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Recent Development Efforts for Military Airships

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Notes and Definitions

The cover shows a U.S. Navy MZ-3A manned airship landing at Lake Front Airport, New Orleans, Louisiana, to provide support for the Deepwater Unified Command and the Gulf of Mexico oil spill. Photo by Mass Communication Specialist 2nd Class Andrew Geraci.

Aerostat: A tethered, unmanned airship.

Airlift: The transportation of people, equipment, or other cargo by air.

Airship: An aircraft that obtains buoyant lift from a contained volume of helium or other gas that is less dense than the surrounding air. Also referred to as a lighter-than-air vehicle.

Conventional Aircraft: An aircraft that does not rely on buoyant lift to achieve flight. In this document the term includes fixed-wing aircraft, tilt-rotor aircraft, and helicopters.

Conventional Airship: An airship that uses only buoyant lift to achieve flight.

Envelope: The external structure of an airship within which the helium or other buoyant gas is located. There are three categories of envelopes: rigid, semirigid and nonrigid. Rigid envelopes use an internal frame to keep their shape. Semirigid envelopes use a "keel" along the bottom of the envelope to distribute weight. Nonrigid envelopes have no frame and use only gas and envelope design to keep their shape.

Hybrid Airship: An airship that uses a combination of buoyant lift from helium, aerodynamic lift from the shape of the envelope, and variable-direction thrust (more commonly called vectored thrust) to stay aloft.

Intelligence, Surveillance, and Reconnaissance (ISR): Reconnaissance operations observe an area to collect information. Surveillance is the systematic observation of a particular area. Intelligence is the product of surveillance and reconnaissance once the information from those operations has been analyzed and evaluated.

Orbit: In this document, orbit refers to the region in the sky in which an aircraft operates while it is observing the activities below. In military parlance, an aircraft orbit is often called a combat air patrol, or CAP.

Payload-duration: Payload-duration is the weight (payload) that could be carried to a location multiplied by the amount of time it could remain there (duration).

Preface

Airships—also known as lighter-than-air vehicles—have been proposed as alternatives to some of the aircraft the Department of Defense uses today for two types of missions: intelligence, surveillance, and reconnaissance; and airlift. The unique characteristics of airships offer some advantages and disadvantages for those missions relative to aircraft currently in the fleet.

At the request of the Chairman of the Senate Armed Services Committee, the Congressional Budget Office (CBO) examined the Department of Defense's plans and proposals for airships. In keeping with CBO's mandate to provide objective, impartial analysis, this study makes no recommendations.

Alec Johnson, formerly of CBO's National Security Division, prepared the document, with assistance from David Arthur, under the general supervision of David Mosher. The line drawings of airships were done by Bernard Kempinski. Charles Whalen of CBO provided helpful comments on the report, as did Mark T. Lewellyn of the Johns Hopkins University Applied Physics Laboratory. The assistance of an external reviewer implies no responsibility for the final product, which rests solely with CBO.

Jeanine Rees and John Skeen edited the document. Maureen Costantino and Jeanine Rees prepared the study for publication, and Maureen Costantino designed the cover. Monte Ruffin printed the initial copies, and Linda Schimmel coordinated the print distribution. This publication is available on CBO's Web site (www.cbo.gov).

Douglas W. Elmendorf
Director

November 2011

List of Exhibits

Recent Development Efforts for Military Airships

During the past decade's operations in Afghanistan and Iraq, the U.S. military has come to rely heavily on the continuous or nearly continuous presence overhead of both manned and unmanned aircraft to support ground troops. Unmanned aircraft that remain aloft in particular locations (or "orbits") have been primarily used to provide timely information about activities on the ground and to attack ground targets on short notice. Most prominent among these aircraft are the Department of Defense's (DoD's) fleets of unmanned Predators, Reapers, and Global Hawks; however, satellites and manned conventional aircraft, including fighters and long-range bombers, have also contributed.

The demand for those so-called "persistent" or "loitering" missions has led the Air Force to substantially enlarge its fleet of unmanned aircraft, and the Army, Navy, and Marine Corps to field or plan to field similar aircraft to provide intelligence, surveillance, and reconnaissance (ISR) and light-attack capabilities of their own.[1] Unmanned aircraft are particularly attractive for such missions because they can be designed to provide durations beyond the physical endurance of human air crews and because they do not put humans at risk during operations in potentially hostile airspace.

1. See Congressional Budget Office, *Policy Options for Unmanned Aircraft Systems* (June 2011).

In light of the demand for aircraft capable of remaining aloft for long periods of time, considerable interest in airships as alternatives to conventional aircraft exists. Although unmanned airships are unproven, they have the potential to remain in the air for long periods—providing mission durations that are many times longer than would be practical for conventional aircraft. Consequently, the military services are exploring a variety of designs for unmanned airships capable of carrying ISR sensors.

The technology needed to field airships for ISR could also be applied to airships meant for airlift—that is, for the transportation of people, equipment, or other cargo. Whether airships designed to carry cargo would be manned or unmanned would depend on the specific missions they performed. Although the military services' investment in developing airships for airlift has been limited, several private companies are exploring potential designs or are in the process of building prototypes.

In this document, the Congressional Budget Office (CBO) examines the potential capabilities of airships for ISR and airlift missions. In brief, CBO finds that:

- If the speed, payload, and endurance proposed for unmanned airships can be achieved, the resulting craft could serve effectively in the ISR and airlift roles;
- Airships' performance characteristics would provide some advantages and suffer from some disadvantages relative to those of the conventional aircraft currently used for ISR and airlift missions; and
- Airships would present new operational challenges such as greater sensitivity to weather conditions and the need to provide unique types of maintenance and support.

Because the development of the technology needed for modern military airships is at an early stage, in most cases cost estimates would be highly speculative; therefore, CBO does not examine the costs of airships here. Although CBO does compare the capabilities of airships to those of other aircraft, assessing cost-effectiveness would require analyzing costs as various technologies mature.

Background

Airships were among the first aircraft to see useful military service. German Navy airships were flying maritime patrol missions as early as 1914, and the first zeppelin bombing raids on Great Britain were staged in early 1915. Beginning in 1917, the U.S.

Navy operated a variety of airships for maritime patrol and fleet reconnaissance. The best known of those were the large rigid-framed airships—such as the U.S.S. *Shenandoah* and the U.S.S. *Akron*—built in the 1920s and early 1930s. In commercial service, airships were used for the first regularly scheduled passenger flights across the Atlantic in the early 1930s, several years before fixed-wing aircraft.

Airships were attractive during the early days of military aviation because, with buoyancy provided by hydrogen or helium, the engines needed only enough power to move the aircraft at relatively low speed, and airframes needed only enough strength to support their own weight and to withstand the relatively mild stresses associated with low-speed flight. Fixed-wing aircraft, in contrast, required stronger airframe structures and more powerful and reliable engines because their lift is derived from pushing wings through the air at high speed. Rapid improvements in airframe design, airframe materials technology, and aircraft engines during World War II largely overcame the shortcomings of fixed-wing aircraft. Moreover, improvements in antiaircraft weapons during and after the war led military planners to conclude later that airships would be too slow and too vulnerable to attack from the ground, particularly when facing a technologically capable adversary such as the Soviet Union. Therefore, interest in airships waned.

The end of the Cold War, however, ushered in an era in which operations against less capable adversaries have been more common. In Iraq and Afghanistan during the past decade, for example, air defenses have been essentially nonexistent, allowing aircraft with limited self-defense features—in particular, the fixed-wing MQ-1 Predator and MQ-9 Reaper unmanned aircraft—to operate effectively in nearly uninterrupted flights over unsecured territory. The nature of the conflicts in those countries and elsewhere has placed an emphasis on persistently remaining aloft to provide ISR and limited missile attacks against ground targets. The Department of Defense is exploring the use of airships for long-endurance missions such as those.[2] Although DoD's current focus is on airships for ISR, there have been proposals for equipping airships with weapons as well.

Using airships for airlift has also periodically stirred interest in military circles. In particular, concern arose during the 1990s that rapid deployments by air, like those to the large airbases in Saudi Arabia during the first Iraq war, would not be possible in a future conflict if such airbases were not available. Transport airships capable of landing in any suitably large open area, proponents argued, could reduce the military's dependence on overseas bases. Although advocates of airships suggested designs capable of carrying payloads many times larger than those of the largest fixed-wing aircraft, work on such aircraft did not progress much past paper designs or small-scale demonstration vehicles.

Modern airships and aerostats (tethered airships usually limited to altitudes of about 1,000 feet) derive some or all of their lift from the buoyancy of helium gas contained within their external structure, or envelope. There are three categories of envelope: rigid, semirigid and nonrigid. Rigid envelopes use an internal frame to keep their shape; early airships such as the German zeppelins had rigid envelopes. Semirigid envelopes use a keel along the bottom of the envelope to distribute weight. Nonrigid airships have no frame and use only gas and envelope design to keep their shape. The blimps frequently present above large sporting events are usually nonrigid airships. Unlike many early airships, which had a significant risk of catching fire because they used a flammable gas in their envelopes (hydrogen), modern airships almost exclusively use helium gas, which cannot catch fire. (But even helium-filled airships face the risk of being lost to fire if other components such as fuel burn.)

Conventional airships, whether rigid, semirigid, or nonrigid, achieve flight from the buoyancy of helium alone. "Hybrid" airships, a more recent innovation, use a combination of buoyant lift from helium, aerodynamic lift from the shape of the envelope, and variable-direction thrust (more commonly called vectored thrust) to stay aloft. The combination of three different forms of lift allows hybrid airships to carry heavier loads (larger payloads) for a given volume of helium and also provides a greater ability to control upward forces

2. Of course, circumstances will not always permit those types of missions. In the 1991 Iraq war and in operations over the former Yugoslavia later in the 1990s, for example, it was possible to attack or otherwise suppress air defenses to the point at which fighters and bombers could operate in relative safety. However, the suppression of air defenses in those conflicts was probably insufficient to allow aircraft such as Predators or airships to orbit continuously overhead.

on the aircraft than is the case with conventional airships that rely on buoyancy alone.

Today, the Navy is using a conventional, nonrigid airship—the MZ-3A—to experiment with potential airship payloads and explore how airships might be used in actual operations. The Army, Air Force, and the Defense Advanced Research Projects Agency (DARPA) are working on designs for other airships, with a primary focus on unmanned craft for ISR. Other organizations within DoD—for example, the Missile Defense Agency and the Joint Improvised Explosive Device Defeat Organization—have made investments in airship technologies as well. Over the past two years alone, DoD has funded more than $500 million for projects related to lighter-than-air platforms, and additional spending is planned for the future.

Other government agencies such as the Department of Homeland Security and the National Aeronautics and Space Administration also have explored or are exploring potential designs and uses for airships, albeit at lower funding levels than DoD. Additionally, several privately funded development efforts are under way that could yield airship designs suitable for adoption by DoD.

Intelligence, Surveillance and Reconnaissance (ISR)

The ISR missions of the type common in Afghanistan and Iraq have been characterized by the desire for nearly continuous aerial presence, the need for only modest payloads to accommodate the appropriate sensor packages, and nearly or totally absent air defenses. Under such circumstances, the performance characteristics of airships offer some significant advantages but also have various disadvantages when compared with those of the fixed-wing aircraft and space satellites that the Department of Defense currently uses to meet its needs for aerial ISR.

Performance of Airships Relative to Other Aircraft

Unmanned airships have the potential to perform ISR tasks with greater efficiency than conventional unmanned aircraft systems. Because unmanned airships could remain aloft for much longer periods than conventional aircraft, maintaining continuous ISR orbits with a smaller number of aircraft might be possible. Airships may also offer greater basing flexibility than conventional aircraft because airships could operate without the need for a long runway. However, airships would probably offer less flexibility to operate in poor weather conditions. High winds can make airships difficult to control, especially when near the ground, and the increased fuel consumption that would be needed to remain over one area in the face of high winds could significantly reduce an airship's time on station.

Like other unmanned aircraft besides stealth ones, ISR airships would probably be primarily used in secure airspace. If, however, airships encountered air defenses, their survival would depend on the specific circumstances of the engagement. Relative to a fixed-wing aircraft such as the RQ-4 Global Hawk, airships operating at high altitude (around 60,000 feet or higher) could be more difficult to detect by adversaries looking for acoustic, thermal, or radar reflections because they could be designed to be quiet and cool and, in some designs, have a structure made of radar-absorbent materials or little rigid structure for radar to detect. They would also be out of range for most surface-to-air missiles or guns. In contrast, airships operating at low altitudes would probably be easier to detect than conventional aircraft at similar altitudes because of their lower speed and much larger size. Once detected, those airships might be easier to hit with ground fire than smaller, faster conventional aircraft, but they might prove to better withstand damage. For example, the low speed of airships makes them less susceptible to the dynamic stresses that can cause conventional aircraft to break up in flight when damaged, and because the gas envelopes rely on just a slightly higher pressure than the ambient atmosphere, helium leaks slowly out of holes that are not too large.

Because airships sacrifice speed in exchange for endurance relative to fixed-wing aircraft, they might offer less flexibility to quickly shift the location of ISR orbits in response to changing circumstances on the ground. Similarly, if air defense threats materialized in a previously benign environment, airships would need more time to exit the area and reach safe airspace. Slower speeds could also reduce search rates for missions that need to cover very large areas. (All else being equal, search rate—the area covered in a given period of time that is theoretically defined as the product of the aircraft's speed and the sensor's detection range to either side of the flight path—is lower for lower speeds.) Such a limitation, however, would be less significant for missions calling for close observation of smaller areas.

Performance of Airships Relative to Satellites

Airships can employ much less sophisticated and less costly sensors than satellites use. Because airships operate at a much lower altitude, they can employ smaller, less sensitive antennas for detecting electronic emissions and smaller, less capable optics for a given image resolution. Also, sensors for use on airships would not need to operate for their entire lives without maintenance or repair, as satellite sensors must. Moreover, satellites are limited to the sensors that they are carrying when they are launched, but the type of sensor carried by an airship could be selected on a mission-by-mission basis, and improved sensors could be used as they became available.

Airships can be continuously located wherever ISR is needed (subject to the constraints of weather, air defenses, and otherwise restricted airspace), while satellite observations are limited to when orbits pass overhead. Satellites, however, have the advantage of a very large field of view because of their great distance above the ground. Additionally, although satellites fly in predictable Earth orbits that can be easy to track, they are very difficult to attack. Also, satellites are free of airspace restrictions.

Other Factors

Advances in airship technology have not been tested in actual operations, and considerable risks remain for modern airships relative to conventional unmanned aircraft systems. Many of the technologies needed for critical systems—propulsion and power, fabric for airship envelopes, flight control systems, and sensors able to operate for weeks or months without maintenance—are in the early stages of development. Furthermore, the military has little contemporary experience in airship operation, maintenance, and support. Concerns include storage of the gas needed to fill airships; storage of the vehicles themselves; maintenance of the vast areas of fabric from which airships' envelopes are constructed; and safe ground maneuvering, especially in the presence of winds.

Cost is another crucial issue. Some proponents have asserted that airships could cost less to purchase and operate than satellites or other aircraft. Those advocates cite, for example, the significantly lower fuel consumption of airships relative to fixed-wing aircraft. The costs of airships remain unknown, however, because technology is at an early stage of development and the details of purchases, operation, maintenance, and support are yet to be determined. For example, the cost of obtaining large volumes of helium and the equipment needed to store and distribute it to combat theaters around the world is unclear.[3] Because of such uncertainty, cost estimates would be highly speculative. In this document, therefore, CBO does not examine the costs of airships relative to other types of aircraft and satellites.

Airlift

Although most current interest in airships is in ISR platforms, airships could also be developed to move cargo—equipment, supplies, or people—within or between combat theaters. Hybrid airships would probably be the preferred design for airlift because they provide greater lift for a given gas volume and they can be easier to handle while near the ground, particularly during loading and unloading, when the total vehicle weight (aircraft plus cargo) changes substantially.

Airships would have several advantages over other means of transportation. In particular, airships are likely to rely on fixed ground facilities to a lesser extent than conventional aircraft, which need airbases, and ships, which need seaports. Airships, therefore, could deliver large payloads to locations that lack such facilities. Moreover, if some proposed designs prove technologically feasible, airships would be able to carry much larger payloads than fixed-wing aircraft and reach their destination more quickly than ships. Additionally, if airships prove to be as fuel efficient as their proponents assert, airships might be able to operate at substantially lower cost than existing aircraft, an

3. Indeed, some reports indicate that DoD has already encountered challenges meeting the helium storage and distribution demands in Iraq and Afghanistan that have resulted from the widespread use of tethered blimps to provide security surveillance at fixed locations. The deployment of much larger airships would dramatically increase the demand for helium. Although those challenges can most likely be resolved, the cost and complexity of doing so has not been determined.

advantage that would grow if fuel prices increase. (Fuel for transport aircraft represented nearly 40 percent of the Air Force's energy costs in fiscal year 2009.) Savings from lower fuel consumption, however, could be offset by costs that have not yet been identified or quantified.

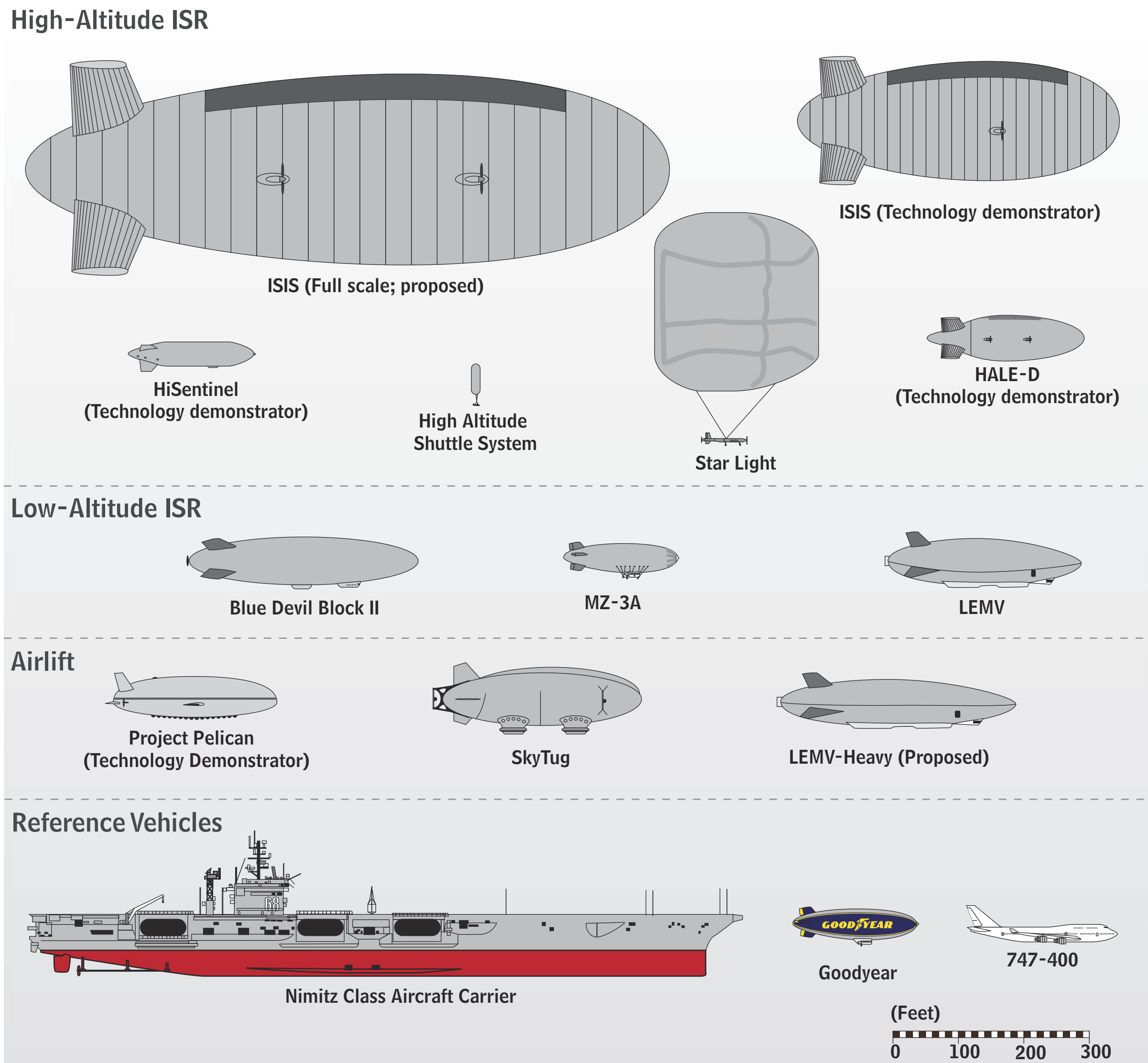
Proposals have been put forward for hybrid airships that could accommodate payloads of various sizes. Airships carrying 20 tons (about the payload of a C-130 intratheater airlift aircraft) could operate independently of runways and only slightly more slowly than helicopters but with substantially larger payloads. Airships carrying 50 tons (about the average payload of a C-17 intertheater airlift aircraft) or more could complement today's strategic airlift aircraft and sealift ships. Very large cargo airships capable of carrying a few hundred tons would offer greater payloads but lower speed than conventional cargo aircraft provide and lesser payloads but greater speed than cargo ships provide. The feasibility of constructing and operating such enormous aircraft—by some estimates, about 1,000 feet in length and 300 feet in width for a 500-ton capacity airship—remains in doubt, however.

Other risks remain in using airships for airlift. Airships would still have the disadvantages discussed above for ISR missions, such as greater sensitivity to weather conditions. As with other types of airships, those used for tactical airlift (airlift within a theater of operations) would be vulnerable to hostile fire if required to fly over unsecured territory. Those airships would operate at similar altitudes and not dramatically lower speeds than helicopters, but they would be much less maneuverable and thus less able to avoid threats. Furthermore, airships would need to demonstrate sufficient dependability in day-to-day operations before they could be relied on to maintain continuous flows of cargo.

Whether or not airships would be worthwhile additions to the military's strategic force providing airlift over intercontinental distances will also depend in part on the progress of their technological development as well as their acquisition and operation costs relative to those of conventional aircraft. The future of airships in airlift will also depend on whether there is a demand for increased deliveries before ships can be expected to arrive and whether there is a need to deliver cargo directly to locations that cannot be easily supplied with existing transportation systems. ◆

Exhibit 1.

Illustrations of Airships



Source: Congressional Budget Office based on data provided by manufacturers.

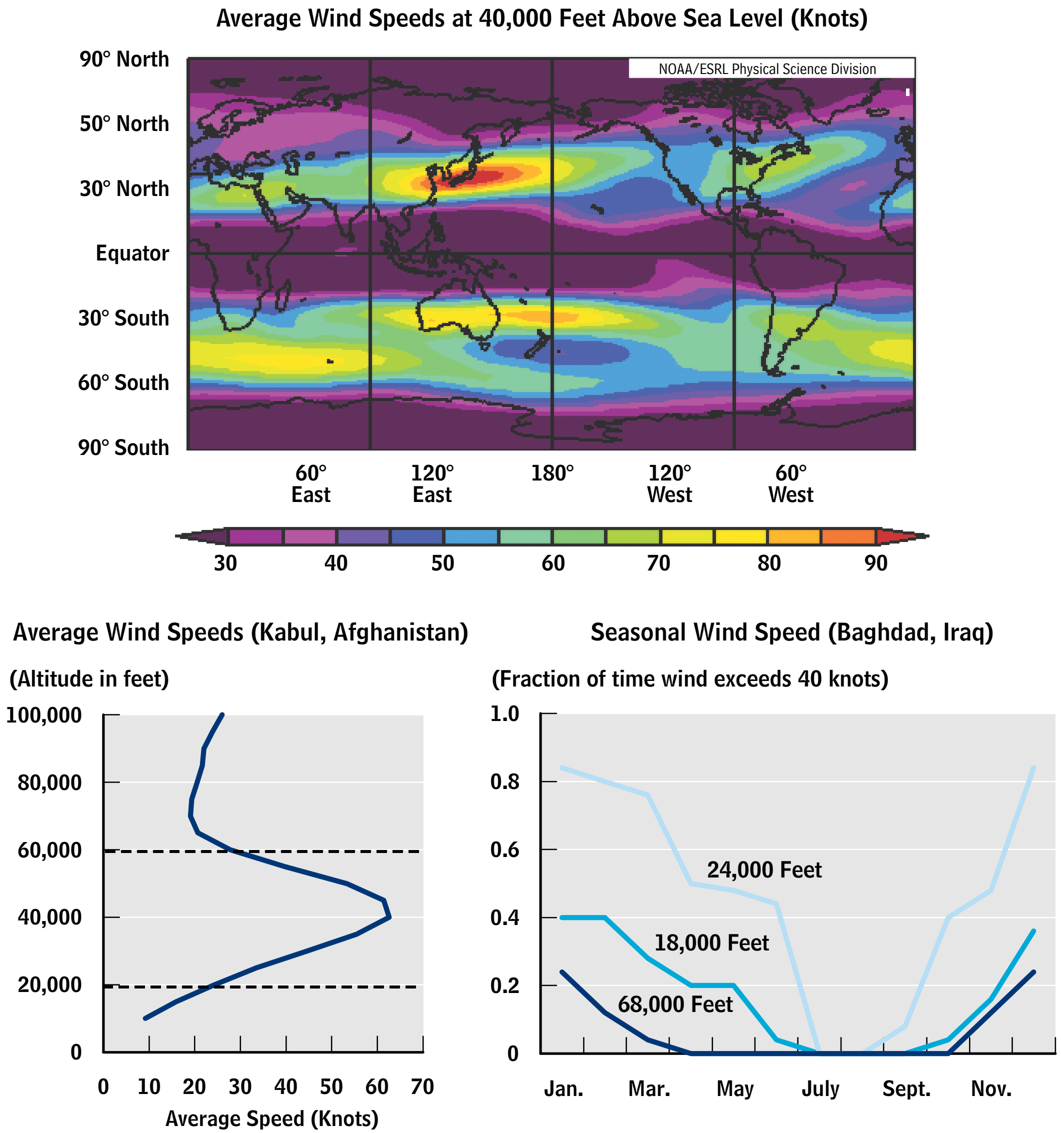
Note: ISR = intelligence, surveillance, and reconnaissance; ISIS = Integrated Sensor Is the Structure; HALE-D = High-Altitude Long-Endurance Demonstrator; LEMV = Long-Endurance Multi-Intelligence Vehicle.

Airship programs that have been proposed or that are being pursued today range in technical maturity: Some are concepts on paper, others are being developed to demonstrate technical feasibility, and a few are based on well-established technologies that could be quickly put to use in the field. In this document, the Congressional Budget Office (CBO) analyzes airships designed for intelligence, surveillance, and reconnaissance (ISR) missions and for airlift of cargo. They range in size from roughly that of a Goodyear blimp to about the size of an aircraft carrier. CBO has not analyzed aerostats—tethered, unmanned airships commonly used for observation.

The airships discussed in this study fall into three operational regimes: high-altitude ISR, low-altitude ISR, and airlift. In this exhibit, six designs, including both subscale demonstration models intended to test new technologies and full-scale aircraft capable of conducting actual operations, show aircraft proposed for operation at high altitudes. High-altitude operation is preferred when large fields of view or long viewing ranges are needed, for example, when looking deep within a country's border while remaining outside its airspace. Four of those high-altitude vehicles are conventional airships, and two—the Star Light and the High Altitude Shuttle System—are payload-return airships. (Upon completion of a mission, the payload detaches from the gas envelope and returns to base, and the envelope is not recovered.) Three designs show aircraft that would operate at low altitudes. Full-motion video sensors are commonly carried by the low- to medium-altitude ISR aircraft flown today, and would probably be used on airships operating at similar altitudes. Finally, three designs show aircraft proposed for the transportation of cargo. ◆

Exhibit 2.

Wind Speed and Location, Altitude, and Time of Year



Sources: National Oceanic and Atmospheric Administration and U.S. Air Force.

Note: NOAA = National Oceanic and Atmospheric Administration; ESRL = Earth System Research Laboratory.

Because airships are large, are relatively lightweight, and use small engines for thrust, they would be affected by weather conditions more than are the conventional aircraft currently used by the military. In particular, airships could be, at best, difficult to control or, at worst, destroyed by high winds when near the ground during launch and recovery. Also, maintaining position in the face of strong winds would increase fuel consumption and thus reduce an airship's time on station. Airships might not be able to maintain position at all if winds were too strong.

Airships' difficulties in high winds generally constrain their operations to below 20,000 feet and above 60,000 feet because prevailing wind speeds tend to be greatest between those altitudes. High winds at intermediate altitudes are especially prevalent over the Earth's middle latitudes, which include areas of particular interest to today's military planners. Airships operating at high altitudes would have to pass through intermediate altitudes and, although not necessarily a hazard to structural integrity, winds could be strong enough to blow an airship off course. Consequently, careful planning would be needed to route a high-altitude airship to its orbit location and back to its base.

Average wind speed calculations, however, obscure the fact that winds can vary substantially at a given place depending on the time of year. For example, the probability of encountering winds in excess of 40 knots over Baghdad is considerably higher from November to May than it is at other times of the year. Such variations mean that maintaining control of airships over a given location could be very difficult or even impossible for long periods of time. ◆

Exhibit 3.

General Characteristics of Airships Under Consideration by DoD

Mission	Operating Altitude	Airship Type	Altitude (Feet)	Endurance or Range	Status of Technology	Characteristics
ISR	*Low Altitude*	Conventional	Up to about 20,000	100 to 300 hours	One system currently operating; others under construction	Relatively mature technology
		Hybrid	Up to about 20,000	500 hours	Technology demonstrations ongoing	Uses static lift from helium, aero-dynamic lift from the shape of the envelope, and vectored thrust to stay aloft
	High Altitude	Conventional	65,000 to 75,000	Greater than 400 hours	Technology demonstrations ongoing	Very large envelope volume to sustain lift
		Payload-Return	65,000 to 75,000	100 to 300 hours	Technology demonstrations ongoing	Payload is detachable and returns to point of origin; airship is single-use
Airlift	*Low Altitude*	Hybrid	9,000 to 12,000	Hundreds to thousands of miles, depending on design	Technology demonstrations ongoing	Uses static lift from helium, aero-dynamic lift from the shape of the envelope, and vectored thrust to stay aloft

Source: Congressional Budget Office.

Note: DoD = Department of Defense; ISR = intelligence, surveillance, and reconnaissance.

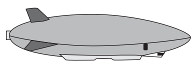
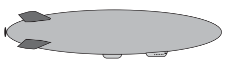
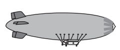
Commercially produced military airships are at various stages of development, with a number of companies across Europe, Asia, and North America involved in their design and manufacture. Analysis in this document is limited to airships designed for ISR that were recently funded by the Department of Defense (DoD) and to selected proposed vehicles for airlift.

As a result of Earth's atmospheric conditions, ISR missions for airships are typically classified as either low-altitude or high-altitude—that is, operating at less than 20,000 feet and at more than 60,000 feet, respectively. Altitudes between 20,000 and 60,000 feet are less suitable for airship operations because of the stronger winds that tend to be prevalent at those altitudes. If the airships being designed for ISR missions prove to be feasible, they would be able to remain aloft longer than conventional aircraft, with proposed endurance of more than 100 hours. Airlift missions would be undertaken only at low altitudes. ◆

Low-Altitude Intelligence, Surveillance, and Reconnaissance

Exhibit 4.

Low-Altitude Airships for Intelligence, Surveillance, and Reconnaissance

	Platform	Sponsor	Date for First Flight	Goal	Type	Status
	LEMV	Army	Late 2011	3 deployable systems	Hybrid	Under construction
	BD2	Air Force	Late 2011	1 deployable system	Conventional	Under construction
	MZ-3A	Navy	2006	1 operational system	Conventional	Currently operating

Source: Congressional Budget Office based on data provided by manufacturers.

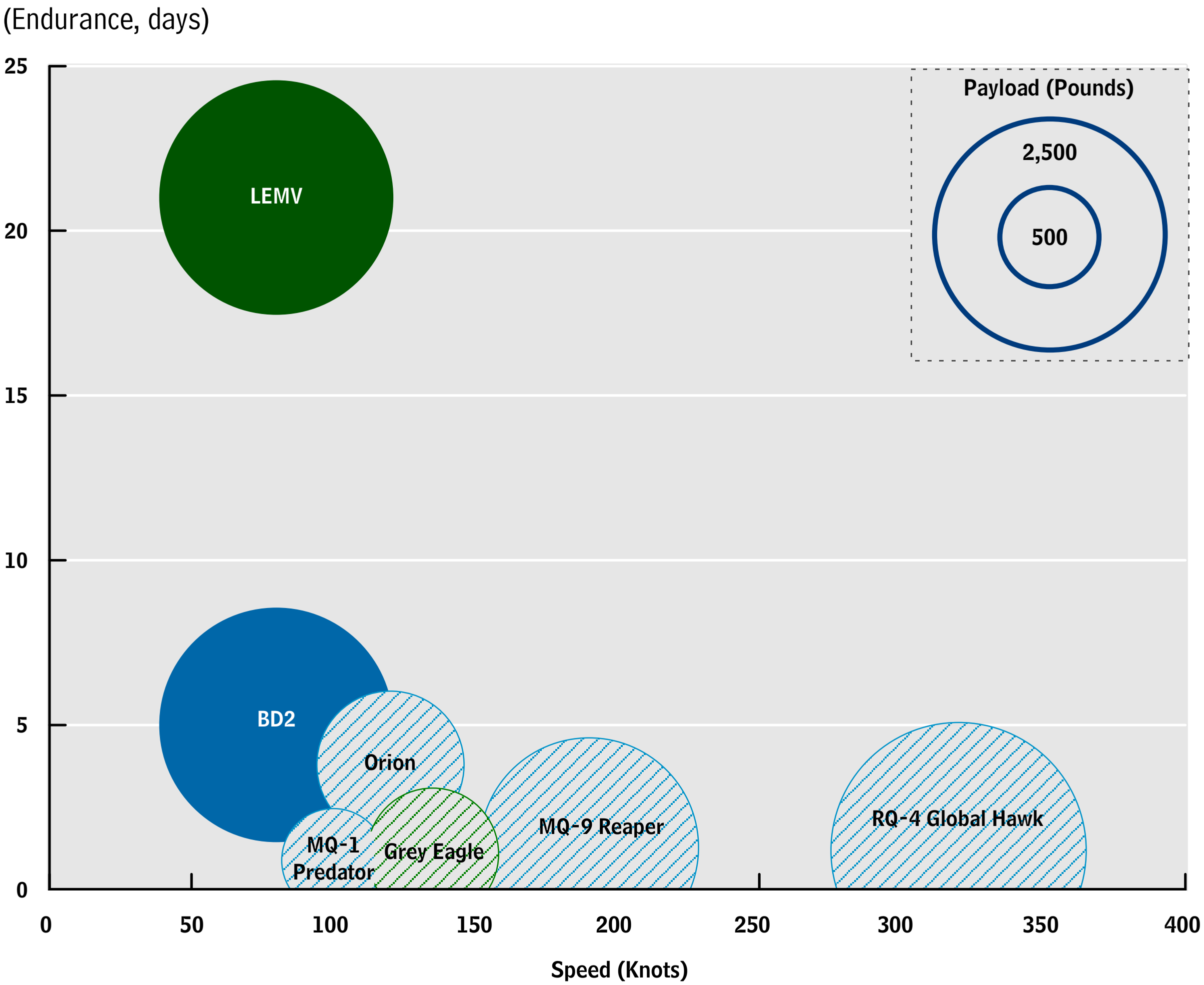
Note: LEMV = Long-Endurance Multi-Intelligence Vehicle; BD2 = Blue Devil Block II.

DoD is currently funding several efforts to field airships that would conduct ISR missions at low altitudes. The most prominent of those are the Navy's MZ-3A, the Air Force's Blue Devil Block II (BD2), and the Army's Long-Endurance Multi-Intelligence Vehicle (LEMV). Conducting ISR missions from lower altitudes has the advantage of needing a smaller volume of buoyant gas to carry a given payload weight. In addition, lighter and less sophisticated sensors are usually sufficient at lower altitudes for a given level of performance because those sensors are closer to the objects and activities they are attempting to observe. Low-altitude operations, however, have the disadvantage of a smaller field of view than is possible from higher altitudes, and low-altitude aircraft are easier for an adversary to detect and attack.

The Navy's MZ-3A, a nonrigid conventional airship that entered service in 2006, is the only currently operational airship. The Navy has no announced plans to deploy the MZ-3A overseas, but it was used to help monitor the Deepwater Horizon oil spill in the Gulf of Mexico, and today it is being used as an experimental platform to test different sensors and to determine how airships could be used in actual operations. In its current configuration, the MZ-3A is the only ISR airship considered here that must carry a crew. The Air Force's nonrigid conventional BD2 is about twice the length and has eight times the gas volume of the MZ-3A. The Air Force's near-term goals for the BD2 are to achieve a first flight in late 2011 and to deploy the aircraft to support operations overseas in 2012. The Army's LEMV, a semirigid hybrid design, will be similar in volume to the BD2 but shorter and wider to create an airfoil-shaped envelope. The first-flight and deployment goals for the LEMV are similar to those for the BD2. ◆

Exhibit 5.

Payload, Endurance, and Speed of Low-Altitude Airships and Fixed-Wing Aircraft



Source: Congressional Budget Office based on data provided by manufacturers.

Notes: Solid circles denote airships, hatched circles denote fixed-wing aircraft. Circle area is proportional to payload.

Performance characteristics are for typical mission profiles.

LEMV = Long-Endurance Multi-Intelligence Vehicle; BD2 = Blue Devil Block II.

The Air Force and the Army have both entered into contracts to purchase low-altitude ISR airships for eventual use in Afghanistan. Two airships being built for this purpose are the Air Force's BD2 and the Army's LEMV. The BD2 is a nonrigid conventional airship; the LEMV is a semirigid hybrid airship.

The BD2 is designed to stay aloft onsite at 20,000 feet with a 2,500-pound payload for five days. Its manufacturer, Mav6, is scheduled to deliver one BD2 to Afghanistan in 2012. The LEMV is designed to remain onsite at 20,000 feet with a 2,500-pound payload for 21 days. The first of three LEMVs is expected to be delivered in time for deployment to Afghanistan by early 2012.

The planned endurance of those two airships is substantially greater than that of operational fixed-wing unmanned aircraft such as the RQ-4 Global Hawk, MQ-9 Reaper and MQ-1 Predator, all of which can remain aloft for a day and a half or less. The Orion, a fixed-wing concept demonstrator, would approach the five-day endurance of the BD2 airship.

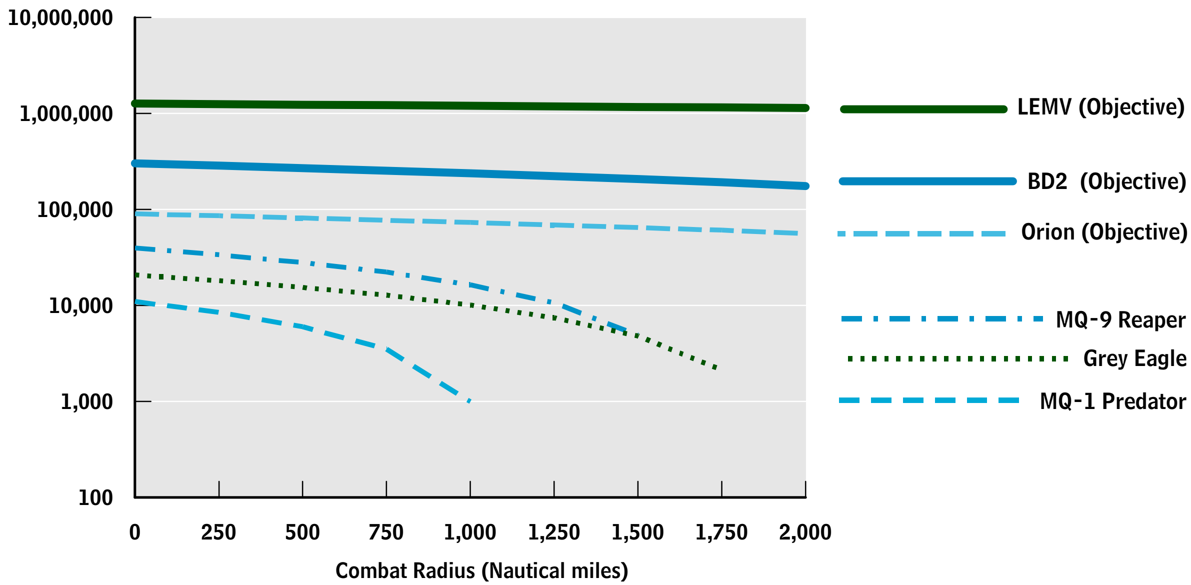
The cruise speeds of the fixed-wing aircraft are greater than those of the airships, particularly for the Global Hawk and the Reaper, which can both fly in excess of 200 knots. That speed gives them the ability to quickly shift to a new orbit location in response to changes in the situation on the ground.

Because many of the technologies needed to produce a modern airship are in early stages of development, the costs per airship in comparison to fixed-wing aircraft are highly uncertain and are not addressed in this report. ◆

Exhibit 6.

Payload-Duration of Low-Altitude Airships and Fixed-Wing Aircraft

(Payload-duration, pound-hours)



Source: Congressional Budget Office based on data provided by manufacturers.

Notes: The vertical axis uses a logarithmic scale.

Solid lines denote airships; dashed lines denote fixed-wing aircraft.

LEMV = Long-Endurance Multi-Intelligence Vehicle; BD2 = Blue Devil Block II.

A summary measure of ISR capability, payload-duration is the weight (payload) that could be carried to a location multiplied by the amount of time it could be kept there (duration). Payload weight serves as a simplified measure of the types and quality of sensors that an airship could carry. CBO estimated the payload-duration for individual aircraft and airships as a function of the distance between where the vehicle is based and where its orbit is located.

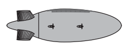
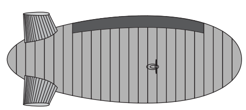
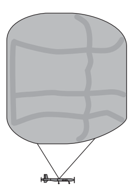
If the BD2 and LEMV meet planned objectives, they will provide substantially greater payload-duration than do the three Predator-class unmanned aircraft in use today: the Air Force's Predator and Reaper and the Army's Grey Eagle. For example, at a 500-nautical mile combat radius, the Air Force's BD2 would have a payload-duration about 60 times greater than the Predator's and more than 10 times greater than the Reaper's, and the Army's LEMV would have a payload-duration about 80 times that of the Grey Eagle. Furthermore, at combat radii greater than 500 nautical miles, the payload-duration of the Predator, Reaper, and Grey Eagle falls off more rapidly than would the payload-duration of the airships because transit time consumes most of the flight time available to the Predator-class aircraft.

The objective performance for Orion does not show the same decrease in payload-duration as the other conventional aircraft because the endurance it is being designed to achieve is much greater than those aircraft's. (The decrease occurs beyond the scale of the figure.) The Orion is, however, still in development. ◆

High-Altitude Intelligence, Surveillance, and Reconnaissance

Exhibit 7.

High-Altitude Airships for Intelligence, Surveillance, and Reconnaissance

	Platform	Sponsor	Date for First Flight	Goal	Type	Status
			Traditional Designs			
	HALE-D	Army/ASMDC	July 2011	Scaled technology demonstrator	Conventional	Prototype flown—suffered failure
	HiSentinel	Army/ASMDC	November 2010	Scaled technology demonstrator	Conventional	Prototype flown—suffered failure
	ISIS Demonstrator	DARPA	2013	Scaled technology demonstrator	Conventional	Under construction
			Designs with Detachable Return Vehicles			
	Star Light	Navy	Undetermined	Technology demonstrator	Conventional with return payload	Under construction
	High Altitude Shuttle System	Army	2009	Technology demonstrator	Conventional with return payload	Prototype flown

Source: Congressional Budget Office based on data provided by manufacturers.

Note: HALE-D = High-Altitude Long-Endurance Demonstrator; ASMDC = Army Space and Missile Defense Command; ISIS = Integrated Sensor Is the Structure; DARPA = Defense Advanced Research Projects Agency.

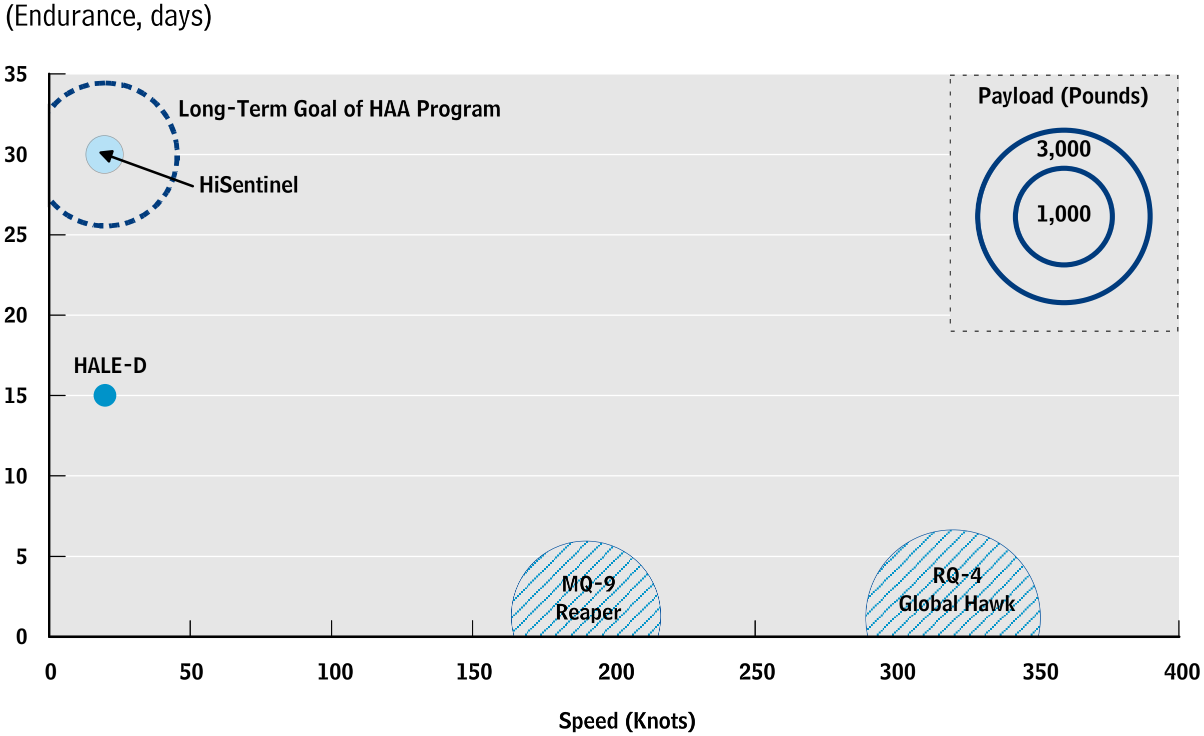
High-altitude ISR vehicles are at an earlier stage of development than low-altitude systems. Most current concepts for high-altitude airships are of conventional design, although there have also been proposals for hybrids. Design challenges for high-altitude airships include manufacturing fabrics that are light, strong enough for very large envelopes, and durable enough to survive in the upper atmosphere. Operational challenges include navigating through altitudes where winds can be greater than the speed of the airship itself. Once at altitude, however, the aircraft would have the advantage of a large field of view and could be threatened only by air defense systems capable of reaching that high.

The Army's High Altitude Airship (HAA) program includes the HiSentinel demonstration aircraft and the High-Altitude Long-Endurance Demonstrator (HALE-D) aircraft. The Army is also working with the Defense Advanced Research Projects Agency (DARPA) on a subscale demonstrator of the Integrated Sensor Is the Structure (ISIS) airship, which would integrate a radar antenna into the structure of the airship. The Star Light and the High Altitude Shuttle System payload-return airships are also technology demonstrators. If the demonstrators are successful, a subsequent generation of vehicles with greater payload capacities and endurance could be developed.

Both the HiSentinel and HALE-D programs, however, have suffered recent setbacks. In November 2010, the HiSentinel had a propulsion failure and landed 8 hours into a planned 24-hour mission. In July 2011, HALE-D had a technical failure and was forced to land 3 hours into a planned 14-day mission. During recovery operations, its envelope and solar cells were destroyed, and its payload was damaged by a fire. ◆

Exhibit 8.

Payload, Endurance, and Speed of High-Altitude Airships and Fixed-Wing Aircraft



Source: Congressional Budget Office based on data provided by manufacturers.

Notes: Solid circles denote airships; hatched circles denote fixed-wing aircraft. Circle area is proportional to payload.

Performance characteristics are for typical mission profiles.

HAA = High Altitude Airship; HALE-D = High-Altitude Long-Endurance Demonstrator.

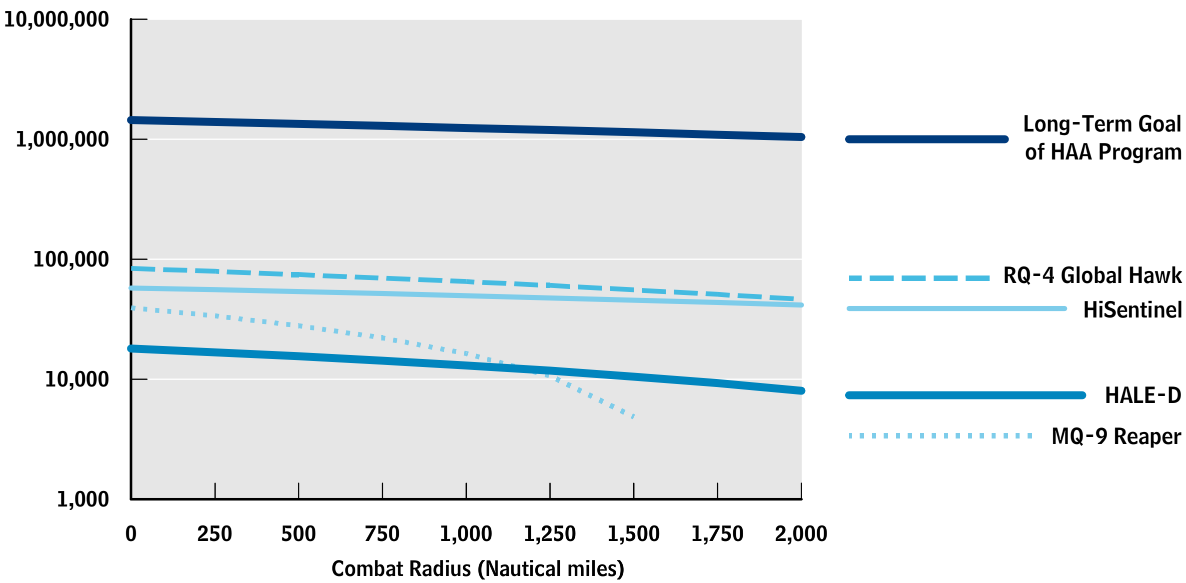
The Army's HAA program, within which the HiSentinel and HALE-D are subscale demonstration aircraft, has the long-term objective of building an airship capable of carrying a 2,000-pound payload and generating 15 kilowatts of power (to run the payload and aircraft systems) at 65,000 feet for more than 30 days. The HiSentinel has those speed and endurance capabilities but can carry a much smaller payload—80 lbs. The HALE-D has an even smaller payload and half the endurance of the HiSentinel. The goal of HiSentinel and HALE-D, however, is to test the technologies needed for long endurance at high altitude, not to demonstrate the capability to carry a large payload.

In comparison with unmanned fixed-wing aircraft, such as the Global Hawk or Reaper, an airship meeting the long-term goals of the HAA program would have a similar payload and substantially longer endurance but considerably slower cruise speed. ◆

Exhibit 9.

Payload-Duration of High-Altitude Airships and Fixed-Wing Aircraft

(Payload-duration, pound hours)



Source: Congressional Budget Office based on data provided by manufacturers.

Notes: The vertical axis uses a logarithmic scale.

Solid lines denote airships; dashed lines denote fixed-wing aircraft.

HAA = High Altitude Airship; HALE-D = High-Altitude Long-Endurance Demonstrator.

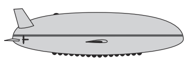
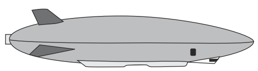
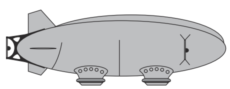
The fixed-wing Global Hawk is the most prominent high-altitude unmanned ISR aircraft in use today, and it provides a useful comparison point for proposed airship designs. An airship meeting the long-term performance goals of the Army's HAA program would have a payload-duration significantly greater than the Global Hawk's and the Reaper's as well as the ability to carry sensors large enough to be useful from over 60,000 feet. To reach such altitudes, however, an operational airship would need to be much larger than the HiSentinel and HALE-D demonstrators. (See, for example, the relative sizes of the ISIS and the ISIS demonstrator in Exhibit 1.)

Designs for unmanned aircraft with a payload-duration even greater than the long-term objective for the HAA program are also being explored. Two programs at DARPA—the ISIS airship and the Vulture, a fixed-wing aircraft—have the goal of developing aircraft that could remain continuously aloft for five years. A vehicle with that endurance and a payload of 1,000 pounds (the reported goal for a Vulture demonstration aircraft) would have a payload-duration at least 30 times larger than even the HAA program's objective. ◆

Airlift

Exhibit 10.

Proposed Airships for Airlift

	Platform	Sponsor	Date for First Flight	Goal	Type	Status
	Project Pelican	DoD RRTO	2012–2013	Scaled technology demonstrator	Hybrid	Under construction
	LEMV-Heavy	Privately funded	Undetermined	Proposed operational system	Hybrid	Designs proposed
	SkyTug	Privately funded	2012	Full-scale prototype	Hybrid	Under construction

Source: Congressional Budget Office based on data provided by manufacturers.

Note: DoD = Department of Defense; RRTO = Rapid Reaction Technology Office; LEMV = Long-Endurance Multi-Intelligence Vehicle.

At least three cargo airship designs that could be fielded to provide airlift capability within the next few years are in development or have been proposed. The Project Pelican is a proposed hybrid airship that would feature a rigid hull and use variable-buoyancy technology to assist with controlling lift. The LEMV-Heavy would be based on the LEMV that is being developed for ISR missions. The SkyTug is a hybrid airship that would be based on the P-791 technology demonstrator that first flew in January 2006.

CBO did not examine in detail proposals for other, much larger cargo airships. For example, from 2003 to 2006, the Defense Advanced Research Projects Agency pursued a program called the Hybrid Ultra-Large Aircraft (HULA), or Walrus, with the goal of building an airship able to carry 500 to 1,000 tons up to 12,000 miles in less than seven days. If such a large aircraft is ever built, it will most likely be a larger version of a smaller hybrid airship such as the three described above. For an analysis of how very large cargo airships might perform relative to sealift ships and conventional strategic airlift aircraft, see Congressional Budget Office, *Options for Strategic Military Transportation Systems* (September 2005). ◆

Exhibit 11.

Approximate Performance Characteristics of Proposed Airships for Airlift

	LEMV-Heavy	SkyTug	Project Pelican (Full-scale version)
Length	365 Feet	300 Feet	435 Feet
Flight Altitude	9,000 Feet	10,000 Feet	10,000 Feet
Average Cruise Speed	80 Knots	80-100 Knots	90 Knots
Maximum Payload	50 Tons	20-30 Tons	60 Tons
Range	1,200 Miles	1,500 Miles	3,100 Miles

Source: Congressional Budget Office based on data provided by manufacturers.

Note: LEMV = Long-Endurance Multi-Intelligence Vehicle.

The LEMV-Heavy, the SkyTug, and the Project Pelican airships would carry payloads from about 20 tons to 60 tons over ranges of about 1,000 to 3,000 nautical miles. Such performance roughly spans the range and payload performance offered by today's fixed-wing transport aircraft such as the C-130 and the larger C-17 and C-5. The airships would offer much lower speeds than the fixed-wing aircraft would, but the airships would offer the advantage of greater independence from airfields. Hybrid airships would be slightly slower than today's transport helicopters but have a larger range and the ability to carry a heavier payload.

In addition to lift capacity, issues such as the airships' cost and vulnerability to ground fire and high winds would need further study to assess the suitability of airships for particular airlift missions. Although airships would operate at similar altitudes and not dramatically lower speeds than helicopters, they would be much less maneuverable and thus less able to avoid threats along their flight path. Demonstration of the needed technology is at an early stage, and costs per airship are highly uncertain and are not analyzed in this document. ◆

Exhibit 12.

Airlift Performance for an Illustrative Deployment to the Middle East

	Aircraft	Airships		Sealift
	C-17	60-Ton Airship	500-Ton Airship	LMSR
Average Throughput Capacity per Single Aircraft or Ship (Million ton-miles/day)				
	0.25	0.12	1.0	9.5
Cargo Delivered per Single Aircraft or Ship (Tons)				
By Day 5:	80	0	0	0
By Day 15:	230	110	900	0
By Day 30:	470	220	1,850	16,500

Source: Congressional Budget Office.

Note: LMSR = large, medium-speed roll-on/roll-off ship.

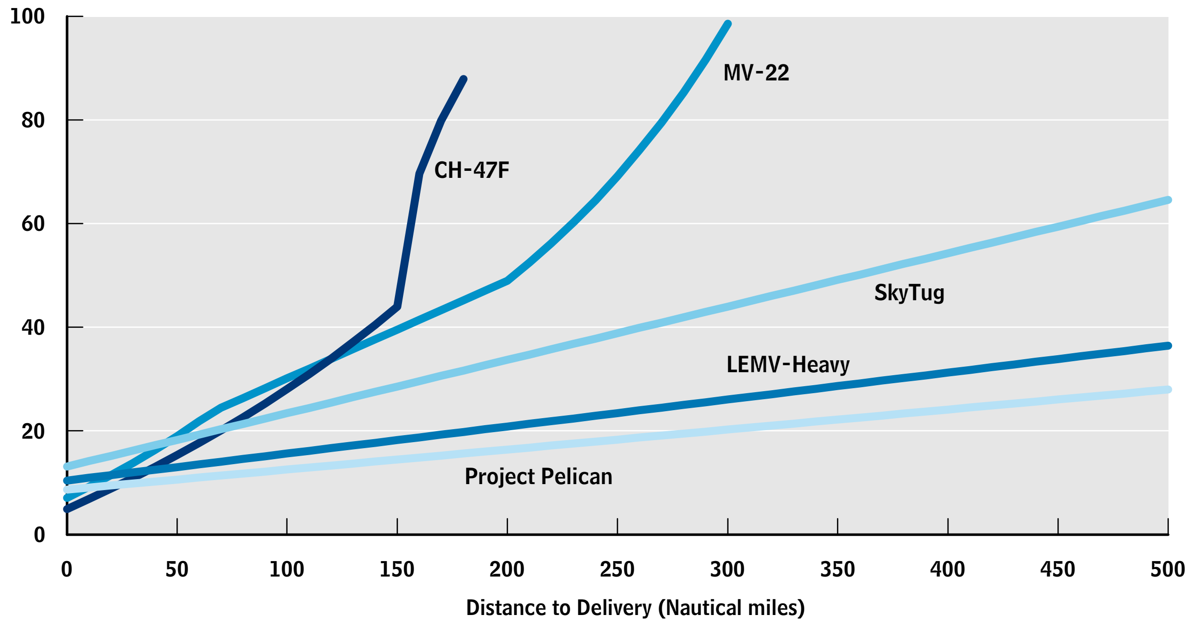
The terms "strategic lift" and "intertheater lift" are typically applied to systems that are designed to move cargo or people over intercontinental distances. The current primary providers of strategic lift are Air Force C-5 and C-17 aircraft and Navy cargo ships. The military also has contracts with civilian aircraft and ship operators to provide additional transportation services when necessary. A simple measure used to characterize strategic lift systems is average throughput capacity: the product of payload and the distance that payload can be moved in a day. Despite their slow speed, ships tend to have the highest throughput capacity, primarily because they can carry much more than aircraft can. For a notional deployment from the United States to the Middle East, a sealift ship would provide nearly 30 times the throughput capacity of a C-17. A C-17, however, could begin delivering cargo much sooner. When considering transporting cargo by ship or aircraft, planners must decide if the need for a given item is urgent enough to allocate it to the limited capacity provided by aircraft.

Cargo airships could provide an intermediate capability, delivering cargo more quickly than ships but not as quickly as conventional aircraft. The average throughput capacity provided by an airship relative to a conventional aircraft or ship would depend on its payload. The proposed payloads of the airships shown earlier in this report would yield lower throughput capacity than a C-17 because their payloads would not be large enough to compensate for their slower speed. Larger airships with payloads of 500 to 1,000 tons have been proposed, and they would yield greater throughput capacity than today's aircraft. An airship with speed and payload large enough to match a ship's throughput capacity would probably be impractical. ◆

Exhibit 13.

Illustration of the Number of Aircraft Needed to Provide 1,000 Tons per Day Throughput Within a Theater of Operations

(Number of aircraft needed to maintain 1,000 tons/day)



Source: Congressional Budget Office.

Notes: Curves illustrate the approximate capabilities of selected aircraft using similar assumptions.

CH-47F = Chinook Helicopter; MV-22 = Osprey Tilt-Rotor Aircraft; LEMV = Long-Endurance Multi-Intelligence Vehicle.

The terms "tactical lift" and "intratheater lift" are applied to systems that are designed to move cargo or people within a theater of operations—typically a few hundred miles or less. Tactical lift can be provided by trucks, fixed-wing aircraft for airbase-to-airbase transport, and vertical takeoff and landing aircraft (helicopters or the tilt-rotor MV-22 Osprey) for transport to locations without access by road or airbases.

Cargo airships with payloads of 20 to 60 tons have the potential to perform well in missions that would currently require a helicopter or MV-22. Although somewhat slower than contemporary helicopters—operating at 80 to 90 knots versus more than 100 knots for helicopters—the LEMV-Heavy, the SkyTug, and the Project Pelican airships would have larger payloads and longer ranges. The MV-22 is considerably faster than airships when flying in "airplane mode," with its rotors oriented like propellers on a fixed-wing aircraft, but at the speed of more than 200 knots, the MV-22 is limited to carrying cargo internally, and it loses the substantial capacity for payload that can be carried suspended beneath the fuselage in "helicopter mode."

At distances up to about 100 nautical miles, the number of airships needed to maintain a given cargo throughput (for example, 1,000 tons per day) would be similar to the number of today's vertical takeoff and landing aircraft. At distances longer than 100 nautical miles, the greater ranges offered by the proposed airships would enable them to maintain a given throughput with fewer aircraft. That advantage would allow a single airship mission to supply several forward outposts sequentially, instead of the several individual missions that would be needed with today's aircraft. ◆