Modern Airships
Part 1

Peter Lobner

Revision 1
21 December 2020

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- GEFA-Flug (Impacto Aereo) AS-105GD/4 & AS-105GD/6
- Skyacht Personal Blimp
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Record of revisions

Revision 1, 21 December 2020: added 15 new articles, split existing Aeros article into two articles, and updated all 23 previously existing articles.

1. Introduction

"Modern Airships" is a three-part document that contains an overview of modern airship technology in Part 1 and links in Parts 1, 2 and 3 to many individual articles on historic and advanced airship designs. This is Part 1. Here are the links to the other two parts:

- Modern Airships – Part 2: https://lynceans.org/all-posts/modern-airships-part-2/
- Modern Airships – Part 3: https://lynceans.org/all-posts/modern-airships-part-3/

You'll find a consolidated Table of Contents for all three parts at the following link. This should help you navigate the large volume of material in the three documents.

- Consolidated TOC: Later

Modern Airships – Part 1 begins with an overview of modern airship technology, continues with a summary table identifying the airships addressed in this part, and concludes by providing links to 38 individual articles on these airships.

If you have any comments or wish to identify errors in these documents, please send me an e-mail to: PL31416@cox.net.

I hope you'll find the Modern Airships series to be informative, useful, and different from any other single document on this subject.

Best regards,

Peter Lobner

21 December 2020

2. Well-established benefits and opportunities, but a risk-averse market

For more than two decades, there has been significant interest in the use of modern lighter-than-air craft and hybrid airships in a variety of military, commercial and other roles, including:

- Heavy cargo carriers operating point-to-point between manufacturer and end-user, eliminating inter-modal load transfers enroute
- Heavy cargo carriers serving remote and/or unimproved sites not adequately served by other modes of transportation
- Disaster relief, particularly in areas not easily accessible by other means
- Persistent optionally-manned surveillance platforms for maritime surveillance / border patrol / search and rescue
- Passenger airships
- Commercial flying cruise liner / flying hotel
- Airship yacht
- Personal airship
- Drone carrier
- High altitude regional communications node

One of the very significant factors driving interest in modern airships is that they offer the potential to link isolated regions with the rest of the world while doing so in a way that should have lower environmental impacts than other transportation alternatives for those regions. This target market for airships exists in more than two-thirds of the world's land area where more than half the world's population live without direct access to paved roads and reliable ground transportation.

This matter is described well in a 21 February 2016 article by Jeanne Marie Laskas, "Helium Dreams – A new generation of airships is born," which is posted on The New Yorker website at the following link:

https://www.newyorker.com/magazine/2016/02/29/a-new-generation-of-airships-is-born

In spite of the significant interest and the development of many promising airship designs, an actual worldwide airship cargo and passenger transportation industry has been very slow in developing. To give you an example of how slow:

- As of December 2020, the Zeppelin NT 07 is the only advanced airship that has been certified and is flying regularly in commercial passenger service.
- At the March 2019 *Aviation Innovations Conference - Cargo Airships* in Toronto, Canada, Solar Ship CEO Jay Godsall proposed an industry-wide challenge to actually demonstrate by July 2021 airships that can move a 3 metric ton (6,614 lb) standard 20 foot intermodal container configured as a mobile medical lab 300 km (186 mi) to a remote location. Godsall noted that this capability would be of great value if it did exist, for example, in support of relief efforts in Africa and other regions of the world.

So in spite of the airship industry having developed many designs capable of transporting 10 to 100 tons of cargo thousands of miles, today there is not a single airship than can transport a 3 metric ton (6,614 lb) payload 300 km (186 mi).

Why has the airship industry been so slow to develop? The bottom line has been a persistent lack of funding. With many manufacturers having invested in developing advanced, detailed designs, the first to secure adequate funding will be able to take the next steps to build a manufacturing facility and a full-scale prototype airship, complete the airship certification process, and start offering a certified airship for sale.

There are a some significant roadblocks in the way:

- **No full-scale prototypes are flying:** The airship firms currently have little more than slide presentations to show to potential investors and customers. There are few sub-scale airship demonstrators, but no full-scale prototypes. The airship firms are depending on potential investors and customers making a “leap of faith” that the “paper” airship actually can be delivered.

- **Immature manufacturing capability:** While the airship industry has been good at developing many advanced designs, some existing as construction-ready plans, few airship firms are in the process of building an airship factory. The industrial scale-up factor for an airship firm to go from the design and engineering facilities existing today to the facilities needed for series production of full-scale airships is huge. Several years ago, Russian airship manufacturer Augur RosAeroSystems proposed building a new factory to manufacture up to 10 ATLANT airships per year. The funding requirement for that factory was estimated at $157 million. The exact amount isn't important. No matter how you look at it, it's a big number. Large investments are needed for any airship firm to become a viable manufacturer.

- **Significant financial risk:** The amount of funding needed by airship firms to make the next steps toward becoming a viable manufacturer exceeds the amount available from venture capitalists who are willing to accept significant risk. Private equity sources typically are risk averse. Public sources, or public-private partnerships, have been slow to develop an interest in the airship industry. The French airship firm Flying Whales appears to be the first to have gained access to significant funding from public institutions.

- **Significant regulatory risk:** Current US, Canadian and European airship regulations were developed for non-rigid blimps and they fail to address how to certify most of the advanced airships currently under development. This means that the first airship manufacturers seeking type certificates for advanced airships will face uphill battles as they have to deal with aviation regulatory authorities struggling to fill in the big gaps in their regulatory framework and set precedents for later applicants. It is incumbent on the aviation regulatory authorities to get updated regulations in place in a timely manner and make the regulatory process predictable for existing and future applicants.

- **No airship operational infrastructure:** There is nothing existing today that is intended to support the operation of new commercial airships tomorrow. The early airship operators will need to develop operating bases, hanger facilities, maintenance facilities, airship routes, and commercial arrangements for cargo and passengers. While many airship manufacturers boast that their designs can operate from unimproved sites without most or all of the traditional ground infrastructure required by zeppelins and blimps, the fact of the matter is that not all advanced airships will be operating from dirt fields and parked outside when not flying. There is real infrastructure to be built, and this will require a significant investment by the airship operators.

- **Steep learning curve for potential customers:** Only the operators of the Zeppelin NT have experience in operating a modern airship today. The process for integrating airship operations and maintenance into a customer's business work flow has more than a few unknowns. With the lack of modern airship operational experience, there are no testimonials or help lines to support a new customer. They'll have to work out the details with only limited support. Ten years from now, the situation should be vastly improved, but for the first operators, it will be a challenge.

- **Few qualified pilots and crew:** The airship manufacturers will need to work with the aviation regulatory authorities and develop programs for training and licensing new pilots and crew. The British airship manufacturer Varialift has stated that one of the roles of their ARH-PT prototype will be to train future pilots.

This uncertain business climate for airships seems likely to change in the early 2020s, when several different heavy-lift airships are expected to be certified by airworthiness authorities and ready for series production and sale to interested customers. If customers step up and place significant orders, we may be able to realize the promise of airship travel and its potential to change our world in many positive ways.

3. Status of current aviation regulations for airships

As noted previously, current aviation regulations have not kept pace with the development of modern airship technology. In this section, we'll take a look at the current regulations.

In the US, the Federal Aviation Administration's (FAA) current requirements for airships are defined in the document FAA-P-8110-2, Change 2, "Airship Design Criteria (ADC)," dated 6 February 1995, which is available here:

https://www.faa.gov/aircraft/air_cert/design_approvals/airships/airships_regs/media/aceAirshipDesignCriteria.pdf

The ADC applies to non-rigid, near-equilibrium, conventional airships with seating for nine passengers or less, excluding the pilot, and it serves as the basis for issuing the type certificate required before a particular airship type can enter commercial service in the US. The limited scope of this current regulation is highlighted by the following definitions contained in the ADC:

- Airship: an engine-driven, lighter-than-air aircraft, than can be steered.
- Non-rigid: an airship whose structural integrity and shape is maintained by the pressure of the gas contained within the envelope.
- Near-equilibrium: an airship that is capable of achieving zero static heaviness during normal flight operations.

Supplementary guidance for non-rigid, near-equilibrium, conventional airships is provided in FAA Advisory Circular (AC) No. 21.17-1A, "Type Certification – Airships," dated 25 September 1992, which is available here:

https://www.faa.gov/documentlibrary/media/advisory_circular/ac_21-17-1a.pdf

The FAA's ADC and the associated AC were written for blimps, not for the range of modern airships under development today. For example, aerostatic lift is only one component of lift in modern hybrid airships, which also depend on powered lift from engines and aerodynamic lift during forward flight. Hybrid airships are not "lighter-than-air" and cannot achieve zero static heaviness during normal operations, yet they are an important class of airships being developed in several countries. In addition, almost all modern airships, except blimps, have rigid or semi-rigid structures that enable them to carry heavy loads and mount powerful engines that cannot possibly be handled by a non-rigid airship.

Recognizing the absence of an adequate regulatory framework for modern airships, civil aviation authorities of Germany and Netherlands developed supplementary guidance to the European Joint Aviation Requirements (JAR-25) and the FAA's ADC for a category of airships called "Transport Airships," which they define as follows:

> "The transport category is defined for multi-engine propeller driven airships that have a capacity of 20 or more passengers (excluding crew), or a maximum take-off mass of 15,000 kg or more, or a design lifting gas volume of 20,000 m^3 or more, whichever is greater."

These supplementary requirements are contained in the document "Transport Airship Requirements" (TAR), dated March 2000, which you will find at the following link:

https://www.faa.gov/aircraft/air_cert/design_approvals/airships/airships_regs/media/aceAirshipTARIssue1.pdf

So, this is the status of US and European airship regulations today.

In the US, Lockheed-Martin currently is in the process of working with the FAA to get a type certificate for their semi-buoyant, hybrid airship, the LMH-1. Clearly, they are dealing with great regulatory uncertainty. Hopefully, the LMH-1 type certification effort will be successful and serve as a precedent for later applicants.

4. Lifting gas

In the US, Canada and Europe, aviation regulations only allow the use of non-flammable lifting gas:

- FAA ADC: "The lifting gas must be non-flammable." (4.48)
- TAR: "The lifting gas must be non-flammable, non-toxic and non-irritant" (TAR 893)
- Canadian Air Regulations: "Hydrogen is not an acceptable lifting gas for use in airships." (541.7)

Without hydrogen, the remaining practical choices for lifting gas are helium and hot air. A given volume of hot air can lift only about one-third as much as the same volume of helium, making helium the near-universal choice, with hot air being relegated to a few, small thermal airships.

The current high price of helium is a factor in the renewed interest in hydrogen as a lifting gas. It's also a key selling point for thermal airships. Most helium is produced as a byproduct from natural gas production. Helium is not "rare." Only a very small fraction of helium available in natural gas currently is recovered, on the order of 1.25%. The remainder is released to the atmosphere. The helium recovery rate could be higher, but is not warranted by the current market for helium. Helium is difficult to store. The cost of transportation to end-users is a big fraction of the market price of helium.

Hydrogen provides 10% more lift than helium. It can be manufactured easily at low cost and can be stored. If needed, hydrogen can be produced with simple equipment in the field. This could be an important capability for recovering an airship damaged and grounded in a remote region. One airship concept described in Modern Airships - Part 3, the Aeromodeller II, is designed for using hydrogen as the lifting gas and as a clean fuel (zero greenhouse gases produced) for its propulsion engines. A unique feature of this airship concept is an on-board system to generate more hydrogen when needed from the electrolysis of water ballast.

A technique for preventing hydrogen flammability is described in Russian patent RU2441685C2, "Gas compound used to prevent inflammation and explosion of hydrogen-air mixtures," which was submitted in 2010 and posted in 2012. This technique appears to be applicable to an airship using hydrogen as its lifting gas. You can read the patent at the following link.

https://patents.google.com/patent/RU2441685C2/en

The Canadian airship firm Buoyant Aircraft Systems International (BASI) is a proponent of using hydrogen lifting gas. Anticipating a future opportunity to use hydrogen, they have designed their lifting gas cells to be able to operate with either helium or hydrogen. BASI claims that lifting gas cells designed originally for helium lifting gas cannot later be used with hydrogen lifting gas.

Regulatory changes will be required to permit the general use of hydrogen lifting gas in commercial airships. Time will tell if that change ever occurs.

Even with the needed regulatory changes, the insurance industry will have to deal with the matter of insuring a hydrogen-filled airship.

5. Types of modern airships

The term "aerostat" broadly includes all lighter than air vehicles that gain lift through the use of a buoyant gas. Aerostats include unpowered balloons (tethered or free-flying) and powered airships.

The following types of powered airships are described in the Modern Airships series of documents:

- Conventional airships
- Semi-buoyant airships and aircraft
- Variable buoyancy airships
- Variable buoyancy propulsion airships / aircraft
- Helistats (airship – helicopter hybrid)
- Stratospheric airships
- Thermal (hot air) airships

5.1 Conventional airships

Conventional airships are lighter-than-air (LTA) vehicles that operate at or near neutral buoyancy. The lifting gas (helium) generates approximately 100% of the lift at low speed, thereby permitting vertical takeoff and landing (VTOL) operations and hovering with little or no lift contribution from the propulsion / maneuvering system. Various types of propulsors may be used for cruise flight propulsion and for low-speed maneuvering and station keeping.

Airships of this type include non-rigid blimps, rigid zeppelins, and semi-rigid airships.

- **Non-rigid airships (blimps)**: These airships have a flexible envelope that defines the shape of the airship, contains the lifting gas cells and ballonets for buoyancy management, and supports the load of a gondola, engines and payload.

- **Rigid airships (zeppelins):** These airships have a lightweight, rigid airframe that defines their exterior shape. The rigid airframe supports the gondola, engines and payload. Lifting gas cells and ballonets are located within the rigid airframe.

- **Semi-rigid airships:** These airships have a rigid internal spine or structural framework that supports loads. A flexible envelope is installed over the structural framework and contains the lifting gas cells and ballonets.

The Euro Airship DGPAtt and the Flying Whales LCA60T are examples of rigid conventional airships.

Source: Euro Airship

Source: Flying Whales

The Zeppelin NT and the SkyLifter are examples of semi-rigid conventional airships.

Source: Author

Source: SkyLifter

After being loaded and ballasted before flight, conventional airships have various means to control the in-flight buoyancy of the airship. Control can be exercised over ballast, lifting gas and the ballonets as described below.

Controlling buoyancy with ballast:

Many conventional airships require adjustable ballast (i.e., typically water or sand) that can be added or removed as needed to establish a desired net buoyancy before flight. Load exchanges (i.e., taking on / discharging cargo or passengers) can change the overall mass of an airship and may require a corresponding ballast adjustment. If an airship is heavy and the desired buoyancy can't be restored with the ballonets or other means, ballast can be removed on the ground or may need to be dumped in flight to increase buoyancy.

Controlling buoyancy with lifting gas:

The lifting gas inside an airship's gas cells is at atmospheric pressure. Normally, there is no significant loss (leakage) of lifting gas to the environment. A given mass of lifting gas will create a constant lift force, regardless of pressure or altitude, when the lifting gas is at equal pressure and temperature with the surrounding air. Therefore, a change in altitude will not change the aerostatic lift.

However, temperature differentials between the lifting gas and the ambient air will affect the aerostatic lift produced by the lifting gas. To exploit this behavior, some airships can control buoyancy using lifting gas heaters / coolers to manage gas temperature.

The lifting gas heaters are important for operation in the Arctic, where a cold-soak in nighttime temperatures may result in the lifting gas temperature lagging behind daytime ambient air temperature. This temperature differential would result in a loss of lift until lifting gas and ambient air temperatures were equal.

Conversely, operating an airship in hot regions can result in the lifting gas temperature rising above ambient air temperature (the lifting gas becomes "superheated"), thereby increasing buoyancy. To restore buoyancy in this case, some airships have coolers (i.e., helium-to-air heat exchangers) in the lifting gas cells to remove heat from the lifting gas.

As described by Boyle's Law, pressure (P) and gas volume (V) are inversely proportional at a constant temperature according to the following relationship: $PV = K$, where K is a constant. As an airship ascends, atmospheric pressure decreases. This means that a fixed mass of lifting gas will expand within the lifting gas cells during ascent, and will contract within the lifting gas cells during descent. As described previously, this lifting gas expansion and contraction does not affect the magnitude of the aerostatic lift as long as the lifting gas is at equal pressure and temperature with the surrounding air.

If an airship is light and the desired buoyancy cannot be restored with the ballonets or lifting gas coolers, it is possible to vent some lifting gas to the atmosphere to decrease aerostatic lift.

Controlling buoyancy with ballonets:

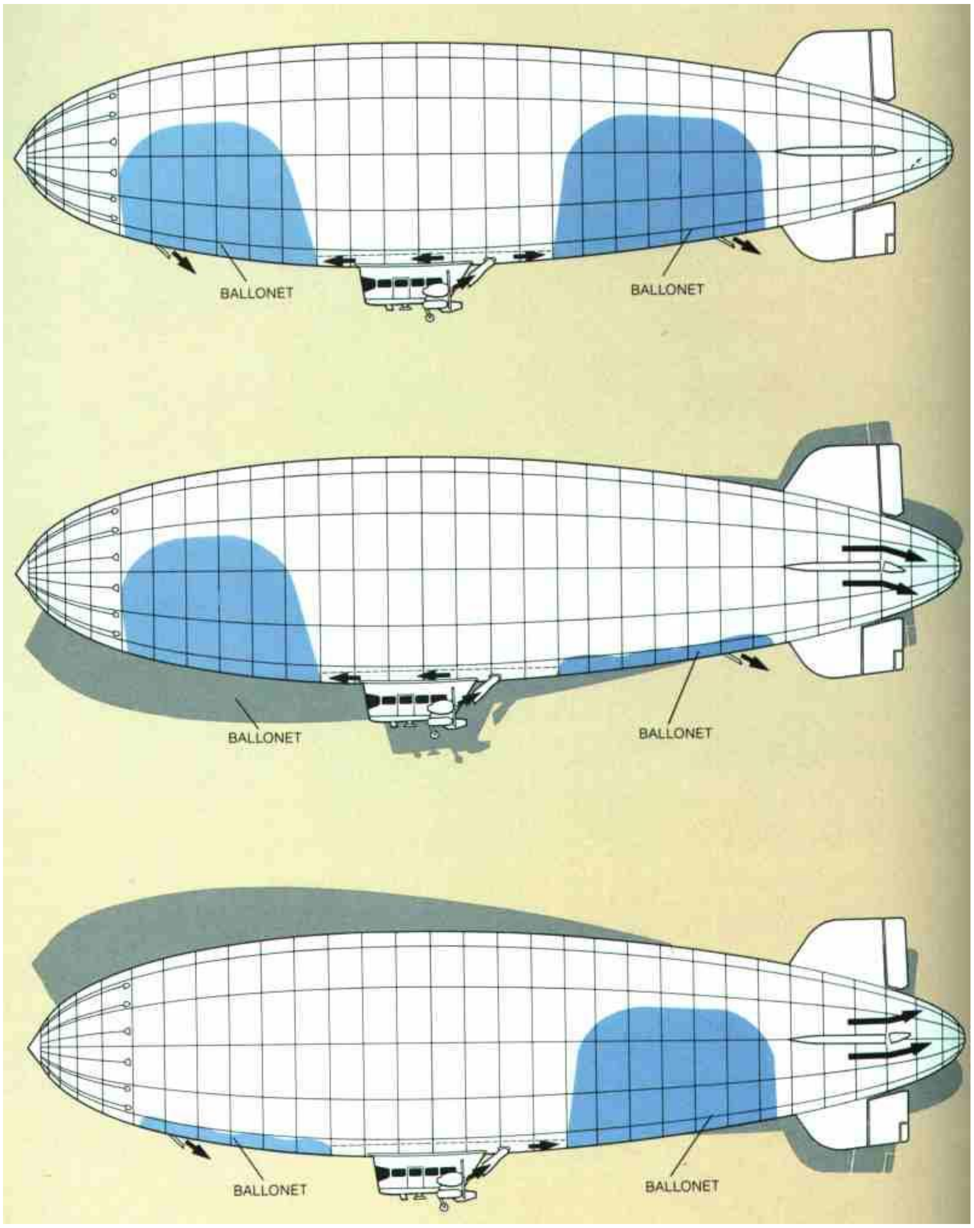
The airship hull / envelope is divided into sealed lifting gas volumes and separate gas volumes called "ballonets" that contain ambient air. The ballonets are used to compensate for modest changes in buoyancy by inflating them with small fans or venting them to the atmosphere to change the gross weight of the airship. Fore and aft ballonets can be operated individually to adjust the trim (pitch angle) of the airship.

On the ground, the ballonets may be inflated with air to make the airship negatively buoyant (heavier-than-air) to simplify ground handling. To takeoff, the ballonets would be vented to the atmosphere, reducing the mass of air carried by the airship.

As the airship gains altitude, external air pressure decreases, allowing the helium gas volume to expand within the gas envelope, into space previously occupied by the air in the ballonets, which vent a portion of their air content overboard. The airship reaches its maximum altitude, known as its "pressure height," when the helium gas volume has expanded to fill the gas envelope and the ballonets are empty. At this point, the airship's mass is at a minimum and the helium lifting gas can expand no further.

To descend, a low-pressure fan is used to inflate the ballonets with outside air, adding mass. As the airship continues to descend into the denser atmosphere, the helium gas volume continues to contract and the ballonets become proportionately larger, carrying a larger mass of air. Ballonet inflation / venting is controlled to manage buoyancy as the airship approaches the ground for a landing.

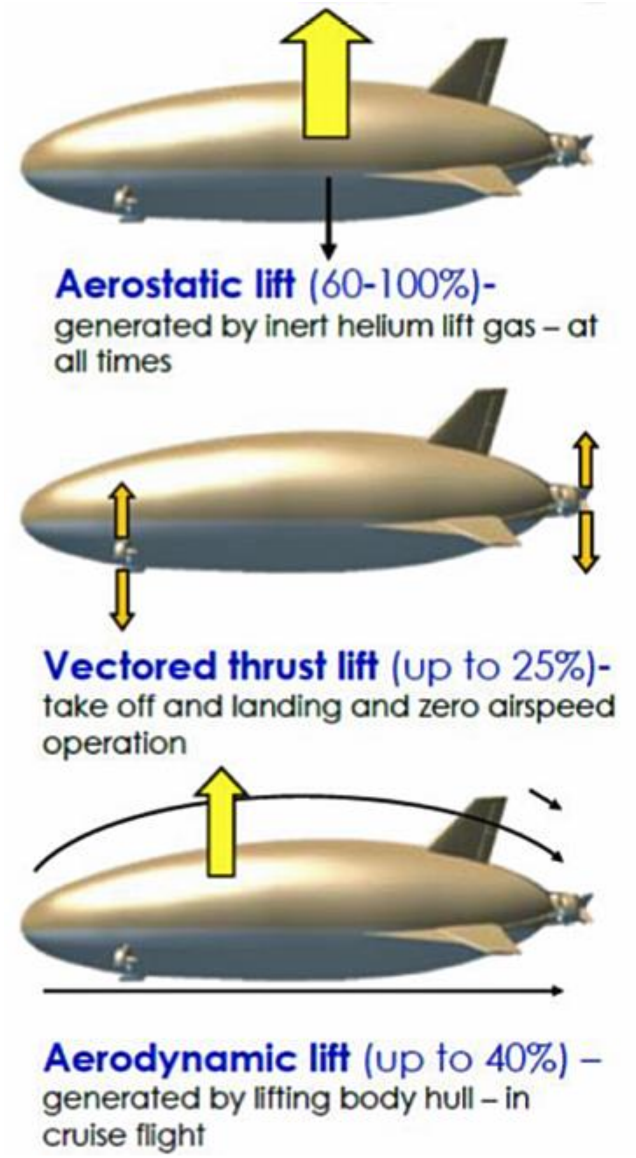
In flight, inflating only the fore or aft ballonet, and allowing the opposite ballonet to deflate, will make the bow or stern of the airship heavier and change the pitch of the airship. These operating principles are shown in the following diagrams of a blimp with two ballonets, which are shown in blue.



Blimp with ballonets (blue). Source: zeppelinfan.de

5.2 Semi-buoyant hybrid airships

Hybrid airships are heavier-than-air (HTA) vehicles. The term “semi-buoyant” means that the lifting gas provides only a fraction of the needed lift (typically 60 – 80%) and the balance of the lift needed for flight is generated by other means, such as vectored thrust engines and aerodynamic lift from the fuselage and wings during forward flight.



Sources of lift for a semi-rigid, hybrid airship. Source: DoD 2012

Basic characteristics of hybrid airships include the following:

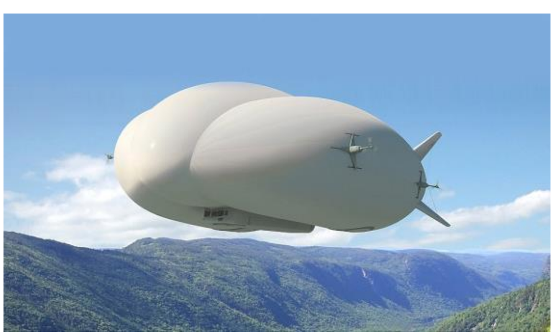
- This type of airship requires some airspeed to generate aerodynamic lift. Therefore, it typically makes a short takeoff and landing (STOL).
- Some hybrid airships may be capable of limited VTOL operations (i.e., when lightly loaded, or when equipped with powerful vectored thrust engines).

- Like conventional airships, the gas envelope in hybrid airship is divided into lifting gas volumes and separate ballonet volumes containing ambient air.
- Hybrid airships are heavier-than-air and are easier to control on the ground than conventional airships.

There are two types of hybrid airships: semi-rigid and rigid.

- **Semi-rigid hybrid airships:** These airships have a structural keel or spine to carry loads, and a large, lifting-body shaped inflated fuselage containing the lifting gas cells and ballonets. Operation of the ballonets to adjust net buoyancy and pitch angle is similar to their use on conventional airships. These wide hybrid airships may have separate ballonets on each side of the inflated envelope that can be used to adjust the roll angle. While these airships are heavier-than-air, they generally require adjustable ballast to handle a load exchange involving a heavy load.
- **Rigid hybrid airships:** These airships have a more substantial structure that defines the shape of the exterior aeroshell. The “hard” skin of the airship may be better suited for operation in Arctic conditions, where snow loads and high winds might challenge the integrity of an inflated fuselage of a semi-rigid airship. Otherwise, the rigid hybrid airship behavior is similar to a semi-rigid airship.

The Lockheed-Martin LMH-1 is an example of a semi-rigid hybrid airship. The AeroTruck being developed by Russian firm Airship GP is an example of a rigid hybrid airship.



Source: Lockheed-Martin

Source: Airship GP

5.3 Semi-buoyant aircraft

Semi-buoyant aircraft are heavier-than-air, rigid, winged aircraft that carry a large helium volume to significantly reduce the weight of the aircraft and improve its load-carrying capability. Aerostatic lift provides a smaller fraction of total lift for a semi-buoyant aircraft, like a Dynalifter, than it does for a semi-buoyant, hybrid airship.

A semi-buoyant aircraft behaves much like a conventional aircraft in the air and on the ground, and is less affected by wind gusts and changing wind direction on the ground than a hybrid airship.

The semi-buoyant aircraft has some flexibility for loading and discharging cargo without having to be immediately concerned about exchanging ballast, except in windy conditions.

The Aereon Corporation's Dynairship and the Ohio Airships Dynalifter are examples of semi-buoyant aircraft.

Source: Aereon Corp.

Source: Ohio Airships

5.4 Variable buoyancy airships

Variable buoyancy airships are rigid airships that can change their net lift, or "static heaviness," to become LTA or HTA as the circumstances require.

Basic characteristics of variable buoyancy airships include the following:

- Variable buoyancy airships are capable of VTOL operations and hovering, usually with a full load.

- The buoyancy control system may enable in-flight load exchanges from a hovering airship without the need for external ballast.
- On the ground, variable buoyancy airships can make themselves heavier-than-air to facilitate load exchanges without the need for external infrastructure or ballast.
- It is not necessary for a “light” airship to vent the lifting gas to the atmosphere.

Variable buoyancy / fixed volume airships

Variable buoyancy commonly is implemented by adjusting the net lift of a fixed volume airship. For example, a variable buoyancy / fixed volume airship can become heavier by compressing the helium lifting gas or ambient air:

- Compressing some of the helium lifting gas into smaller volume tanks aboard the airship reduces the total mass of helium available to generate aerostatic lift.
- Compressing ambient air into pressurized tanks aboard the airship adds mass (ballast) to the airship and thus decreases the net lift.

The airship becomes lighter by venting the pressurized tanks:

- Compressed helium lifting gas is vented back into the helium lift cells, increasing the mass of helium available to generate aerostatic lift.
- Compressed air is vented to the atmosphere, reducing the mass of the airship and thus increasing net lift.

The Aeros Aeroscraft *Dragon Dream* and the Varilift ARH-50 are examples of variable buoyancy / fixed volume airships.

Source: Aeros

Source: Varialift

Variable buoyancy / variable volume airships

Variable buoyancy also can be implemented by adjusting the total volume of the helium envelope without changing the mass of helium in the envelope.

- As the size of the helium envelope increases, the airship displaces more air and the buoyant force of the atmosphere acting on the airship increases. Static heaviness decreases.
- Likewise, as the size of the helium envelope decreases, the airship displaces less air and the buoyant force of the atmosphere acting on the airship decreases. Static heaviness increases.

The concept for a variable buoyancy / variable volume airship seems to have originated in the mid-1970s with inventor Arthur Clyde Davenport and the firm Dynapods, Inc. The EADS Tropospheric Airship is a modern example of a variable buoyancy / variable volume airship.

Source: EADS

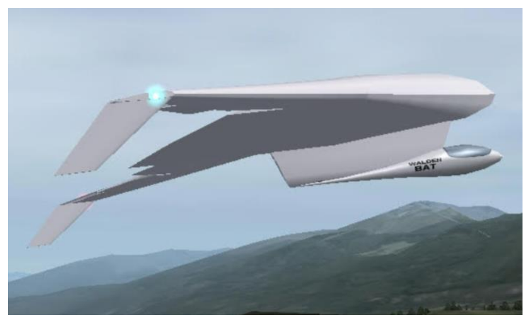
5.5 Variable buoyancy propulsion airships / aircraft

Back in the 1860s, Dr. Solomon Andrews invented the directionally maneuverable, hydrogen-filled airship named *Aereon* that used variable buoyancy (VB) and airflow around the airship's gas envelope to provide propulsion without an engine.

VB propulsion airships / aircraft fly a repeating sinusoidal flight profile in which they gain altitude as positively buoyant hybrid airships, then decrease their buoyancy at some maximum altitude and continue to fly under the influence of gravity as a semi-buoyant glider. After gradually losing altitude during a long glide, the pilot increases buoyancy and starts the climb back to higher altitude in the next cycle.

The UK's Phoenix and Michael Walden's HY-SOAR BAT concept are two examples of variable buoyancy propulsion airships / aircraft.

Source: phoenixuas.co.uk



Source: Walden Aerospace

5.6 Helistats (airship / helicopter hybrid)

There have been many different designs of airship / helicopter hybrid aircraft (a helistat) in which the airship part of the hybrid aircraft carries the weight of the aircraft itself and helicopter rotors deployed around the base of the airship work in concert to propel the aircraft and to lift and deliver heavy payloads without the need for an exchange of ballast.

The Piasecki PA-97-34J and the Boeing / Skyhook International SkyHook JLH-40 are examples of helistats.

Source: US Navy *Source: Boeing / Skyhook Intn'l*

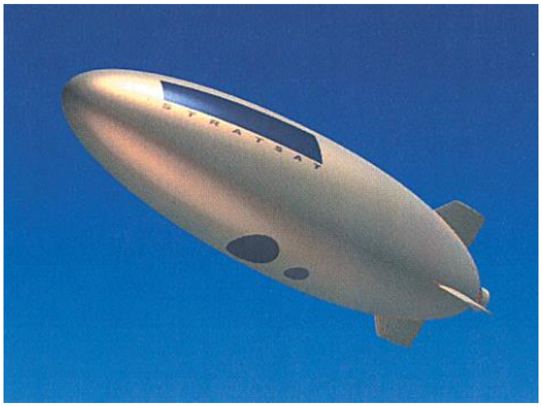
5.7 Stratospheric airships

Stratospheric airships are designed to operate at very high altitudes, well above the jet stream and in a region of relatively low prevailing winds typically found at altitudes of 60,000 to 75,000 feet (11.4 to 14.2 miles / 18.3 to 22.9 km). This is a harsh environment where airship materials are exposed to the damaging effects of ultraviolet radiation and corrosive ozone. These airships are designed as unmanned vehicles.

Applications for stratospheric airships include military intelligence, surveillance and reconnaissance (ISR) missions, civil environmental monitoring / resource management missions, military / civil telecommunications / data relay functions, and research missions such as high-altitude astronomy. All of these can be long term missions that can last weeks, months or even years.

Typically, the stratospheric airship will operate as a "pseudo-satellite" from an assigned geo-stationary position. Station keeping 24/7 is a unique challenge. Using a hybrid electric power system, these airships can be solar-powered during the day and then operate from an energy storage source (i.e., a battery or regenerative fuel cell) at night. Some propulsion systems, such as propellers that work well at lower altitudes, may have difficulty providing the needed propulsion for station keeping or transit in the very low atmospheric pressure at operating altitude.

The DARPA ISIS airship and the ATG StratSat are two examples for stratospheric airships.



Source: DARPA *Source: ATG*

5.8 Thermal (hot air) airships

Thermal airships use hot air as the lifting gas in place of helium or hydrogen. A given volume of hot air can lift only about one-third as much as the same volume of helium. Therefore, the gas envelope on a thermal airship is proportionally larger than it would be on a comparable airship using helium as the lifting gas.

The non-rigid GEFA-Flug four-seat AS-105GD/4 and six-seat AS-105GD/6 and the semi-rigid, two-seat Skyacht Personal Blimp are examples of current thermal airships that use propane burners to produce the hot air for lift. Pitch can be controlled with fore and aft burners. There are no ballonets.

Source: Skyacht *Source: GEFA-Flug*

Advanced concepts for solar-powered thermal airships are described in Modern Airships – Part 3.

6. How does an airship pick up and deliver a heavy load?

The term “load exchange” refers to the pickup and delivery of cargo by an airship, with or without an exchange of external ballast to compensate for the mass of cargo being moved on or off the airship. This isn’t a simple problem to solve.

The problem of buoyancy control

In Jeanne Marie Laskas’ article, Igor Pasternak, CEO of airship manufacturer Worldwide Aeros Corp. (Aeros), commented on the common problem facing all airships when a heavy load is delivered:

> “The biggest challenge in using lighter-than-air technology to lift hundreds of tons of cargo is not with the lifting itself—the larger the envelope of gas, the more you can lift—but with what occurs after you let the stuff go. ‘When I drop the cargo, what happens to the airship?’ Pasternak said. ‘It’s flying to the moon.’ An airship must take on ballast to compensate for the lost weight of the unloaded cargo, or a ground crew must hold it down with ropes.”

Among the many current designers and manufacturers of large airships, the matter of maintaining the airship’s net buoyancy within certain limits while loading and unloading cargo and passengers is handled in several different ways depending on the type of airship involved. Some load exchange solutions require ground infrastructure at fixed bases and/or temporary field sites for external ballast handling, while others require no external ballasting infrastructure and instead use systems aboard the airship to adjust buoyancy to match current needs or provide vectored thrust (or suction) to temporarily counteract the excess buoyancy. The solution chosen for managing airship buoyancy during a load exchange strongly influences how an airship can be operationally employed and where it can pickup and deliver its payload.

Additional problems for airborne load exchanges

Several current designers and manufacturers of large airships report that their airships will have the ability to conduct airborne load exchanges of cargo from a hovering airship. Jeremy Fitton, the Director of SkyLifter, Ltd., described the key issues affecting a precision load exchange executed by a hovering airship as follows:

> "The buoyancy management element of (an airborne) load-exchange is not the main control problem for airships. Keeping the aircraft in a geo-stationary position - in relation to the payload on the ground - is the main problem, of which buoyancy is a component."

The matters of precisely maintaining the airship's geo-stationary position throughout an airborne load exchange and controlling the heading of the airship and the suspended load are handled in different ways depending on the type of airship involved. The time required to accomplish the airborne load exchange can be many minutes or much longer, depending on the weight of the cargo being picked up or delivered and the time it takes for the airship to adjust its buoyancy for its new loaded or unloaded condition. Most of the airships offering an airborne load exchange capability are asymmetrical (i.e., conventional "cigar shaped" or hybrid aerobody-shaped) and must point their nose into the wind during an airborne load exchange. Their asymmetrical shape makes these airships vulnerable to wind shifts during the load exchange. The changing cross-sectional area exposed to the wind complicates the matter of maintaining a precise geo-position with an array of vectoring thrusters.

During such a delivery in variable winds, even with precise geo-positioning over the destination, the variable wind direction may require the hovering airship to change its heading slightly to point into the wind. This can create a significant hazard on the ground, especially when long items, such as a wind turbine blade or long pipe segment are being delivered. For example, the longest wind turbine blade currently in production is the GE Haliade-X intended for off-shore wind turbine installations. This one-piece blade is 107 meter (351 ft) long. A two degree change in airship heading could sweep the long end of the blade more than three meters (10 feet), which could be hazardous to people and structures on the ground.

Regulatory requirements pertaining to load exchanges

The German / Netherlands “Transport Airship Requirements” (TAR), includes the following requirement for load exchanges in TAR 80, “Loading / Unloading”:

> (c) During any cargo exchange…the airship must be capable of achieving a safe free flight condition within a time period short enough to recover from a potentially hazardous condition.”

This requirement will be a particular challenge for airships designed to execute an airborne load exchange from a hovering airship.

The CargoLifter approach to an airborne load exchange

One early approach for delivering a load from a hovering airship was developed for the CargoLifter CL160. As described on the Aviation Technology website (https://www.aerospace-technology.com/projects/cargolifter/), the CL160 would have performed an in-flight delivery of cargo as follows:

> “The airship hovers at about 100 m above the ground and a special loading frame, which is fixed during flight to the keel of the airship, is then rigged with four cable winches to the ground, a procedure which is to assure that the airship’s lifting gear stays exactly above the desired position. Ballast water is then pumped into tanks on the frame and the payload can be unloaded. The anchor lines are released and the frame is pulled back into the payload bay of the airship.”

In a 2002 test using a heavy-lift CargoLifter CL75 aerostat as an airship surrogate, a 55 metric ton German mine-clearing tank was loaded, lifted and discharged from the loading frame as water ballast was unloaded and later reloaded in approximately the same time it took to secure the tank in the carriage (several minutes). In this test, the 55 metric tons cargo was exchanged with about 55 cubic meters (1,766 cubic feet, 14,530 US gallons) of water ballast.

CL160 hovering with the loading frame partially lowered and secured to the ground by four cables. Source: CargoLifter

The SkyLifter approach to an airborne load exchange

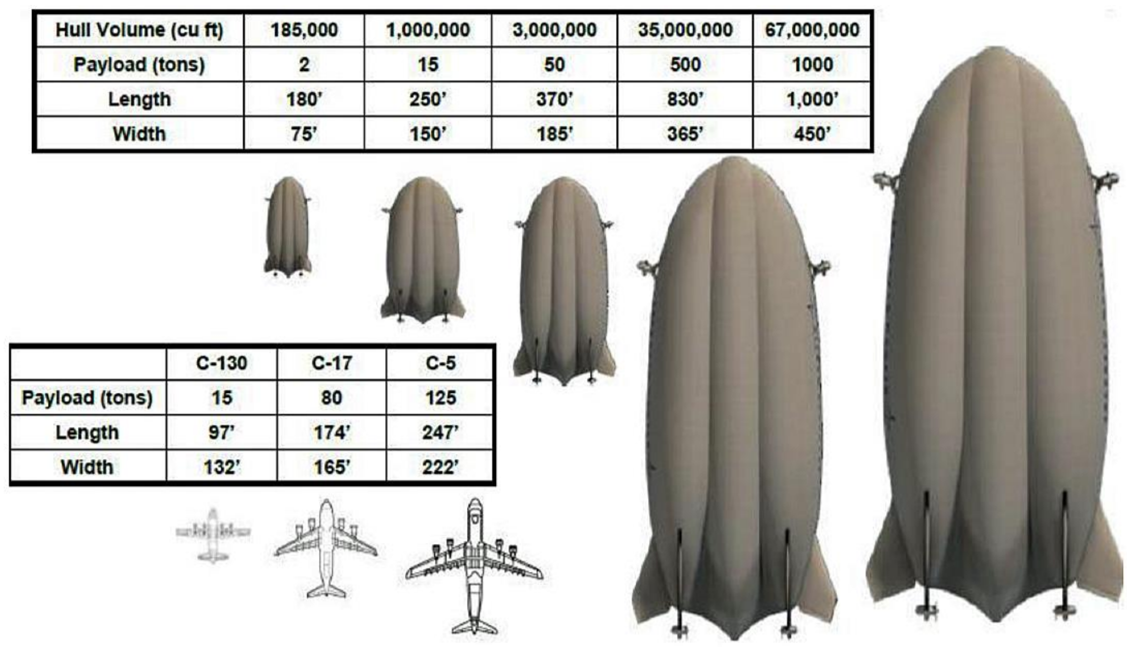
One airship design, the SkyLifter, addresses the airborne load exchange issues with a symmetrical, disc-shaped hull that presents the same effective cross-sectional area to a wind coming from any direction. This airship is designed to move equally well in any direction (omni-directional), simplifying airship controls in changing wind conditions, and likely giving the SkyLifter an advantage over other designs in conducting a precision airborne load exchange.

You'll find more information on airship load exchange issues in a December 2017 paper by Charles Luffman, entitled, "A Dissertation on Buoyancy and Load Exchange for Heavy Airships (Rev. B)", which is available at the following link:

https://www.luffships.com/wp-content/uploads/2018/02/buoyancy_and_load_exchange.pdf

7. The scale of large cargo airships

Some of the advanced airship concepts being developed, especially for future heavy-lift cargo carriers, will result in extremely large air vehicles on a scale not seen since the heyday of the giant zeppelins in the 1930s. Consider the following semi-rigid hybrid airships shown to scale with contemporary fixed-wing cargo aircraft.



Hull Volume (cu ft)	185,000	1,000,000	3,000,000	35,000,000	67,000,000
Payload (tons)	2	15	50	500	1000
Length	180'	250'	370'	830'	1,000'
Width	75'	150'	185'	365'	450'

	C-130	C-17	C-5
Payload (tons)	15	80	125
Length	97'	174'	247'
Width	132'	165'	222'

Size comparison for hybrid airships sized for various lift applications.
Source: DoD (2012)

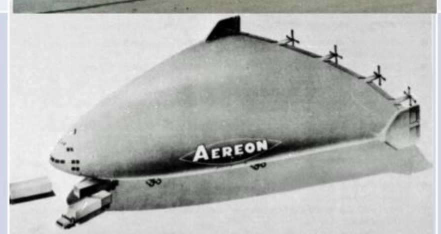
8. Specific airships in Part 1

The wide variety of airships reviewed in Modern Airships - Part 1 are summarized in the following set of tables. Links to the individual articles on these airships are provided at the end of this document.

Airship	Country	Airship type	Lift control	Graphic	Status
CargoLifter CL160	Germany	Conventional, semi-rigid	Ballonets + water ballast		Conceptual design phase started in 1996; Joey & CL75 AC aerostat flew; firm bankrupt in 2002.
ZLT Zeppelin Luftschifftechnik GmbH Zeppelin NT 07	Germany	Conventional, semi-rigid	Ballonets + vector thrust + aero lift + ballast		First flight in 1997; several are in regular commercial service. Goodyear blimp fleet replaced by Zeppelin NTs.
Science Applications International Corporation (SAIC) Skybus 80K	USA	Conventional, non-rigid	Ballonets + ballast		Prototype flew in 2010; now retired.
SAIC and ArcXeon International Airstation Unmanned Air Systems (UAS) Carrier	USA	Likely conventional, semi-rigid	Likely ballonets + vector thrust + aero lift + ballast		Concept circa 2016

Airship	Country	Airship type	Lift control	Graphic	Status
Airship do Brasil (ADB) ADB 3-X01, 3-3, 3-30 & 3-15/30	Brazil	Likely conventional, non-rigid	Ballonets + vector thrust + ballast		ADB 3-X01 prototype flew in 2017. Others under development.
Aeros Aeroscraft Dragon Dream	USA	Variable buoyancy, fixed volume, rigid	Lift gas pressurization / release + ballonets + vector thrust + reversible ACLS on the ground		First flew in January 2013; later damaged by hanger roof partial collapse; retired.
Aeros Aeroscraft ML866 / Aeroscraft Gen 2	USA	Variable buoyancy, fixed volume, rigid	Lift gas pressurization / release + ballonets+ vector thrust + reversible ACLS on the ground		Under development
Halo	USA	Variable buoyancy, fixed volume, rigid	Lift gas pressurization / release + ballonets + vector thrust		Luxury concept based on Aeros ML866

Airship	Country	Airship type	Lift control	Graphic	Status
Piasecki PA-97	USA	Helistat (semi-buoyant airship - helicopter hybrid)	Fixed helicopter rotors		Prototype first flight in April 1986; destroyed in crash in July 1986; development cancelled.
Boeing / Skyhook International SkyHook JLH-40	USA / Canada	Helistat (semi-buoyant airship - helicopter hybrid)	Vectored thrust ducted rotors		Concept under development 2008 - 2010, then abandoned.
Megalifter	USA	Semi-buoyant aircraft, rigid	Aero lift + ballonets		Concept under development 1972 - 1976, then abandoned.
Ohio Airships Dynalifter DL-100 & Patroller	USA	Semi-buoyant aircraft, rigid	Aero lift + ballonets		DL-100 taxi tests in 2012; currently inactive. Patroller is a comparably-sized concept.

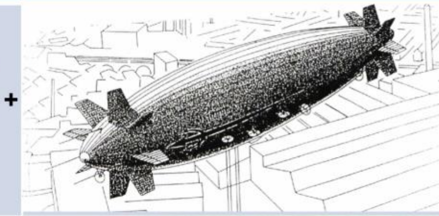
Airship	Country	Airship type	Lift control	Graphic	Status
Ohio Airships Dynalifter Freighter & Cruiser	USA	Semi-buoyant aircraft, rigid	Aero lift + ballonets		Concept
Ohio Airships Dynalifter Drone Runner	USA	Semi-buoyant aircraft, rigid	Aero lift + ballonets		Concept, under development
Aereon Corp. Aereon III	USA	Hybrid airship, rigid, triple hull	Helium heating and cooling + aero lift + ballonets		Crashed during 1966 taxi test. Not rebuilt. Never flew.
Aereon Corp Aereon 26	USA	Heavier-than-air aerobody, rigid	Aero lift		Prototype to validate Dynalifter aero design. First flight in 1971; retired; in museum.
Aereon Corp. Dynairship	USA	Semi-buoyant aerobody, semi-rigid	Aero lift + ballonets		Concept & patent circa early 1970s by William M. Miller, Jr.

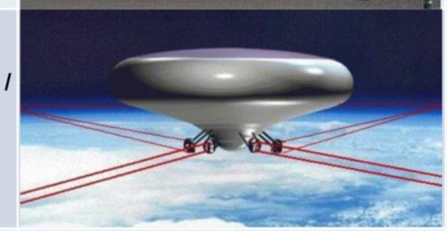
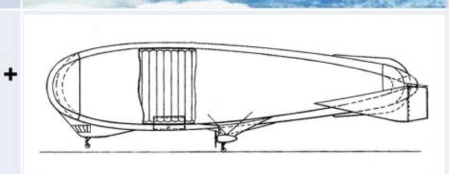
Airship	Country	Airship type	Lift control	Graphic	Status
Defense Advanced Projects Research Agency (DARPA) Project Walrus	USA	Various, including hybrid semi-buoyant and variable buoyancy	Various		Started in mid-2003; tradeoff studies and two technology demonstrators – LM P-791 & Aeros Dragon Dream; project cancelled in mid-2006.
ATG / SkyCat Group SkyCat	UK	Hybrid, semi-buoyant, semi-rigid	Vector thrust + aero lift + ballonets + ballast		SkyKitten demonstrator flew in 2000. ATG failed in 2005, became SkyCat Group, which failed in 2007 & was acquired by Hybrid Air Vehicles (HAV).
Hybrid Air Vehicles (HAV) / Northrop Grumman HAV-304 (LEMV)	UK / USA	Hybrid, semi-buoyant, semi-rigid	Vector thrust + aero lift + ballonets + ballast		ATG SkyKitten renamed HAV-3 demonstrator. HAV-304 first flew in 2012 as Army LEMV; became the HAV Airlander 10 prototype in 2013.

Airship	Country	Airship type	Lift control	Graphic	Status
Hybrid Air Vehicles (HAV) Airlander 10	UK	Hybrid, semi-buoyant, semi-rigid	Vector thrust + aero lift + ballonets + ballast		Prototype made its first flight in 2016; retired in 2018. Production model under development.
Hybrid Air Vehicles (HAV) Airlander 50	UK	Hybrid, semi-buoyant, semi-rigid	Vector thrust + aero lift + ballonets + ballast + reversible ACLS on the ground		Concept, to follow Airlander 10.
Lockheed Martin P-791	USA	Hybrid, semi-buoyant, semi-rigid	Vector thrust + aero lift + ballonets + ballast + reversible ACLS on the ground		Prototype flight tested in 2006; now retired.
Lockheed Martin LMH-1	USA	Hybrid, semi-buoyant, semi-rigid	Vector thrust + aero lift + ballonets + ballast + reversible ACLS on the ground		Derived from P-791; originally named SkyTug. Production model under development.

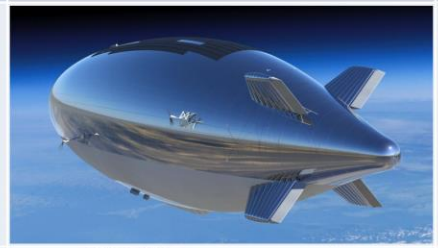
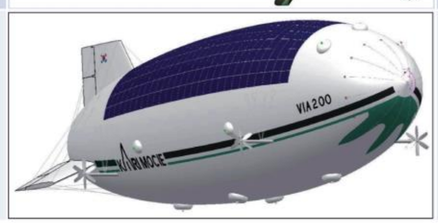
Airship	Country	Airship type	Lift control	Graphic	Status
Vantage Airship Manufacturing Co., Ltd. CT-60T & CT-200T	China	Hybrid, semi-buoyant, semi-rigid	Vector thrust + aero lift + ballonets + ballast		Conceptual design phase; seeking development partners.
Voliris V901	France	Hybrid, semi-buoyant, non-rigid	Aero lift		Sub-scale Demonstrator 1st flight in 2012.
Voliris V930	France	Hybrid, semi-buoyant, semi-rigid	Aero lift		Development cancelled, redirected to NATAC V932.
Voliris V902 mini-NATAC	France	Hybrid, semi-buoyant inflated wing, semi-rigid	Aero lift		Sub-scale mini-NATAC demonstrator 1st flight in 2017.

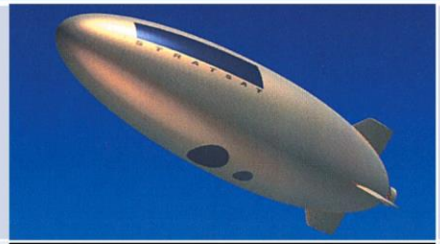
Airship	Country	Airship type	Lift control	Graphic	Status
Voliris NATAC V932	France	Hybrid, semi-buoyant inflated wing, semi-rigid	Aero lift		Under development
GEFA-Flug (Impacto Aereo) AS-105GD/4 & AS-105GD/6	Germany / Mexico	Non-rigid thermal airship	Hot air control		Operational. GEFA-Flug type certificates were sold to Mexican firm Impacto Aereo circa 2017.
Skyacht Personal Blimp	USA	Semi-rigid thermal airship	Hot air control		Operational
APEX Balloons Thermal airship	USA	Non-rigid thermal airship	Hot air control		Development discontinued

Airship	Country	Airship type	Lift control	Graphic	Status
Airfloat HL	UK	Conventional, rigid	Ballonets + vector thrust + ballast		Concept circa early-1970s.
Shell / Aerospace Developments Methane gas transporter	UK	Conventional, rigid	Ballonets + vector thrust + ballast		Concept development started circa late-1960s; cancelled in 1974.
CargoLifter Joey	Germany	Conventional, semi-rigid	Ballonets + vector thrust + ballast		Operational 1999 – 2002. Sold after CargoLifter bankruptcy in 2002. Now privately owned in France.
ZET Zeppelin Luftschifftechnik GmbH Zeppelin NT 07	Germany	Conventional, semi-rigid	Ballonets + vector thrust + aero lift + ballast		Development plans announced in 2003, cancelled in 2018 when sponsor ZET insolvent.

Airship	Country	Airship type	Lift control	Graphic	Status
Walden Aeospace / LTAS T-90 & T-280	US	Variable buoyancy, fixed volume, rigid	Lift gas pressurization / release + ballonets + vector thrust		Concepts circa 1992 – 1996.
Walden Aeospace / LTAS 222-PAD & 30-XB	US	Variable buoyancy, fixed volume, rigid	Lift gas pressurization / release + ballonets + vector thrust		Concepts circa 1982 to 2004.
Walden Aeospace / LTAS S.O.S.C.S	US	Variable buoyancy, fixed volume, rigid, stratospheric	Lift gas pressurization / release + ballonets + vector thrust		Telcom airship concept circa early-1970s to 1980s.
Goodyear Aerospace Corp. Dynamic lift airships - Dynastat	US	Hybrid, non-rigid & semi-rigid	Ballonets + vector thrust + aero lift + ballast		Several concepts circa mid-1950s to late-1960s.

Airship	Country	Airship type	Lift control	Graphic	Status
US Navy (NAVAIR) **Hybrid Ultra Large Airship (HULA) program**	**US**	**Hybrid, semi-rigid**	**Ballonets + vector thrust + aero lift + ballast**		**DoD/Navy program 2001 – mid-2003, then subsumed by Project WALRUS, then returned to Navy program after WALRUS cancelled in 2006. Mainly trade studies.**
Southwest Research Institute (SwRI) **HiSentinel**	**US**	**Non-rigid, stratospheric**	**Initial helium charge + ballast**		**Military ISR airship; active program with three test vehicles 2005 – 2010.**
Lockheed Martin **High Altitude Airship (HAA)**	**US**	**Semi-rigid, stratospheric**	**Ballonets + aero lift + ballast**		**HAA program started in 1998; LM selected in 2003 to develop HAA prototype; program cancelled in 2008.**
Lockheed Martin **HALE-D**	**US**	**Semi-rigid, stratospheric**	**Ballonets + aero lift + ballast**		**Military ISR airship program started in 2003; only one test flight ended in a crash in 2011; program cancelled.**

Airship	Country	Airship type	Lift control	Graphic	Status
Air Force / Mav6 LLC Blue Devil Block II	US	Non-rigid, medium-altitude	Ballonets + aero lift + ballast		Military ISR airship program started in 2010; one airship built but never flown; program cancelled in 2012.
DARPA / Lockheed Martin ISIS	US	Semi-rigid, stratospheric	Ballonets + aero lift + ballast		Military ISR airship program; DARPA started in 2003; LM contracted in 2009; program cancelled in 2014.
Japan Stratospheric System SkyNet	Japan	Semi-rigid, stratospheric	Ballonets + aero lift + ballast		Telcom airship program started in 1998; two subscale demonstrators flew in 2003 & 2004; program cancelled in 2005.
South Korea stratospheric airship VIA-200	South Korea	Semi-rigid, stratospheric	Ballonets + aero lift + ballast		Telcom airship program started in 2000; subscale VIA-50 flew 2003 – 2005; program cancelled 2005.

Airship	Country	Airship type	Lift control	Graphic	Status
ATG StratSat	UK	Semi-rigid, stratospheric	Ballonets + aero lift + ballast		Telcom airship program started in 2001; subscale prototype flew; program cancelled in 2005.
US Navy (NAVAIR) / GNSS StarLight	US	Non-rigid, maneuverable stratospheric balloon with "fly-down" recovery vehicle	Initial helium charge + ballast		Military ISR airship; NAVAIR started in 2008; prototype balloon & recovery vehicle partially built but not flown; program cancelled in 2011.
Airship do Brasil (ADB) SAGA	Brazil	Likely non-rigid, stratospheric	Ballonets + ballast		Active program to develop a multifunction high altitude platform (HAP).

The Aerofloat HL, CargoLifter CL160, helistats, Megalifter, Aereon Dynairship, Project Walrus and the HULA program are included because they are of historical interest as early, though largely unsuccessful, attempts to develop heavy-lift cargo airships. Concepts and technologies developed on these airship projects have contributed to the development of modern airships.

Among the airships in the above tables, the following have flown:

Conventional airships:
- Cargolifter Joey airship & ACL75 AC aerostat
- Skybus 80K
- Zeppelin NT 07

Variable buoyancy, fixed volume airships:
- Aeros Aeroscraft *Dragon Dream*

Helistats (airship / helicopter hybrid):
- Piasecki PA-97-34J

Hybrid, semi-buoyant aircraft:
- Dynalifter DL-100
- Aereon 26 (only as a heavier-than-air craft)

Hybrid, semi-buoyant airships:
- ATG SkyKitten
- Lockheed Martin P-791
- Hybrid Air Vehicles HAV-3 & HAV-304
- Hybrid Air Vehicles Airlander 10
- Voliris 901 & 902

Stratospheric airships:
- SwRI HiSentinel
- Lockheed Martin HALE-D

Thermal (hot air) airships:
- GEFA-Flug AS-105GD/4 & AS-105GD/6
- Skyacht Personal Blimp

As of December 2020, the Zeppelin NT 07 is the only advanced airship that has been certified and is flying regularly in commercial passenger service. The simpler GEFA-Flug and Skyacht thermal (hot air) airships also are flying regularly. Among the others that have flown, most have been retired and a few were damaged or destroyed.

The remaining airships in the Part 1 tables are under development or remain as concepts only.

Among the airships in the above tables, the following cargo airships seem likely to receive their airworthiness certification in the next several years. The leading candidates identified in Part 1 are:

- Lockheed Martin: LMH-1 hybrid airship
- Hybrid Air Vehicles (HAV): Airlander 10 hybrid airship

These airships will be competing in the worldwide airship market with the leading candidates identified in Part 2, which may enter the market in the same time frame:

- Flying Whales: LCA60T rigid airship
- Varialift: ARH-PT variable buoyancy airship prototype and the larger ARH 50
- Euro Airship: Corsair & DGPAtt variable buoyancy airships
- Solar Ship: 24-meter Caracal light cargo semi-buoyant airship and the Wolverine medium cargo semi-buoyant aircraft
- Egan Airships: The PLIMP drone and Model J plane / blimp hybrids

All of these candidates depend on a source of funding to bring their advanced designs to market.

This next decade will be an exciting time for the airship industry. We'll finally get to see if the availability of several different heavy-lift airships with commercial airworthiness certificates will be enough to open a new era in airship transportation. Aviation regulatory agencies need to help reduce risk by eliminating regulatory uncertainty and putting in place an adequate regulatory framework for the wide variety of advanced airships being developed. Customers with business cases for airship applications need to step up, place firm orders, and then begin the pioneering task of employing their airships and building a worldwide airship transportation network with associated ground infrastructure.

9. Links to the individual articles

The following links will take you to the 38 individual Modern Airships - Part 1 articles.

Conventional airships:

- Airfloat HL: https://lynceans.org/wp-content/uploads/2020/12/Airfloat-HL.pdf
- Shell / Aerospace Developments methane gas transporter: https://lynceans.org/wp-content/uploads/2020/12/Shell-AD_Methane-gas-carrier.pdf
- CargoLifter Joey, CL75 AC (AirCrane) & CL160: https://lynceans.org/wp-content/uploads/2020/12/Cargolifter.pdf
- Zeppelin NT: https://lynceans.org/wp-content/uploads/2020/12/Zeppelin-NT.pdf
- Zeppelin ZET: https://lynceans.org/wp-content/uploads/2020/12/Zeppelin-ZET.pdf
- Science Applications International Corp. (SAIC) Skybus 80K: https://lynceans.org/wp-content/uploads/2020/12/SAIC_Skybus-80K.pdf
- SAIC & ArcXeon International Airstation UAS Carrier: https://lynceans.org/wp-content/uploads/2020/12/SAIC-ArcXeon_UAS-carrier-airship.pdf
- Airship do Brasil (ADB) ADB 3-3 & 3-15/30: https://lynceans.org/wp-content/uploads/2020/12/Airships-do-Brasil.pdf

Variable buoyancy, fixed volume airships:

- Walden Aerospace / LTAS lenticular, toroidal, variable buoyancy airships: https://lynceans.org/wp-content/uploads/2020/12/Walden-LTAS-Part-1_Lenticular-toroidal-DCB-airships.pdf
- Aeros Aeroscraft *Dragon Dream*: https://lynceans.org/wp-content/uploads/2020/12/Aeros_Dragon-Dream.pdf
- Aeros ML866 / Aeroscraft Generation 2: https://lynceans.org/wp-content/uploads/2020/12/Aeros_Aeroscraft.pdf
- Halo luxury airship: https://lynceans.org/wp-content/uploads/2020/12/Halo-luxury-airship.pdf

Helistats (airship / helicopter hybrid):

- Piasecki PA-97, Boeing / Skyhook International SkyHook JLH-40 and other helistats: https://lynceans.org/wp-content/uploads/2020/12/Heli-stats_Airship-Helicopter-Hybrids.pdf

Hybrid, semi-buoyant aircraft:

- Megalifter: https://lynceans.org/wp-content/uploads/2020/12/Megalifter-hybrid-aircraft.pdf
- Ohio Airships Dynalifters DL-100 & Patroller, Freighter & Cruiser, Drone Runner: https://lynceans.org/wp-content/uploads/2020/12/Ohio-Airships_Dynalifter.pdf
- Aereon Corporation Aereon III, Aereon 26 & Dynairships: https://lynceans.org/wp-content/uploads/2020/12/Aereon_Aereon-III-Dynairships.pdf

Hybrid, semi-buoyant airships:

- Goodyear dynamic lift airships & Dynastats: https://lynceans.org/wp-content/uploads/2020/12/Goodyear_Dynamic-lift-airships.pdf
- DARPA Project Walrus: https://lynceans.org/wp-content/uploads/2020/12/DARPA_Project-WALRUS.pdf
- Navy HULA program: https://lynceans.org/wp-content/uploads/2020/12/Navy_Hybrid-Ultra-Large-Aircraft-HULA.pdf
- ATG SkyKitten & SkyCat: https://lynceans.org/wp-content/uploads/2020/12/ATG-SkyCat.pdf
- Hybrid Air Vehicles / Northrop Grumman HAV-3 & HAV-304 (LEMV): https://lynceans.org/wp-content/uploads/2020/12/HAV-Northrop-Grumman_LEMV.pdf
- Hybrid Air Vehicles Airlander 10 & 50: https://lynceans.org/wp-content/uploads/2020/12/HAV_Airlander-10-50.pdf
- Lockheed Martin P-791: https://lynceans.org/wp-content/uploads/2020/12/Lockheed-Martin_P791.pdf
- Lockheed Martin SkyTug & LMH-1: https://lynceans.org/wp-content/uploads/2020/12/Lockheed-Martin_SkyTug-LMH-1.pdf

- Vantage Airship Manufacturing Co., Ltd. CA-60T & CA-200T: https://lynceans.org/wp-content/uploads/2020/12/Vantage-Airship.pdf
- Voliris V900, V901, V902, V930, V932 NATAC & SeaBird: https://lynceans.org/wp-content/uploads/2020/12/Voliris.pdf

Stratospheric airships:

- SwRI HiSentinel: https://lynceans.org/wp-content/uploads/2020/12/SwRI_HiSentinel.pdf
- Lockheed Martin high-altitude airship (HAA): https://lynceans.org/wp-content/uploads/2020/12/Lockheed-Martin_HAA.pdf
- Lockheed Martin HALE-D: https://lynceans.org/wp-content/uploads/2020/12/Lockheed-Martin_HALE-D.pdf
- Air Force Blue Devil Bock II: https://lynceans.org/wp-content/uploads/2020/12/USAF_Blue-Devil-Block-II.pdf
- DARPA / Lockheed Martin ISIS: https://lynceans.org/wp-content/uploads/2020/12/DARPA-LM_ISIS.pdf
- Japan stratospheric platform (SPF) & SkyNet: https://lynceans.org/wp-content/uploads/2020/12/Japan_Stratospheric-Platform-SkyNet.pdf
- South Korea stratospheric airship VIA-200: https://lynceans.org/wp-content/uploads/2020/12/South-Korea_Stratospheric-Airship.pdf
- Walden Aerospace / LTAS S.O.S.C.S.: https://lynceans.org/wp-content/uploads/2020/12/Walden-LTAS-Part-1_Lenticular-toroidal-DCB-airships.pdf
- ATG StratSat: https://lynceans.org/wp-content/uploads/2020/12/ATG_StratSat.pdf
- Navy StarLight: https://lynceans.org/wp-content/uploads/2020/12/Navy_StarLight.pdf
- SAGA: https://lynceans.org/wp-content/uploads/2020/12/Airships-do-Brasil.pdf

Thermal (hot air) airships:

- GEFA-Flug (Impacto Aereo) AS-105GD/4 & AS-105GD/6: https://lynceans.org/wp-content/uploads/2020/12/GEFA-Flug-thermal-airships.pdf

- Skyacht Personal Blimp: https://lynceans.org/wp-content/uploads/2020/12/Skyacht-Aircraft_Personal-Blimp.pdf
- APEX Balloons thermal airship: https://lynceans.org/wp-content/uploads/2020/12/APEX-thermal-airship.pdf