The Lyncean Group of San Diego

Modern Airships – Part 1

August 18, 2019 Aeronautical, All Posts, Aviation, Engineering, Transportation Advanced Technology Group, Aereon Corporation, Aerocraft, Aerocrane, Aeroscraft, Aeroscraft Gen 2, Airfloat HL, Airlander, airship, Airship Industries, airship technology, Alcyon, American Blimp Corp, ANR-1, ANVCE, APEX Balloons, Ascender, AT-10, AVIC, Blue Devil Block II, Boeing Vertol, Cargo Airship Ltd, CargoLifter, Champlain, Conrad Airship, Cyclo-Cruiser, Cyclocrane, Dark Dry Station, DARPA, DARPA ISIS, Dynalifter, dynamic lift airship, EERM Dinosaure, GEFA_Flug, Goodyear blimp, Gordon Vaeth, HALE-D, Helicostat, Helipsoid, Helitruck, helium horse, High Altitude Shuttle System, HiSentinel, Holland Navigator, Hov-Air-Ship, Hybrid Air Vehicles, hybrid airship, JP Aerospace, Lindstrand Technologies, LMH-1, Lockheed Martin, LTA Research and Exploration, Megalifter, Memphis Airships, Michael Walden, ML866, Model 138S, N-Class blimps, Near Space Corporation, Near Space Maneuvering Vehicle, Obélix, Ohio Airships, P-791, Pathfinder 1, Pégase, Personal Blimp, Piasecki, PongSat, Sentinel 1000, Sentinel 5000, Skyacht, Skybus 80, SkyCat, Skyhook, SkyKitten, SkyNet, SkyRider Airships, Solar Airship Ltd, SPACIAL, StarLight, StarShadow, StratoComm Corp, stratospheric airship, StratSat, thermal airship, Thunder & Colt, Tucker Airships, Tumencotrans, UPship, Vantage Airship, Voliris, Walden Aerospace, WDL, Wendel R Wendel, Worldwide Aeros Corporation, Wren Skyships, YEZ-2A, zeppelin, Zeppelin NT, Zeppelin ZET, ZPG-3W Drummer

Peter Lobner, updated 30 October 2022 (post-Rev. 5)

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 more than 225 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 (as of Rev. 5): https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2022/03/Modern-Airships-–-Consolidated-TOC_20Mar2022.pdf

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 93 individual articles on these airships. A downloadable pdf copy of Part 1 is available here:

- Part 1 main body & tables (as of Rev. 5): https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2022/03/Part-1_Intro-text-and-tables_R5_8Mar2022-compressed.pdf

If you have any comments or wish to identify errors in this document, 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

30 October 2022

Record of revisions to Part 1

- **Original *Modern Airships* post, 26 August 2016:** addressed 14 airships in a single post.
- **Expanded the *Modern Airships* post and split it into three parts, 18 August 2019:** Part 1 included 22 linked articles.
- **Part 1, Revision 1, 21 December 2020**: Added 15 new articles, split the existing Aeros article into two articles and updated all of the original articles. Part 1 now had 38 articles.
- **Part 1, Revision 2, 3 April 2021:** Updated the main text and 10 existing articles, and expanded and re-organized the graphic tables. Part 1 still had 38 articles
- **Part 1, Revision 3, 26 August 2021**: Added 34 new articles, split the existing Helistat article into five articles and the Aereon article into two articles, and expanded and reorganized the graphic tables. Also updated 23 existing articles. Part 1 now had 77 articles.
- **Part 1, Revision 4, 12 February 2022:** Added 12 new articles, split the existing Airlander article into two updated articles (prototype, production), moved Halo to Part 3, expanded the graphic tables and updated 17 additional existing articles. Part 1 now had 89 articles.
- **Part 1, Revision 5, 10 March 2022:** Added 2 new articles, split rigid & semi-rigid airships in the graphic tables, and updated 58 existing articles. With this revision, all Part 1 linked articles have been updated in February or March 2022. Part 1 now has 91 articles.

Since Rev. 5 was posted, the following additions and updates have been made in Part 1.

New articles:

- ISL Aeronautical & Space Systems (formerly Bosch Aerospace Inc.) – UAV blimps and tethered aerostats (12 June 2022)
- Detroit Aircraft Corporation – ZMC-2 metalclad airship (31 July 2022)

Updated articles:

- LTA Research and Exploration – rigid airships (24 July 2022)
- Airship Industries Ltd. (3 September 2022)

- Walden Aerospace / LTAS – Lenticular, toroidal, variable buoyancy airships (30 October 2022)

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 military intelligence, surveillance & reconnaissance (ISR), 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 world-wide airship cargo and passenger transportation industry has been very slow in developing. To give you an example of how slow:

- As of August 2021, other than a modest number of commercially certified blimps used largely as advertising platforms, 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's to 100's of 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 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, hangar 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 and passenger 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.

US Federal Aviation Administration (FAA)

In the US, the FAA's 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 on locations other than the gondola of a non-rigid airship.

On March 12, 2012 the FAA announced that Lockheed Martin Aeronautics submitted an application for type certification for their model LMZ1M (LMH-1), which is "a manned cargo lifting hybrid airship incorporating a number of advanced features." The FAA assigned that application to their docket number FAA-2013-0550.

To address the gap in airship regulations head-on, Lockheed Martin submitted to the FAA their recommended criteria document, "Hybrid Certification Criteria (HCC) for Transport Category Hybrid Airships," which is a 206 page document developed specifically for the LMZ1M (LMH-1). The HCC is also known as Lockheed Martin Aeronautics Company Document Number 1008D0122, Rev. C, dated 31 January 2013. You can download the HCC document and related public docketed items on the FAA website here:

https://www.regulations.gov/docket/FAA-2013-0550/document

In November 2015, Lockheed Martin announced that the FAA's Seattle Aircraft Certification Office had approved the project-specific certification plan for the LMZ1M (LMH-1). Since then, nothing new has been posted on the docket.

Germany & Netherlands

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

European Union Aviation Safety Agency (EASA)

On 11 February 2021, the European Union Aviation Safety Agency (EASA) proposed a new regulatory framework for the certification of large airships. The proposed document went through a public review and comment period before the final document was issued on 21 January 2022 as Doc. No. SC GAS, "Special Condition 'SC GAS' Gas Airships," which is available here: https://www.easa.europa.eu/downloads/134946/en

EASA explained their rationale for this special condition document:

"EASA has received applications for the type certification of large Airships but has not yet published Certification Specifications (CS) for these products…… In the absence of agreed and published certification specifications for Airships by EASA…….a complete set of dedicated technical specifications in the form of a Special Condition for Gas Airships has been developed. This Special Condition addresses the unique characteristics of Airships and defines airworthiness specifications that may be used to demonstrate compliance with the essential requirements in Annex II of regulation (EU) 2018/1139 of the European Parliament and Council. That is required before the issuance of the EASA type certificate, as well as for the approval of later changes to type certificate."

"The Special Condition is a high-level set of objective driven and performance-based requirements. It was developed in close cooperation with the industry working group. The Special Condition addresses two designs, one being a 260,000 m^3 rigid equilibrium Airship for cargo operations, the other one a 45,000 m^3 non-rigid hybrid Airship for up to 100 passengers. However, the authors believe the SC can be applied to all manned Airships with non-pressurized crew or passenger compartments. It will be subject to EASA Certification Team agreement whether this Special Condition can be deemed sufficient as a Certification Basis, for example unmanned designs are not sufficiently addressed by this proposal. Due to the low number of projects no categories have been established. The different safety levels applicable to specific Airship designs will be addressed through the Means of Compliance (MOC)."

The EASA is ahead of the FAA in terms of having published usable interim regulations for advanced airships. However, both EASA and FAA regulators are lagging the development of advanced civilian airship designs that may be submitted for type certification in the next decade. The lack of mature regulations for advanced airship designs will increase the regulatory risk for the designers / manufacturers of those airships.

4. Lifting gas

In the US, Europe and Canada, the following 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)

The EASA proposed Special Condition issued on 21 January 2022 creates an opportunity to use flammable lifting gases, subject to the following conditions:

- **SC GAS.2355 Lifting gas system**
  - Lifting gas systems required for the safe operation of the Airship must:
    - withstand all loading conditions expected in operation including emergency conditions
    - monitor and control lifting performance and degradation
  - If the lifting gas is toxic, irritant or flammable, adequate measures must be taken in design and operation to ensure the safety of the occupants and people on the ground in all envisaged ground and flight conditions including emergency conditions.
- **SC GAS.2340 Electrostatic Discharge**

    - There must be appropriate electrostatic discharge means in the design of each Airship whose lift-producing medium contains a flammable gas to ensure that the effects of electrostatic discharge will not create a hazard.

- **SC GAS.2325 Fire Protection**
    - The design must minimize the risk of fire initiation caused by:
        - Anticipated heat or energy dissipation or system failures or overheat that are expected to generate heat sufficient to ignite a fire;
        - Ignition of flammable fluids, gases or vapors; and
        - Fire propagating or initiating system characteristics (e.g. oxygen systems); and
        - A survivable emergency landing.

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 and larger thermal-gas (Rozier) 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, hence, helium is not "rare." However, 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 filed in 2010 and granted 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.

Additional regulatory changes will be required to permit the general use of hydrogen in aviation. With the growing interest in the use of hydrogen fuel in aviation, it seems only a matter of time before it is approved for use as a lifting gas in commercial airships.

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 aerostats are described in the *Modern Airships* series of documents:

- Conventional airships
    - Rigid airships
    - Semi-rigid airships
    - Non-rigid airships (blimps)
- Semi-buoyant hybrid airships
- Semi-buoyant hybrid aircraft (Dynairship, Dynalifter, Megalifter)
- Variable buoyancy airships
    - Variable buoyancy / fixed volume airships
    - Variable buoyancy / variable volume airships
    - Variable buoyancy propulsion airships / aircraft
- Helicopter / airship hybrids (helistats, Dynastats, rotostats)
- Stratospheric airships
- Thermal (hot air) airships
- Hybrid thermal-gas (Rozier) airships
- Rocket / balloon (Rockoon) hybrid airships
- Unpowered aerostats

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 rigid zeppelins, semi-rigid airships and non-rigid blimps.

- **Rigid airships (zeppelins):** These airships have a lightweight, rigid airframe that defines their exterior shape. This airframe supports the gondola, engines and payload. Most have atmospheric pressure lifting gas cells and air ballonets located within the rigid airframe. A special case is a metal-clad rigid airship, where the metal hull is a slightly pressurized lift gas container.
- **Semi-rigid airships:** These airships have a rigid structural framework that supports loads and is connected via a load distribution system to the flexible, pressurized envelope that defines the exterior shape and contains air ballonets.
- **Non-rigid airships (blimps)**: These airships have a pressurized flexible envelope that defines the exterior shape of the airship. Most loads are attached to the gondola and are transferred via a load distribution system to the envelope.

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

Source: Euro Airship

Source: Flying Whales

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

Source: Author

Source: SkyLifter

The Aeros 40D Sky Dragon and the SAIC Skybus 80K are examples of conventional non-rigid airships.

Source: Aeros

Source: SAIC

After being loaded and ballasted before flight, conventional airships have various means to exercise in-flight control over their aerostatic buoyancy, internal pressure and trim. Buoyancy control is exercised with ballast and lifting gas. Internal pressure is controlled with air ballonets and lifting gas vents. Trim is adjusted with the air ballonets or moveable ballast.

Conventional airships with thrust vectoring propulsors have the ability to operate with some degree of net aerostatic heaviness or lightness that can be compensated for with the dynamic thrust (lift or downforce) from the adjustable propulsors.

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 or discharging cargo or passengers) can change the overall mass of an airship and may require a corresponding ballast adjustment during or after the load exchange.

In-flight use of fuel and other consumables can change the overall mass of an airship. The primary combustion products of diesel fuel are water and carbon dioxide. To reduce the loss of mass from fuel consumption, some airships use a rather complex system to recover water from the engine exhaust. A modern diesel engine water recovery system being developed for the Aerovehicles AV-10 blimp is expected to recover 60% to 70% of the weight of the fuel burned, significantly reducing the change in airship mass during a long mission.

Some Navy blimps and other long-range airships have had a hoist system that could be used in flight to retrieve water from the ocean or any other body of water to increase the amount of on-board ballast.

If an airship becomes heavy, ballast can be dumped in flight to increase aerostatic buoyancy.

Controlling buoyancy with lifting gas

The lifting gas inside an airship may be at atmospheric pressure (most rigid airships) or at a pressure slightly greater than atmospheric (semi-rigid and non-rigid airships). 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.

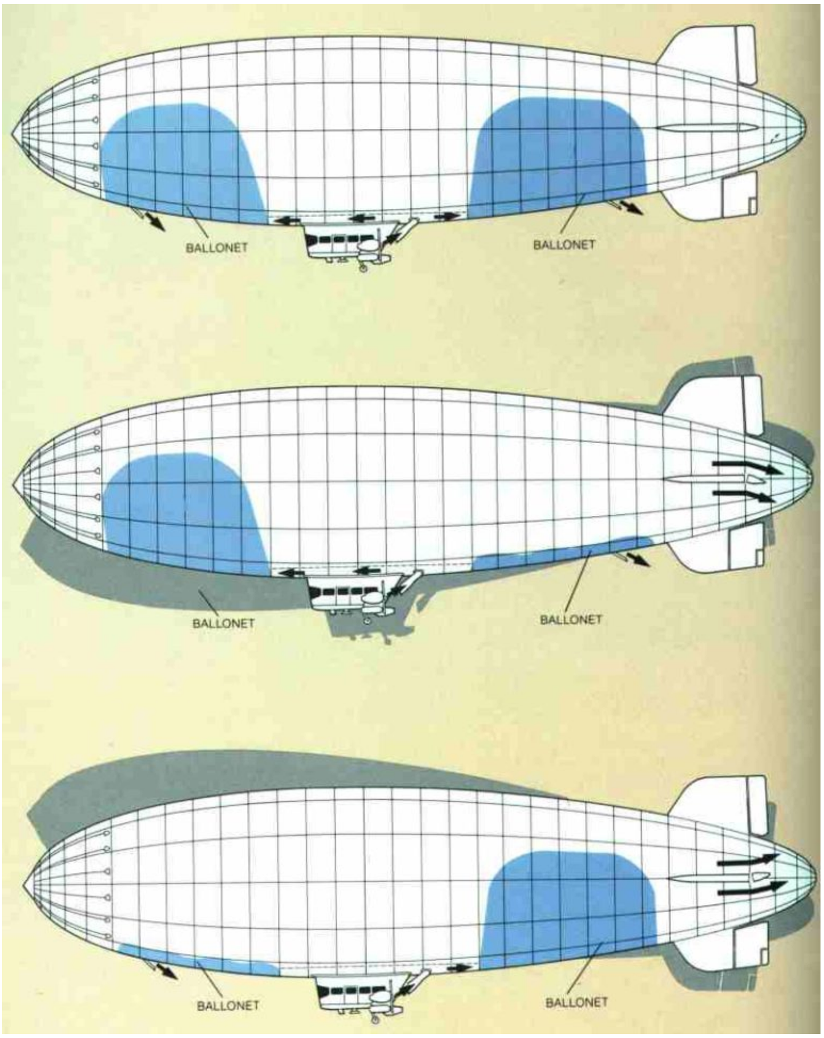
If an airship is light and the desired buoyancy cannot be restored with lifting gas coolers, it is possible to vent some lifting gas to the atmosphere to decrease aerostatic lift. Usually there are two types of vents: a manually-operated vent controlled by the pilot and an automatically-operated safety vent designed to protect the envelope from overpressure.

Role of the ballonets

The airship hull / envelope is divided into one or more sealed lifting gas volumes and separate gas volumes called "ballonets" that contain air at ambient, or near-ambient pressure. The ballonets serve as the expansion space that is available for the lifting gas cells as the airship ascends.

The ratio of the total envelope volume to the total ballonet volume is a measure of the expansion space for the lifting gas and is a key factor in determining the airship's "pressure altitude." This is the altitude at which the lifting gas cells are fully expanded, and the ballonets are empty. For example, with an envelope volume of 8,255 m^3 (290,450 ft^3) and a ballonet volume of 2,000 m^3 (71,000 ft^3), or about 24% of the envelope volume, a Zeppelin NT semi-rigid airship has a reported maximum altitude of 3,000 m (9,842 ft), with the envelope positive pressure of 5 mbar. With a smaller ballonet volume, the Zeppelin NT would have a lower maximum altitude at the specified internal pressure.

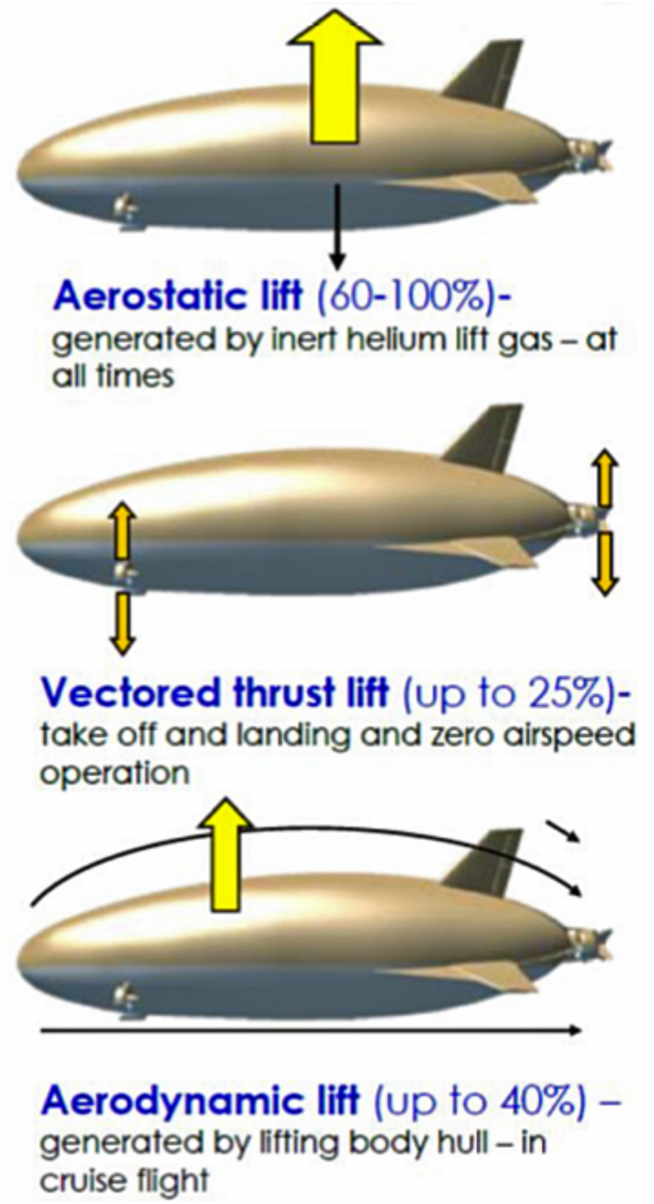
In semi-rigid and non-rigid airships with pressure-stabilized hulls, the ballonets are part of the airship's pressure control system, which automatically maintains the envelope pressure in a desired range. Pressure control is accomplished by changing the volume of the ballonets. An air induction system draws atmospheric air and delivers it at a slight positive pressure (relative to envelope pressure) to increase ballonet volume. An air vent system will discharge air from the ballonets to the ambient atmosphere. While there is a change in mass during these ballonet operations, it is relatively small and does not significantly affect the aerostatic buoyancy of the airship.Fore and aft ballonets can be operated individually to adjust the trim (pitch angle) of the airship. Inflating only the fore or aft ballonet, and allowing the opposite ballonet to deflate, will make the bow or stern of the airship slightly heavier and change the pitch angle of the airship without significantly affecting the overall aerostatic buoyancy. These ballonet operating principles are shown in the following diagrams of a blimp with two ballonets, which are shown in blue.



Blimp with two ballonets (blue). Top diagram shows airship with both ballonets full for level cruise flight at low altitude. The middle diagram shows the forward ballonet full and the aft ballonet empty, creating a slightly nose-heavy condition for descending flight. The bottom diagram shows the forward ballonet empty and the aft ballonet full, creating a slightly tail-heavy condition for ascending flight. 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

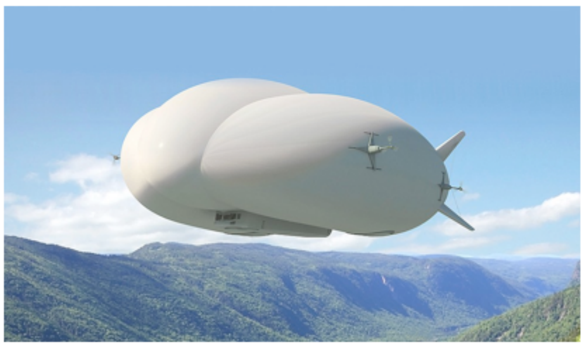
Basic characteristics of hybrid airships include the following:

- 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 one or more 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

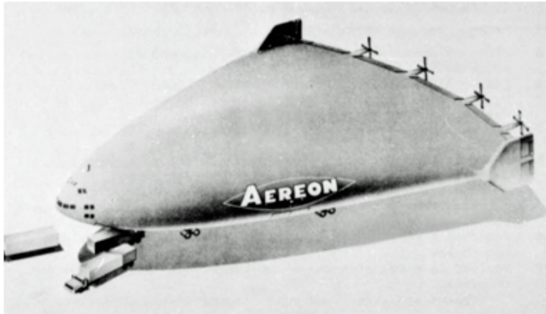
5.3 Semi-buoyant hybrid aircraft

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 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.
- 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 tri-lobe Voliris airships and the EADS Tropospheric Airship are modern examples of variable buoyancy / variable volume airships.


Source: Voliris


Source: EADS

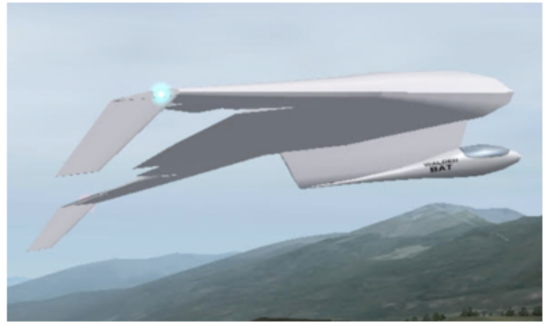
Variable buoyancy propulsion airships / aircraft

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

5.5 Helicopter / airship hybrids

There have been many different designs of helicopter / airship hybrids, including helistats, Dynastats and rotostats. Typically, the airship part of the hybrid craft carries the weight of the craft itself and helicopter rotors deployed in some manner around the airship work in concert to propel the craft and 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 / reddit

Source: Boeing / Skyhook Intn'l

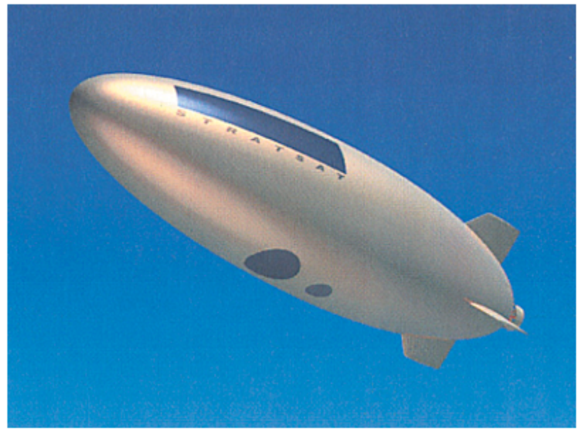
5.6 Stratospheric airships

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.

Source: DARPA



Source: ATG

5.7 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

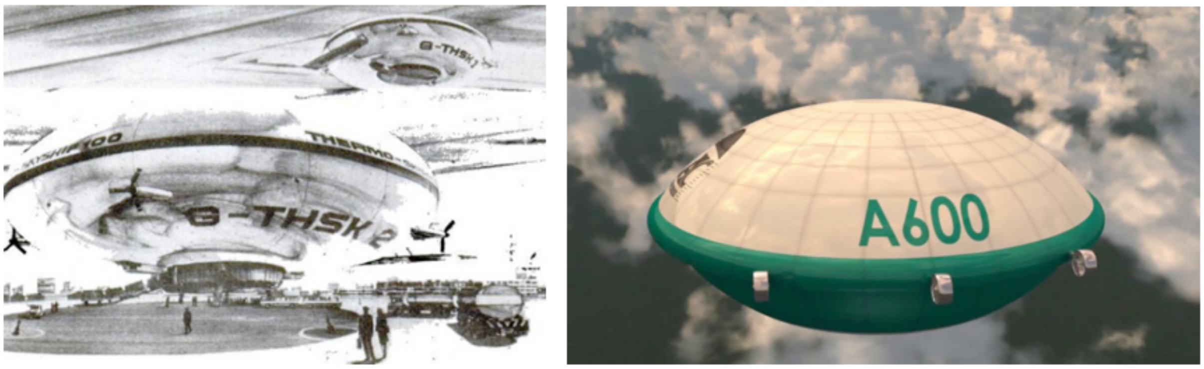
Source: GEFA-Flug

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

5.8 Hybrid thermal-gas (Rozier) airships

This buoyancy control concept was developed and applied in the 1700s in hybrid balloons designed by Jean-François Pilâtre de Rozier. Such "Rozier" balloons have separate chambers for a non-heated lift gas (hydrogen or helium) and a heated lift gas (air). This concept has been carried over into airships. With helium alone the airship is semi-buoyant (heavier-than-air). Buoyancy is managed by controlling the heating and cooling of the air in a separate "thermal volume."

Examples of hybrid thermal (Rozier) airships are the British Thermo-Skyship (circa 1970s to early 1980s), Russian Thermoplane ALA-40 (circa 1980s to early 1990s), and the heavy-lift Aerosmena (AIDBA) "aeroplatform" currently being developed in Russia. All are lenticular (lens-shaped) airships.

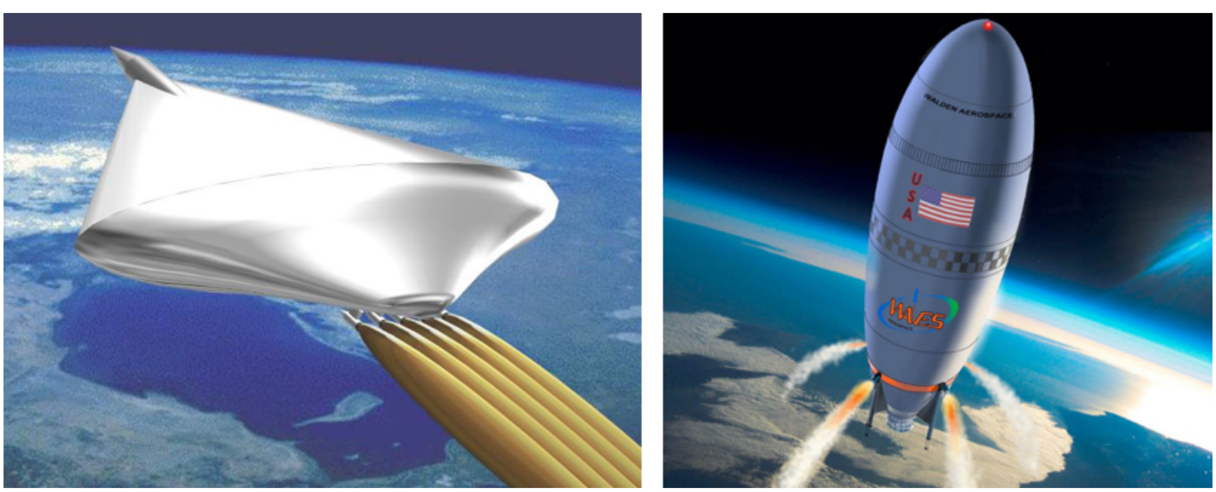


(L) Thermo-Skyship. Source: Popular Science, July 1980
(R) Aerosmena A600. Source: AIDBA

5.9 Rocket / balloon (Rockoon) hybrid airships

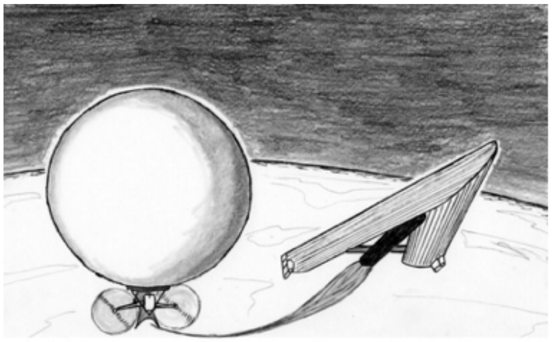
The term "Rockoon" has been used to refer to a ground-launched, high-altitude balloon that carries a small sounding rocket aloft to be launched in the stratosphere, perhaps 15 to 20 miles (24 to 32 km) above the ground. Starting the rocket's powered flight at high altitude enables it to reach a much higher altitude than from a conventional ground launch.

Airship designers Michael Walden (LTAS / Walden Aerospace) and John Powell (JP Aerospace) have applied the rocket / balloon hybrid concept more broadly to produce several diverse design concepts for airships capable of operating in the stratosphere, in near-space, and all the way to Earth orbit.



Michael Walden's Silver Dart stratospheric airship shuttle (L) and

W.A.V.E.S. manned sub-orbital rocket / airship vehicle (R). Source: Walden Aerospace



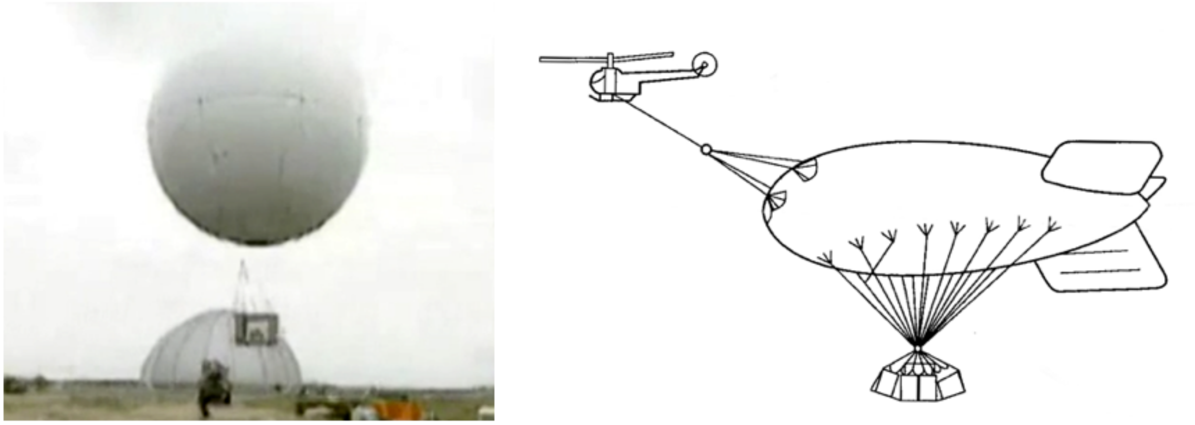

John Powell's Mach Glider launched from a high-altitude airship (L) and an Orbital Ascender airship slowly accelerating from the stratosphere into orbit (R). Source: JP Aerospace

5.10 Unpowered aerostats

Unpowered aerostats include tethered and free-flying balloons used in a wide variety of applications. Many firms offer tethered aerostats for missions such as persistent surveillance and environmental monitoring, with instruments carried on the aerostat to an altitude of several hundreds or thousands of feet (meters), with power and a data link provided via the tether. Examples are the T-C350 from the French firm A-NSE and the medium volume tethered aerostat from the Israeli firm Atlas LTA Advanced Technology.


A-NSE's T-C350 tethered aerostat (L) and the Atlas medium volume aerostat (R). Sources: A-NSE & Atlas

Another tethered aerostat application is as a heavy load lifter. In this application, the aerostat is designed to lift a payload and be towed to a delivery site by a vehicle on the ground, a helicopter or by some other means. Examples are the German CargoLifter CL75-AC Air Crane and the Russian aero barge designed by Novosibirsk OKB.



CL75-AC load test (L) and Novosibirsk OKB aero barge concept (R).
Sources: CargoLifter & Boyko (2001)

Some aerostats are designed to operate on a tether and, on command, detach and continue the mission as a free-flying airship. This hybrid vehicle can operate on station for a long period of time as an tethered aerostat until something of interest is detected. Then the vehicle detaches and flies away to provide a closeup investigation at the point of interest. Examples are the Sanswire / WSGI Argus Hybrid aerostat / UAV and the Detachable Airship from a Tether (DATT) being developed by UAV Corp.

Argus One (L) and DATT (R).
Sources: Sanswire / WSGI & UAV Corp

Yet another application is as a vehicle for access to the stratosphere. JP Aerospace has flown more that 130 civilian stratospheric balloon missions carrying small, low-cost research packages and other payloads. The firms World View Enterprises, Inc. and Space Perspective are developing very large stratospheric balloons as vehicles to carry “space tourists” to maximum altitude of about 25 miles (40 km) and return them safely to the ground, with flights starting in this decade.

JP Aerospace high altitude balloon, Away Mission 130, 16 July 2020 (L) and rendering of a World View manned tourism balloon (R). Sources: JP Aerospace & World View.

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."

Similar requirements exist in the EASA proposed Special Conditions published in February 2021, in SC GAS.2125, "Loading / Unloading."

These requirements 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/cargo-lifter/), 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 the 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

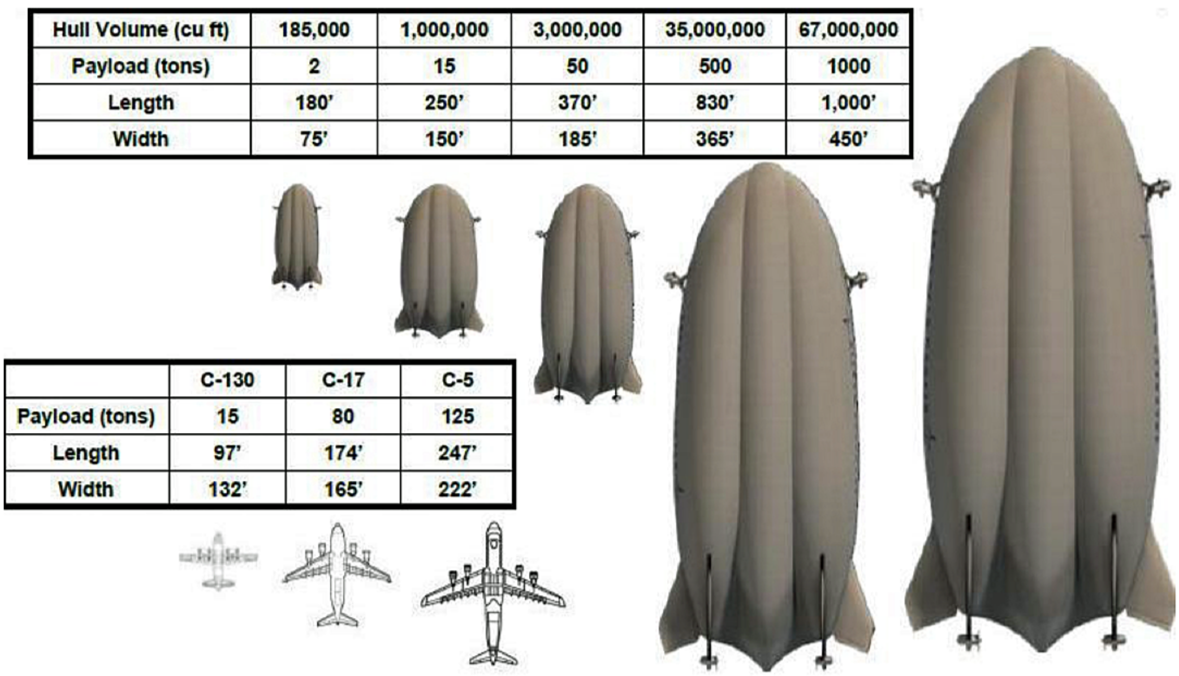
The SkyLifter approach to an airborne load exchange

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 US Air Force 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

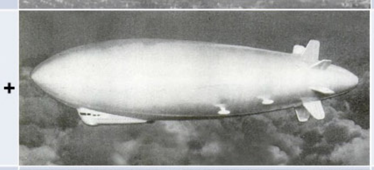
The airships and aerostats reviewed in *Modern Airships – Part 1* are summarized in the following set of graphic tables that are organized into the categories listed below:

- Conventional rigid airships
- Conventional semi-rigid airships
- Conventional non-rigid airships (blimps)
- Variable buoyancy, fixed volume airships
- Variable buoyancy, variable volume airships
- Helicopter / airship hybrids
- Semi-buoyant hybrid aircraft
- Semi-buoyant hybrid airships
- Stratospheric airships
- Thermal (hot air) airships
- Rocket / balloon (Rockoon) hybrid airships
- LTA drones
- Unpowered aerostats

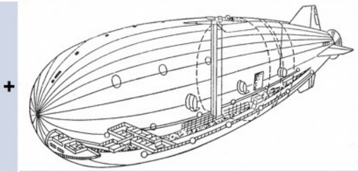
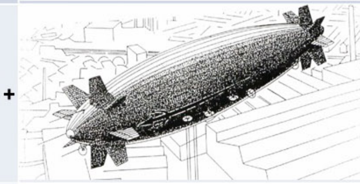
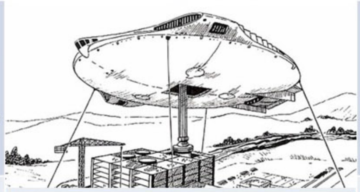
Within each category, each page of the table is titled with the name of the category and is numbered (P1.x), where P1 = *Modern Airships – Part 1* and x = the sequential number of the page in that category. For example, "Stratospheric airships (P1.2)" is the page title for the second page in the "Stratospheric airships" category in Part 1. There also are stratospheric airships addressed in Modern Airships – Part 2. Within a category, the airships are listed in the graphic tables in approximate chronological order.

Links to the individual Part 1 articles on these airships are provided in Section 9. Some individual articles cover more than one particular airship.

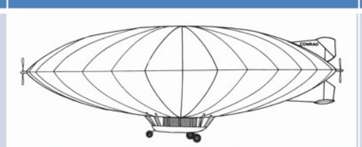
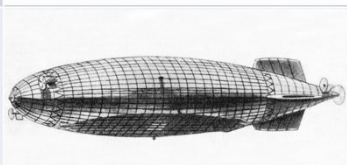
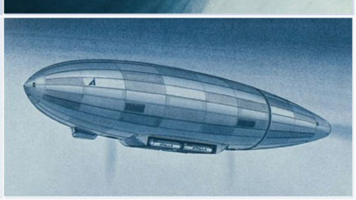
Conventional rigid airships (P1.1)

Airship	Country	Airship type	Lift control	Graphic	Status
Detroit Aircraft Corporation ZMC-2	USA	Conventional, rigid, metal-clad	Ballonets + vector thrust + ballast		Metal-clad hull design by V. Pavlecka. Operational 1929 - 1939. World's only successful metal-clad airship.
Detroit Aircraft Corporation 20-ton cargo airship	USA	Conventional, rigid, metal-clad	Ballonets + vector thrust + ballast		Concept design by V. Pavlecka, circa 1932, offered to US Army.
Airship Advertising / Laws Corp. Rigid airship	USA	Conventional, rigid	Lift gas heating / cooling + ballast		Concept 1967 – 72.
Shell / Aerospace Developments Methane gas transporter	UK	Conventional, rigid	Ballonets + vector thrust + ballast		Concept development started in the late-1960s; cancelled in 1974.

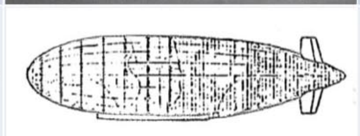
Conventional rigid airships (P1.2)

Airship	Country	Airship type	Lift control	Graphic	Status
Cargo Airship Ltd. Shipping container carrier	UK	Conventional, rigid	Ballonets + vector thrust + ballast		Concept development started late-1960s; cancelled about 1970.
Airfloat Transport Ltd. HL, GF, CL, MTA, MTB, & GP	UK	Conventional, rigid	Ballonets + vector thrust + ballast		Founded 1970 by Edwin Mowforth; developed concepts for a family of rigid airships, circa early-1970s.
C.N.R.S. Titan	France	Conventional, rigid, lenticular	Ballonets + vector thrust from peripheral jets + ballast		Heavy-lift sky crane concept developed 1973 – 75 by Pierre Balaskovic.
Conrad Airship Company CA220	USA	Conventional, rigid	Ballonets + ballast		Cylindrical truss frame construction; started 1974; damaged by windstorm 1975; not repaired.

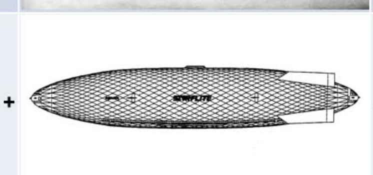
Conventional rigid airships (P1.3)

Airship	Country	Airship type	Lift control	Graphic	Status
Conrad Airship Company CA80	USA	Conventional, rigid, lenticular	Lift fan + ballonets + ballast		Spoke & rim construction; started 1975; abandoned 1977.
Martin Marietta Model 836	USA	Conventional, rigid	Ballonets + vector thrust + ballast		1976 – 1979 concept for Navy's ANVCE program, "Fully Air Buoyant" (FAB) airship.
Airships International MC-7	USA	Conventional, rigid, metal-clad	Ballonets + vector thrust + ballast		Several concepts by Kiernan & Pavlecka, circa 1977, based on Detroit Aircraft's ZMC-2 & later designs.
Airships International Heavy-lift cargo airships	USA	Conventional, rigid, metal-clad	Ballonets + vector thrust + ballast		Several concepts by Kiernan & Pavlecka, circa 1977, based on ZMC-2 & later designs.

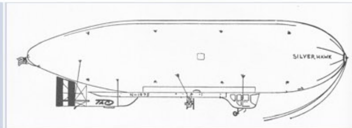
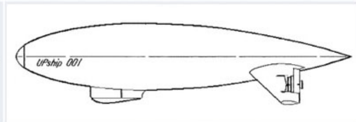
Conventional rigid airships (P1.4)

Airship	Country	Airship type	Lift control	Graphic	Status
Airship Industries R40 / R130	UK	Conventional, rigid	Ballonets + ballast		Concept 1980, based on R100 (circa 1920s).
Airship Industries R150	UK	Conventional, rigid, metal-clad	Ballonets + vector thrust + ballast		Concept, circa 1980 – 82.
SPACIAL SA MLA-24, -32A & -32B	Mexico	Conventional, rigid, lenticular	Ballonets + vector thrust + ballast		Three airships built 1973 – 90. MLA-32B flew in 1989, becoming 1st rigid airship to fly in 50 years. Destroyed in 1990 crash.
SPACIAL SA XEM-4	Mexico	Conventional, rigid, lenticular	Ballonets + vector thrust + ballast		Subscale testbed built with design support from Michael Walden, circa 1980, used to validate MLA airship designs.

Conventional rigid airships (P1.5)

Airship	Country	Airship type	Lift control	Graphic	Status
Wren Skyships Ltd. R.30 & RS.1	UK	Conventional, rigid, metal-clad	Ballonets + vector thrust + ballast		Similar design concepts, circa 1982 – 87, based on metal-clad Airship Industries R150.
Wendel R. Wendel STAR*FLITE	USA	Conventional, rigid	Ballonets + vector thrust + ballast		Geodesic hull design concept circa mid-1980s for passenger service. Not built.
Rigid Airship Design (RAD) RA-180 Holland Navigator	Netherlands	Conventional, rigid	Ballonets + vector thrust + ballast		Ian Alexander unveiled concept in 1996, RAD formed, but folded in 2001 without building airship.
LTA Research and Exploration Pathfinders 1 & 3	USA	Conventional, rigid	Ballonets + vector thrust + aero lift + ballast		Both under construction in 2022, Pathfinder 1 first flight expected later in 2022.

Conventional semi-rigid airships (P1.1)

Airship	Country	Airship type	Lift control	Graphic	Status
Tucker Airships TX-1	USA	Conventional, semi-rigid	Ballonets + ballast		Mid-1970s, low-cost blimp prototype built.
UpShip Upship 100	USA	Conventional, semi-rigid	Ballonets + vector thrust + ballast		Several concepts by Jesse Blenn, circa 1989 – 2006.
CargoLifter CL160	Germany	Conventional, semi-rigid	Ballonets + vector thrust + water ballast		Concept design started in 1996; CL75 AC aerostat demonstrated load exchange; firm bankrupt in 2002.
CargoLifter Joey (now Ziphius 900)	Germany	Conventional, semi-rigid	Ballonets + ballast		Operational 1999 – 2002. Sold after CargoLifter bankruptcy. Now privately owned in France.

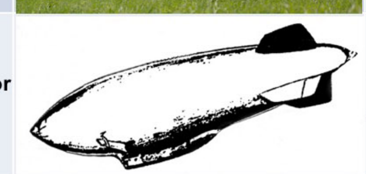
Conventional semi-rigid airships (P1.2)

Airship	Country	Airship type	Lift control	Graphic	Status
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.
ZLT Zeppelin Luftschifftechnik GmbH Zeppelin ZET	Germany	Conventional, semi-rigid	Ballonets + vector thrust + aero lift + ballast		Development plans announced in 2003, cancelled in 2018 when sponsor ZET insolvent.
SAIC Skybus 1500	USA	Conventional, semi-rigid	Ballonets + vector thrust + aero lift + ballast		Concept circa 2010.
Airship do Brasil (ADB) ADB 3-30	Brazil	Likely conventional, semi-rigid	Ballonets + vector thrust + ballast		Development started circa 2012; terminated circa 2108 in favor of ADB 3-15/30.

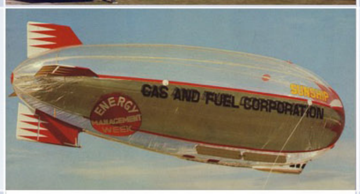
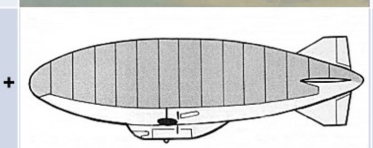
Conventional semi-rigid airships (P1.3)

Airship	Country	Airship type	Lift control	Graphic	Status
SAIC and ArcXeon International Airstation Unmanned Air Systems (UAS) Carrier	USA	Conventional, semi-rigid	Ballonets + vector thrust + aero lift + ballast		Concept circa 2016.
Airship do Brasil (ADB) ADB 3-15/30	Brazil	Likely conventional, semi-rigid	Ballonets + vector thrust + ballast		Development started circa 2018.

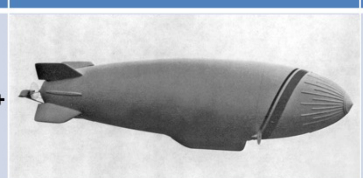
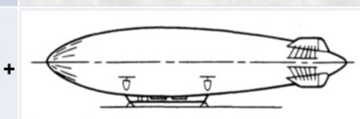
Conventional non-rigid airships (P1.1)

Airship	Country	Airship type	Lift control	Graphic	Status
Goodyear Aerospace N-class blimps ZPG-1, -2, -2W & -3W	USA	Conventional, non-rigid	Ballonets + ballast		In US naval service 1952 – 1961. End of an era. Largest non-rigid airship ever to fly (as of early-2022).
Goodyear Aerospace Goodyear blimps GZ-19, -19A, -20, -20A	USA	Conventional, non-rigid	Ballonets + ballast		GZ-19 started Goodyear's "modern" era in 1959, based on WW II tech. All retired by 2017.
WDL WDL-1 & -1B	Germany	Conventional, non-rigid	Ballonets + ballast		First flight in 1972. Two WDL-1 and 10 WDL-2 blimps manufactured. Also WDL-II and -III concepts.
Goodyear Aerospace ZPG-X	USA	Conventional, non-rigid	Ballonets + tilt wing vector thrust + ballast		1976 – 1979 concept for Navy's ANVCE program, "Fully Air Buoyant" (FAB) airship.

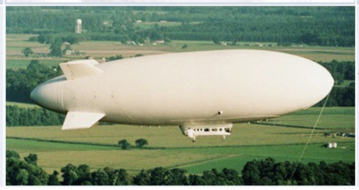
Conventional non-rigid airships (P1.2)

Airship	Country	Airship type	Lift control	Graphic	Status
Aerospace Development AD-500	UK	Conventional, non-rigid	Ballonets + vector thrust + ballast		Recognized as first "modern" blimp. 1st flight in 1979; damaged in windstorm & not repaired. Basis for AI Skyship blimps.
Solar Airship Ltd. Prototype	UK / Australia	Conventional, non-rigid, unmanned	Ballonets + ballast		1st solar-powered airship built in Australia; 1st flight in 1979 in Melbourne. Retired.
Solar Airship Ltd. Sunship	UK / Australia	Conventional, non-rigid	Ballonets + vector thrust + ballast		Solar powered airship concept circa late 1970s.

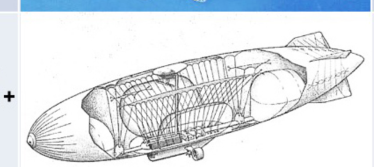
Conventional non-rigid airships (P1.3)

Airship	Country	Airship type	Lift control	Graphic	Status
Goodyear Aerospace ZP3G	USA	Conventional, non-rigid	Ballonets + vector thrust + ballast		1980 concept for Navy's Maritime Patrol Airship (MPA) study.
Bell Aerospace Textron MPA	USA	Conventional, non-rigid	Ballonets + vector thrust + ballast		1980 concept for Navy's MPA study.
Airship Industries Skyship 500, 500HL & 600	UK	Conventional, non-rigid	Ballonets + vector thrust + ballast		Total of 16 Skyships manufactured 1981 thru 1990 when company failed.
Thunder & Colt GA-42	UK	Conventional, non-rigid	Ballonets + ballast		First flight early 1980s. Type cert. acquired by American Blimp Corp (ABC) in 2000. Lindstrand Tech licensed to manufacture.

Conventional non-rigid airships (P1.4)

Airship	Country	Airship type	Lift control	Graphic	Status
US-LTA Model 138S	USA	Conventional, non-rigid	Ballonets + ballast		Two 138S blimps manufactured in 1986 & 1993.
Goodyear Aerospace Goodyear blimp GZ-22	USA	Conventional, non-rigid	Ballonets + vector thrust + ballast		First Goodyear blimp with thrust vectoring; 1st flight in 1987; damaged in 1999 crash & not repaired.
Advanced Airship Corporation (AAC) ANR (Advanced Non-Rigid)	UK	Conventional, non-rigid	Ballonets + vector thrust + ballast		Development 1987 – 1993. ANR-1 nearly complete & ANR-2 started when AAC failed in 1993.
Westinghouse Airships Inc. (WAI) Sentinel 1000	USA	Conventional, non-rigid	Ballonets + vector thrust + ballast		Development 1987 – 1995 for US Navy. 1st flight in 1991. Destroyed in hangar fire in 1995.

Conventional non-rigid airships (P1.5)

Airship	Country	Airship type	Lift control	Graphic	Status
Westinghouse Airships Inc. (WAI) Sentinel 5000 (YEZ-2A)	USA	Conventional, non-rigid	Ballonets + vector thrust + ballast		Development 1987 – 1995 for US Navy, full-size gondola mockup built. Program cancelled in 1995.
Goodyear Aerospace YEZ-2A (proposal)	USA	Conventional, non-rigid	Ballonets + vector thrust + ballast		1987 proposal for Navy's YEZ-2A program. Lost to WAI team.
American Blimp Corp. A-60+, A-150 & A-170 Lightships & Navy MZ-3A (A-170G)	USA	Conventional, non-rigid	Ballonets + ballast		Prototype A-50 flew in 1988. 41 blimps manufactured 1990 thru 2021.
Skyrider Airships BA-2	USA	Conventional, non-rigid	Ballonets + ballast		One BA-2 built by Frank Rider. 1st flight in 1988. Type certificate in 1990, tail N25FR, de-registered 2012.

Conventional non-rigid airships (P1.6)

Airship	Country	Airship type	Lift control	Graphic	Status
Memphis Airship Inc. Zephyr 500	USA	Conventional, non-rigid	Ballonets + ballast		First flew in 1996. Previous models were the EXP II (1988) & Zephyr 200 (1990).
Lindstrand Technologies GA-42	UK	Conventional, non-rigid	Ballonets + ballast		Lindstrand Tech. licensed to manufacture from ABC after 2000.
ATG / HAV AT-10	UK	Conventional, non-rigid	Ballonets + vector thrust + ballast		Developed by ATG; 1st flight in 2002. Acquired by HAV in 2007.
Voliris V900	France	Conventional, non-rigid	Ballonets + ballast		First flight June 2003. Only one built. Engineering development vehicle.

Conventional non-rigid airships (P1.7)

Airship	Country	Airship type	Lift control	Graphic	Status
Vantage Airship Manufacturing Co., Ltd. CA-80, -150, -180 & -300	China	Conventional, non-rigid	Ballonets + ballast		Family of manned blimps from 42 – 65 m (138 – 213 ft) length.
Mav6 LLC Blue Devil Block II	USA	Conventional, on-rigid	Ballonets + vector thrust + ballast		Air Force medium altitude ISR airship program started in 2010; one airship built but never flown; program cancelled in 2012.
Airship do Brasil (ADB) ADB 3-X01	Brazil	Conventional, non-rigid	Ballonets + vector thrust + ballast		ADB 3-X01 prototype 1st flight in 2017. 1st manned airship built in Brazil.
Airship do Brasil (ADB) ADB 3-3	Brazil	Conventional, non-rigid	Ballonets + vector thrust + ballast		ADB 3-3 is production model of 3-X01. Certification in progress.

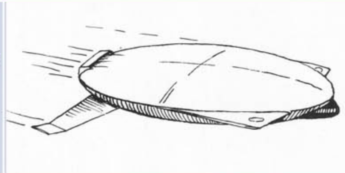
Conventional non-rigid airships (P1.8)

Airship	Country	Airship type	Lift control	Graphic	Status
Aviation Industry Corporation of China (AVIC) AS700	China	Conventional, non-rigid	Ballonets + vector thrust + ballast		Development started in 2018. First flight expected late 2021 or 2022.

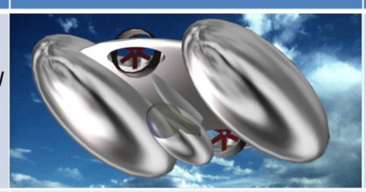
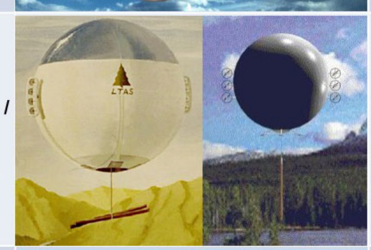
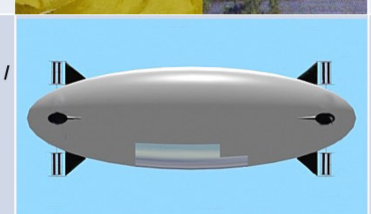
Variable buoyancy, fixed volume airships (P1.1)

Airship	Country	Airship type	Lift control	Graphic	Status
Vaeth & Stehling Flying environmental laboratory (Helium horses)	USA	Variable buoyancy, fixed volume, rigid	Variable buoyancy control + ballonets + vector thrust		NOAA concept circa 1974. Onboard helicopter, rocket launcher, submersible & spill cleanup system
Vaeth & Stehling Heavy-lift airship (Helium horses)	USA	Variable buoyancy, fixed volume, rigid	Variable buoyancy control + ballonets + vector thrust		NOAA concept circa 1974. Cargo and luxury passenger versions.
Walden Aeospace / LTAS T-90 & T-280	USA	Variable buoyancy (DCB), fixed volume, rigid, lenticular	Lift gas pressurization / release + ballonets + vector thrust		Michael Walden's density controlled buoyancy (DCB) airship concepts, originated in mid-1970s. None built.
Walden Aeospace / LTAS 222-PAD & 30-XB	USA	Variable buoyancy (DCB), fixed volume, rigid, lenticular	Lift gas pressurization / release + ballonets + vector thrust		Michael Walden's DCB design concepts for US Coast Guard, circa 1982 to 2004. None built.

Variable buoyancy, fixed volume airships (P1.2)

Airship	Country	Airship type	Lift control	Graphic	Status
S.E.A.B. Champlain	France	Variable buoyancy, fixed volume, rigid, lenticular	Lift gas pressurization / release + ballonets + vector thrust		Pierre Balaskovic design for a lenticular cruising airship, circa 1983. Alcyon scale-up. Not built.
Aeros Modified 40D *Sky Dragon*	USA	Variable buoyancy (COSH), fixed volume, non-rigid	Lift gas pressurization / release + ballonets		1st flight in July 2008, demonstrated flight-weight COSH system.
Aeros Aeroscraft *Dragon Dream*	USA	Variable buoyancy (COSH), fixed volume, rigid	Lift gas pressurization / release + ballonets + vector thrust + reversible ACLS on the ground		Work started circa 2007; 1st flight in Jan 2013; damaged by hangar roof collapse; not repaired.
Aeros Aeroscraft ML866 / Aeroscraft Gen 2	USA	Variable buoyancy (COSH), fixed volume, rigid	Lift gas pressurization / release + ballonets+ vector thrust + reversible ACLS on the ground		Introduced in 2007. Detailed design exists. Focus is on subsystem testing, awaiting a funding source to support prototype development.

Variable buoyancy, fixed volume airships (P1.3)

Airship	Country	Airship type	Lift control	Graphic	Status
Walden Aeospace / LTAS Twin hull yacht	USA	Variable buoyancy (DCB), fixed volume, rigid, twin hull	Lift gas pressurization / release + ballonets + vector thrust		Michael Walden's concept, circa 1980s, for a DCB airship yacht. Not developed.
Walden Aeospace / LTAS Solar spherical logger	USA	Variable buoyancy (DCB), fixed volume, rigid, spherical hull	Lift gas pressurization / release + ballonets + vector thrust		Michael Walden's concept, circa 1982, for a DCB heavy lift logging airship, 220 ft (67 m) diameter. Not developed.
Walden Aeospace Cycloidal propeller airship	USA	Variable buoyancy (DCB), fixed volume, rigid, elliptical hull	Lift gas pressurization / release + ballonets + vector thrust cycloidal propellers		Michael Walden's 2002 concept for a DCB airship with cycloidal propellers. Not developed.

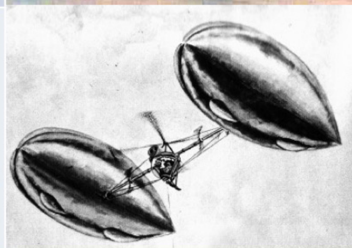
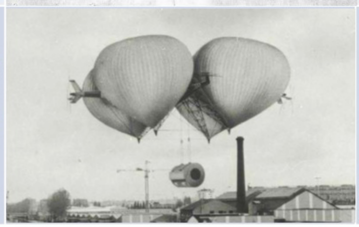
Variable buoyancy, variable volume airships (P1.1)

Airship	Country	Airship type	Lift control	Graphic	Status
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		Unveiled in 2012. Development later 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.
Voliris NATAC V932	France	Hybrid, semi-buoyant inflated wing, semi-rigid	Aero lift		Active development program, 2022.

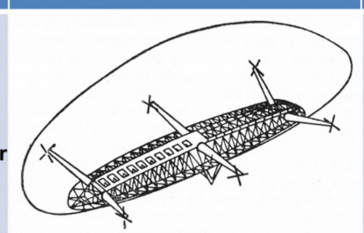
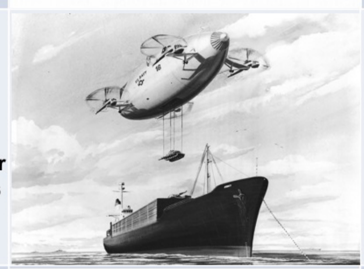
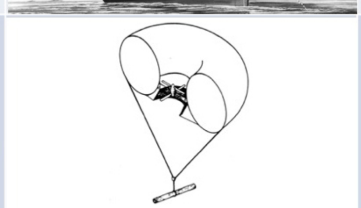
Variable buoyancy, variable volume airships (P1.2)

Airship	Country	Airship type	Lift control	Graphic	Status
Voliris SeaBird	France	Hybrid, semi-buoyant inflated wing, semi-rigid	Aero lift		Active development program, 2022.

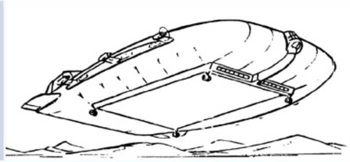
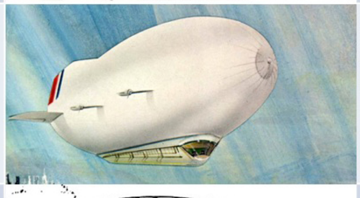
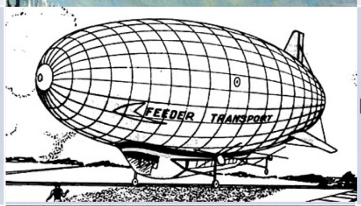
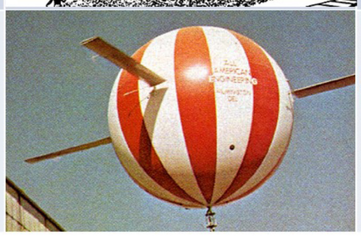
Helicopter / airship hybrids (P1.1)

Airship	Country	Airship type	Lift control	Graphic	Status
Aérospatiale Hélicostat	France	Helistat (helicopter / airship hybrid)	One buoyant envelope + two or four cantilevered rotors		Originally developed in the 1920s. Renewed interest in the 1970s. None built.
Aérospatiale Hélicostat	France	Helistat (helicopter / airship hybrid)	Twin buoyant envelopes + one or two rotors on the centerline		Single rotor, twin hull design developed for logging. None built.
Aérospatiale Obélix	France	Helistat (helicopter / airship hybrid)	4 x buoyant envelopes + 2 x vectoring rotor systems for lift, 6 x rotors for propulsion		Flying crane concept to move heavy nuclear power plant components proposed in 1974. Project abandoned several years later.

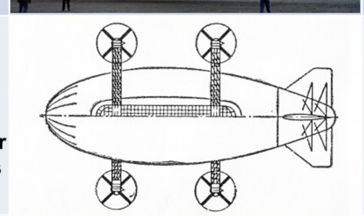
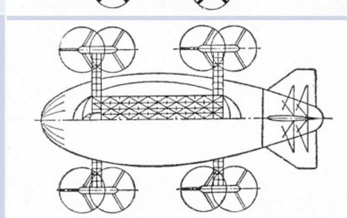
Helicopter / airship hybrids (P1.2)

Airship	Country	Airship type	Lift control	Graphic	Status
Aérospatiale Obélix II	France	Helistat (helicopter / airship hybrid)	Single large buoyant envelope + 6 vectoring rotor systems		Flying crane concept to move heavy nuclear power plant components. Project abandoned in mid-1970s.
NASA Heavy-Lifter	USA	Helistat (helicopter / airship hybrid)	Buoyant envelope + four helicopter rotor systems		Design concept, circa 1975.
Tentai III	Japan	Helistat (helicopter / airship hybrid)	Buoyant toroidal envelope + single ducted rotor		Design concept, circa mid-1970s.

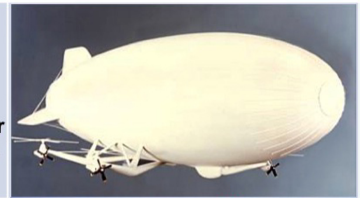
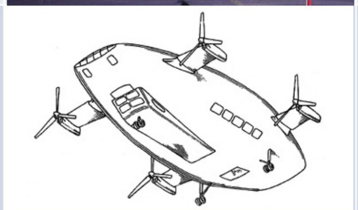
Helicopter / airship hybrids (P1.3)

Airship	Country	Airship type	Lift control	Graphic	Status
Goodyear Aerospace Heavy lift Dynastat	USA	Dynastat (helicopter / airship hybrid)	Buoyant envelope + vectoring prop / rotors		Design concept for very heavy lift, circa late 1960s.
Goodyear Aerospace VTOL Dynastat	USA	Dynastat (helicopter / airship hybrid)	Buoyant envelope + vectoring prop / rotors		Design concept for short-haul commuter passenger service, early 1970s.
Goodyear Aerospace Airline feeder	USA	Helistat (helicopter / airship hybrid)	Buoyant envelope + vectoring prop / rotors		Design concept, circa 1976-1977, NASA Feasibility of Modern Airships – Phase I study.
All American Engineering Aerocrane	USA	Rotostat (helicopter / airship hybrid)	Buoyant, rotating envelope + rotors		Subscale test models flown 1972 to mid-1980s. Advanced design patented 1999.

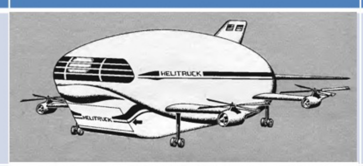
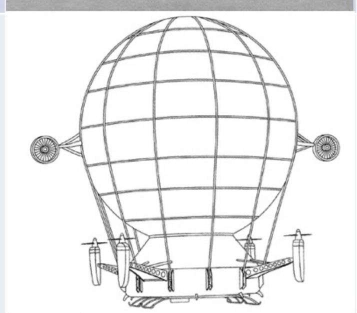
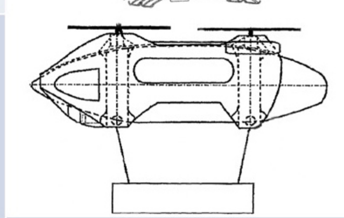
Helicopter / airship hybrids (P1.4)

Airship	Country	Airship type	Lift control	Graphic	Status
Piasecki Helistats & PA-97 prototype	USA	Helistat (helicopter / airship hybrid)	Buoyant envelope + four helicopter rotor systems		Early designs for heavy lift in mid-1970s; PA-97 first flight in April 1986; destroyed in crash in July 1986; development cancelled.
Kawasaki Heavy Industries (KHI) Helistat	Japan	Helistat (helicopter / airship hybrid)	Buoyant envelope + four helicopter rotor systems		Design concept for passenger service, circa late 1970s. Development abandoned.
Kawasaki Heavy Industries (KHI) Helistat	Japan	Helistat (helicopter / airship hybrid)	Buoyant envelope + four dual helicopter rotor systems		Design concept for cargo service, circa late 1970s. Development abandoned.

Helicopter / airship hybrids (P1.5)

Airship	Country	Airship type	Lift control	Graphic	Status
Goodyear Aerospace Heavy Lift Aircraft (HLA) helistat	USA	Helistat (helicopter / airship hybrid)	Buoyant envelope + four helicopter rotor systems		Design concepts for heavy lift cargo, circa 1975 to mid-1980s.
AeroLift Inc. Cyclocrane & Cyclo-Cruiser	USA	Rotostat (helicopter / airship hybrid)	Buoyant, rotating envelope + four cycloid rotors		Two prototypes developed. 1st damaged in 1982 before first flight, re-built 2nd prototype flew 1984 – 1990.
Bothe Semi-buoyant hybrid aircraft	Canada	Helicopter / airship hybrid	Buoyant envelope + vectorable prop / rotors		Design concept & patent circa 1996.

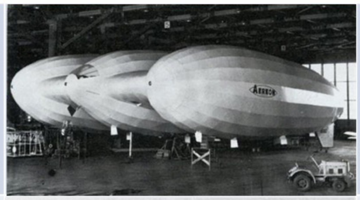
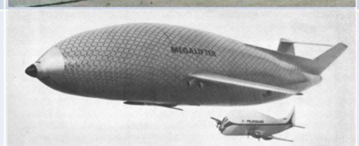
Helicopter / airship hybrids (P1.6)

Airship	Country	Airship type	Lift control	Graphic	Status
Bothe Helitruck	Germany & USA	Helistat (helicopter / airship hybrid)	Buoyant envelope + quad rotors		Concept, early 2000s. Development abandoned.
Skyhook International Jess Hybrid Lift Air Vehicle	Canada	Helistat (helicopter / airship hybrid)	Buoyant envelope + reversible prop /rotors		Design concept & patent circa 2007.
Boeing Helistat	USA	Helistat (helicopter / airship hybrid)	Buoyant envelope + tandem helicopter rotors		Design concept & patent circa 2007.

Helicopter / airship hybrids (P1.7)

Airship	Country	Airship type	Lift control	Graphic	Status
Skyhook International / Boeing SkyHook JLH-40	Canada / USA	Helistat (helicopter / airship hybrid)	Buoyant envelope + vectored thrust ducted rotors		Design concept & patent 2009. Development abandoned mid-2010.

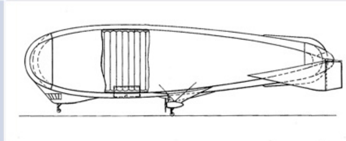
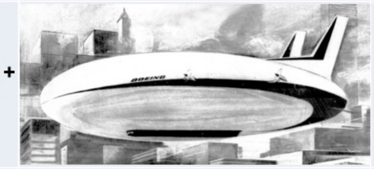
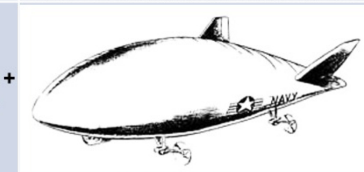
Semi-buoyant hybrid aircraft (P1.1)

Airship	Country	Airship type	Lift control	Graphic	Status
Aereon Corporation Aereon III	USA	Semi-buoyant hybrid aerobody, rigid	Aero lift + lift gas temperature control		Rigid triple hull. Constructed early 1960s, then damaged in 1966 taxi test. Never flew.
Aereon Corp. Dynairship	USA	Semi-buoyant hybrid aerobody, semi-rigid	Aero lift		Concept & patents circa early 1970s by William M. Miller, Jr. None built.
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.
Megalifter Co. Megalifter	USA	Semi-buoyant hybrid aircraft, semi-rigid	Aero lift		Concept by Frank M. Clark, under development 1972 - 1976, then abandoned.

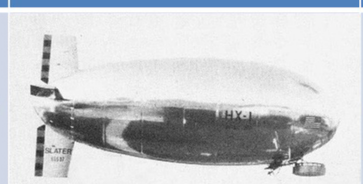
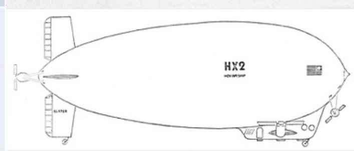
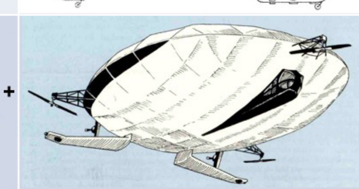
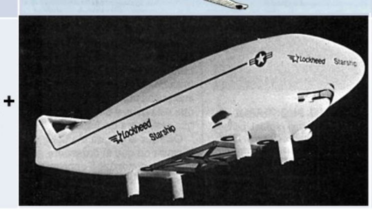
Semi-buoyant hybrid aircraft (P1.2)

Airship	Country	Airship type	Lift control	Graphic	Status
Tumenecotrans BARS & Bella-1	Soviet Union / Russia	Semi-buoyant hybrid aircraft, rigid	Aero lift + lift fan		Prototype developed with SibNIIA; Bella-1 1st flight in 1995; now in storage.
Ohio Airships Dynalifter DL-100 prototype & Patroller	USA	Semi-buoyant hybrid aircraft, semi-rigid	Aero lift		Concepts circa 1999. DL-100 taxi tests in 2012; currently inactive.
Ohio Airships Dynalifter Freighter & Cruise	USA	Semi-buoyant hybrid aircraft, semi-rigid	Aero lift		Concepts circa 1999 for large freighter & passenger versions.
Ohio Airships Dynalifter Drone Runner	USA	Semi-buoyant hybrid aircraft, semi-rigid	Aero lift		Concept circa 2015 for drone carrier mothership & deployable drones.

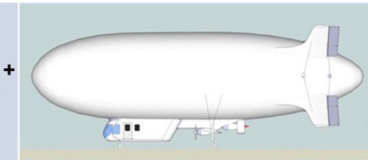
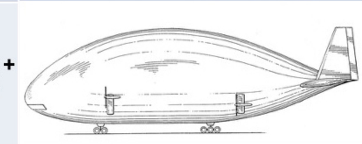
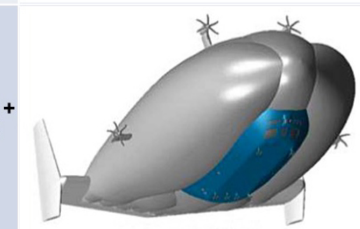
Semi-buoyant hybrid airships (P1.1)

Airship	Country	Airship type	Lift control	Graphic	Status
Goodyear Aerospace Corp. Dynamic lift airship	US	Semi-buoyant hybrid, non-rigid	Aero lift + ballonets + ballast		Semi-buoyant hybrid airship patent circa mid-1950s.
Boeing Vertol Helipsoid	USA	Semi-buoyant hybrid, semi-rigid	Aero lift + vector thrust + ballonets + ballast		1975 design concept, NASA Feasibility of Modern Airships – Phase I study.
Goodyear Aerospace Corp. SABV (semi-air buoyant vehicle)	USA	Semi-buoyant hybrid, semi-rigid	Aero lift + vector thrust + ballonets + ballast		1976 – 1979 concept for Navy's ANVCE program.
EERM Dinosaure & Dino 2 prototype	France	Semi-buoyant hybrid, semi-rigid	Aero lift + ballonets + ballast		Unmanned sub-scale Dino 2 1st flight in 1978. Program ended in 1980.

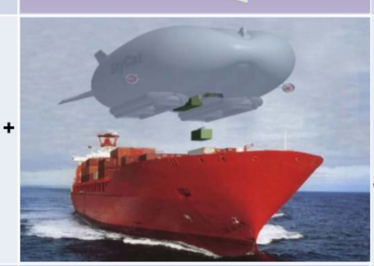
Semi-buoyant hybrid airships (P1.2)

Airship	Country	Airship type	Lift control	Graphic	Status
Hov-Air-Ship Inc. HX-1	USA	Semi-buoyant hybrid airship, semi-rigid, unmanned, tethered	Vector thrust		Technology demonstrator flew in 1978.
Hov-Air-Ship Inc. HX-2	USA	Semi-buoyant hybrid airship, semi-rigid	Vector thrust + ballonets		Proposed to Department of Defense in 1979. Not built.
S.E.A.B. Alcyon	France	Semi-buoyant hybrid airship, semi-rigid	Aero lift + vector thrust + ballonets + ballast		Pierre Balaskovic's design concept for a lenticular hybrid airship, circa 1981 - 1982. Basis for design of Champlain.
Lockheed Martin Small Rigid Airship (SRA) Starship	USA	Semi-buoyant, hybrid airship, rigid	Aero lift + vector thrust + ballonets + ballast		Concept circa 1984 by Roy Gibbins.

Semi-buoyant hybrid airships (P1.3)

Airship	Country	Airship type	Lift control	Graphic	Status
Advanced Hybrid Aircraft Ltd. Patroller 3	Canada	Semi-buoyant hybrid airship, semi-rigid	Aero lift + vector thrust + ballonets + ballast		Bruce Blake design circa 1992 based on subscale Albatross flown in Australia 1986 - 1987.
Lockheed Martin Ultra-large hybrid airship	USA	Semi-buoyant, hybrid airship, rigid	Aero lift + vector thrust + ballonets + ballast		Patent applications filed in 1998 & 1999.
Lockheed Martin Aerocraft	USA	Semi-buoyant hybrid airship, semi-rigid	Aero lift + vector thrust + ballonets + ballast		Concept circa 2000. Design featured in several LM patents.
ATG / HAV SkyKitten / HAV-3	UK	Semi-buoyant hybrid airship, semi-rigid	Aero lift + vector thrust + ballonets + ballast		ATG's SkyKitten technology demonstrator 1st flight in 2000; became HAV-3 in 2007.

Semi-buoyant hybrid airships (P1.4)

Airship	Country	Airship type	Lift control	Graphic	Status
ATG SkyCat 15, 20, 200, 1000	UK	Semi-buoyant hybrid airship, semi-rigid	Aero lift + vector thrust + ballonets + ballast		Design concepts circa 2000 for civil & military versions. ATG failed in 2005, assets ultimately acquired by Hybrid Air Vehicles (HAV).
US Navy (NAVAIR) Hybrid Ultra Large Airship (HULA) program	USA	Semi-buoyant hybrid airship, semi-rigid	Aero lift + vector thrust + ballonets + 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.
Defense Advanced Projects Research Agency (DARPA) Project Walrus	USA	Various, including semi-buoyant hybrid & variable buoyancy, fixed-volume	Various		Started in mid-2003; tradeoff studies; two technology demonstrators – LM P-791 & Aeros Dragon Dream; project cancelled in mid-2006.

Semi-buoyant hybrid airships (P1.5)

Airship	Country	Airship type	Lift control	Graphic	Status
ATG / HAV Condor	UK	Semi-buoyant hybrid airship, semi-rigid	Aero lift + vector thrust + ballonets + ballast		Surveillance airship concept circa 2004. HAV acquired in 2007, basis for LEMV.
Lockheed Martin P-791	USA	Semi-buoyant hybrid airship, semi-rigid	Aero lift + vector thrust + ballonets + ballast + reversible ACLS on the ground		Prototype flight tested in 2006 under Project Walrus; now retired.
GNSS / NSS / ENSS StarShadow	USA	Semi-buoyant hybrid airship, semi-rigid	Aero lift + vector thrust + ballonets + ballast		2010 concept for optionally-manned, solar powered, medium altitude multi-mission airship.
Lockheed Martin LMH-1	USA	Semi-buoyant hybrid airship, semi-rigid	Aero lift + vector thrust + ballonets + ballast + reversible ACLS on the ground		Derived from P-791; originally named SkyTug in 2011 & LMH-1 in 2013. Production model under development & FAA review.

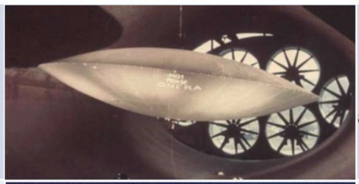
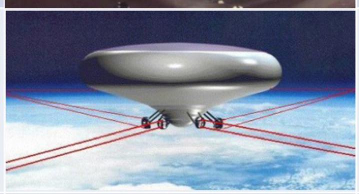
Semi-buoyant hybrid airships (P1.6)

Airship	Country	Airship type	Lift control	Graphic	Status
Hybrid Air Vehicles (HAV) / Northrop Grumman HAV-304 (LEMV)	UK / USA	Semi-buoyant hybrid airship, semi-rigid	Aero lift + vector thrust + ballonets + ballast		HAV-304 first flew in 2012 as Army LEMV; became the HAV Airlander 10 prototype in 2013.
Hybrid Air Vehicles (HAV) Airlander 10 prototype	UK	Semi-buoyant hybrid airship, semi-rigid	Aero lift + vector thrust + ballonets + ballast		Prototype made its first flight in 2016; retired in 2018.
Hybrid Air Vehicles (HAV) Airlander 10	UK	Semi-buoyant hybrid airship, semi-rigid	Aero lift + vector thrust + ballonets + ballast + reversible ACLS on the ground		Production model under development since early 2010s. HAV plans 1st flight in 2024, with all-electric model in 2030.
Hybrid Air Vehicles (HAV) Airlander 50	UK	Semi-buoyant hybrid airship, semi-rigid	Aero lift + vector thrust + ballonets + ballast + reversible ACLS on the ground		Design under development since early 2010s. HAV plans 1st delivery in 2033.

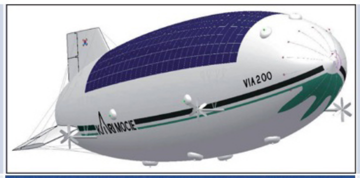
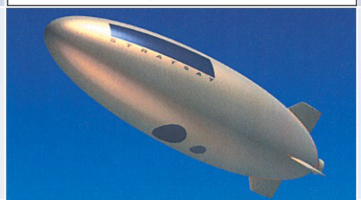
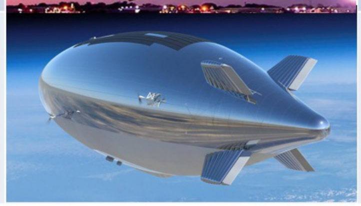
Semi-buoyant hybrid airships (P1.7)

Airship	Country	Airship type	Lift control	Graphic	Status
Vantage Airship Manufacturing Co., Ltd. CT-60T & CT-200T	China	Semi-buoyant hybrid airship, semi-rigid	Aero lift + vector thrust + ballonets + ballast		Conceptual design circa 2015; seeking development partners.

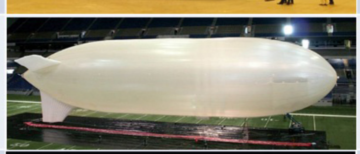
Stratospheric airships (P1.1)

Airship	Country	Airship type	Lift control	Graphic	Status
C.R.N.S. Pégase	France	Rigid, stratospheric	Ballonets + aero lift + ballast		Pierre Balaskovic's design concept for a lenticular hybrid stratospheric airship for research & telecom relay, circa 1969 - 1975.
Walden Aeospace / LTAS S.O.S.C.S	USA	Variable buoyancy, fixed volume, rigid, stratospheric	Lift gas pressurization / release + ballonets + vector thrust		Michael Walden's telcom airship concept, circa early-1970s to 1980s.
Lockheed Martin High Altitude Airship (HAA)	USA	Semi-rigid, stratospheric	Ballonets + aero lift + ballast		HAA program started in 1998; LM selected in 2003 to develop HAA prototype; program cancelled in 2008.
Japan Stratospheric Platform (SPF) 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.

Stratospheric airships (P1.2)

Airship	Country	Airship type	Lift control	Graphic	Status
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.
ATG StratSat	UK	Semi-rigid, stratospheric	Ballonets + aero lift + ballast		Telcom airship program started in 2001; subscale prototype flew; program cancelled in 2005.
Lockheed Martin / DARPA HALE-D	USA	Semi-rigid, stratospheric	Ballonets + aero lift + ballast		Army ISR airship program started in 2003; only one test flight ended in a crash in 2011; program cancelled.
Lockheed Martin ISIS	USA	Semi-rigid, stratospheric	Ballonets + aero lift + ballast		DARPA ISR airship program started in 2003; LM contracted in 2009; program cancelled in 2014.

Stratospheric airships (P1.3)

Airship	Country	Airship type	Lift control	Graphic	Status
JP Aerospace Ascender 175 / Near Space Maneuvering Vehicle (NSMV)	USA	Semi-rigid, stratospheric	Initial helium charge + ballast		USAF ISR airship program 2002 – 2004; damaged before 1st flight & not flown. Also Ascenders 20, 90, 100.
Southwest Research Institute (SwRI) HiSentinel	USA	Non-rigid, stratospheric	Initial helium charge + ballast		Army ISR airship program 2005 – 2010; three test vehicles flown.
GNSS / ENSS StarLight	USA	Non-rigid, maneuverable stratospheric balloon with "fly-down" recovery vehicle	Initial helium charge + ballast		NAVAIR ISR airship program 2008 - 2011; prototype balloon & recovery vehicle partially built but not flown.

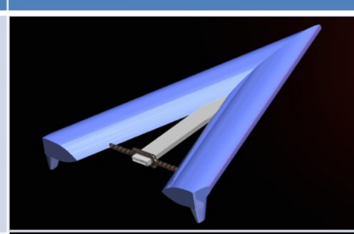
Stratospheric airships (P1.4)

Airship	Country	Airship type	Lift control	Graphic	Status
StratoComm Corp Stratospheric Telecom System (STS)	USA	Semi-rigid, stratospheric	Ballonets + aero lift + ballast		Concept, 2007 – 2010. Security & Exchange Commission filed fraud charges in 2014.
JP Aerospace Atmospheric Ascenders 26, 36, 9, Ellipse	USA	Semi-rigid, stratospheric transport	Initial helium charge + propulsive lift + aero lift + ballast		Active airship development & flight test program; also active subsystem, structure & material test programs.
JP Aerospace Dark Sky Station	USA	Semi-rigid, stratospheric base	Initial helium charge + ballast		Concept circa 2008; sub-scale DS-1 & DS-2 flew in 2001; sub-scale DS-3 built but not yet flown.

Stratospheric airships (P1.5)

Airship	Country	Airship type	Lift control	Graphic	Status
Airship do Brasil (ADB) SAGA	Brazil	Likely non-rigid, stratospheric	Ballonets + aero lift + ballast		Active program to develop a multifunction high altitude platform (HAP).

Rocket / balloon (Rockoon) hybrid airships (P1.1)

Airship	Country	Airship type	Lift control	Graphic	Status
JP Aerospace Mach Gliders	USA	Semi-rigid, buoyant, inflated V-wing, stratosphere -to-near space flight test vehicle	Initial helium charge + aero lift + hybrid rocket propulsion		These will be test vehicles for the orbital ascender subsystem, structure & material development programs.
JP Aerospace Orbital Ascender	USA	Semi-rigid, buoyant, inflated V-wing, stratosphere -to-Earth orbit transport	Initial helium charge + aero lift + hybrid rocket propulsion		Concept circa 2008; active subsystem, structure & material test programs.

Thermal (hot air) airships (P1.1)

Airship	Country	Airship type	Lift control	Graphic	Status
GEFA-Flug (Impacto Aereo) AS-105GD/4 & AS-105GD/6	Germany / Mexico	Non-rigid thermal airship	Hot air control		Founded 1975 by Karl-Ludwig Busemeyer in Aachen, Germany. GEFA-Flug type certificates were sold to Mexican firm Impacto Aereo circa 2017.
APEX Balloons Thermal airship	USA	Non-rigid thermal airship	Hot air control		Founded in 1998. Development of thermal airships discontinued; focusing on hot air balloons.
Skyacht Personal Blimp	USA	Semi-rigid thermal airship	Hot air control		Founded in 2002; 1st flight in 2006.

Drone airships (P1.1)

Airship	Country	Airship type	Lift control	Graphic	Status
Bosch Aerospace (now ISL Aeronautical & Space Systems) SASS LITE	USA	Conventional, non-rigid drone	Ballonets + ballast		Small Airship Surveillance System, Low Intensity Target Exploitation. 1st flight in 1996. Six produced.
Lindstrand Technologies GA-22 drone	UK	Conventional, non-rigid, drone	Ballonets + ballast		22 m (72.2 ft) drone developed and flown in 2004.
ISL Aeronautical & Space Systems (formerly Bosch Aerospace) ACE	USA	Conventional, non-rigid, drone	Ballonets + ballast		Airborne Communication Extender (ACE). One built. 1st flight in 2006. Did not enter production.
Science Applications International Corporation (SAIC) Skybus 80K	USA	Conventional, non-rigid drone	Ballonets + ballast		1st flight in 2010. 1st US FAA certificate for an unmanned experimental airship. Retired.

Drone airships (P1.2)

Airship	Country	Airship type	Lift control	Graphic	Status
Vantage Airship Manufacturing Co., Ltd. CA-24R, -25R, -30R, -32R & -36R drones	China	Conventional, non-rigid, drone	Ballonets + ballast		Family of 24 – 36 m (79 – 118 ft) LTA non-rigid drones. Current products.

Unpowered aerostats (P1.1)

Airship	Country	Airship type	Lift control	Graphic	Status
CargoLifter CL75 AC	Germany	Tethered, non-rigid, heavy-lift transportation aerostat	Helium charge + water ballast		61 m (200 ft) diam. aerostat demonstrated CargoLifter load exchange using ballasted "load frame." Destroyed in storm in 2002.
StratoComm Transitional Telcom System (TTS)	USA	Tethered, non-rigid telcom aerostat	Variable helium inventory (exchanged with ground system) + ballonets		Concept, 2007 – 2010. Security & Exchange Commission filed fraud charges in 2014.
Near Space Corp (NSC) High Altitude Shuttle System (HASS)	USA	Free-flying, non-rigid, stratospheric balloon with "fly-down" recovery vehicle	Helium charge + ballast		Military ISR airship; funded by US Army 2009 – 2010. Several flights for NASA 2013 – 2017. Active program at NSC.

Unpowered aerostats (P1.2)

Airship	Country	Airship type	Lift control	Graphic	Status
GNSS / NSS / ENSS StarTower	USA	Tethered, non-rigid surveillance aerostat	Helium charge + ballast		Tethered, hybrid, large aerostat developed circa 2010. Designed to operate up to 2,000 ft (609 m) AGL. Basis for free-flying StarShadow.
ISL Aeronautical & Space Systems (formerly Bosch Aerospace) REAP XL	USA	Tethered, non-rigid aerostat	Helium charge + ballast		Rapid Deployment Elevating Platform (REAP). Circa 2010. Carried surveillance & communications relay payloads.
JP Aerospace High-altitude balloons	USA	Free-flying, non-rigid, stratospheric balloon with payload recovery via parachute	Helium charge + ballast		By early 2022, more that 130 civilian missions carried small, low-cost research packages & other payloads.

Among the new airships described in Part 1, the following advanced airships seem to be the best candidates for achieving type certification in the next five years:

- **LTA Research and Exploration (USA):** Pathfinder 1 rigid airship, which is expected to make its first flight in 2022. The program appears to be well funded.
- **Lockheed Martin (USA):** LMH-1 hybrid airship, which has been in the FAA certification process for several years. However, Lockheed Martin has not reported on its certification progress or its schedule for flying a first prototype.

The following airship manufacturers in Part 1 have advanced designs and they seem to be ready to manufacture a first prototype if they can arrange funding:

- **Aeros (USA):** Aeroscraft ML866 / Aeroscraft Gen 2 variable buoyancy / fixed volume airship
- **Hybrid Air Vehicles (UK):** Production prototype of the Airlander 10 hybrid airship
- **Voliris (France):** V932 NATAC & SeaBird semi-buoyant, inflated wing airships

Recent changes in European aviation regulations reduce some of the regulatory uncertainty for advanced airship type certification in the EU. The US FAA has not yet published comparable guidance for advanced airships, resulting in continuing regulatory uncertainty in the USA.

The promising airships in Part 1, as listed above, will be competing in the worldwide airship market with candidates identified in *Modern Airships – Part 2*, which potentially could enter the market in the same time frame. Among the airships described in Part 2, the following advanced airship seems to be the best candidate for achieving type certification in the next five years:

- **Flying Whales (France):** The LCA60T rigid airship was significantly redesigned in 2021, which resulted in a schedule delay for completing the first prototype until 2024. However, the project appears to be well funded from diverse international sources in France, Canada, China and Morocco. Full-scale production facilities are planned in France, China and Canada and commercial airship operating infrastructure is being planned.

The following airship manufacturers in Part 2 have advanced designs and they seem to be ready to manufacture a first prototype if they can arrange funding:

- **Aerovehicles (USA / Argentina):** They claim their AV-10 non-rigid, multi-mission blimp can carry a 10 metric ton payload and be type certified within existing regulations for blimps. This should provide a lower-risk route to market for an airship with an operational capability that does not exist today.
- **Aerosmena (AIDBA, Russia):** The firm offers the latest designs for heavy-lift hybrid thermal (Rozier) "aeroplatforms," which use two lift gases: helium and heated air. The A20 will be the prototype for the entire family of Aerosmena aeroplatform.
- **Atlas LTA Advanced Technology (Israel):** After acquiring the Russian firm Augur RosAeroSystems in 2018, Atlas is continuing to develop the ATLANT variable buoyancy, fixed volume heavy lift airship. They also are developing a new family of non-rigid Atlas-6 and -11 blimps and unmanned variants. However, the development plans and schedules have not yet been made public.
- **BASI (Canada):** The firm has a well developed design in the MB-30T and a fixed-base operating infrastructure design that seems to be well suited for their primary market in the Arctic.
- **Egan Airships (USA):** PLIMP Model J plane / blimp hybrid based on a flying unmanned prototype.
- **Euro Airship (France):** The firm claims that production-ready drawings exist for their Corsair and the larger DGPAtt.
- **Millennium Airship (USA & Canada):** The firm has well developed designs for their SF20T and SF50T SkyFreighters, has identified its industrial team for manufacturing, and has a business arrangement with SkyFreighter Canada, Ltd., which would become a future operator of SkyFreighter airships in Canada. In addition, their development plan defines the work needed to build and certify a prototype and a larger production airship.
- **Solar Ship (Canada):** 24-meter Caracal light cargo semi-buoyant airship and the Wolverine medium cargo semi-buoyant aircraft.
- **Varialift (UK):** The factory in France and the ARH-PT prototype are under construction, but the schedule for completing the prototype has slipped, perhaps by three years to 2022, primarily because of tenuous funding. Without a stronger funding stream, the future schedule is unpredictable.

The 2020s 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 type certificates will be enough to open a new era in airship transportation. Aviation regulatory agencies need to help reduce investment risk by reducing 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. This will require consistent investment over the next decade or more before a basic worldwide airship transportation network is in place to support the significant use of commercial airships in cargo and passenger transportation and other applications. Perhaps then we'll start seeing the benefits of airships as a lower environmental impact mode of transportation and a realistic alternative to fixed-wing aircraft, seaborne cargo vessels and heavy, long-haul trucks.

9. Links to the individual articles

The following links will take you to the 91 individual Modern Airships – Part 1 articles. The organization of the following list matches the graphic table.

Note that several of these articles address more than one airship design from the same manufacturer / designer and they may be in different categories (i.e., Airship Industries, Ohio Airships, Walden Aerospace). These designs are listed separately in the above graphic tables and in the following index. The links listed below will take you to the correct article.

Conventional, rigid airships:

- Airfloat Transport Ltd.: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2020/12/Airfloat-HL-converted.pdf
- Airship Advertising / Laws Corp. – rigid airship: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Airship-Advertising-Laws-Corp_rigid-airship-converted.pdf
- Airship Industries – R40/R130 & R150: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Airship-Industries-converted-compressed.pdf
- Airships International – metal-clad airships:
- Cargo Airship Ltd.: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2022/02/Cargo-Airship-Ltd-converted.pdf
- C.N.R.S. – Titan: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/CNRS_Titan-converted.pdf
- Conrad Airship Company – CA220 & CA80: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/09/Conrad-Airship-Company_R1-converted-compressed.pdf
- Detroit Aircraft Corporation – ZMC-2 metal-clad airship: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2022/09/ZMC2-metalclad-airship-compressed.pdf
- LTA Research and Exploration – rigid airships: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2022/03/LTA-Research-and-Exploration-converted-compressed-1.pdf
- Rigid Airship Design (RAD) – RA-180 Holland Navigator: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/RAD_RA-180_Holland-Navigator.pdf
- Shell / Aerospace Developments – methane gas transporter: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2020/12/Shell-AD_Methane-gas-carrier.pdf
- SPACIAL SA – XEM-4, MLA-24, -32A & -32B: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/SPACIAL-SA_lenticular-airships-converted-compressed.pdf
- Wendel R. Wendel – STAR*FLITE: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2022/03/Wendel-R-Wendel_STARFLITE-airship-converted.pdf
- Wren Skyships Ltd. – R.30 & RS.1: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Wren-Skyships-AAC-converted-compressed.pdf

Conventional, semi-rigid airships:

- Airship do Brasil (ADB) – ADB 3-30 & 3-15/30: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/04/Airships-do-Brasil_R1-converted.pdf
- CargoLifter – CL160 & Joey: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2020/12/Cargolifter-converted-compressed.pdf
- SAIC – Skybus 1500: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/SAIC_Skybus-1500-converted.pdf
- SAIC & ArcXeon International – Airstation UAS Carrier: https://gkzaeb.a2cdn1.secureserver.net/wp-

content/uploads/2021/04/SAIC-ArcXeon_UAS-carrier-airship_R1-converted.pdf

- Tucker Airships – TX-1: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Tucker-Airships_TX-1-converted-compressed.pdf
- UpShip – UpShip 100: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2022/02/UPship-converted.pdf
- Zeppelin NT: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Zeppelin-NT_R1-converted-compressed.pdf
- Zeppelin ZET: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2020/12/Zeppelin-ZET.pdf

Conventional, non-rigid airships (blimps):

- Advanced Airship Corp. (AAC) – ANR-1: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Wren-Skyships-AAC-converted-compressed.pdf
- Aerospace Development – AD-500: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Airship-Industries-converted-compressed.pdf
- Airship do Brasil (ADB) ADB 3-X01 & 3-3: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/04/Airships-do-Brasil_R1-converted.pdf
- Airship Industries – Skyship 500, 500HL & 600: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Airship-Industries-converted-compressed.pdf
- American Blimp Corp – A-60+, A-150 & A-170 Lightships & Navy MZ-3A (A-170G): https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/American-Blimp-Corp-converted-compressed-1.pdf
- ATG / HAV – AT-10: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/ATG_HAV_AT-10-blimp-converted.pdf
- Aviation Industry Corporation of China (AVIC) – AS700: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/AVIC_AS700-converted.pdf
- Bell Aerospace Textron – MPA (Navy MPA): https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/US-Navy_Maritime-Patrol-Airship-Study_1980-converted.pdf
- Goodyear Aerospace – N-Class blimps ZPG-1, -2, -2W & -3W: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Goodyear_N-class-blimps-converted-compressed.pdf
- Goodyear Aerospace – Civilian blimps GZ-19, -19A, -20, -20A & GZ-22: https://gkzaeb.a2cdn1.secure-server.net/wp-content/uploads/2021/08/Goodyear_civilian-blimps-converted-compressed.pdf
- Goodyear Aerospace – ZPG-X (Navy ANVCE): https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/US-Navy_ANVCE-program-airships_1976-converted.pdf
- Goodyear Aerospace – ZP3G (Navy MPA): https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/US-Navy_Maritime-Patrol-Airship-Study_1980-converted.pdf
- Goodyear Aerospace – YEZ-2A (Navy Sentinel 5000 proposal): https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/US-Navy_YEZ-2A_Sentinel-1000-5000-converted-compressed.pdf
- Lindstrand Technologies – GA-42: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2022/02/Lindstrand-GA-42-GA-22-converted.pdf
- Martin Marietta – Model 836 (Navy ANVCE): https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/US-Navy_ANVCE-program-airships_1976-converted.pdf
- Mav6 LLC – Blue Devil Bock II: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2020/12/USAF_Blue-Devil-Block-II.pdf
- Memphis Airships – EXP II, Zephyr 200 & 500: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2022/02/Memphis-Airships-Inc-converted.pdf
- SAIC – Skybus 80K: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/04

/SAIC_Skybus-80K_R1-converted.pdf

- Skyrider – BA-2: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2022/02/SkyRider-Airships-converted.pdf
- Solar Airship Ltd. – sub-scale demonstrator & Sunship: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2022/02/Solar-Airship-Ltd_Sunship-converted-compressed.pdf
- Thunder & Colt – GA-42: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2022/02/Thunder-Colt_GA42-blimp-converted.pdf
- US-LTA – Model 138S: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/US-LTA-Corp_Model-138S-blimps-converted.pdf
- Vantage Airship Manufacturing Co. – blimps: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Vantage-Airship_R2-converted.pdf
- Voliris V900: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Voliris_R1-converted-compressed.pdf
- Westinghouse Airships Inc. (WAI) – Sentinel 1000 & 5000: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/US-Navy_YEZ-2A_Sentinel-1000-5000-converted-compressed.pdf
- WDL – WDL-1: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/WDL-converted-compressed.pdf

Variable buoyancy, fixed volume airships:

- Aeros – Aeroscraft *Dragon Dream*: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/04/Aeros_Dragon-Dream_R1-converted.pdf
- Aeros – Aeroscraft ML866 / Aeroscraft Generation 2: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Aeros_Aeroscraft_R2-converted-compressed.pdf
- S.E.A.B. – Champlain: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/SEAB_Alcyon-Champlain_lenticular-airships-converted.pdf
- Vaeth & Stehling – Helium Horses: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2022/03/Vaeth-Stehling_Helium-Horses-converted-compressed.pdf
- Walden Aerospace / LTAS – lenticular, toroidal, variable buoyancy airships: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Walden-LTAS_Lenticular-toroidal-DCB-airships-1.pdf

Variable buoyancy, variable volume airships:

- Voliris V901, V902, V930, V932 NATAC & SeaBird: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Voliris_R1-converted-compressed.pdf

Helicopter / airship hybrids:

- Aerolift Inc. – Cyclocrane & Cyclo-Cruiser: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/AeroLift-Inc_Cyclocrane-Cyclo-Cruiser-converted-compressed.pdf
- Aérospatiale – Hélicostats: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Helicostats-converted.pdf
- Aérospatiale – Obélix & Obélix II: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Obelix-helistat-converted.pdf
- All American Engineering – Aerocrane: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/All-American-Industries_Aerocrane-converted-compressed-1.pdf
- Bothe – Helitruck & semi-buoyant hybrid aircraft: https://gkzaeb.a2cdn1.secureserver.net/wp-content

/uploads/2021/08/Bothe_Helitruck-semi-buoyant-hybrid-converted-compressed.pdf

- Goodyear Aerospace – Dynastats & airline feeder: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Goodyear-Aerospace_Dynastat-airline-feeder-converted-compressed.pdf
- Goodyear Aerospace – Quad-rotor heavy-lift helistats: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Goodyear-Aerospace_Quad-rotor-heavy-lift-helistats-converted.pdf
- Piasecki – Quad-rotor heavy-lift helistats & PA-97: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Piasecki_Quad-rotor-heavy-lift-helistats-converted-compressed.pdf
- Skyhook International / Boeing – SkyHook JLH-40: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/SkyHook-International-Boeing_JHL-40-HLV-converted.pdf
- Other helistats (NASA heavy lifter, Tentai III, Kawasaki helistats, Jess hybrid lift air vehicle & Boeing LTA vertical load lifting system): https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Helistats-converted.pdf

Semi-buoyant hybrid aircraft:

- Aereon Corp. – Aereon III: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Aereon-Corp_Aereon-III-converted.pdf
- Aereon Corp. – Dynairships & Aereon 26: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Aereon-Corp_Dynairships-Aereon-26-converted-compressed-1.pdf
- Megalifter Co. – Megalifter: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Megalifter-hybrid-aircraft_R1-converted-compressed.pdf
- Ohio Airships – Dynalifters DL-100 & Patroller, Freighter & Cruiser, Drone Runner: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Ohio-Airships_Dynalifter_R1-converted-compressed.pdf
- Tumencotrans – BARS & Bella-1: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Tumenecotrans_BARS-Bella-1-converted-compressed.pdf

Semi-buoyant hybrid airships:

- Advanced Hybrid Aircraft Ltd. – Patroller 3: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Advanced-Hybrid-Aircraft_AHA-Patroller-converted-1.pdf
- ATG – SkyCat & SkyKitten: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/ATG_SkyCat-SkyKitten-converted-compressed-1.pdf
- ATG / HAV – Condor: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/ATG_HAV_Condor_R1-converted.pdf
- Boeing Vertol – Helipsoid: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Boeing-Vertol_Helipsoid-converted.pdf
- DARPA – Project Walrus: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2020/12/DARPA_Project-WALRUS-converted.pdf
- EERM – Dinosaure & Dino 2: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/EERM_Dinosaure-converted.pdf
- GNSS / ENSS – StarShadow: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/GNSS-_StarShadow-converted.pdf
- Goodyear Aerospace – SABV (Navy ANVCE): https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/US-Navy_ANVCE-program-airships_1976-converted.pdf
- Goodyear Aircraft – Dynamic lift airship: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Goodyear-Aircraft_Dynamic-lift-airship_R1-converted.pdf
- Hov-Air-Ship Inc. – HX-1 & HX-2: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2022/02

/Hov-Air-Ship-converted.pdf
- Hybrid Air Vehicles / Northrop Grumman – HAV-3 & HAV-304 (LEMV): https://gkzaeb.a2cdn1.secure-server.net/wp-content/uploads/2021/08/HAV-Northrop-Grumman_LEMV_R1-converted.pdf
- Hybrid Air Vehicles – Airlander 10 prototype: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2022/02/HAV_Airlander-10-prototype-converted-compressed.pdf
- Hybrid Air Vehicles – Airlander 10 & 50: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/HAV_Airlander-10-50_R1-converted-compressed.pdf
- Lockheed Martin – Aerocraft: https://gkzaeb.a2cdn1.secureserver.net/wpcontent/uploads/2021/08/Lockheed-Martin_Aerocraft-converted.pdf
- Lockheed Martin – P-791: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Lockheed-Martin_P791_R2-converted.pdf
- Lockheed Martin – SkyTug & LMH-1: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Lockheed-Martin_SkyTug-LMH-1_R1-converted-compressed.pdf
- Lockheed Martin – Rigid hybrid airships: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2022/02/Lockheed-Martin-rigid-hybrid-airships-converted.pdf
- S.E.A.B. – Alcyon: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/SEAB_Alcyon-Champlain_lenticular-airships-converted.pdf
- US Navy (NAVAIR) – HULA program: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2020/12/Navy_Hybrid-Ultra-Large-Aircraft-HULA.pdf
- Vantage Airship Manufacturing Co., Ltd. – CA-60T & CA-200T: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Vantage-Airship_R2-converted.pdf

Stratospheric airships:

- Airship do Brasil (ADB) – SAGA: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/04/Airships-do-Brasil_R1-converted.pdf
- ATG – StratSat: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/ATG_StratSat_R1-converted.pdf
- C.R.N.S. – Pégase: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/CNRS_Pegase-converted.pdf
- GNSS / ENSS – StarLight: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/US-Navy_NAVAIR-GNSS_StarLight-converted.pdf
- Japan stratospheric platform (SPF) – SkyNet: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2020/12/Japan_Stratospheric-Platform-SkyNet.pdf
- JP Aerospace – Ascender 175 / NSMV, Atmospheric Ascenders & Dark Sky Station: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2022/03/JP-Aerospace_High-altitude-airships-compressed.pdf
- Lockheed Martin – High-Altitude Airship (HAA): https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Lockheed-Martin_HAA_R1-converted-compressed.pdf
- Lockheed Martin / DARPA – HALE-D: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2020/12/Lockheed-Martin_HALE-D.pdf
- Lockheed Martin / DARPA – ISIS: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2020/12/DARPA-LM_ISIS.pdf
- StratoComm Corp. – STS: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2022/02/StratoComm-Corp-converted-compressed.pdf
- South Korea stratospheric airship – VIA-200: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2020/12/South-Korea_Stratospheric-Airship.pdf
- Southwest Research Institute (SwRI) – HiSentinel: https://gkzaeb.a2cdn1.secureserver.net/wp-

content/uploads/2020/12/SwRI_HiSentinel.pdf

- Walden Aerospace / LTAS – S.O.S.C.S.: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Walden-LTAS_Lenticular-toroidal-DCB-airships-1.pdf

Rocket / balloon (Rockoon) hybrid airships:

- JP Aerospace – Mach Gliders & Orbital Ascender: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2022/03/JP-Aerospace_High-altitude-airships-compressed.pdf

Thermal (hot air) airships:

- APEX Balloons thermal airship: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2020/12/APEX_thermal-airship-converted.pdf
- GEFA-Flug (Impacto Aereo) – AS-105GD/4 & AS-105GD/6: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2020/12/GEFA-Flug-thermal-airships.pdf
- Skyacht – Personal Blimp: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2020/12/Skyacht-Aircraft_Personal-Blimp.pdf

LTA drones:

- ISL Aeronautical & Space Systems (formerly Bosch Aerospace Inc.) – SASS LITE & ACE: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2022/07/ISL-BOSCH-Aerospace.pdf
- Lindstrand Technologies – GA-22 drone blimp: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2022/02/Lindstrand-GA-42-GA-22-converted.pdf
- SAIC – Skybus 80K drone blimp: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/04/SAIC_Skybus-80K_R1-converted.pdf
- Vantage Airship Manufacturing Co., Ltd. – drone blimps: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/Vantage-Airship_R2-converted.pdf

Unpowered Aerostats:

- CargoLifter – CL75 AC (AirCrane): https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2020/12/Cargolifter-converted-compressed.pdf
- GNSS / ENSS – StarTower: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2021/08/GNSS-_StarShadow-converted.pdf
- ISL Aeronautical & Space Systems (formerly Bosch Aerospace Inc.) – REAP XL: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2022/07/ISL-BOSCH-Aerospace.pdf
- JP Aerospace – High-altitude balloons: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2022/03/JP-Aerospace_High-altitude-airships-compressed.pdf
- NSC – High Altitude Shuttle System (HASS): https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2022/02/NSC_HAAS-converted-compressed.pdf
- StratoComm Corp. – TTS: https://gkzaeb.a2cdn1.secureserver.net/wp-content/uploads/2022/02/StratoComm-Corp-converted-compressed.pdf