391
T73347	3930014172886	TRUCK LIFT: FORK VARIABLE REACH ROUGH TERRAIN	8	ATLAS	349	101	34,040	245
T76541	2430014232819	TRACTOR FULL TRACKED HIGH SPEED: DEPLOYABLE LT ENGINEER (DEUCE)	6	DUECE	230	116	35,750	186
T87243	2320011007672	TRUCK TANK: FUEL SERVICING 2500 GALLON 8X8 HEAVY EXP MOB	10	M978	401	140	38,165	390
T91308	2320014421940	TRANSPORTER COMMON BRIDGE:	4	M1977W/CBT	395	141	37,240	387
T92242	2320011289551	TRUCK UTILITY: ARMT CARRIER ARMD 1-1/4 TON 4X4 W/E (HMMWV)	8	M1025	180	85	6,104	107
T92446	2320014133739	TRUCK UTILITY: EXPANDED CAPACITY UP ARMORED HMMWV 4X4 W/E	3	M1114 WWN	197	110	9,800	151
T96496	2320014711326	TRUCK CARGO: TACTICAL 8X8 HEAVY EXPANDED MOB W/LHS and M1076 trailers	63	M1120	730	96	51,830	487
		Total	**829**		**288,928**	**86,873**	**19,777,155**	**211,236**

Source: Created by Author. Data derived from U.S. Army Force Management Support Agency, (USAFMSA), "Force Management System Website (FMSWEB)," UIC query "WD8XFF" with EDATE August 17, 2012 and July 16, 2012, https://fmsweb.fms.army.mil/protected/hierarchy/divorg/3LevelChart.asp?Update=DRAWCHART&UIC=WD8XFF&MID=WD8XFF&DOCST=A_FY_2013&FY=2013&exp=false (accessed May 8, 2013) and dimensional data from U.S. Departments of the Army and the Navy, Technical

Bulletin (TB) 55-46-1, *Standard Characteristics (Dimensions, Weight, and Cube) for Transportability of Military Vehicles and Other Outsize/Overweight Equipment* (Washington, DC: Government Printing Office, March 2009), https://portal.navfac.navy.mil/portal/page/portal/docs/doc_store_pub/navfac%20p-1055.pdf (accessed May 8, 2013).

Table 8. Movement Requirements for Self Propelled Equipment Transported by LCU-2000 in Scenario

LIN	NSN	NOMENCLATURE	QTY OH	MODEL	Length (in)	Width (in)	Weight (lb)	SF (ft^2)
A83852	2355014818576	ANTI-TANK GUIDED MISSILE VEH: (ATGM)	9	M1134	294	125	41,160	256
A93374	2355014376957	ARMORED SECURITY VEHICLE: WHEELED W/MOUNT (ASV)	6	M1117	237	101	29,560	167
C41314	2355014818573	COMMAND VARIANT VEH: (CV)	29	M1130	299	125	39,160	260
F86821	2355014818574	FIRE SUPPORT VEHICLE: (FSV)	17	M1131	297	123	38,160	254
H53576	2420015354061	HIGH MOBILITY ENGINEER EXCAVATOR (HMEE): TYPE I	6	JCB HMEE-1	407	96	26,300	272
J22626	2355014818575	INFANTRY CARRIER: VEHICLE (ICV)	44	M1126	294	123	38,640	252
J97621	2355014818570	ENGINEER SQUAD VEHICLE: (ESV)	12	M1132	304	118	40,000	250
M30567	2355014818580	MEDICAL EVACUATION VEHICLE: (MEV)	16	M1133	293	129	39,900	263
M53369	2355014818578	MORTAR CARRIER VEHICLE: (MCV)	20	M1129	290	127	40,100	256
M57720	2355014818577	MOBILE GUN SYSTEM: (MGS)	9	M1128	296	128	44,196	264
N96543	2355014818579	NUCLEAR BIO CHEM RECON VEH: (NBC RV)	3	M1135	297	132	38,041	273
R62673	2355014818572	RECONNAISSANCE VEH: (RV)	25	M1127	289	123	38,760	247
S25681	4940013338470	SHOP EQUIPMENT: CONTACT MAINTENANCE ORD/ENG TRUCK MOUNTING	17	CMTH	191	89	9,200	119
T07543	2320011467193	TRUCK UTILITY: S250 SHELTER CARRIER 4X4 W/E (HMMWV)	1	M1037	189	85	5,269	112
T07679	2320013469317	TRUCK UTILITY: HEAVY VARIANT HMMWV 4X4 10000 GVW W/E	41	M1097	191	93	5,600	124
T34704	2320015187330	TRUCK UTILITY: ECV ARMAMENT CARRIER W/IAP ARMOR READY M1151A1	8	M1151	194	86	8,053	116
T38844	2310011112274	TRUCK AMBULANCE: 4 LITTER ARMD 4X4 W/E (HMMWV)	18	M997	204	86	7,500	122
T41135	2320013601895	TRUCK CARGO: MTV W/E W/W	16	M1083 WWN	278	96	23,463	186
T41203	2320013543387	TRUCK CARGO: MTV W/MHE W/E	7	M1084	306	96	26,152	204
T41271	2320015303843	TRUCK VAN: EXPANSIBLE MTV W/E M1087A1	1	W/E M1087A1	337	96	28,685	225
T56383	2320015402017	TRUCK UTILITY EXPANDED CAPACITY ENHANCED 4X4: M1165A1	5	M1165A1	194	91	7,230	123
T58161	2320010970249	TRUCK TANK: FUEL SERVICING 2500 GALLON 8X8 HEAVY EXP MOB W/WINCH	4	M978 WWN	401	140	38,165	390
T61239	2320013554332	TRUCK TRACTOR: MTV W/E	7	M1088	282	96	20,393	188
T61494	2320011077155	TRUCK UTILITY: CARGO/TROOP CARRIER 1-1/4 TON 4X4 W/E (HMMWV)	198	M998	187	96	5,280	125
T61562	2320011077156	TRUCK UTILITY: CARGO/TROOP CARRIER 1-1/4 TON 4X4 W/E W/W (HMMWV)	2	M1038 WWN	186	108	5,200	140
T61630	2320014120143	TRUCK UTILITY: EXPANDED CAPACITY 4X4 W/E HMMWV M1113	69	M1113	191	98	6,380	130
T61704	2320013544530	TRUCK CARGO: MTV LWB W/E	6	M1085	352	96	23,762	235
T61908	2320013543386	TRUCK CARGO: MTV W/E	114	M1083	278	96	22,486	186
T63093	2320010970248	TRUCK WRECKER: TACTICAL 8X8 HEAVY EXPANDED MOBILITY W/WINCH	17	M984 WWN	402	140	53,100	391
T73347	3930014172886	TRUCK LIFT: FORK VARIABLE REACH ROUGH TERRAIN	8	ATLAS	349	101	34,040	245
T76541	2430014232819	TRACTOR FULL TRACKED HIGH SPEED: DEPLOYABLE LT ENGINEER (DEUCE)	6	DUECE	230	116	35,750	186
T87243	2320011007672	TRUCK TANK: FUEL SERVICING 2500 GALLON 8X8 HEAVY EXP MOB	10	M978	401	140	38,165	390
T91308	2320014421940	TRANSPORTER COMMON BRIDGE:	4	M1977W/CBT	395	141	37,240	387
T92242	2320011289551	TRUCK UTILITY: ARMT CARRIER ARMD 1-1/4 TON 4X4 W/E (HMMWV)	8	M1025	180	85	6,104	107
T92446	2320014133739	TRUCK UTILITY: EXPANDED CAPACITY UP ARMORED HMMWV 4X4 W/E	3	M1114 WWN	197	110	9,800	151
T96496	2320014711326	TRUCK CARGO: TACTICAL 8X8 HEAVY EXPANDED MOB W/LHS	63	M1120	401	96	35,300	268
		Total	**829**		**214,315**	**86,128**	**17,525,116**	**158,023**

Source: Created by Author. Data derived from U.S. Army Force Management Support Agency, (USAFMSA), "Force Management System Website (FMSWEB)," UIC query "WD8XFF" with EDATE August 17, 2012 and July 16, 2012, https://fmsweb.fms.army.mil/protected/hierarchy/divorg/3LevelChart.asp?Update=DRAWCHART&UIC=WD8XFF&MID=WD8XFF&DOCST=A_FY_2013&FY=2013&exp=false (accessed May 8, 2013) and dimensional data from U.S. Departments of the Army and the Navy, Technical Bulletin (TB) 55-46-1, *Standard Characteristics (Dimensions, Weight, and Cube) for Transportability of Military Vehicles and Other Outsize/Overweight Equipment* (Washington, DC: Government Printing Office, March 2009), https://portal.navfac.navy.mil/portal/page/portal/docs/doc_store_pub/navfac%20p-1055.pdf (accessed May 8, 2013).

Table 9. Rolling Stock Movement Requirements for Towed Equipment Transported by LCU-2000 in Scenario

LIN	NSN	NOMENCLATURE	QTY OH	MODEL	Length (in)	Width (in)	Weight (lb)	SF (ft^2)
D34883	2330011677262	DOLLY SET LIFT TRANSPORTABLE SHELTER: 7 1/2 TON	1	M1022	198	96	5,580	132
E02807	2330003312307	CHASSIS TRAILER: GENERATOR 2-1/2 TON 2 WHEEL W/E	6	M200A1	169	94	2,445	111
G17460	6115013172133	GENERATOR SET: DIESEL TRL/MTD 60KW 400HZ PU806 CHASSIS W/FENDER	1	PU-806	165	95	6,813	109
G78306	6115013172134	GENERATOR SET: DIESEL TRL/MTD 60KW 50/60HZ PU805 CHASSIS W/FENDE	1	PU-805	165	95	6,720	109
G78374	6115013199033	GENERATOR SET: DIESEL ENG TRLR -MTD 15KW 60HZ	1	PU-801	147	84	3,160	86
H57916	1025994111447	HOWITZER MEDIUM TOWED: M777	6	M777	383	102	9,400	272
P42194	6115014743776	POWER PLANT: ELECTRIC TRL/MTD 60KW 50/60HZ AN/MJQ 41	1	AN/MJQ-41B	165	95	10,224	109
P63530	6115015408433	POWER PLANT: ELETRIC TRAILER MOUNTED	6	AN/MJQ-48	136	86	3,485	82
S70517	2330003176448	SEMITRAILER LOW BED: 25 TON 4 WHEEL W/E	7	M172A1 25TON	416	115	16,285	333
T30377	4910010365784	TOOL OUTFIT HYDRAULIC SYSTEM: TEST AND REPAIR 3/4 TON TLR MTD	1	ADC 1000	151	79	2,860	83
T93761	2330013035197	TRAILER: PALLETIZED LOADING 8X20	72	M1076	329	96	16,530	220
T95555	2330014491776	TRAILER CARGO: MTV W/DROPSIDES M1095	43	M1095	230	96	10,129	154
T95924	2330013875426	TRAILER CARGO: HIGH MOBILITY 1-1/4 TON	72	M1102	136	86	1,400	82
T95992	2330013875443	LIGHT TACTICAL TRAILER: ¾ TON	123	M1101	136	86	1,400	82
W98825	2330008328801	TRAILER TANK: WATER 400 GALLON 1-1/2 TON 2 WHEEL W/E	40	M149A1	162	82	2,800	93
		Total	**381**		**74,604**	**34,131**	**2,252,039**	**47,921**

Source: Created by Author. Data derived from U.S. Army Force Management Support Agency, (USAFMSA), "Force Management System Website (FMSWEB)," UIC query "WD8XFF" with EDATE August 17, 2012 and July 16, 2012, https://fmsweb.fms.army.mil/protected/hierarchy/divorg/3LevelChart.asp?Update=DRAWCHART&UIC=WD8XFF&MID=WD8XFF&DOCST=A_FY_2013&FY=2013&exp=false (accessed May 8, 2013) and dimensional data from U.S. Departments of the Army and the Navy, Technical Bulletin (TB) 55-46-1, *Standard Characteristics (Dimensions, Weight, and Cube) for Transportability of Military Vehicles and Other Outsize/Overweight Equipment* (Washington, DC: Government Printing Office, March 2009), https://portal.navfac.navy.mil/portal/page/portal/docs/doc_store_pub/navfac%20p-1055.pdf (accessed May 8, 2013).

Table 10. Movement requirements for secondary loaded equipment that contributed to the overall weight in all scenarios, but did not affect the total square footage

LIN	NSN	NOMENCLATURE	QTY OH	MODEL	Length (in)	Width (in)	Weight (lb)	SF (ft²)
A94943	7360015605161	ASSAULT KTCHN: (AK)	15	NONE	53	23	285	9
B24592	5420014813959	BRIDGE FIXED: RAPIDLY	4	M21	300	110	20,856	230
B83002	3990013077676	PLATFORM: CONTAINER ROLL IN/ROLL OUT	179	M1077A1	240	96	3,200	160
C84930	2320014839755	CONTAINER HANDLING: HEAVY EXP MOBIL TACT TRK (HEMTT)	8	HEMTT LHS	84	96	4,775	56
F64544	4940014637940	FORWARD: REPAIR SYSTEM (FRS)	12	M7	240	96	24,200	160
G12034	6115012747390	GEN SET: DED SKID MTD 60KW 50/60HZ	1	MEP-806A	87	36	4,000	22
G18052	6115012747395	GEN SET: DED SKID MTD 60KW 400HZ	1	MEP-816A	87	36	4,050	22
M30688	8145015343597	MULTI-TEMPERATURE REFRIGERATE CONTAINER SYSTEM: MTRCS	6	NONE	239	96	12,000	160
P42126	6115014743783	POWER PLANT: ELECTRIC TRAILER MTD 30KW 50/60HZ AN/MJQ 40	1	AN/MJQ-40B	165	95	16,490	109
R14284	5840013900529	RADAR SET: AN/TPQ-36(V)10	1	AN/TPQ-36V8	360	89	31,009	223
S01359	5411011369838	SHELTER: TACTICAL EXPANDABLE TWOSIDE	3	S-785/G	240	96	6,900	160
S01427	5411004896076	SHELTER: NONEXPANDABLE S250	9	S250/G	87	79	770	48
S01428	5411015061774	SHELTER NONEXPANDABLE: S-842A/G	2	S-842 A/G	52	48	2,300	18
S01495	5411000014093	SHELTER: NONEXPANDABLE S280	4	S280B/G	147	87	1,410	89
S01563	5411013335941	SHELTER: NONEXPD LTWR MP RIGID -WALL S788 102LX84WX67H MTD HMMWV	1	VALVETY2	102	89	700	64
S25885	4910014906453	SHOP EQUIPMENT: AUTOMOTIVE VEHICLE	2	NONE	240	96	13,420	160
T14017	4610014889656	TACTICAL WATER PURIFICATION SYSTEM (TWPS) 1500 GPH:	1	1500 GPH	240	96	22,588	160
T20131	4930015176939	TANK UNIT FUEL DISPENSING: TRUCK	14	NONE	239	96	7,720	160
T31784	4931007540740	SHOP EQUIP INSTR AND FIRE CONT SYS REPAIR: FM BASIC LESS POWER	1	NONE	239	96	8,490	160
T32629	5430014877760	LOAD HANDLING SYS (LHS): 2000 GAL COMP WATER TANK-RACK (HIPPO)	20	2000 GAL	240	96	9,060	160
W30051	4610014950046	WATER: PURIFIER LIGHTWEIGHT	2	NONE	78	96	1,110	52
YA0654	5419013996391	20 FT ISO CONTAINER	200	NONE	240	96	44,800	160
Z01595	0	MODULAR FUEL SYSTEM (MFS): PUMP RACK MODULE (PRM)	2	MFS PRM	239	90	19,470	150
		Total	**295**		**62,520**	**26,081**	**1,566,082**	**41,611**

Source: Created by Author. Data derived from U.S. Army Force Management Support Agency, (USAFMSA), "Force Management System Website (FMSWEB)," UIC query "WD8XFF" with EDATE August 17, 2012 and July 16, 2012, https://fmsweb.fms.army.mil/protected/hierarchy/divorg/3LevelChart.asp?Update=DRAWCHART&UIC=WD8XFF&MID=WD8XFF&DOCST=A_FY_2013&FY=2013&exp=false (accessed May 8, 2013) and dimensional data from U.S. Departments of the Army and the Navy, Technical Bulletin (TB) 55-46-1, *Standard Characteristics (Dimensions, Weight, and Cube) for Transportability of Military Vehicles and Other Outsize/Overweight Equipment* (Washington, DC: Government Printing Office, March 2009), https://portal.navfac.navy.mil/portal/page/portal/docs/doc_store_pub/navfac%20p-1055.pdf (accessed May 8, 2013).

APPENDIX C

THROUGHPUT CALCULATIONS FOR SHIP TO SHORE

(1) Number of deliveries for single lighter to discharge vessel.

$$Quantity_{(Deliveries)} = \frac{\sum \text{Re}\,quirements}{Capacity_{(Vessel)}}$$

(2) Travel time for single lift.

$$Time_{(Single\ Lift)} = \frac{\sum Dis\tan ce}{Speed_{(Vessel)}}$$

(3) Total travel time to complete deliveries and return to the discharged vessel.

$$\sum Time_{(Movement)} = \frac{\sum Dis\tan ce}{Speed_{(Vessel)}} \times \left(2 \times \left(\frac{\sum \text{Re}\,quirements}{Capacity_{(Vessel)}} \right) - 1 \right)$$

(4) Total time for approaching and mooring at RORO discharge facility and along ship and floating causeway at beach.

$$\sum Time_{(Load\ Lighterage)} = Time_{(Approach\,\&\,Moor\ at\ RRDF)} + Time_{(Clear\,\&\,Castoff\ \ from\ RRDF)} + Time_{(AvgLoadTime)}$$

(5) Total time for lighterage to cast off and clear RORO discharge facility along ship and floating causeway at beach.

$$\sum Time_{(Offload\ Lighterage)} = Time_{(Approach\,\&\,Moor\ at\ FloatingCausway)} + Time_{(Clear\,\&\,Castoff\ \ from\ FloatingCauseway)} + Time_{(AvgOffloadTime)}$$

(6) Total discharge time for single lighter to discharge entire vessel.

$$\sum Time_{(Disch\arg e\,Complete)} = \sum Time_{(Load\ Lighterage)} \sum Time_{(Movement)} + \sum Time_{(Offload\ Lighterage)}$$

APPENDIX D

DISCHARGE PLANNING FACTORS

Joint Publication 4-01.6 provided planning factors derived from an Office of the Secretary of Defense sponsored joint services test and evaluation program called JLOTS III, performed in June 1993. These planning factors captured the time it takes for the LSV, LCU-2000, LCU-1600, and Causeway Ferries to load, offload, moor, and castoff during JLOTS. There were no planning factors for the LCAC and the study pre-dated the JHSV. Table 11 estimates the planning factors for the JHSV and airships based on the square footage of watercraft used in the JLOTS III test and evaluation. The LCAC timing was derived from the Federation of American Scientists website.

Table 11. Calculated Loading/Offloading Planning Factors

Vessel	SF (ft^2)	Vehicles Loaded/ Vessel (qty)	Load Time/ Vessel (hr:min)	Load Time per Wheeled Vehicle (min:s)	Offload Time/ Vessel (hr:min)	Offload Time per Wheeled Vehicle (min:s)
CF	7,056	16	1:38	0:06:07	0:28	0:01:45
LCU1600	3,025	4	0:26	0:06:30	0:08	0:02:00
LCU2000	3,800	13	1:33	0:07:09	0:30	0:02:18
LSV	10,684	50	5:50	0:07:00	1:33	0:01:52
Vessel	**Well Deck Ops for Vehicle (h:min)**			**Friction (h:min)**	**Beach Ops (h:min)**	
LCAC			1:02	1:00		0:30
Vessel	**SF (ft^2)**	***Estimated Vehicles/ Vessel (qty)**	****Est. Load Time/Vessel (hr:min)**	**Est. Load Time per Wheeled Vehicle (min:s)**	****Est. Offload Time/Vessel (hr:min)**	**+Est. Offload Time per Wheeled Vehicle (min:s)**
1000t	24,640	116	12:34	0:06:30	3:23	0:01:45
500t	12,320	58	6:17	0:06:30	1:41	0:01:45
200t	9,714	46	4:59	0:06:30	1:20	0:01:45
80t	1,920	9	0:58	0:06:30	0:15	0:01:45
40t	960	5	0:32	0:06:30	0:08	0:01:45
JHSV	11,552	55	6:33	0:07:09	2:06	0:02:18

** Estimated vehicles per vessel based on quantity of vehicles on LSV with its given square footage in JLOTS III test and evaluation*
*** Used for Table 19 Planning Factors*
+ Estimates based on expected ease of loading relevant to known watercraft

Source: Created by Author. Derived from Author Calculations; U.S. Joint Chiefs of Staff, Joint Publication 4-01.6, *Joint Logistics Over-the-Shore (JLOTS)* (Washington, DC: Government Printing Office, August 2005), A-6; Federation of American Scientists, "Landing Craft, Air Cushion (LCAC)," http://www.fas.org/man/dod-101/sys/ship/lcac.htm (accessed May 9, 2013).

Table 12. Cycle Times for RORO Discharge

	Ship Side			Beach Side			Characteristics	
Vessel	A&M RRDF (hr:m)	Load (hr:m)	C&C Ship (hr:m)	A&M FC or Beach (hr:m)	Offload (hr:m)	C&C FC or Beach (hr:m)	Speed (kts)	Ramps
JHSV	* 0:09	** 6:33	* 0:07	* 0:13	** 2:06	* 0:07	35 kts	Bow/Stern
LSV	0:09	5:50	0:07	0:13	1:33	0:07	12kts	Bow/Stern
LCU2000	0:09	1:33	0:04	0:12	0:30	0:07	10 kts/ 12 kts	Bow
LCU1600	0:06	0:26	0:02	0:01	0:08	0:02	12 kts	Bow/ Stern
LCAC	-	1:02	1:00 for friction		0:30	-	40 kts	Bow/ Stern
CSP+3	0:34	1:38	0:23	0:05	0:28	0:04	7 kts	NA
Large Airship 1K ton	* 0:09	** 12:34	* 0:07	* 0:13	** 3:23	* 0:07	100 kts	Bow/ Stern
Large Airship 500-ton	* 0:09	** 6:17	* 0:07	* 0:13	** 1:41	* 0:07	100 kts	Bow/ Stern
Large Airship 200-ton	* 0:09	** 4:59	* 0:07	* 0:13	** 1:20	* 0:07	100 kts	Bow/ Stern
Medium Airship 80-ton	* 0:09	** 0:58	* 0:07	* 0:13	** 0:15	* 0:07	100 kts	Bow/ Stern
Small Airship 40-ton	* 0:09	** 0:32	* 0:07	* 0:13	** 0:08	* 0:07	100 kts	Bow/ Stern

*** used LSV planning factors because these were unavailable for the particular vessel or aircraft**

**** calculated in Table 11**

C&C FC - Cast off and Clear at Floating Causeway
A&M RRDF - Approach and Moor at RORO Discharge Facility
A&M FC - Approach and More at Floating Causeway
C&C Ship - Cast off and Clear from the Ship
A&M Ship - Approach and Moor directly to the Ship
FC - Floating causeway

Source: Created by Author. Derived from table 18; U.S. Joint Chiefs of Staff, Joint Publication 4-01.6, *Joint Logistics Over-the-Shore (JLOTS)* (Washington, DC: Government Printing Office, August 2005), A-6; Federation of American Scientists, "Landing Craft, Air Cushion (LCAC)," http://www.fas.org/man/dod-101/sys/ship/lcac.htm (accessed May 9, 2013).

Table 13. Cycle Times for Container Discharge

	Ship Side			Beach Side			Characteristics	
Vessel	A&M Ship (hr:m)	+Load (hr:m)	C&C Ship (hr:m)	A&M FC or Beach (hr:m)	++Offload (hr:m)	C&C FC or Beach (hr:m)	Speed (kts)	Container Capacity
JHSV	*0:09	0:44	*0:07	*0:13	0:54	*0:07	35 kts	6
LSV	0:13	6:14	0:07	0:16	7:30	0:07	12kts	50
LCU2000	0:09	1:33	0:04	0:12	3:36	0:07	10 kts 12 kts	24
LCU1600	0:06	0:26	0:02	0:01	1:12	0:02	12 kts	8
LCAC	NA	NA	NA	NA	NA	NA	40 kts	NA
CSP+3	0:34	1:38	0:23	0:05	3:36	0:04	7 kts	24
Large Airship 1K ton	*0:09	19:12	*0:07	*0:13	23:06	*0:07	100 kts	154
Large Airship 500-ton	*0:09	9:36	*0:07	*0:13	11:33	*0:07	100 kts	77
Large Airship 200-ton	*0:09	3:44	*0:07	*0:13	4:30	*0:07	100 kts	30
Medium Airship 80-ton	*0:09	1:29	*0:07	*0:13	1:48	*0:07	100 kts	12
Small Airship 40-ton	*0:09	0:44	*0:07	*0:13	0:54	*0:07	100 kts	6

*** used LSV planning factors because these were unavailable for the particular vessel or aircraft**

+ Load times were calculated by the max number of containers on a vessel time 7:29 minutes per container to be offloaded by a single crane derived from the estimates in JP 4-01.6

++ Offload times were calculated by the max number of containers on a vessel time 9:00 per container derived from the estimates in JP 4-01.6

C&C FC - Cast off and Clear at Floating Causeway
A&M RRDF - Approach and Moor at RORO Discharge Facility
A&M FC - Approach and More at Floating Causeway
C&C Ship - Cast off and Clear from the Ship
A&M Ship - Approach and Moor directly to the Ship
FC - Floating causeway

Source: Created by author. Derived from Joint U.S. Joint Chiefs of Staff, Joint Publication 4-01.6, *Joint Logistics Over-the-Shore (JLOTS)* (Washington, DC: Government Printing Office, August 2005), A-8.

APPENDIX E

THROUGHPUT CALCULATIONS FOR GROUND

There were two ground requirements that were added to the overall throughput calculations in order to deliver the containers to the Tactical Assembly Area or road march the Stryker Brigade Combat Teams vehicles. For both movements, convoys were planned using the below calculations.

$$Time\,gaps = \left(\left[\#\ of\ march\,units - 1\right] \times time\,gap_{march\,unit}\right) + \left(\left[\#\ of\ serials - 1\right] \times \left[time\,gap_{serial} - time\,gap_{march\,unit}\right]\right)$$

$$Road\,space = \left(\frac{\#\ of\ vehicles}{density}\right) + \left(\frac{time\,gaps \times rate\,of\ march}{60\ \text{min}\,utes}\right)$$

$$Pass\,time = \left(\frac{Road\,space \times 60}{rate\,of\ march}\right)$$

The Stryker Brigade Combat Team had nine serials, 42 march units, 25 meters between vehicles, two minutes between march units, and five minutes between serials, and traveling at 56 kilometers per hour over a 326 kilometer distance from the beach site in vicinity of Poti, Republic of Georgia to the Tactical Assembly Area in vicinity of Tbilisi, Republic of Georgia. The resulting time for the entire convoy to complete its ground movement was eight hours and 41 minutes, highlighted green in table 14. This time was added to the throughput JLOTS that only delivered rolling stock

The container movement used the same distances and timings, but only had one serial and three march units. Each delivery to the Tactical Assembly Area took six hours and 30 minutes, highlighted green in table 14. The container movements exceeded the capability of a PLS Medium Truck Company to deliver the requirement in a single lift. A second trip was required deliver all of the containers. Based on a ten hour operational day for driving and MHE handling drivers could not safely make the return trip until the following day. Table 15 depicts the planning factors used in this analysis that resulted in an operation that took two full days, 13 hours, and four minutes to complete. This time was added to the throughput for all the ground calculations in the analysis except those that only delivered rolling stock.

Table 14. Ground Movements

INPUT DATA FOR MOVEMENT TABLE:		INFORMATION ABOUT THE ROUTE	
Poti to Tbilisi	Route Name	29	Traffic Density w/I March Unit (Veh/km)
326	Route Length	2	Number of Res Stops on Route (qty)
05:00	Start Time of First Vehicle (hr:min)	0	Number of Refueling Stops (ROMS) on Route
56	Average March Unit Speed (kph)	05:49	Total Driving Time per Vehicle (hr:min)
25	Average Interval between Vehicles (meters)	00:35	Rest and/or ROM Halts per Vehicle (hr:min)
20	Time at Rest Halts (minutes)	06:24	Total Time to Close per Vehicle (hr:min)
4	Time between Rest Halts, after 1st hour (hour)	12	Total # Serials Traveling Route (qty)
0	Time at ROM Halts (minutes)	51	Total # March Units Travelling Route (qty)
0	Distance between ROM Halts (kilometers)	991	Total # Vehicles Traveling Route (qty)
5	Time Gaps between Serials (minutes)	0:9:14	Total Time for all Units to Complete (d:hr:min)
2	Time Gaps between March Units (minutes)		
2	Extra Time Allowance for misc. (min/25 veh)		
20	# Vehicles per Mission Unit (qty)		
5	# March Units in a Serial		
10	Average Length of Vehicle (meters)		

MOVEMENT TABLE

UNIT	**Total Veh/ Unit**	**# Serials (qty)**	**# March Units**	**Avg # Veh/ March Unit**	**Start Time**	**1st Veh RP**	**Pass Time**	**Last Veh RP**	**TIME FOR INDIVIDUAL UNITS TO SP-RP**
PLS Co Delivery	*54*	1	3	18.0	06:00	12:24	00:06	12:30	**6:30**
PLS Co Return	*54*	1	3	18.0	06:00	12:24	00:06	12:30	**6:30**
PLS Co Delivery	*54*	1	3	18.0	06:00	12:24	00:06	12:30	**6:30**
SBCT	*829*	9	42	19.7	06:00	12:24	02:17	14:41	**8:41**
		0	0	0.0	00:00	00:00	00:00	00:00	
								14:14	

Source: Created by author.

Table 15. Throughput for Container Ground Movements

Requirements:				
326	Distance (km)			
LOLO Containers				
200	Containers (TEU)			
32,000	SF (ft^2)			
1,294	Weight (ton)			
	6.47 ton/container; FM 55-15, C-2			
Capability:				
Trucks OH	1	60	111 required for 1 lift	
Speed (kph)	56.0	**35mph**		
Container Capacity (Single)	2			
Carrying Capacity (STON)	28			
Carrying Capacity (SF)	320			
Range				
Time Single Lift (d/hr/min)	0:6:24	from Table 14	`	
Throughput:				
	Containers by Ground			
	Single Trk	**90 percent Trk OH=54 vics**	**1 lift**	
# Deliveries	100	**2**	1	
Load Time	0:02	**0:02**	0:02	
Offload Time	0:02	**0:02**	0:02	
Total Travel Time (d/hr/min)	22:2:32	**0:19:12**	0:6:24	
Pass Time	0:00	**0:06**	0:17	
*Total Time to Complete Road Mvt (d/hr/min)	22:15:52	1:8:32	0:19:44	
Operational Day (hr/min)	10:00	**10:00**	10:00	
**this time does not account for operational day and rest cycles*				
MHE Planning Factors				
MHE On Hand at Each Site		1	**2**	
Loading/Offloading Totals (d:hr:min)		0:13:20	**0:6:40**	
Load Container & Drive to TAA			**0:9:44**	1st Day
Offload Containers & Return to Poti			**0:9:44**	2nd Day
Load Container, Drive to TAA, & Offload Containers			**0:13:04**	3rd Day
Total to complete (d:hr:min)			**2:13:04**	

Source: Created by author.

APPENDIX F

VARIANCE CAUSED BY PLANNING FACTORS

Table 16. Variance for Rolling Stock and Containers, Caused by Mooring and Casting Off Planning Factors

Rolling Stock and Containers			
Throughput R&C	**5km (d:hr:min)**	**Moor & Cast Off (d:hr:min)**	**Delta (d:hr:min)**
JHSV w/o	4:1:15	3:18:03	0:7:12
JHSV w/o	9:15:14	8:11:38	1:3:36
CSP+3	10:15:14	8:22:38	1:16:36
Large Airship 500-ton	12:6:53	11:15:53	0:15:0
Large Airship 1K ton	14:6:51	13:20:39	0:10:12
LSV Watercraft	14:20:2	14:0:50	0:19:12
LCU-1600 Watercraft	18:12:15	15:23:14	2:13:1
Large Airship 200-ton	23:9:37	21:21:01	1:12:36
LCU-2000 Watercraft	27:9:9	24:8:50	3:0:19
LCAC w/o Container	28:4:38	20:9:38	7:19:0
Small Airship 40-ton	29:22:44	22:10:08	7:12:36
Medium Airship 80-ton	30:0:53	26:6:53	3:18:0
		Standard Deviation	**2.59**

Rolling Stock and Containers			
Throughput R&C	**5km (d:hr:min)**	**On/Offload (d:hr:min)**	**Delta (d:hr:min)**
JHSV w/o	4:1:15	17:39	3:7:36
JHSV w/o	9:15:14	3:23:35	5:15:39
CSP+3	10:15:14	5:8:41	5:6:33
Large Airship 500-ton	12:6:53	3:10:33	8:20:20
Large Airship 1K ton	14:6:51	2:7:14	11:23:37
LSV Watercraft	14:20:2	3:22:21	10:21:41
LCU-1600 Watercraft	18:12:15	10:7:5	8:5:10
Large Airship 200-ton	23:9:37	8:13:30	14:20:7
LCU-2000 Watercraft	27:9:9	7:20:36	19:12:33
LCAC w/o Container	28:4:38	12:8:24	15:20:14
Small Airship 40-ton	29:22:44	20:12:2	9:10:42
Medium Airship 80-ton	30:0:53	21:5:28	8:19:25
		Standard Deviation	**4.72**

Source: Created by author.

Table 17. Variance for Rolling Stock, Caused by Mooring and Casting Off Planning Factors

Rolling Stock			
Throughput R&C	**5km (d:hr:min)**	**Moor & Cast Off (d:hr:min)**	**Delta (d:hr:min)**
CSP+3 Watercraft	5:12:22	4:1:10	1:11:12
Large Airship 500-ton	9:6:35	8:17:23	0:13:12
LSV Watercraft	10:4:43	9:11:55	0:16:48
Large Airship 1K ton	10:12:49	10:3:49	0:9:0
LCU2000 Watercraft	11:20:54	9:20:22	2:0:32
LCU1600 Watercraft	12:22:47	11:0:46	1:22:1
JHSV Watercraft	13:7:48	11:21:0	1:10:48
Large Airship 200-ton	18:14:28	17:7:52	1:6:36
Small Airship 40-ton	19:21:5	13:13:17	6:7:48
Medium Airship 80-ton	23:9:12	20:5:36	3:3:36
LCAC w/o Container	26:0:15	18:5:15	7:19:0
		Standard Deviation	**2.43**
Rolling Stock			
Throughput R&C	**5km (d:hr:min)**	**On/Offload (d:hr:min)**	**Delta (d:hr:min)**
CSP+3 Watercraft	5:12:22	0:11:8	5:1:14
Large Airship 500-ton	9:6:35	0:8:50	8:21:45
LSV Watercraft	10:4:43	1:1:33	9:3:10
Large Airship 1K ton	10:12:49	0:5:25	10:7:24
LCU2000 Watercraft	11:20:54	2:20:13	9:0:41
LCU1600 Watercraft	12:22:47	1:8:44	11:14:3
JHSV Watercraft	13:7:48	2:17:3	10:14:45
Large Airship 200-ton	18:14:28	3:15:12	14:23:16
Small Airship 40-ton	19:21:5	3:14:37	16:6:28
Medium Airship 80-ton	23:9:12	3:8:33	20:0:39
LCAC w/o Container	26:0:15	6:18:31	19:5:44
		Standard Deviation	**4.72**

Source: Created by author.

Table 18. Variance for Containers, Caused by Mooring and Casting Off Planning Factors

Containers			
Throughput R&C	**5km (d:hr:min)**	**Moor & Cast Off (d:hr:min)**	**Delta (d:hr:min)**
CSP+3 Watercraft	5:12:22	2:22:29	2:13:53
Large Airship 500-ton	9:6:35	3:0:17	6:6:18
JHSV Watercraft	10:4:43	3:9:35	6:19:8
Large Airship 1K ton	10:12:49	3:18:2	6:18:47
LCU2000 Watercraft	11:20:54	4:18:22	7:2:32
Large Airship 200-ton	12:22:47	4:19:9	8:3:38
LSV Watercraft	13:7:48	5:0:0	8:7:48
LCU1600 Watercraft	18:14:28	5:22:9	12:16:19
Medium Airship 80-ton	23:9:12	6:15:4	16:18:8
Small Airship 40-ton	26:0:15	10:1:38	15:22:37
		Standard Deviation	**4.53**

Containers			
Throughput R&C	**5km (d:hr:min)**	**On/Offload (d:hr:min)**	**Delta (d:hr:min)**
CSP+3 Watercraft	5:12:22	2:17:5	2:19:17
Large Airship 500-ton	9:6:35	2:22:29	6:8:6
JHSV Watercraft	10:4:43	2:13:11	7:15:32
Large Airship 1K ton	10:12:49	3:16:50	6:19:59
LCU2000 Watercraft	11:20:54	4:14:10	7:6:44
Large Airship 200-ton	12:22:47	4:13:9	8:9:38
LSV Watercraft	13:7:48	4:21:36	8:10:12
LCU1600 Watercraft	18:14:28	5:7:9	13:7:19
Medium Airship 80-ton	23:9:12	6:1:16	17:7:56
Small Airship 40-ton	26:0:15	8:20:50	17:3:25
		Standard Deviation	**4.79**

Source: Created by author.

APPENDIX G

COST ESTIMATES

The research used the Operating and Support Management Information System (OSMIS) database that tracks operating and support costs for the Office of the Deputy Assistant Secretary of the Army for Cost and Economics (DASA-CE). Unfortunately, the data represented annual operating costs and could not be computed to hourly operating costs without annual usage per watercraft system. As an alternative, the research captured data from the TRADOC Capabilities Manager – Transportation Army Watercraft Systems (TCM-T AWS), table 19. The SLWT is the Side Loadable Warping Tug and its operating costs comparable to the Causeway Ferry. OSMIS database did provide operational costs for the PLS and other vehicles, table 22.

The research contacted support personnel for the Visibility and Management of Operating and Support Costs (VAMOSC) used by the US Naval Center for Cost Analysis. The database did not maintain information for LCAC or LCU-1600. Also, the support team warned that the JHSV operating and sustainment costs were not an accurately depicted because the ships were not commissioned in 2012. As an alternative, the research found data in a Naval Postgraduate Thesis "Cost Benefit And Capability Analysis of Seabase Connectors" written by Justin A. Dowd. Using his FY10 data and the DASA-CE's FY14 Joint Inflation Calculator the data was converted to the estimated FY12 costs for comparison with the costs provide by TCM-T AWS, table 20.

Another cost factors is how much it costs to deploy the Hybrid Airships versus the LOTS equipment to the site, table 23. As an example the RRDFs may be deployed aboard a vessel like the MV LTC John U. D. Page, a Military Sealift Command container ship. Based on modeling in JFAST, the Page consumes 71 long tons or 534.5 barrels of fuel per day. If it were used to deliver an RRDF across 5,782 nautical miles between Fort Eustis, Virginia and the Port of Poti, it would require 7,215.6 barrels of fuel. This would cost $581,414 in fuel costs alone, based on $614 per metric ton of intermediate fuel oil 280 on May 14, 2013 market rates in Istanbul, Turkey.[1]

Table 19. US Army Watercraft Operational Costs

Vessel	Fuel Cost Per Gallon	Fuel Use Per Hour	Fuel Cost Per Hour	Class IX Per Hour	Class III Per Hour	Total Per Hour	Lifts	Throughput (hr:min)	Cost to Complete Move
LSV	$3.73	204	$760.92	$223.89	$1.50	$986.31	32	356:02	**$351,159**
LCU-2000	$3.73	75	$279.75	$43.76	$0.87	$324.38	123	657:09	**$213,166**
SLWT	$3.73	59	$220.07	$31.33	$0.25	$251.65	41	255:14	**$64,229**
(1)LSV + (8)LCU200	Lane 1 LSV – 93:04 Lane 2 LCU2000 - 24:18 Lane 3 LCU-2000 -73:15 Lane 4 LCU-2000 -73:15 Lane 5 LCU2000 – 73:15 Lane 6 LCU-2000 - 73:15 Lane 7 LCU-2000 - 73:15 Lane 8 LCU-2000 – 7:38								**$173,433**

Source: Created by author. Derived from CW4 John J. Semmes, TRADOC Capabilities Manager–Transportation Army Watercraft Systems (TCM-T AWS), personal correspondence, January 2013.

Table 20. US Navy and Joint Watercraft Operational Costs

Vessel	Operation & Sustainment in FY07	Inflation Index	Estimated Operation & Sustainment in FY10	Operation & Sustainment Per Hour	Operation & Sustainment Per Hour	Lifts	Cost to Complete Move
LCAC	$734,500	1.065	$782,169	$5,214	$5,214	187	**$975,018**
JHSV	$22,300,000	1.092	$24,344,910	$8,088	$8,088	46	**$372,048**
JHSV w/o containers	$22,300,000	1.092	$24,344,910	$8,088	$8,088	12	**$97,056**

Source: Created by author. Derived from table 1 and Justin Dowd, "Cost Benefit And Capability Analysis of Seabase Connectors" (Thesis, Naval Postgraduate School, Monterey, CA, September 2009), 33.

Table 21. Estimated Airship Operational Costs

Airship	$0.22 per ton mile	Cost from LOTS to TAA per airship (160.9 miles)	Lifts	Cost to Complete Move	Fleet (Qty)	Lifts per Airship in Fleet	Cost for Fleet to Complete Move
Large Airship 1K-ton	$220	$35,398	17	$601,766	4	**5**	**$707,960**
Large Airship 500- ton	$110	$17,699	25	$442,475	4	**7**	**$495,572**
Large Airship 200- ton	$44	$7,080	61	$431,856	7	**9**	**$446,040**
Medium Airship 80-ton	$18	$2,832	150	$424,776	8	**19**	**$430,464**
Small Airship 40-ton	$9	$1,416	301	$426,192	8	**38**	**$430,464**

Source: Created by author.

Table 22. Estimated Operational Costs for PLS Medium Truck Company

OSMIS Data										
Nomen.	**Consum-ables**	**Repar-ables**	**Total Parts/ Mile**	**Fuel Used/ Mile**	**Fuel Cost**	**Total POL Cost**	**Grand Total Per Mile**	**Distance One Way (miles)**	**Cost Per Truck/ 3x Trips**	**Total Cost**
TRUCK HVY PLS 15T M1075	$3.00	$0.80	$3.80	0.41	$1.32	$1.35	$5.15	202.56	$3,129	**$168,995**

Source: Created by author. Derived from table 14, table 15, and Office of the Deputy Assistant Secretary of the Army for Cost and Economics (DASA-CE), "Operating and Support Management Information System (OSMIS)" LIN query "T40999," https://www.osmisweb.army.mil/ (accessed May 8, 2013).

Table 23. Deployment Costs

Ship	Type	Port to LOTS Distance (nm)	Voyage (d:hr)	Fuel Used per Day (LT)	Total Fuel Estimate (LT)	Cost per (MT)	Cost for Voyage
SP5 Erick G Gibson	Container & RORO	4,782	11:06	58	652.5	$614	$405,531
LTC John U.D, Page	Container	5,782	13:15	72	788.8	$614	$490,242
American Cormorant	Heavy Lift Ship	4,782	13:18	79	797.5	$614	$495,649
USAV Major General Robert Smalls	LSV	1,817	6:07	$986.31 per hour	NA	NA	$148,933
							$1,540,355
Airship	**Type**	**Port to LOTS Distance (miles)**	**Flight (d:hr)**	**Fuel Used per ton mile**	**Tons per Aircraft**	**Total Cost per Aircraft**	**Total Cost for Flight**
(4) 500-ton Airships	Airship	5,535	1:10	$0.22	500	$608,850	**$2,435,400**
(4) 1000-ton Airships	Airship	5,535	1:10	$0.22	1000	$1,217,700	$4,870,800
(7)200-ton Airships	Airship	5,535	1:10	$0.22	200	$243,540	$1,704,780
(8) 80-ton Airships	Airship	5,535	1:10	$0.22	80	$97,416	$779,328
(8) 40-ton Airships	Airship	5,535	1:10	$0.22	40	$48,708	$389,664

Source: Created by author. Derived from author's JFAST modeling and table 21.

[1] Ship and Bunker, "Istanbul Bunker Prices, IFO380 in Istanbul," http://shipandbunker.com/prices/emea/medabs/tr-ist-istanbul (accessed May 14, 2013).

APPENDIX H

HYBRID AIRSHIP DESIGNS

Table 24. Hybrid Airship Designs

Contractor(s)	**Name**	**Prototype Flown**	**Payload**	**Speed**	**Max Alt.**	**Range**	**Dimensions**
Aereon[1]-United States	Aereon 26	1971 Flight	Unknown	50mph	Unknown	Unknown	Unknown
	VectoRotor	Unknown	6 & 12 tons	50mph	Unknown	Unknown	Unknown
	Dynairship	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Aeros[2]-United States	Aeroscraft ML866	Lift-off in 2013[3]	20	Cruise 120kts	12,200	1,000nm	310 ft long 142 ft wide
	Aeroscraft ML868		60	Cruise 120kts	12,200	3,100nm	500 ft long 160 ft wide
	Aeroscraft ML86X		500	Cruise 120kts	12,200	5,300nm	787 ft long 184 ft wide
World SkyCat Ltd.[4]-United Kingdom	Sky Kitten	SkyKitten in 2000	Unknown	Unknown	Unknown	Unknown	Unknown
	SkyCat 20		14.5t VTOL 20t STOL	Unknown	Unknown	2,400nm	81 m long 41 m wide
	Sky Cat 200		160t VTOL 220t STOL	Cruise 80kts	Unknown	3,225nm	185 m long 77.3 m wide
	Sky Cat 1000		1000t	Unknown	Unknown	Unknown	Unknown
	Sky Cat 1500		1500t	Unknown	Unknown	Unknown	Unknown
Lockheed Martin[5]-United States	P-791	2006 Flight	500ton	Unknown	20,000	6,000nm	Unknown
Dynalifter[6]-United States	DL-1000	DL100 in 2012	160T	Cruise 120kts	Unknown	3,200nm	990 ft long 533 ft wide
Boeing/ SkyHook International Inc[7]-US/Canada	SkyHook JL	Unknown	40-ton	70knots	Unknown	800 nm	Unknown
SkyLifter [8]-Australia	SL150	Model Flew	165.3 ton	Cruise 83 km/h	10000	2000km	Unknown
Northrop Grumman[9]-United States	LEMV-ISR	2012	2.5 ton	Unknown	Unknown	Unknown	Unknown
Airship-GP[10]	Super Hybrid Cargo Airship	Unknown	50 ton	Cruise 85 kph	5000 m	5600km	110m long 70m wide

Source: Created by author. Data from Aereon Corporation, February 19, 2004, http://www.aereoncorp.com/index.html (accessed May 15, 2013); Aeros, "Aeroscraft Family," http://www.aeroscraft.com/#/aeroscraft-family/4565621879 (accessed May 15, 2013); Graham Warwick, "Aeros Tests Pelican Variable-Buoyancy Airship," *Aviation Week*, January 3, 2013, http://www.aviationweek.com/blogs.aspx?plckpostid= blog:27ec4a53-dcc8-42d0-bd3a-01329aef79a7post:119fbb0b-5c10-4b47-86d9-848a10cc6032 (accessed May 15, 2013); World SkyCat, http://www.worldskycat.com/ images/SkyCat.pdf (accessed May 15, 2013); Lockheed Martin, "Hybrid Airship," http://www.lockheedmartin.com/us/products/HybridAirship.html (accessed May 15, 2013); Dynalifter, "DL-1000 Super Freighter," http://www.dynalifter.com/page19.html (accessed May 15, 2013); Boeing, "Boeing Teams With Canadian Firm to Build Heavy-Lift Rotorcraft," July 8, 2008, http://www.boeing.com/news/releases/2008/q3/080708c_nr.html (accessed May 15, 2013); SkyLifter, "SkyLifters are heavy-lifting aircraft in development," http://multimedia.skylifter.com.au/files/news_media/skylifter_sl150_heavy_airlift_brochure.pdf (accessed May 15, 2013); Northrop Grumman, "Long Endurance Multi-Intelligence Vehicle (LEMV)," http://www.northropgrumman.com/Capabilities/lemv/Pages/default.aspx (accessed May 15, 2013); Airship GP, "Super Hybrid Airships," http://airship-gp.com/index_htm_files/A-GP_008.pdf (accessed May 15, 2013).

---

[1]Aereon Corporation, February 19, 2004, http://www.aereoncorp.com/index.html (accessed May 15, 2013).

[2]Aeros, "Aeroscraft Family," http://www.aeroscraft.com/#/aeroscraft-family/4565621879 (accessed May 15, 2013).

[3]Graham Warwick, "Aeros Tests Pelican Variable-Buoyancy Airship," *Aviation Week*, January 3, 2013, http://www.aviationweek.com/blogs.aspx?plckpostid=blog:27ec4a53-dcc8-42d0-bd3a-01329aef79a7post:119fbb0b-5c10-4b47-86d9-848a10cc6032 (accessed May 15, 2013).

[4]World SkyCat Ltd, World SkyCat, http://www.worldskycat.com/images/SkyCat.pdf (accessed May 15, 2013).

[5]Lockheed Martin, "Hybrid Airship," http://www.lockheedmartin.com/us/products/HybridAirship.html (accessed May 15, 2013).

[6]Dynalifter, "DL-1000 Super Freighter," http://www.dynalifter.com/page19.html (accessed May 15, 2013).

[7]Boeing, "Boeing Teams With Canadian Firm to Build Heavy-Lift Rotorcraft," July 8, 2008, http://www.boeing.com/news/releases/2008/q3/080708c_nr.html (accessed May 15, 2013).

[8]SkyLifter, "SkyLifters are heavy-lifting aircraft in development," http://multimedia.skylifter.com.au/files/news_media/skylifter_sl150_heavy_airlift_brochure.pdf (accessed May 15, 2013), 2.

[9]Northrop Grumman, "Long Endurance Multi-Intelligence Vehicle (LEMV)," http://www.northropgrumman.com/Capabilities/lemv/Pages/default.aspx (accessed May 15, 2013).

[10]Airship GP, "Super Hybrid Airships," 6.

BIBLIOGRAPHY

Books

Althoff, William F. *Skyships: A History of the Airship in the United States Navy.* New York: Orion Books, 1990.

Appleman, Roy E. *South to the Naktong, North to the Yalu.* Washington, DC: Government Printing Office, 1961.

Collier, Basil. *The Airship, A History*. New York: G.P. Putnam's Sons, 1975.

Fehrenbach, T. R. *This Kind of War, The Classic Korean War History*. New York: Macmillian, 1994.

King, Benjamin, Richard Biggs, and Eric Criner. *Spearhead of Logistics, A History of the U.S. Army Transportation Corps*. Fort Eustis, VA. Government Printing Office, 1994.

Knox, MacGregor, and Williamson Murray. *The Dynamics of Military Revolution, 1300-2050*. NewYork: Cambridge University Press, 2001.

Murray, Williamson, and Allen R. Millet, ed. *Military Innovation in the Interwar Period*. New York: Cambridge University Press, 1998.

Thompson, Julian. *Lifeblood of War, Logistics in Armed Conflict*. Great Britain: Biddles, 1998.

Vaeth, Gordon J. *They Sailed The Skies*. Annapolis, MD: Navy Institute Press, 2005.

Periodicals

Coleman, Brian F., and Mark MacCarley. "The 8th Theater Sustainment Command Leads the Way During Operation Pacific Strike 2008." *Army Logistician* (March-April 2009): 24-28.

Pacquette, Richard A. "Expeditionary Logistics in Its Truest Form." *Army Logistician* (March-April 2009): 20-23.

Sweetman, Bill. "Up Ship Airship with a difference nears flight test." *Aviation Week* (October 15, 2012): 46-47.

Electronic Publications and Websites

Ackerman, Spencer. "Army Kills the Military's Last Remaining Giant Spy Blimp." *Wired*. February 14, 2013. http://www.wired.com/dangerroom/2013/02/spy-blimp-deflates/ (accessed May 3, 2013).

Aereon Corporation. "Aereon III." February 19, 2004. http://www.aereoncorp.com/index.html (accessed May 15, 2013).

———. "Aereon 26." February 19, 2004. http://www.aereoncorp.com/index.html (accessed May 15, 2013).

Aeros. "Aeroscraft Family." http://www.aeroscraft.com/#/aeroscraft-family/4565621879 (accessed May 15, 2013).

AerospaceTechnology.com. "Advanced Technologies Group SkyCat, United Kingdom." http://www.aerospace-technology.com/projects/skycat/ (accessed May 2, 2013).

Airship GP. "Super Hybrid Airships." http://airship-gp.com/index_htm_files/A-GP_008.pdf (accessed May 15, 2013).

Austal News. "USNS Millinocket (JHSV 3) Christened." April 20, 2013. http://www.austal.com/us/media/media-releases/13-04-20/USNS-Millinocket-JHSV-3-Christened.aspx (accessed May 1, 2013).

Best of Discovery. "Piasecki PA97 Helistat Accident Crash–helicopter helium blimp hybrid air vehicle heavy lift." http://www.youtube.com/watch?v=_7jENWKgMPY (accessed May 3, 2013).

Boeing. "Boeing Teams With Canadian Firm to Build Heavy-Lift Rotorcraft." July 8, 2008. http://www.boeing.com/news/releases/2008/q3/080708c_nr.html (accessed May 15, 2013).

Braganca, Eric. "The V-22 Osprey: From Troubled Past to Viable and Flexible Option." *JFQ* 66 (July 2012). http://www.ndu.edu/press/v-22-osprey.html (accessed November 12, 2012).

Brannen, Kate. "DoD Sheds Light on Joint Future Theater Lift." *Air Force Times*, July 15, 2012. http://www.airforcetimes.com (accessed September 23, 2012).

Carey, Bill. "U.S. Army Cancels LEMV Surveillance Airship." *AINonline*. February 22, 2013. http://www.ainonline.com/aviation-news/ain-defense-perspective/2013-02-22/us-army-cancels-lemv-surveillance-airship (accessed May 3, 2013).

Defense Industry Daily Staff. "Walrus/HULA Heavy-Lift Blimps Rise, Fall…Rise?" *Defense Industry Daily*. October 23, 2012. http://www.defenseindustrydaily.com/ (accessed September 23, 2012).

Dornheim, Michael A. “Skunks Working.” *Aviation Week & Space Technology* 164, no. 6 (2006): 24-25.

Dynalifter. “DL-1000 Super Freighter.” http://www.dynalifter.com/page19.html (accessed May 15, 2013).

Eger, Christopher. “Warship Wednesday, February 13.” February 13, 2013. http://laststandonzombieisland.com/2013/02/13/warship-wednesday-febuary-13/ (accessed April 10, 2013).

Federation of American Scientists. “Landing Craft, Air Cushion (LCAC).” http://www.fas.org/man/dod-101/sys/ship/lcac.htm (accessed May 9, 2013).

Gordon, Walter O., Chuck Holland, and Karen S. Wilhelm. “Back to the Future: Airships and the Revolution in Strategic Airlift.” *Air Force Journal of Logistics* 29, no. 3 (2005): 46-56.

Hanlon, Mike. “The Walrus: the US Army contemplates building an aircraft the size of a football field.” *Gizmag*, September 5, 2005. http://www.gizmag.com/go/4538/ (accessed October 15, 2012).

Hills, Waring. “First Airship to Land on Aircraft Carrier, 1928!” January 27, 2011. http://www.patriotspoint.org/news_events/first-airship-to-land-on-aircraft-carrier-1928/ (accessed March 10, 2013).

Hudson, Jen. “Army Deflates LEMV Airship; Cost And Schedule Cited.” *InsideDefense.com*, February 13, 2013. http://insidedefense.com/201302132424647/Inside-Defense-General/Public-Articles/army-deflates-lemv-airship-cost-and-schedule-cited/menu-id-926.html (accessed May 1, 2013).

Hutnik, Michael J. “A--RAVB Demonstrator, Solicitation: NNA08BC43C.” FedBizzOpps.gov. February 4, 2013. https://www.fbo.gov/index?s=opportunity&mode=form&id=5941115e43d3a56b245dc2b36c9bcfa8&tab=core&tabmode=list&= (accessed May 3, 2013).

Larson, Trish, and Mike Neuhardt. “Lummus and JLOTS Lift Hearts in Haiti.” *Sealift U.S. Navy’s Military Sealift Command* (March 2010). http://www.msc.navy.mil (accessed September 23, 2012).

“Lockheed Martin, Aeros Aeronautical Systems Win Walrus Work.” *Defense Daily* 227, no. 42 (August 2005). http://search.proquest.com/docview/234096269?accountid=28992 (accessed May 3, 2013).

Lockheed Martin. “Hybrid Airship.” http://www.lockheedmartin.com/us/products/HybridAirship.html (accessed May 15, 2013).

Majumdar, Dave. “Blue Devil 2 Airship Expected to be Canceled.” *AirForceTimes.* March 28, 2013. http://www.airforcetimes.com/article/20120318/NEWS/203180319/Blue-Devil-2-airship-expected-canceled (accessed May 1, 2013).

McKeegan, Noel. “Northrop Grumman to build football field-sized Hybrid Airship.” *Gizmag*, June 16, 2010. http://www.gizmag.com/hybrid-airship-us-army/15432/ (accessed September 9, 2012).

McLeary, Paul. “U.S. Army Leaders Ponder How To Get Troops To Next Fight.” *DefenseNews.com*. September 18, 2012. http://www.defensenews.com/article/20120918/DEFREG02/309180006/U-S-Army-Leaders-Ponder-How-Get-Troops-Next-Fight (accessed September 19, 2012).

Miles, Donna. “‘Golden hour’ initiative pays off in Afghanistan.” *U.S. Air Force News* May 20, 2011. http://www.af.mil/news/story.asp?id=123256862 (accessed March 25, 2013).

Northrop Grumman. “Long Endurance Multi-Intelligence Vehicle (LEMV).” http://www.northropgrumman.com/Capabilities/lemv/Pages/default.aspx (accessed May 15, 2013).

Prentice, Barry E. “There is a global need for airships.” Buoyant Aircraft Systems International (BASI). November 8, 2012. http://www.buoyantaircraft.com/there-is-a-global-need-for-airships/ (accessed May 9, 2013).

PRWeb. “Aeros CEO Igor Pasternak Announces Successful Completion of the First Movement Test of the Aeroscraft Vehicle.” January 9, 2013. http://www.prweb.com/releases/igorpasternak2/01/prweb10309799.htm (accessed November 22, 2012).

Ship and Bunker. “Istanbul Bunker Prices, IFO380 in Istanbul.” http://shipandbunker.com/prices/emea/medabs/tr-ist-istanbul (accessed May 14, 2013).

SkyLifter. “SkyLifters are heavy-lifting aircraft in development.” http://multimedia.skylifter.com.au/files/news_media/skylifter_sl150_heavy_airlift_brochure.pdf (accessed May 15, 2013).

Szondy, David. “US Army cancels LEMV airship project.” *Gizmag*, February 15, 2013. http://www.gizmag.com/lemv-airship-canceled/26274/ (accessed March 1, 2013).

Warwick, Graham. “Aeros Tests Pelican Variable-Buoyancy Airship.” *Aviation Week,* January 3, 2013. http://www.aviationweek.com/blogs.aspx?plckpostid=blog:27ec4a53-dcc8-42d0-bd3a-01329aef79a7post:119fbb0b-5c10-4b47-86d9-848a10cc6032 (accessed May 15, 2013).

World SkyCat Ltd. “World SkyCat.” http://www.worldskycat.com/images/SkyCat.pdf (accessed May 15, 2013).

Government Documents

Bolkcom, Christopher. *Potential Military Use of Airships and Aerostats*. Washington, DC: Congressional Research Service, 2004.

———. *Strategic Airlift Modernization: Background, Issues and Options*, Washington, DC: Congressional Research Service, 2005.

Bolkom, Christopher, and Williams Knight. *Strategic Airlift Modernization: Analysis of C-5 Modernization and C-17 Acquisition Issues*. Washington, DC: Congressional Research Service, 2007.

Congressional Budget Office. *Options for Strategic Military Transportation Systems*. Washington, DC: Government Printing Office, 2005.

———. *Recent Development Efforts for Military Airships*. Washington, DC: Government Printing Office, 2011.

———. *Sea Basing and Alternatives for Deploying and Sustaining Ground Combat Forces*. Washington, DC: Government Printing Office, 2007.

Frank, Benis M., and Henry I. Shaw Jr. "Amphibious Doctrine in World War II." In *Victory and Occupation: History of the U.S. Marine Corps Operations in World War II*. Quantico, VA Historical Branch, US Marine Corps, 1968. Excerpt reprinted in US Army Command and General Staff College, H200 Book of Readings. Fort Leavenworth, KS: USACGSC, October 2012.

Gillum, Donald E. "Gallipoli: Its Influence on Amphibious Doctrine." *Marine Corps Gazette* 51, 1967. Excerpt reprinted in US Army Command and General Staff College, H200 Book of Readings. Fort Leavenworth, KS: USACGSC, October 2012.

Huett, Steve. "The Art of Possible, Hybrid Airship History." PowerPoint presentation, NAVAIR Research and Engineering, March 2010. http://paxpartnership.org/Knowledgebase/Attach/11%20Hybrid%20History%2029MARCH%20Optimized.pdf (accessed May 2, 2013).

Margesson, Rhoda, and Maureen Taft-Morales. *Haiti Earthquake: Crisis and Response*. Washington, DC: Congressional Research Service, February 2, 2010.

Meade, Brian, and Michael McGuiness. "EUCOM-AFRICOM-TRANSCOM, Point-of-need Delivery (POND)." EUCOM J8-C, PowerPoint Presentation April 7, 2010. http://paxpartnership.org/Knowledgebase/Attach/6%20Mead%20POND%20brief%20to%20HAHC_Mar%2010.pdf (accessed May 8, 2013).

Military Surface Deployment and Distribution Command Transportation Engineering Agency (SDDC-TEA). *Logistics Handbook for Strategic Mobility Planning*. Newport News, VA: Government Printing Office, September 2002.

———. *Port Accessibility of Future Sealift Vessel Candidate Study*. Newport News, VA: Government Printing Office, March 2008. March 2004.

Office of the Assistant Secretary of Defense for Research and Engineering, Rapid Reaction Technology Office. *Lighter-Than-Air Vehicles*. Washington, DC: Government Printing Office, 2005. http://www.defenseinnovationmarket place.mil/resources/Final_LTA_report.pdf (accessed May 1, 2013).

Tornai, Marie. Draft Statement of Objectives (SOO) for the Long Endurance Multi-INT Vehicle LEMV, Solicitation Number: W91260-LEMV. *FedBizOpps.gov*. April 22, 2009. https://www.fbo.gov/?s=opportunity&mode=form&tab=core&id=8a9576adda671991e001a322c98a6a44&_cview=1 (accessed May 1, 2013).

U.S. Air Force. Air Force Pamphlet 10-1403, *Air Mobility Planning Factors.* Washington, DC: Government Printing Office, December 18, 2003.

U.S. Army Combined Arms Support Command (CASCOM). *Army Watercraft Master Plan, Fleet Strategy*. Fort Lee VA: Government Printing Office, March 2008.

U.S. Army Command and General Staff College. Student Text (ST) 4-1, *Sustainment in the Theater of War.* Ft. Leavenworth, KS: Government Printing Office, June 2012.

U.S. Department of Defense. *Defense Budget Priorities and Choices.* Washington, DC: Government Printing Office, January 2012.

———. *Hybrid Airships Operational Concepts*. Prepared by Office of the Assistant Secretary of Defense for Research and Engineering, Rapid Reaction Technology Office.

U.S. Department of the Army. Army Tactics, Techniques, and Procedures (ATTP) 4-15, *Army Water Transport Operations*. Washington, DC: Government Printing Office, February 2011.

———. Field Manual (FM) 55-15, *Transportation Reference Data*. Washington, DC: Government Printing Office, October 1997.

———. Technical Manual (TM) 55-2200-001-12, *Operators Manual for Modular Causeway System (MCS) Roll-On/Roll-Off Discharge Facility (RRDF) RRDF-1 NSN 1945-01-473-2282.* Washington, DC; Government Printing Office, May 2002.

U.S. Departments of the Army and the Navy Technical Bulletin (TB) 55-46-1. *Standard Characteristics (Dimensions, Weight, and Cube) for Transportability of Military Vehicles and Other Outsize/Overweight Equipment*. Washington, DC: Government Printing Office, March 2009. https://portal.navfac.navy.mil/portal/page/portal/docs/doc_store_pub/navfac%20p-1055.pdf (accessed May 8, 2013).

U.S. Joint Chiefs of Staff. Joint Publication 4-0, *Doctrine for Logistics Support of Joint Operations Logistics Over-the-Shore (JLOTS)*. Washington, DC: Government Printing Office, August 2005.

———. Joint Publication 4-01.2, *Sealift Support to Joint Operations*. Washington, DC: Government Printing Office, June 2012.

———. Joint Publication 4-01.6, *Joint Logistics Over-the-Shore (JLOTS)*. Washington, DC: Government Printing Office, August 2005.

U.S. Transportation Command. "Department of Defense and Hybrid Airship Development." PowerPoint presentation, by Earl Wyatt, August 25, 2011.

<u>Government Databases</u>

Office of the Deputy Assistant Secretary of the Army for Cost and Economics (DASA-CE). "Operating and Support Management Information System (OSMIS) LIN query 'T40999.'" https://www.osmisweb.army.mil/ (accessed May 8, 2013).

U.S. Army Force Management Support Agency. "LIN query V00426." https://fmsweb.fms.army.mil/protected/WebTAADS/Listing_LIN.asp?LIN=V00426&MACOM=P1&DOCNO=55530LP145&CCNUM=0109&PARNO=101 (accessed May 8, 2013).

———. "LIN query L36989." https://fmsweb.fms.army.mil/protected/WebTAADS/Listing_LIN.asp?LIN=L36989&MACOM=X1&DOCNO=55829LX110&CCNUM=0107&PARNO=102 (accessed May 8, 2013).

———. "UIC query WD8XFF." with EDATE August 17, 2012 and July 16, 2012, https://fmsweb.fms.army.mil/protected/hierarchy/divorg/3LevelChart.asp?Update=DRAWCHART&UIC=WD8XFF&MID=WD8XFF&DOCST=A_FY_2013&FY=2013&exp=false (accessed May 8, 2013).

Other Sources

Beakey, Dan J. "Logistics Over The Shore, Do We Need It?" National Security Affairs Monograph Series 82-6, National Defense University, Ft. Lesley J. McNair, Washington, DC, 1983.

Dowd, Justin. "Cost Benefit and Capability Analysis of Seabase Connectors." Thesis, Naval Postgraduate School, Monterey, CA, September 2009.

Hauser, John. "Aerocrane in LOTS Operations." Master's Thesis, Command and General Staff College, Ft. Leavenworth, KS, 1976.

Lynch, Philip W. "Hybrid Airships: Intratheater Operations Cost-Benefit Analysis." Master's thesis," AFIT/IMO/ENS/11-08, School of Engineering and Management, Air Force Institute of Technology (AU), Wright-Patterson AFB, OH, June 2011.

Newbegin, Charles. "Modern Airships: A Possible Solution for Rapid Force Projection of Army Forces." Monograph, School of Advanced Military Studies, Ft. Leavenworth, KS, 2003.

Rapp, Timothy J. "Analysis of Hybrid Ultra Large Aircraft's Potential Contribution to Intertheater Mobility." Master's thesis, AFIT/IMO/ENS/06E-16, School of Engineering and Management, Air Force Institute of Technology (AU), Wright-Patterson AFB, OH, June 2006.

Rice, Mark. *Current Limitations to Joint Logistics Over-the-Shore (LOTS) and the Road head*. Newport, RI: Joint Military Operations Department, Naval War College, February 2006.

Systems Engineering and Analysis-6 Cohort. "Seabasing and Joint Expeditionary Logistics." Master's thesis, Naval Postgraduate School, Monterey, CA, December 2004

Zwolensky, Todd S. "Logistics Over The Shore: A Review of Operation Chromite, Operation Bluebat, and Its Relevance to Today." Master's Thesis, Command and General Staff College, Ft. Leavenworth, KS, 2007.