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HYBRID AIRSHIPS FOR LIFT: A NEW LIFT PARADIGM AND A PRAGMATIC ASSESSMENT OF THE VEHICLE'S KEY OPERATIONAL CHALLENGES

by

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With its reduced operating costs and point-of-need (PON) delivery ability, the hybrid airship is one lift option that offers promising capabilities to meet the DoD‟s future logistical challenges throughout the spectrum of conflict. When examining the hybrid airship in this capacity, it is essential for personnel to evaluate the platform through the appropriate framework without dismissing the idea based on inaccurate misconceptions. Establishing a new paradigm, distinct from traditional airlift and sealift frameworks, is critical in understanding how hybrid airships would be viable lift options in filling the current cost/speed gap in the distribution system.

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ABSTRACT

With its reduced operating costs and point-of-need (PON) delivery ability, the hybrid airship is one lift option that offers promising capabilities to meet the DoD's future logistical challenges throughout the spectrum of conflict. When examining the hybrid airship in this capacity, it is essential for personnel to evaluate the platform through the appropriate framework without dismissing the idea based on inaccurate misconceptions. Establishing a new paradigm, distinct from traditional airlift and sealift frameworks, is critical in understanding how hybrid airships would be viable lift options in filling the current cost/speed gap in the distribution system.

Assessing the hybrid airship in a distinct framework allows for a pragmatic examination of its key operational challenges. The vehicle proves to be far more robust and capable in terms of threat and weather survivability, along with ground and terminal operations, than commonly perceived. These vehicles hold potential for global employment in threat and weather environments where organic fixed and rotary-wing platforms are currently utilized and might release these high-demand assets for other critical taskings.

Hybrid airships give the military and its commercial partners a solution for tactical and strategic delivery to PON locations, without regard to intermodal infrastructure or destination austerity. The vehicle is now a viable lift option and the DoD should strongly consider a partnership with industry to fund and develop the hybrid airship to meet future requirements. While procurement for an organic fleet may not be fiscally or operationally realistic,

vehicle development for a CRAF-type system allows the DoD to leverage this tremendous capability when needed, while negating the associated costs of operating and maintaining an organic fleet when traditional lift platforms can meet steady-state requirements.

INTRODUCTION

The United States military's mobility platforms provide the basis for the nation's global reach and power projection across the full range of military operations. As the Department of Defense (DoD) enters the second decade of the 21st century, it faces daunting challenges in fulfilling current and future mobility requirements. Pending budgetary cuts necessitate difficult decisions in determining the optimal combination of mobility platforms across all services to meet DoD logistical requirements. These choices may prove to be more critical in light of a future joint operating environment requiring flexible lift platforms to accomplish point-of-need (PON) cargo delivery for the war fighter. To overcome these challenges, all viable options for future transportation modes must be sensibly evaluated, including the development of a hybrid airship (HA) for lift.[1]

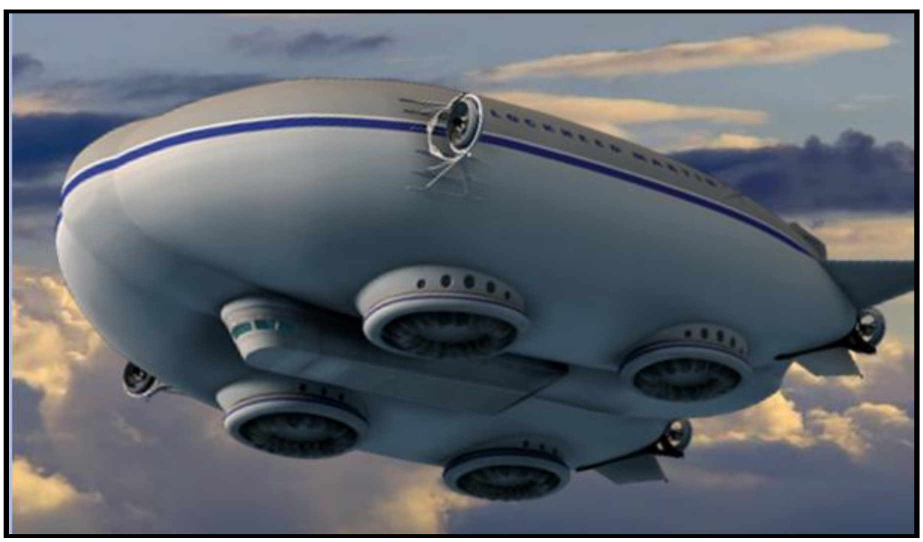

Figure 1. Lockheed Martin Hybrid Air Vehicle Concept. (Reprinted from Dr. Robert Boyd, "Hybrid Aircraft: A Different Look at Transportation," Briefing to USTRANSCOM J5/4, 31 August 2009. Used with permission from Lockheed Martin Corp. Slide 5.)

While HA are currently demonstrating military utility and value in a number of applications, including ISR, border patrols, anti-drug trafficking and communications platforms, there is still considerable resistance encountered when proposing their use for military lift. When presented as a transportation option, pragmatic HA assessment is hampered by stove-piped mobility analysis and restricted thinking or misconceptions concerning the operational challenges facing the platform in a military environment.

With the ability to efficiently transport a large range of payloads across strategic distances to austere locations, HA hold potential to fill a gap in the current mobility system. Employing faster than surface modes, but more economical than transport aircraft and without the complex, costly infrastructure currently required for air and sea modes, these vehicles offer promising advantages for use in the future transportation distribution network. While aircraft and sealift vessels are proven transport modes, they must always terminate at air/sea ports, which rarely coincide with PON requirements—HA offer potential for direct delivery to avoid the complications inherent in multimodal port operations. From combat cargo lift to humanitarian assistance and disaster relief operations to civilian cargo delivery in austere environments, HA technology is now poised to transform the transportation landscape. The fusion of over a century of extraordinary technological advancements has shifted HA development from the future concept field to near-term realistic production possibilities.

However, while military logisticians are beginning to realize the potential capabilities of HA for lift, misinformed opinions on airship challenges continue to plague a rational analysis on the topic. A balanced assessment of the vehicle's potential use for military lift is not possible without personnel detaching themselves from traditional paradigms of current airlift analysis and accepting that Hybrid Airships offer potential to be a separate-but-equal transportation mode. The HA "is not well characterized by either airplane-derived or airship-derived relations…the implicit sensitivity to both speed and size sets this type of vehicle apart from other flight vehicles, yielding unique design constraints and objectives."[2] Therefore, to address the viability of employing Hybrid Airships as a future mode of US military airlift, the following analysis is two-fold: (1) demonstrate the value of assessing hybrid airships as a different transportation mode—essentially a new paradigm, distinctive of a traditional airlift analysis and, (2) reasonably examine the key operational challenges they face when operating in the global military distribution network.

***All notes appear in shortened form. For full details, see the appropriate entry in the Bibliography.**

[1] Detailed operational concepts (including land & water operations) and engineering principles for cargo hybrid airships have been well established in a number of research efforts beyond the scope of this analysis. It is assumed the reader is aware of the overarching principles in design and employment of the vehicle, and also possesses a basic understanding of the advantages & challenges when considering the vehicle for lift. A thorough grasp of the topic can be attained from a cursory review of "Back to the Future: Airships and the Coming Revolution in Strategic Airlift," a 2005 study conducted by Colonel's Walter Gordon and Chuck Holland published in the Air Force Journal of Logistics "2006 Logistics Dimensions" collection (www.aflma.hq.af.mil/shared/media/document/AFD-100120-037.pdf, 19-35)

[2] Boyd, *Performance of Hybrid Air Vehicles*, 1.

PARADIGM SHIFT: A DISTINCT TRANSPORTATION MODE

Amongst US military personnel, notions regarding the perceived operational disadvantages of employing hybrid airships for lift allow critics (and neutral members alike) to summarily dismiss the idea based on misinformed preconceptions rooted in a cursory selection of historical airship disasters and well-intentioned, but flawed understanding of the topic. Before the operational challenges can be appropriately addressed, it is necessary to demonstrate that the viability of these platforms require a definite paradigm shift in analysis. Hybrid airships cannot be scrutinized as a typical military airlift platform and should be considered as a different mode of transport altogether. This can be done with a brief examination of general airship history and the basic concepts of using Hybrid Airships for military transport, while considering the strategy & doctrine shaping lift requirements in the future joint operating environment.

AIRSHIP HISTORY: AN EXEMPLARY RECORD

A candid assessment of Hybrid Airships and their potential operational challenges in the future joint operating environment require senior civilian and military leaders to evaluate the platform with the appropriate perspective. Thus, HA should be examined as a distinctive mode of transportation for the global logistics system, instead of trying to model it strategically and operationally as simply another airlifter. Although airships are different for a number of reasons, the first barrier to a reasonable assessment arises from a selective deliberation on general airship history. In most military discourse, airships invoke a false idea of obsolete technology and most personnel immediately envision Hindenburg crash of 1937. Despite over seventy years of technological and engineering advancement, the Hindenburg connection quickly devolves the debate into presupposed airship safety inadequacies, which make the military lift platform seemingly easy to dismiss. Thus, the first step in detaching the airship analysis from the standard airlift paradigm is revealing an often forgotten history of its extraordinary performance in a challenging military environment ending over fifty years ago.

While a number of historical airship tragedies easily impact current airship analysis, it is equally important to recall impressive operational record of airships during the first half of the 20^{th} century. Twenty years before the Hindenburg was destroyed, a German airship transported over 30,000 pounds of cargo 3,600 miles from Bulgaria to Africa in 95 hours—landing with 64 hours of fuel remaining.[1] In 1929, Hindenburg's sister ship, Graf Zeppelin, circumnavigated the globe in four stops, including a 7,000 mile leg between Germany and Japan completed in 100 hours.[2] Both feats were unimaginable by aircraft at the time and proved that airships offered incredible potential for numerous military applications despite primitive technology and engineering in the contemporary aerospace field. In addition, the US operated only four rigid airships from 1923 to 1941, suffering a 75% loss rate due to weather—a significant fact given the problematic weather prediction and monitoring capabilities of the time.[3] Few recall that three of these four USN airships logged over 1,500 flight hours before loss or retirement, a record far more remarkable than that of the first four US military aircraft.[4] All things considered, in a period of limited weather technology and primitive technological development, rigid airships performed exemplary in a demanding global aviation environment.

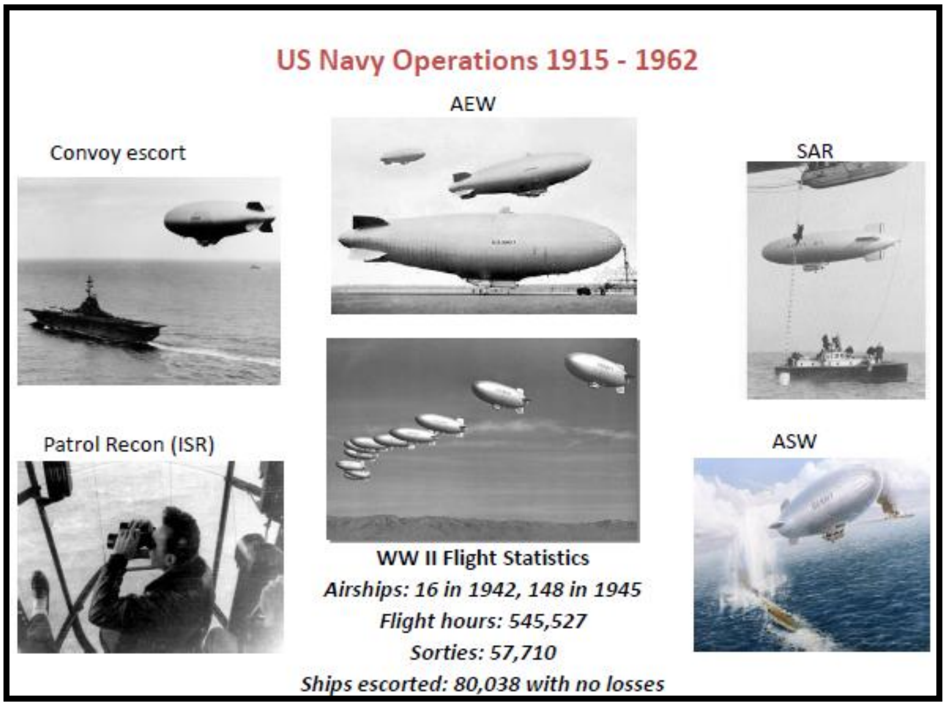

Figure 2. US Navy WWII Airship Performance. (Reprinted from Pete Buckley, "Airships: Everything You Thought You Knew", Briefing to *2010 Hybrid Airships for Heavy Lift Conference*, 31 March 2010. Slide 5.)

The transition to non-rigid airships realized even more robust vehicles executing a number of complex military missions as depicted in Figure 2. During WWII, using non-rigid airships for anti-submarine warfare, convoy escort and airborne early warning, the USN operated 134 blimps at 87% availability with only one combat loss.[5] Flying 36,000 missions, the service accumulated a remarkable 412,000 flight hours, retiring the last non-rigid vehicle in 1961.[6] Equally impressive was the 1957 flight of the USN's non-rigid ZPG-2 Snowbird, which took the crew on a 264.2 hour, 9,448 nautical mile voyage--breaking world records for total continuous un-refueled distance and time aloft.[7]

Thus, for a fifty year period ending over half-a-century ago, airships posted noteworthy safety and mission completion records in a number of dynamic environments despite the limited technology at the time. If it weren't for the tremendous advancements in fixed-wing aircraft technology, airship development might have accelerated in parallel and HA cargo platforms would be employed today. Although this only offers a small sampling of the historical capabilities of airships, it is the first step in demonstrating that airships should not be assessed using a traditional airlift paradigm. While historical airship difficulties are important to consider, their tremendous accomplishments during the same period are also critical to assess when contemplating the vehicles for future use.

THE HYBRID AIRSHIP: AN AUGMENTING CAPABILITY

A second aspect of the vehicle that is essential in accurately framing the analysis is a basic understanding of the hybrid airship itself. A working knowledge of its capabilities and operational concepts is critical in recognizing that it does not fit into a standard airlift paradigm.

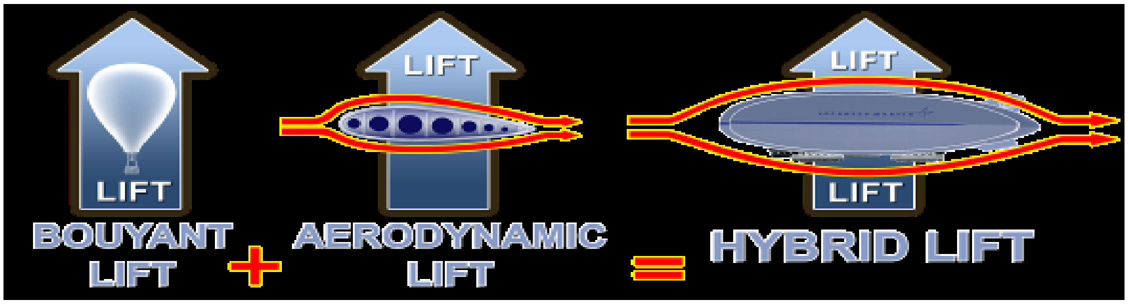

Figure 3. Hybrid Lift Basics. (Reprinted from Dr. Robert Boyd, "Hybrid Aircraft: A Different Look at Transportation," Briefing to USTRANSCOM J5/4, 31 August 2009. Used with permission from Lockheed Martin Corp. Slide 4.)

When developing airship platforms for heavy lift, modern aircraft manufacturing companies are developing concepts based on the Hybrid Airship (Figure 3: Hybrid Lift Basics). Unlike traditional airships that rely on a contained gas within the envelope to provide all required lift for flight, Hybrid Airships use a combination of buoyant lift (provided by a gas such as Helium), aerodynamic lift (generated by airflow across the surfaces of the vehicle) and, in some cases, direct vertical lift provided by propulsion systems (similar to current rotary wing platforms). In essence, this lift combination allows the vehicle to climb and descend heavier-than-air—a critical attribute that allows for a greater useful payload range and overcomes the historical challenges of buoyancy control that have plagued engineers when designing airships for lift. With envelope buoyancy to providing 70%-80% of the required lift and aerodynamic lift providing the remainder, engineers can maximize payload ranges and optimize fuel and speed efficiencies.[8] This gives HA significant advantages and potential operational capabilities when augmenting traditional lift modes. Tremendous fuel efficiency, 100 knot cruise capability, payloaddriven STOL/VTOL capability and self-contained ground-handling systems place hybrid airships in an entirely different category of lift options.

Many aspects of this platform are drastically different than current land and sea mobility platforms and it is beneficial to use perspectives from both modes to best assess HA operational capability. Instead of a flight deck, HA would be controlled in the fashion of a traditional ship's bridge, with a mission commander overseeing critical phases of the mission—similar to naval operations. Also, traditional runway and terminal operations do not apply to the HA. Instead of a runway, operators will be concerned about a clearway and crosswind arrival and departure operations aren't an issue—the vehicles always operate into the wind. In light of these, and many other non-traditional factors, HA operational assessments diverge significantly from traditional fixed and rotary wing platforms—it does not replace mobility modes, but rather enhances future distribution systems.

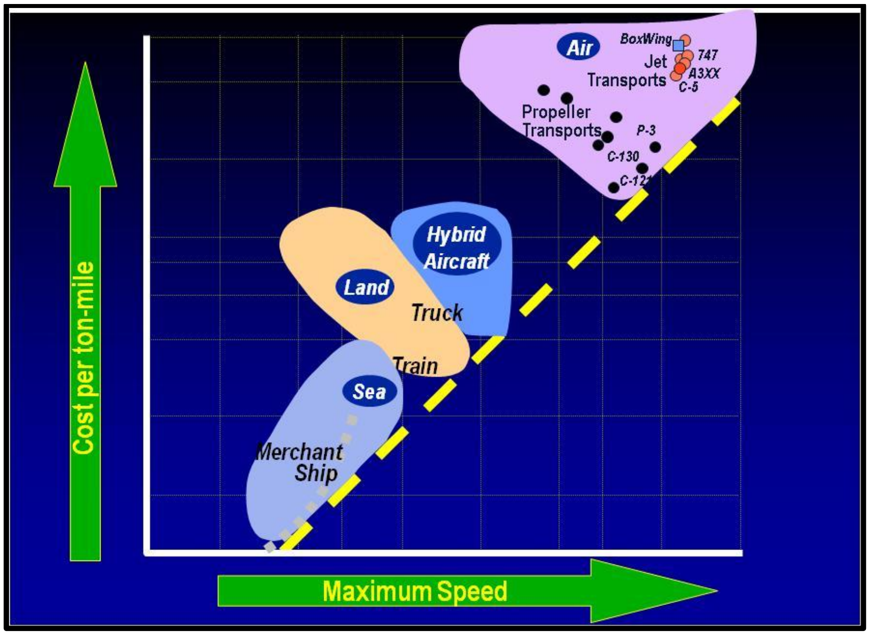

Figure 4. Gabrielli-Von Karman: Lift Mode Cost vs. Speed. (Reprinted from Dr. Robert Boyd, "Hybrid Aircraft: A Different Look at Transportation," Briefing to USTRANSCOM J5/4, 31 August 2009. Used with permission from Lockheed Martin Corp. Slide 3.)

Instead of supplanting the other air, sea and land modes of transport, HAs would augment the intermodal system and operate in the critically uncontested cost and speed gap (see Figure 4). Upon quantitative and qualitative analyses, USTRANSCOM recently released its 2011 Future Deployment and Distribution Assessment, which provides a cogent summary of HA capabilities:

> The capabilities of hybrid airships could be applied to a multitude of missions throughout the range of military operations. They offer the payload and range to deliver operationally significant forces and sustainment over strategic distances. They could access any open location in the Joint Operations Area (JOA), have the ability to bypass enemy defenses and overcome area denial efforts, and have the precision to deliver to or near the desired point of need that may not have adequate infrastructure.[9]

Employing faster than a ship, but significantly cheaper than strategic and tactical aircraft, including both fixed and rotary wing, HA can deliver cargo directly to the land and sea points-of-need (PON) with minimal fixed infrastructure requirements, minimizing the cost and trans-load time requirements inherent in contemporary multi-modal operations. In fact, recent analysis suggest that while costlier than surface shipping, Hybrid Airship operating and sustainment (O&S) costs range from one-half to one-tenth of current air modes (CH-47 to 747-400) while following a procurement cost line more than ten-times lower than commercial and military aircraft development.[10] This is a critical consideration for a potential joint-vehicle supporting all DoD branches as aircraft development costs can now reach tens of billions of dollars and aging equipment/fuel costs push O&S costs prohibitively higher. In addition, advancements in materials, propulsion and ground-handling technology have resulted in the potential for a wide range of payload options, ranging from 20 to 500 tons with self-contained on/off-load capability and mooring systems that negate the intensive manpower requirement that plagued early airships (industry experts believe 500-ton variants technologically viable within twenty years).[11]

These are simply a few of the many advantages inherent to HA employment for lift and demonstrate that the platform does not neatly fit the traditional airlift model. In a pragmatic assessment of future military use, HA size, employment and capability are remarkably different than conventional airlift and should be viewed as such. Linking this idea with logistics doctrine and strategy reinforce the idea that HA should be appraised through its own framework.

DOCTRINE & STRATEGY: FUTURE REQUIREMENTS

The US national strategy and military doctrine provide the basis for future military logistical requirements and how they assist the DoD in fulfilling national security requirements. The key strategy and doctrine excerpts below provide the basis for leveraging potential Hybrid Airship capabilities in conjunction with current and future lift modes, and reinforce the requirement to analyze them as a distinctive, but complementary transportation mode.

- **2011 National Military Strategy**: Joint Forces will "become more expeditionary in nature and will require a smaller logistical footprint." They will "perform full spectrum operations to assure…rapid global mobility…and retain the ability to project power into distant, anti-access environments."[12]

- **2010 Joint Operating Environment (JOE)**: "In planning for future conflicts, Joint Force commanders and their planners must factor two important constraints into their calculations: logistics and access".[13]

- **2009 Capstone Concept for Joint Operations (CCJO)**: "We will need to develop new capabilities….We will need to develop new technologies and adapt existing ones to new missions."[14] Joint forces "will require a mix of air and sea strategic and operational lift capable of delivering forces and materiel to their destinations, often in the absence of capable airfield and port facilities."[15]

- **2006 Joint Logistics Distribution-Joint Integrating Concept (JLD-JIC)**: The capabilities of the "theater distribution segment(s) fall short of what is required to integrate into a comprehensive end-to-end distribution pipeline…Intra-theater lift (*will be*) challenged to accommodate demands of increasingly more simultaneous, distributed, and non-contiguous operations."[16] An essential task of the JDDE [Joint Deployment & Distribution Enterprise] will be to "accomplish the closure of early-deploying, expeditionary joint forces across strategic and theater movement segments in a single movement from their point of origin to a point designated by the JFC and bypassing, if necessary, traditional

> ports of debarkation, enabling units to move to points of need for prompt operational employment in support of 'seizing the initiative'."[17]

Without assessing HA within the framework of future mobility requirements set forth by US civilian & military leaders in these guidelines, an accurate appraisal is not possible. Most importantly, these guidelines dictate that future logistics operations must be able to execute into anti-access, area-denied environments without regard to damaged or insufficient infrastructure normally required for current intermodal operations. Within these challenging constraints, the DoD will be required to develop robust capabilities that enable theater access to austere land & sea ports while reducing reliance on intermodal cargo transfers. Current airlift platforms and the intermodal nature of the existing distribution network are not optimized for this direct-delivery environment—HA can fill the void.

In essence, as a distinct mobility airlift platform Hybrid Airships cannot replace current transportation modes, but instead augment their capabilities by employing in the critical cost/speed gap. They provide capabilities that aren't necessarily better or worse than fixed and rotary wing lift assets—they are just different and should be viewed as such. A true understanding of this capability cannot be acquired without developing a new paradigm, different than that of current mobility aircraft, for HA analysis. Contemplating airship history (both good and bad) and basic Hybrid Airship operational concepts while understanding the future joint logistics environment provides the appropriate perspective when assessing their viability for future lift.

[1] Gordon and Holland, *Back to the Future*, 19.
[2] Ibid., 20.
[3] RAND, *Military Potential of Hybrid Airships*, 27.
[4] Gordon and Holland, *Back to the Future*, 20.
[5] RAND, *Military Potential of Hybrid Airships*, 27.
[6] Ibid., 27.
[7] Grossnick, *Kite Balloons to Airships*, 73-75.
[8] Boyd, interview (31 August 2011).
[9] FDDA, 2-3.
[10] Boyd, interview (31 August 2011).
[11] Ibid.
[12] *National Military Strategy*, 18-19.
[13] *JOE*, 63.
[14] *CCJO*, iv.
[15] Ibid., 31.
[16] *JLDJIC*, 10.
[17] Ibid., 14.

OPERATIONAL LIMITATIONS: COMMON MISCONCEPTIONS

The second part of this research effort assesses what many consider the principle operational challenges that are commonly misunderstood when evaluation hybrid airships for military lift. Similar to the criticality of treating the vehicle as a separate transportation mode, it is equally important to disregard the tendency to summarily dismiss HA as an option for lift based on misinformed assumptions. The platform is predictably rejected as an option for employment in a global military distribution network over concerns in a number of areas. However, technological, engineering, and operational advances over the past fifty years have solved a majority of the frequently cited issues that preclude military consideration for lift options. While not an inclusive list, the following three areas should be addressed as the key issues currently prohibiting HA development: threat survivability, weather survivability and ground/terminal operations.

THREAT SURVIVABILITY

When examining Hybrid Airships as a military lift platform, the first and strongest concern is centered on the idea of threat survivability. Mission effectiveness is a critical component of any platform analysis: will it get there on-time, safely and with the required cargo in the face of kinetic threats.[1] The surprising answer is that Hybrid Airships are far more robust than commonly accepted. In platform assessment, it is critical to appreciate the difference between vulnerability and survivability, as HA are different in both areas when evaluated against current transportation modes. Vulnerability should be viewed as the potential of incurring battle damage, whereas survivability is its capacity to continue the mission (mission effectiveness) or at least exit the threat area and safely land to minimize damage if engaged by an enemy. This distinction, while minor, is important and many times the lack of its understanding prevents a rational assessment of HA capabilities.

In comparison to surface ships, their ability to overfly, or with the right threat-mitigation planning, out-distance most sea-based threats (mines, torpedoes, pirates, etc.) makes HA less vulnerable than surface ships. In addition, if the vehicle is unsuccessful at out-distancing sea-based fighters or surface-to-air threats, it is then no more vulnerable than a normal surface ship, so "it is readily apparent that only a small subset of the possible threats to surface ships could threaten an airship."[2]

When compared to fixed and rotary wing airlift platforms, HA also demonstrate equal if not better survivability potential. While their immense surface areas, slower speeds and lower operating altitudes in typical engagement zones combine to make them far more vulnerable to successful kinetic engagement with common combat threats such as rifles, RPGs, AAA and MANPADS, they prove to be more survivable for a number of reasons.

Weapon	AK-47	ZU-23-2	S-60
Caliber (mm)	7.62	23	57
Max Range (ft)	1,300	5,000	13,000
Time (hrs) to Forced Landing (Days) * After a single shot	5,669 (236)	93 (4)	36 (1.5)
Rounds Requiring "B" Kill (Down w/in 30 min)	4,385	72	28

Figure 5. Hybrid Air Vehicle Threat Survivability (Medium Sized Vehicle). (Reprinted from James Mach, "Hybrid Airships." Brief. 2011 Airlift/Tanker Association (A/TA) National Convention. 4 November 2011. Information used with permission from Dr. Robert Boyd and Lockheed Martin Corporation.)

First, the helium-filled envelope is only slightly pressurized for structural integrity (less than 0.5 psid), so the lifting gas is not forced out of the envelope if it is punctured with even large-diameter holes. In contrast to standard fixed and rotary wing assets which succumb to loss of controlled flight due to dynamic loading, this allows the vehicle to exit the weapons engagement zone and continue the mission with minor damage, or at lease safely land the vehicle in the worst of cases. Even after sustaining multiple hits from large large-caliber weapons, HA can theoretically remain aloft for hours before forced landing (Figure 5). As a reference point, the only US airship lost in combat during World War II, "took three 88mm gun hits and 200 rounds of 20mm cannon fire from a submarine it was attacking before finally going down."[3] Second, unlike Hydrogen used in the early airships, the helium used today is non-flammable and actually acts as a fire-suppressant, so the envelope will not ignite when struck with a projectile.[4] Moreover, since propulsion systems aren't as critical for producing lift when compared to fixed and rotary wing platforms, their loss due to enemy engagement is less critical and the threat of fire would be mitigated by externally mounting the engines and the inclusion of standard fire suppression systems. Lastly, damaged subsystems that might lead to catastrophic vehicle loss such as fuel bladders, flight deck and cargo areas and flight controls could be hardened essentially without regard to additional weight penalties depending on vehicle size and additional lift capacity. HA could "easily carry an extensive set of defensive systems, such as missile countermeasures and even air-to-air missiles to defend against hostile aircraft…The cargo [and flight crew] compartments could be armored with materials that are too heavy or bulky for use on conventional aircraft."[5] In summary, while HA are more vulnerable to kinetic threats, it is essential to judiciously evaluate their robustness in the tactical environment—airships have demonstrated on numerous occasions the ability to withstand punishing engagements and continue to operate safely as long as critical systems can be protected. Moreover, HA would not be employed in any threat environment where legacy fixed and rotary wing transportation assets would be sent unless dictated by extreme contingency requirements. This is critical in lower threat sustainment scenarios where HA employment would release critical fixed/rotary wing assets for employment in higher threat areas or priority taskings.

WEATHER SURVIVABILITY

After a half-century of technological advancements, HA now also prove to be more robust when assessing the vehicle's potential weather survivability. As a military lift platform, HA would need to be capable of operating around the clock in all weather conditions. The common misperception that these vehicles cannot withstand environmental hazards as well as standard airlift platforms is simply misinformed. This fact was proven in 1957, when a non-rigid USN airship maintained a ten-day patrol off the northeast coast of New Jersey through snow, freezing rain, icing, sleet, fog and high surface winds when "all military and commercial aircraft were grounded due to severe weather."[6] Equipping HA with on-board, real-time weather monitoring and forecasting equipment and employing them under uniform, simple operating restrictions significantly increases weather survivability and is critical to ensuring mission success.

Historically, most large airships lost on the ground to weather were moored to a fixed position. While a seemingly logical decision, mooring or anchoring a large airship to the ground in a storm subjects the vehicle to immense structural loads, many times resulting in extensive damage, if not complete destruction.[7] However, advancements in global weather monitoring and forecasting capabilities have transformed most of these concerns into manageable responses.[8] HA survivability is highly dependent on accurate weather prediction and sound decision making. With precise and timely weather forecasting these vehicles would be evacuated or diverted in lieu of confronting severe weather at a ground or sea location—similar to current procedures for air and sea mobility assets.

Rain has little, if any, impact on operations while dry snow can be removed with high-speed taxi operations.[9] However, while on-ground icing would not destroy an airship, it would prohibit operations due to the logistics of de-icing, especially as vehicle size increases in medium and large sized airships. Therefore, similar to severe storm procedures, the vehicles would also be required to reposition off-station during icing conditions. Thus, like surface ships and aircraft, HA are safer off-station than “in port during a hurricane or heavy weather.”[10]

Similarly, when airborne, HA would maximize use of weather monitoring and real-time updates, along with sound operating procedures, to cope with different weather phenomena. “Sprint power is essential”—if thunderstorms are encountered enroute, HA speed will allow it to outmaneuver or outrun storm cells, which wasn’t possible in early airships.[11] In-flight icing impacts would be mitigated using anti-icing and de-icing equipment on critical propulsion and flight control components, similar to conventional airlift platforms. However, for envelope considerations, the weight of ice accumulation is a more critical problem than loss of lift. While options such as anti-adhesive coatings and internal shakers/heaters are being considered for envelope anti-icing, these are unproven technologies, making route planning and icing avoidance the key mitigation strategy for in-flight icing, while the vehicle is capable of safely exiting conditions for mission continuation if required.[12] The slower HA operating speeds make it vulnerable to the adverse impacts of strong headwinds, especially over long enroute distances. However, its operating efficiency allows operators to plan or redirect missions for favorable flight profiles based on optimal wind route analysis "so that significant deviation from the most direct route in pursuit of tailwinds can have a large benefit."[13]

In summary, while this is a small sampling of typical HA weather issues cited when abandoning the idea of using it for airlift, the vehicle is proving to be more viable than commonly thought. Its survivability is ultimately dependent on using modern weather monitoring and forecasting technologies along with sensible operating restrictions.

GROUND & TERMINAL OPERATIONS

Ground and terminal operations in austere land and sea environments form a third key operational challenge facing employment of HA for airlift. Airships used for ISR, weather monitoring and other military operations using stationary airships aren't plagued with the various problems that arise when attempting to use HA for transport operations. In order to fulfill their missions successfully, these vehicles must be able to maintain a fixed position during ground handling operations and safely launch and recover into both established and austere stations. There are many minor issues in this area that must be addressed operationally if the HA is further developed, but ground stability and arrival/departure safety are commonly cited by opponents as insurmountable obstacles for HA employment. Therefore, they are essential when considering potential HA airlift operations at this stage in conceptual development.

A number of problems require engineering attention when contemplating the dynamics of a medium-sized HA (approximately 400 feet long and 100 feet high) during ground operations. The biggest ground stability issue plaguing HA development thus far has been buoyancy management as cargo is on and off-loaded. However, the hybrid, heavier-than-air aspect of the vehicle mentioned prior has largely solved this problem in small to medium-sized vehicles. In fulfilling their role for PON delivery, these vehicles will be required to self-moor on any land or sea surface that is relatively flat, including conditions ranging from prepared asphalt to snow and ice. Thus, surface winds and their presupposed destabilizing impacts become a dangerous challenge during ground handling operations when any vertical or lateral movement could cause significant structural damage to ground equipment and the vehicle itself, or most importantly, injury or death to personnel performing ground duties. Many contend that while fixed and rotary wing aircraft may shift slightly during high cross winds, the immense sail area of a HA make it unacceptably vulnerable to significant movement if strong winds are encountered on the ground.

This assumption turns out to be somewhat misinformed when considering the advancements in technologies that would be employed by manufacturers if HA are constructed. The two common ground stability systems proposed for HA are fixed ground mooring masts and Air Cushion

Landing Systems (ACLS). Fixed ground mooring systems, while traditionally used for airship operations are expensive and defeat the purpose of employing HA in austere environments with minimal infrastructure. Therefore, the ACLS, a most promising and capable self-contained suction system, provides the best method for mooring a military HA and should be the standard in any future vehicle design. Using only slight suction pressure differentials that can be continually adjusted, these systems are capable of keeping HA in a static position on ground or water using surprisingly small power requirements. For example, engineering analyses have determined that an appropriately sized ACLS would keep a medium-sized airship in position during ground operations in cross winds up to 25 knots with less than a 0.5 psid suction pressure requirement.[14] Moreover, engineering analysis of a HA with a 550 ton payload (830 ft long and 250 ft high) revealed that "with ACLS suction active and friction associated with typical operation, the worst-case (0% heavy) [*cross*]wind limit is 15 knots…if the vehicle were to maintain its nose into the wind, that limit increases to 60 knots.[15] Thus, an enormous vehicle could potentially maintain position in sub-hurricane winds, at which point ground operations would have ceased and the consideration of ground stability would give way to serious risk of structural damage to the aircraft. Furthermore, assuming the HA is parked in an appropriately sized location, procedures would be implemented to continually rotate the vehicle in position if required to keep it "weathervaned" into the wind, thus allowing for continued ground operations in fairly substantial winds while always defaulting to vehicle evacuation if dangerous wind conditions are predicted—similar to current aircraft and ship procedures.

Even if HA are engineered to provide adequate stability during ground operations, it is equally important that they demonstrate the ability to safely arrive and depart from both fixed and austere locations—a requisite for the PON delivery capability that sets this vehicle apart. While HA do not need a fixed runway for takeoff and landing, a defined clearway with unobstructed ingress and egress routing is required for aerodynamic lift requirements. While water-based operations are less critical in this respect, forward delivery locations "may be located in mountainous, forested, heavily populated, or otherwise obstructed areas, where room to maneuver and unload…may be difficult to find."[16] Since airships are not constrained by conventional runway requirements and will always takeoff and land into a headwind, it is important to realize that there are essentially no crosswind issues that normally impact fixed-wing operations. During the arrival phase of flight, obstacle clearance and final landing maneuverability issues can be overcome with GPS-based approaches and proven thrust-vectoring technologies, thus necessitating a relatively small clearway for touchdown.[17]

The departure phase, especially when larger or loaded HA are examined, presents complex issues that must be fully considered. Critics commonly question "what happens when a 1,000 ton semi-rigid airship has an engine failure during takeoff?…while the take off speed may not be great, the inertial forces of such a mass would be prodigious."[18] Just as fixed and rotary wing vehicles are required to meet obstacle clearance requirements, procedures would have to be developed for HA to ensure safe flight operations. It is important to understand that a number of physical forces interact when assessing HA departure capability—VTOL/STOL capability, buoyancy, aero lift and immense inertial forces are only a few that present significant complications. However, due to advances in propulsion systems and the immense lifting force provided by buoyant gases, HA climb capability appears to be far better than commonly assumed. Industry engineers maintain that small to medium payload vehicles (20-80 ton cargo capacity) will require a takeoff ground run only one to three times the length of the vehicle (roughly 1000-1500 feet) to meet current obstacle clearance standards.[19] Preliminary analysis demonstrates that even a 1,000 ton payload HA, which is still more than a decade away technologically, would require a 10,000 foot clearway to depart in the worst environmental conditions fully loaded (Figure 7).[20] Lastly, in a critical obstacle clearance situation, the HA's minimal turn radius and buoyant lift capability would allow it to essentially spiral up in within a small lateral area to a minimum safe enroute altitude if necessary.

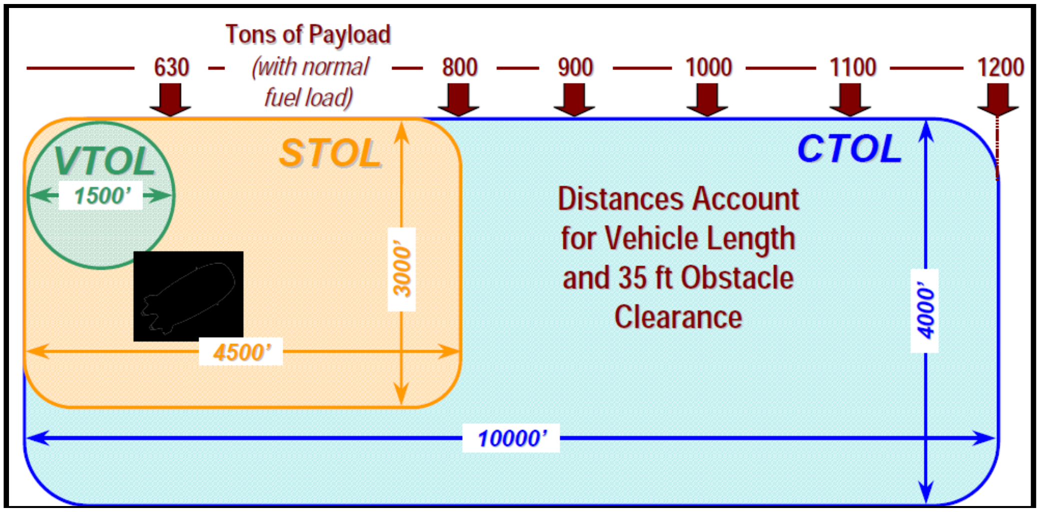

Figure 6. Large HA Takeoff/Landing Clearway Requirements. (Reprinted from Camber Corporation and SkyCat Technologies, Inc., "SkyCat 1000 Engineering Study: Final Report." Prepared for US Department of Defense, Joint Chiefs of Staff/J4 and US Army Deputy Assistant Secretary for Research and Technology, undated. Information used with permission from US Department of Defense, Joint Chiefs of Staff/J4 Logistics Directorate Analysis & Resource Division. Page 37.)

Therefore, while HA arrival and departure obstacle clearance procedures would have to be further developed, especially when considering employment in austere environments, notional engineering studies have concluded that these vehicles will be able to meet or exceed required obstacle gradients, even with malfunctions or emergencies involving loss of propulsion systems. Buoyancy characteristics and vectored propulsion systems provide capabilities that differ from legacy airlift platforms and can overcome wind and inertia issues that threaten operations during these critical phases of flight.

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[1] Gordon and Holland, *Back to the Future*, 56.
[2] Ibid., 56.
[3] Ryan, *The Airship's Potential for Intratheater and Intertheater Airlift*, 58.
[4] Boyd, interview (31 August 2011).
[5] CBO, *Options for Strategic Military Transportation Systems*, 39.
[6] Grossnick, *Kite Balloons to Airships*, 71.
[7] Boyd, interview (31 August 2011)
[8] Camber Corporation, "SkyCat 1000 Engineering Study: Final Report," 4.
[9] Boyd, interview (31 August 2011)
[10] Shaughnessy, "Navy is changing the way it prepares for storms."
[11] RAND, *High Altitude Airships for the Future Force Army*, 32.
[12] Boyd to author, email, 23 September 2011.

[13] Gordon and Holland, *Back to the Future*, 55.
[14] Jones to author, email, 16 November 2011.
[15] Camber Corporation, "SkyCat 1000 Engineering Study: Final Report," 107.
[16] Ibid., 59.
[17] Boyd, interview (31 August 2011).
[18] Bolkcom, *Potential Military Use of Airships and Aerostats*, 6.
[19] Boyd, interview (31 August 2011).
[20] Camber Corporation, "SkyCat 1000 Engineering Study: Final Report," 37.

RECOMMENDATIONS

Clearly understanding the HA's unique operational characteristics and visualizing its employment as a distinct transportation mode reveal that it has potential to fill the critical transportation cost/speed gap and increases lift options across the range of military operations—from humanitarian assistance to combat employment. Once the concept is judiciously examined, the DoD should consider means to procure the platforms organically or incentivize industry partners to acquire the assets for commercial use and military employment under a Civil Reserve Air Fleet (CRAF)-type construct, whereas commercial users would own/operate the vehicles and augment the DoD organic lift fleet when needed during peacetime and contingency operations.

A significant difference between HA and traditional military lift vehicles is commercial practicability. While military variants might include defensive systems and other items or redundancies to meet military specifications, the principle platform, from small to large variants, are being considered for a range of commercial lift requirements. The vehicle has the potential to meet the critical needs of energy and mining logistics operations in the austere locations of far northern Canada, the Arctic, and Africa. Unfortunately, the commercial demands of this niche market will not induce the funding necessary for aerospace companies to design and develop a cargo HA without a clear demand signal and investment from potential military or other government users.[1] For this reason, it is critical for the DoD to engage with industry to complete risk-reduction analysis and insist on cost-sharing arrangements for future HA development and production. The success of the military and industry "are now mutually related, perhaps more than they have ever been, and especially with the ongoing convergence of fiscal pressures and strategic uncertainty."[2]

With pending budget constraints, once the platform is developed and produced for commercial use, the DoD must consider HA employment under a CRAF-type construct. This gives the nation access to these critical assets when necessary, while cost-sharing initial design and development efforts with commercial partners.

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[1] FDDA, 2-6.
[2] Schwartz, "2011 AFA Address."

CONCLUSIONS

In order to meet global mobility requirements in the future joint operating environment under constrained budgets, senior military leaders must pragmatically assess the capabilities and liabilities of hybrid airships for lift. Realistically assessing the vehicle's operational capabilities and challenges in the future joint operating environment requires personnel to examine the HA through the appropriate framework—a distinct mode of transportation that can significantly enhance the distribution network. This framework must be properly constructed through an honest examination of airship successes throughout history in dynamic military environments, as well as achieving a working knowledge of the capabilities and operational concepts that set it apart from legacy lift platforms. When assessing the vehicle in this light, along with significant technological leaps in all aspects of HA, the platforms might be seen as viable lift options to fill the current cost/speed gap in the distribution system.

Once the importance if examining the HA through a new paradigm is recognized, its key operational challenges of survivability and ground/terminal operations can be reasonably evaluated for further development options. Engineering analyses prove that these vehicles are far more robust in threat and severe weather environments than commonly assumed. As long as the vehicles are employed in the same environments as current airlift platforms and practical threat and weather avoidance/evacuation procedures are employed, HA will demonstrate equitable mission success in filling the cost/speed gap.

Hybrid airship concepts present the DoD with incredible capabilities for future joint logistics at a critical time in US history. HA technology continues to mature, giving the military and its commercial partners a solution for tactical and strategic delivery to PON locations without regard to intermodal infrastructure or destination austerity. HA engineering and operational technologies are mature--it is now a viable lift option and the military must partner with industry to fund and develop the HA to meet future requirements. While procurement for an organic fleet may not be fiscally or operationally realistic, vehicle development for a CRAF-type system allows the DoD to leverage this tremendous capability when needed, while negating the associated costs of operating and maintaining an organic fleet when traditional lift platforms can meet steady-state requirements. While commonly dismissed as a feasible lift option for a number of flawed or misinformed reasons, HA should be strongly and rationally considered for use in the future joint transportation distribution system.

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