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TECHNICAL REPORT

High-Altitude Airships for the Future Force Army

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Summary

Across the services, there is an increasing demand for overhead communications capacity. For the U.S. Army, this is a result of its transition to a new force structure that will be knowledge-based and network-centric. Future forces may be more dispersed. Extending their range of communication will be key. Messages will have to be relayed through a multilayered network of terrestrial-, air-, and space-based retransmission nodes. Currently, satellite communications (SATCOM) is being relied on to connect distant units, hopefully in an assured manner.¹ However, the exclusive use of military or commercial SATCOM may not be available to meet all of the Army's connectivity needs, and high-altitude airships (HAAs) are being considered as an optional surrogate, which could be even more cost-effective if proved technically feasible.

New, lighter-than-air (LTA) vehicles that operate at very high altitudes have an obvious attraction for planners of surveillance and communication missions; the ability to see to a more distant horizon results in greatly expanded surveillance volumes (assuming that appropriately powerful sensors are carried onboard). Low probability of intercept (LPI) direct line-of-sight communications will also increase their reach.

In recent years, increased emphasis has been placed on systems that can provide extended surveillance and communications support at such high altitudes. These are generically known as High Altitude Long Endurance (HALE) systems or High Altitude Long Loiter (HALL) systems. The Global Hawk unmanned aerial vehicle (UAV) was perhaps the first of these systems to achieve operational success. Flight at high altitude (say, over 60,000 feet) for extended periods (for a matter of days or more) is an extreme technical challenge for fixed-wing aircraft.

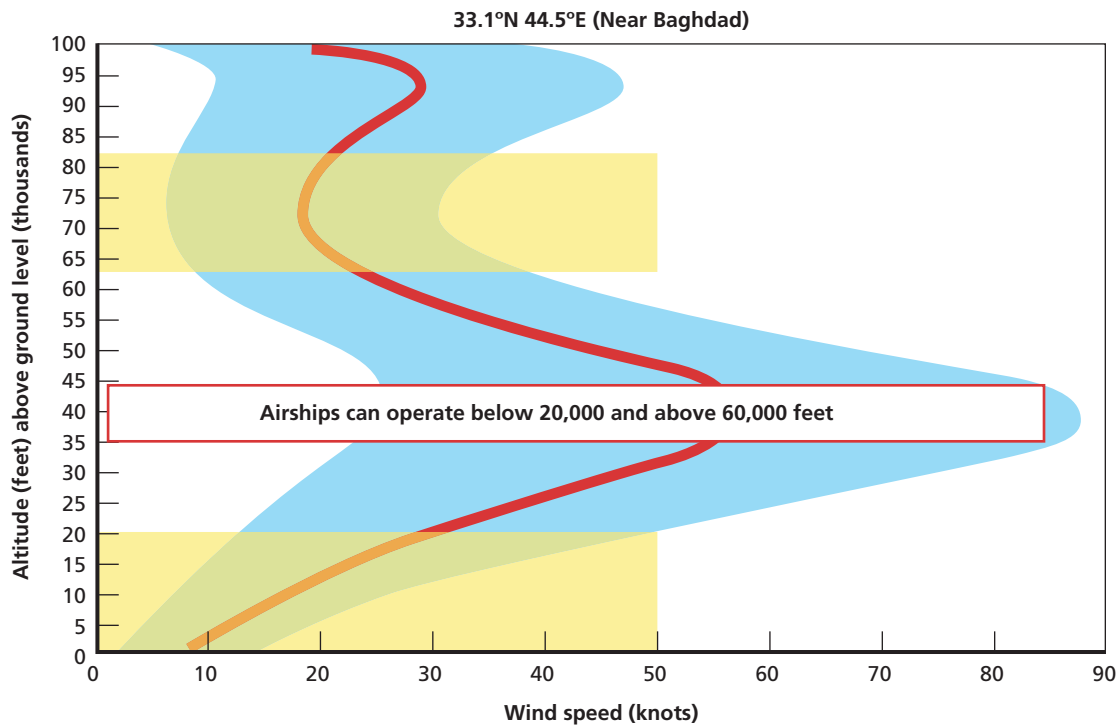
In recognition of this fact, advocates of LTA systems have pointed out that systems relying upon aerostatic (buoyant) lift avoid many of the design difficulties associated with fixed-wing aircraft. High-altitude scientific balloons represent an existence proof of sorts, regularly operating far above the altitudes achievable by airplanes. On the other hand, LTA systems introduce their own set of unique technological and operational difficulties. Worse, many of these difficulties fall into the category of "unknown unknowns"—hence, the role of demonstrators (and in particular, operational trials of such demonstrators) is unusually critical. The purpose of this report is to examine both the potential benefits and the unique risks associated with the design and operation of HAAs, i.e., those intended to fly above 65,000

¹ A SATCOM link that enables a simple connection (e.g., single hop) increases the probability of assured receipt and reduces the opportunities for signal intercept and interference.

feet.² This is an altitude that has been proposed to facilitate solar-powered station-keeping, which requires a fairly benign environment. There is a sweet spot where wind and turbulence are minimal. It is an area of the atmosphere³ that is above the jet stream⁴ and below the upper layers of the stratosphere (between 20 and 30 km). Figure S.1 shows a profile of peak wind speeds near Baghdad. This figure indicates that most weather occurs in the troposphere.⁵

Many organizations around the world, commercial and military, are interested in HAAs. Design efforts and prototype builds are in progress. Three U.S. combatant commanders are also interested in using HAAs in their overseas theaters for communications and surveillance.⁶

Figure S.1
Annual Winds Aloft Near Baghdad



NOTE: Summary product created from raw weather data collections provided by AFCCC/DOPT (Asheville, North Carolina) dated from 1958 through 1990.

SOURCE: Stephen Huett, Director, Advanced Development Program Office for Airship Concepts, Naval Air Systems Command, "Current State-of-the-Art for LTA Systems," briefing, January 2005. Used with permission.

² But well below 350,000 feet.

³ Wind speed is different at different heights.

⁴ The jet stream can exist between 25,000 feet and 40,000 feet (7.6 to 12 km) with winds that can exceed 130 knots.

⁵ The actual "boundary" of the troposphere varies with season and latitude. For example, in the tropics, thunderstorms have been known to rise to 50,000 feet.

⁶ Central Command (CENTCOM), Pacific Command (PACOM), and United States Force Korea (USFK) seek HAAs for a variety of tasks.

Now, with efforts to expand commercial high-bandwidth data services (particularly the “last mile” to the consumer) and the high cost of using satellites for that purpose, manufacturers are proposing high-altitude platforms (HAPs, including fixed-wing aircraft and HAAs) to serve as surrogate satellites at a presumably reduced cost.

Potential Benefits

Communication and surveillance capabilities could considerably improve force performance in a theater battlespace with the successful introduction of airships. Airships can function as surrogate satellites but offer the advantages over satellites of shorter transmission distances for relaying ground-based communications and shorter ranges for sensor surveillance of the battlefield and acquisition of ground targets.

Potentially, airships may provide communications satellite capabilities for the Warfighter Information Network–Tactical (WIN-T) network at less expense than satellites. An HAA communications platform could be a strong addition to the Multi-Sensor Command and Control Constellation (MC2C).⁷

Persistent surveillance from a fixed position is an important need that HAAs can meet. Over time, they can facilitate continuous collection and comparison analysis of terrain covered by different sensors, such as infrared (IR), electro-optical (EO), and hyper-spectral imagery (HSI). Comparisons can highlight changes, such as freshly turned dirt along a roadway where bombs have been emplaced, and the fusion of data from multiple sensors may furnish tracking data on targets under foliage.

Combatant commanders in a crisis situation may wish to use HAAs as soon as possible, but deployment times have to be considered. An HAA may take days to reach a distant theater after launching. For example, a deployment from the Las Vegas, Nevada area to a geostation near Baku, Azerbaijan at an airship airspeed of 30 knots (kt), with no favorable winds, would take eight and a half days by a great circle route in the summer, and ten days, via the 45° north latitude, during the winter.

Limitations and Vulnerabilities

The HAA Advanced Concept Technology Demonstration (ACTD) program documentation summarizes the effort as having “some technical risk” but “enormous potential benefits.” It also includes the acknowledgment that “HAA is a fast-paced program.” Against these statements, it is critical to note the following sobering point: this program is attempting to design and fly an unmanned airship that is orders of magnitude larger (in terms of volume) than any other previously attempted. There is substantial uncertainty surrounding all aspects of vehicle performance and control at this scale.

⁷ Quoting from the GlobalSecurity.org web site (<http://www.globalsecurity.org/intell/systems/mc2c.htm>): “The Multi-Sensor Command and Control Constellation is a future ‘constellation’ of air and space command and control, intelligence, surveillance and reconnaissance capabilities—consisting of space-based systems, unmanned aerial vehicles, ground stations, and possibly a new multi-sensor command and control aircraft to replace the existing array of command and control (C2) intelligence, surveillance, reconnaissance (C2ISR) aircraft.”

Specific areas of technical risk are shown in Table S.1, based on a review of contractor design data, a review of LTA technical literature, and the experience of the authors with prior HALE UAV and LTA programs. There is a very tight interaction between technical risk and operational utility. Many risk areas can be lowered by restricting the use of the airship in adverse conditions, by accepting reduced performance, or by providing extra airships to relieve those that are on-station when environmental conditions warrant. These risks may not be manageable. In fact, there are recent assessments (Siomacco, 2005) suggesting that technical risks are too high for even proceeding with the HAA ACTD. Furthermore, there will likely be additional risks that are unpredictable and can result in catastrophic and unexpected system failure. These risks stem from the stochastic nature of the environment in which the vehicle operates: the effects of weather and particularly (in the case of an airship) wind.

Many of the risks depicted in Table S.1 can be lowered by operational restriction. However, envelope strength, weatherability, and launch and recovery all interact and are problematic in the sense that conditions will arise that are not forecast.⁸ When this occurs, it will be of little solace that such conditions were beyond those exercised in the ACTD plan. The vehicle will be lost.⁹

A review of operational experience with existing commercial airships, coupled with prior airship operations in the U.S. Navy (and interviews by Naval Airship program office personnel with then-surviving airship pilots) resulted in the following principles that can be applied to HAA design with a corresponding increase in operational robustness.

Table S.1
HAA Issues and Risks

Issues	Risk Management Approach
Envelope material (strength and weight)	Restrict ascent/descent conditions
Thermal control (superheat)	Incorporate reflective envelope
Helium leakage	Limit endurance; use hydrogen from fuel cells
Photovoltaic cells	Limit endurance
Fuel cells	Use Li-polymer batteries as fallback
Weatherability	Restrict ascent/descent conditions; improve weather prediction; provide emergency ballast dump; add sprint engine(s)
Survivability	Operate within own air defense envelope
Airspace access	Restrict ascent/descent locations and times
Launch/recovery	Mechanization; restrict ascent/descent locations/times

⁸ Historically, this has been a major cause of loss of the surveillance aerostats on the U.S. southern border: thunderstorms bear down on the sites before the aerostats can be fully winched down.

⁹ This was a fallacy realized early in the Naval Airship program. Contractors would design to “10 percent wind exceedance curves” (because, for example, a 1 percent exceedance curve would require truly prodigious amounts of propulsive power). Yet this implied that 10 percent of the time, the airship would either be held on the mooring mast, if lucky, or blown out to sea; an unacceptable result.

1. “Sprint power” is essential.
2. Immediately disposable ballast is essential to allow instant recovery from difficulties during ground handling.
3. Immediately disposable lift is essential to allow the airship to collapse to the ground in the event of difficulties.

Airships will be vulnerable to air defenses. Air superiority will be a prerequisite for airship operations near enemy-held areas. Complete destruction of long-range ground-to-air missile units will probably be necessary before the full communications and surveillance strengths of airship payloads can be realized. With that accomplished, however, the airships’ ability to rise to heights above the ranges of most air defense weapons and to operate in a benign high-altitude environment should allow these platforms to survive theater operations.

Detecting a stationary platform that may have a very small radar and thermal cross section will be a challenge for any air defense system. Firm conclusions about the vulnerability of HAAs to air defenses will have to await knowledge about the ultimate composition of HAA structures.

Weather will be a risk factor that could be significant if airships are not furnished with reliable sensors for on-site meteorological data by which airship controllers can predict turbulence, icing, and violent gusts that can jeopardize the craft. The experience with high-altitude tropospheric operations from around-the-world balloonist teams and weather teams must be collected and codified to aid computer predictions at higher altitudes. This aspect of airship operations will take strong preparation and close attention during operations.

An airship will be in the troposphere for over five hours while descending¹⁰ to its home mooring base. The conditions in 65,000 feet of airspace at a home location will have to be within allowable weather parameters before a letdown can commence. This requirement could cause an airship to hold at 65,000 feet for up to two to five days before descending. Launch operations could cause similar time delays, although the ascent should be at a faster 1,000 feet per minute or 65 minutes long. Operational planning may have to allow days of nonproductive time in an airship rotation schedule for an ongoing operation.

Beyond proving the physical feasibility of using HAAs for communications relays, surveillance, and other tasks, a major feasibility challenge for military acquisition of HAAs is the issue of funding. A number of commercial uses for lower-altitude airships have been proposed. Scientists and entrepreneurs in the United Kingdom have been examining the usefulness of HAPs, either airships or airplanes, to serve as fixed, wireless communications and television relays over urban areas.¹¹ Potential military users will prefer to share development and production costs with civilian users and, in fact, may insist on a cost-sharing arrangement before contracting for HAAs, as has happened with low-altitude, heavy-lift airships.

¹⁰ The HAA ACTD airship will descend at about 200 feet per minute.

¹¹ Commercial HAAs would most likely be solar powered with fuel cell storage. Successful demonstrations of high-altitude operations, solar cells, and fuel cells are needed before serious commercial funding can be anticipated (Tozer and Grace, 2001).

Suggested Actions

In view of the above airship capabilities and limitations in the near term, the U.S. Army should:

- Closely monitor the development and testing of HAA prototypes in combination with the Missile Defense Agency, U.S. Navy, U.S. Air Force, and U.S. Coast Guard while continuing to pursue detailed technical and operational analysis of high-altitude airships.
- Ensure that the major limiting factors for HAA development are among the Army's science and technology objectives for development by the Army research and development community.
- Recognize that an operationally useful HAA would most likely incorporate features that are not included in the HAA ACTD, which is being designed for the particular requirements of an ACTD demonstration. This would have the effect, all else equal, of reducing the operational ceiling, endurance, and/or payload of any production HAA.

In the longer run, if the HAA ACTD proves successful, the U.S. Army should:

- Join in efforts to interest potential commercial users of HAAs or HAPs and include them in development discussions.
- Conduct computer analyses of the potential value of HAA communications and surveillance payload capabilities to force-on-force operations in various scenarios but taking into consideration the likelihood of reduced ceiling, endurance, or payload relative to the HAA ACTD, as above.
- Consider basing HAAs in sparsely populated desert or island locations in latitudes of less than 38° to provide adequate sunlight and the best possible weather and security environment.
- Emphasize weather analysis in planning HAA routes and airborne control operations.
- Consider co-locating HAA control facilities with the control facilities of military satellites and Global Hawk to utilize existing command and control communications facilities and surveillance control and exploitation systems.
- Understand and exploit the Air Force's efforts to protect aircraft from attack by missiles, specifically, the efforts to improve and employ the ALQ-214 IDECM RFCM suite¹² on aircraft to detect and counter surface-to-air and air-to-air RF/IR/EO missiles.

Alternatively, if the HAA ACTD does not prove successful, and/or the financial constraints preclude adoption of fully maneuverable high-altitude airships, the U.S. Army should consider the options it has with respect to other types of balloons (free floaters and semi-steered balloons); these (possibly) cheaper and smaller balloons could serve as disposable

¹² Quoting the web site of ITT Industries' Avionics Division (<http://www.ittavionics.com/214.asp>): "The ALQ-214 Integrated Defensive Electronic Countermeasures (IDECM) RFCM [radio frequency countermeasure] system is comprised of an on-board technique generator developed by ITT Industries integrated with an off-board fiber optic towed decoy that its developers claim will provide self-protection capabilities [for vulnerable aircraft]."

assets that could be employed in large numbers; they would not be stationary, however, and would not be able to carry the large mission packages envisioned for HAAs.