Lockheed Martin – Large, conventional, semi-rigid cargo airship

Peter Lobner, 9 September 2023

1. Introduction

Beginning in the early 1980s, the Lockheed-Georgia Company (a division of Lockheed Corporation) was engaged in developing several advanced airship concepts. One design that emerged in the early 1990s was a large, conventional, semi-rigid, heavy-lift, cargo airship, with a long, rigid keel structure that housed a series of side-loading and unloading cargo bays.

This Lockheed airship and its associated systems are described in the following series of U.S. patents that were granted between 1994 and 1995:

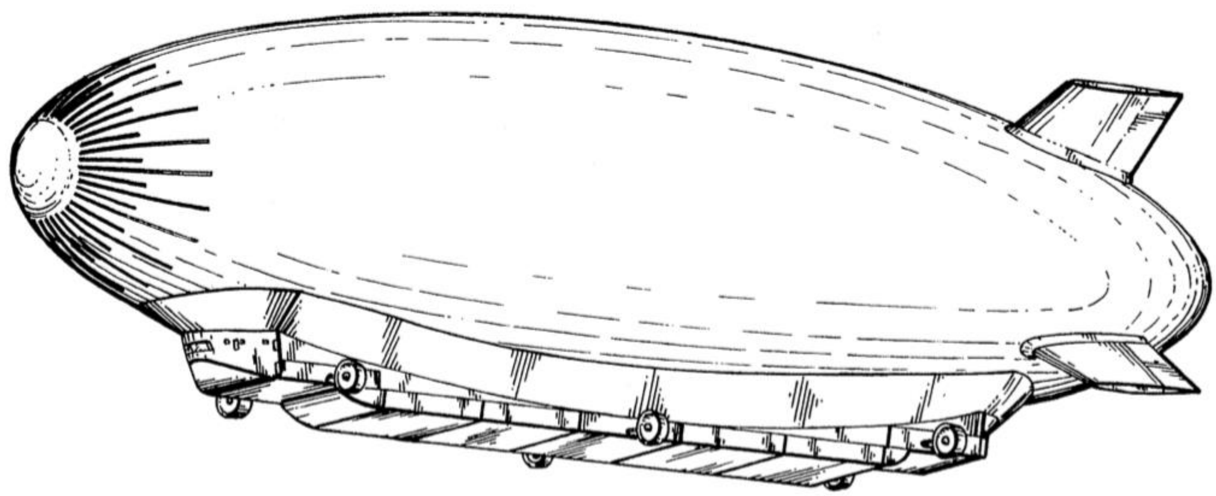
- General arrangement ("ornamental design"): USD358575
- Ballonet system: US5333817
- Propulsion system: US5449129A
- Shrouded reversible thrust fan: US5516061
- Mooring & cargo handling systems: US5346162

This article provides an overview of the design features of this Lockheed large, conventional semi-rigid cargo airship. With its long, rigid keel supported by a huge non-rigid gas envelope, this airship resembled the German CargoLifter CL-160 heavy-lift airship, which began development in 1996.

Lockheed Corp. and Martin Marietta merged in 1995 to form Lockheed Martin Corp. Building on the prior airship experiences of both firms, Lockheed Martin continued developing a variety of advanced airship designs. The large, conventional, semi-rigid cargo airship patents were assigned to Lockheed Martin; however, no such airship was actually developed by the firm. Instead, Lockheed Martin focused their airship development efforts on hybrid airship design concepts.

2. General arrangement of the cargo airship

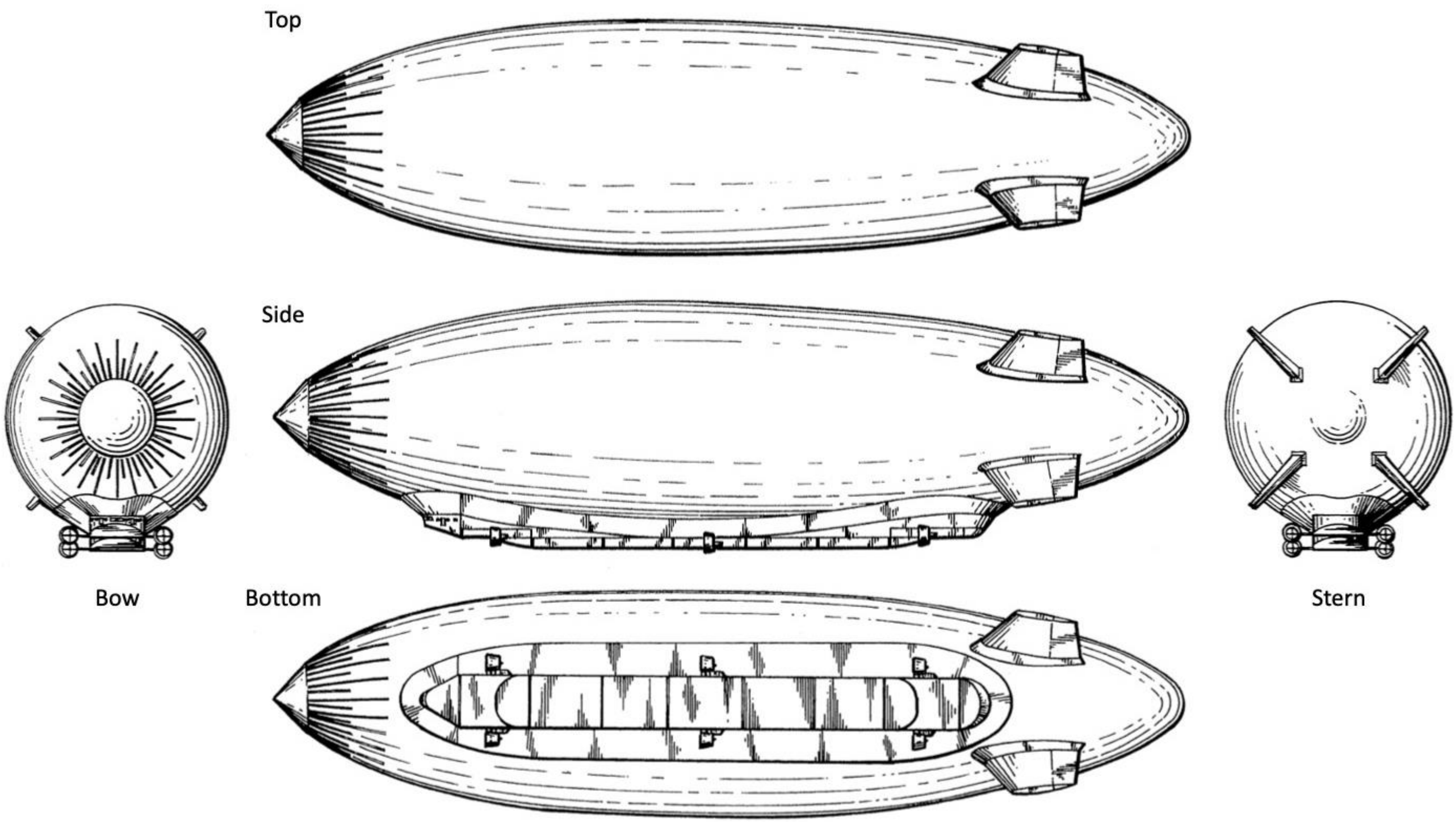
Patent USD358575 defined the general arrangement (the “ornamental design”) of the cargo airship in a series graphics shown below.



Lockheed Martin conventional semi-rigid airship design concept, circa 1995
Source: Patent USD358575, Figure 1

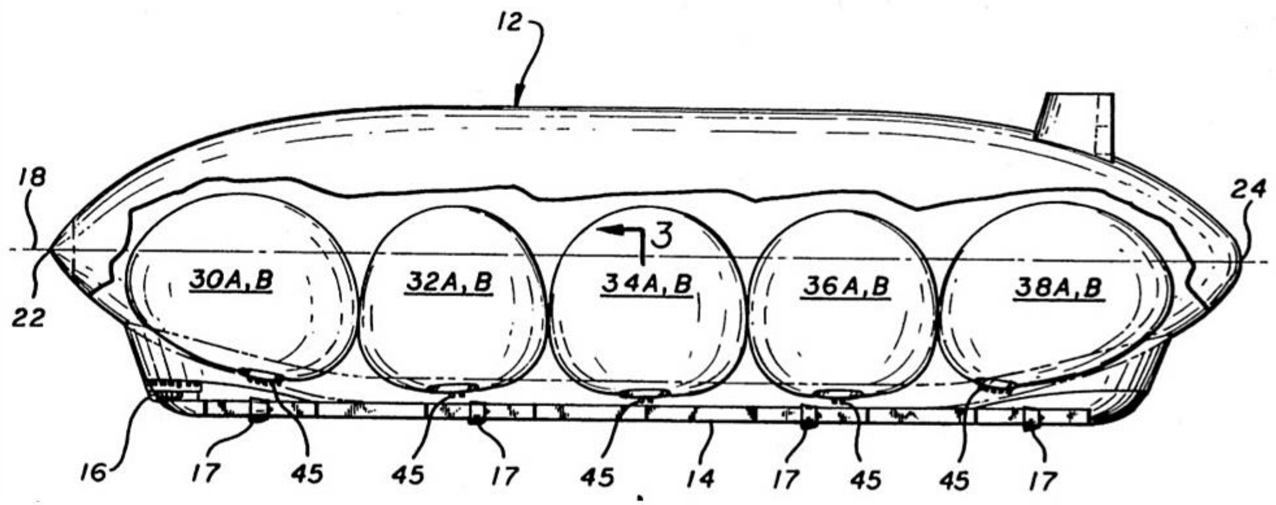
This is a semi-rigid, keeled airship in which the pressure-stabilized gas envelope is not stretched over a rigid structure, but instead, is attached along its bottom to a long, rigid structural keel. The deadweight of the fully-loaded keel structure (including payload, fuel, propulsion system, etc.) are supported by a system of catenaries that distribute the deadweight load and dynamic in-flight propulsion loads into the upper surface of the gas envelope.

The piloting station is at the front of the rigid keel structure, which houses several transverse cargo bays designed to efficiently handle standard-size cargo containers. The airship is propelled and maneuvered by six large, thrust vectoring, reversible thrust, ducted fans that are cantilevered on pylons along the flanks of the rigid keel. Aerodynamic control is provided by four X-configured tailplanes.

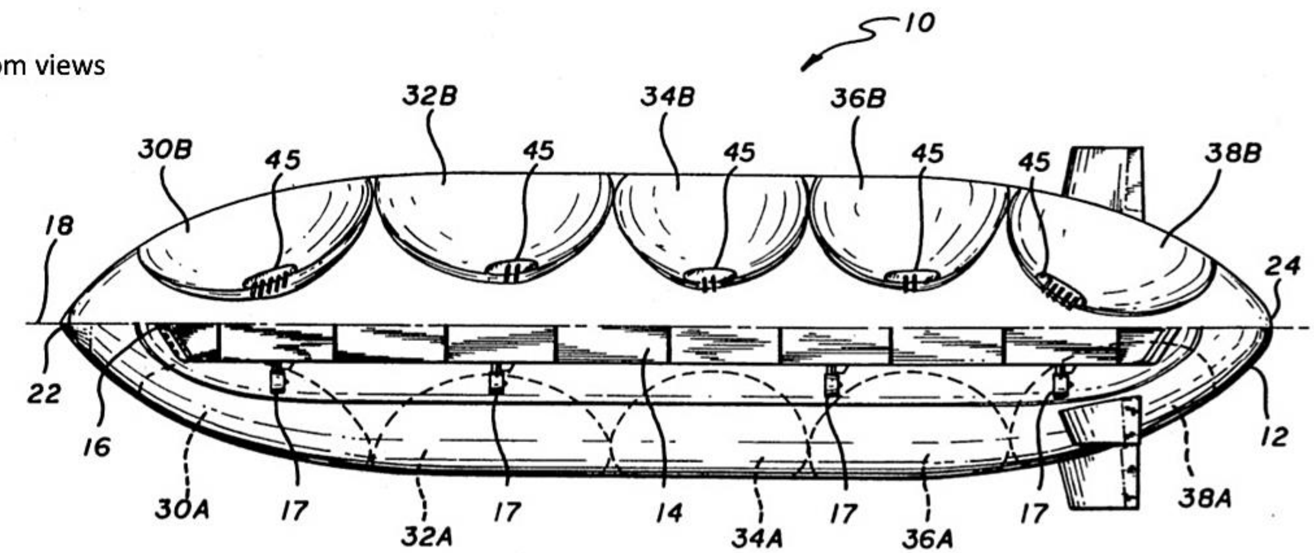


General arrangement of Lockheed Martin conventional semi-rigid airship design concept, circa 1995.
Source: Patent USD358575, composite of Figures 2 to 6

Side view



Top / bottom views



Legend

Lighter-than-air vehicle (10), non-rigid gasbag (12), gondola (14), flight station (crew cockpit, 16), longitudinal axis (18), main propulsion thrust-vectoring shrouded fans (17), nose (22), tail (24), plurality of ballonets along each side of the longitudinal axis (30A/B, 32A/B, 34A/B, 36A/B, 38A/B), ballonet pressurization system (45)

Ballonet system for Lockheed Martin conventional semi-rigid airship design concept, circa 1995.
Source: Patent US5333817, composite of Figures 1 to 5

3. Ballonet system

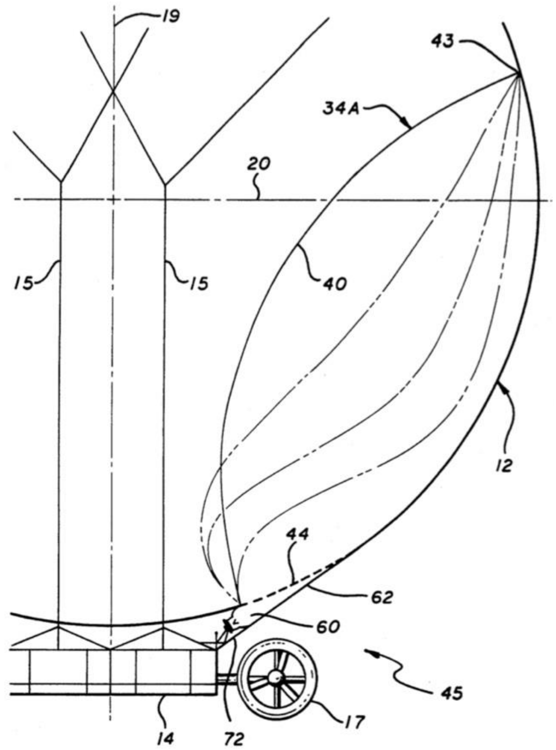
The airship has an unusually complex ballonet system, which is described in Patent US5333817.

The large, non-rigid, pressure stabilized gas envelope contained a system of 10 hemispherical air ballonets, deployed five on each side along the whole length of the inside walls of the gas envelope. Each of the 10 ballonets was made up of an approximately circular, flexible, inner sheet that was joined and sealed at its periphery to a portion of the interior wall of the gas envelope. This system of ballonets was used to maintain helium lifting gas pressure inside the gas envelope and overall aerostatic balance of the airship.

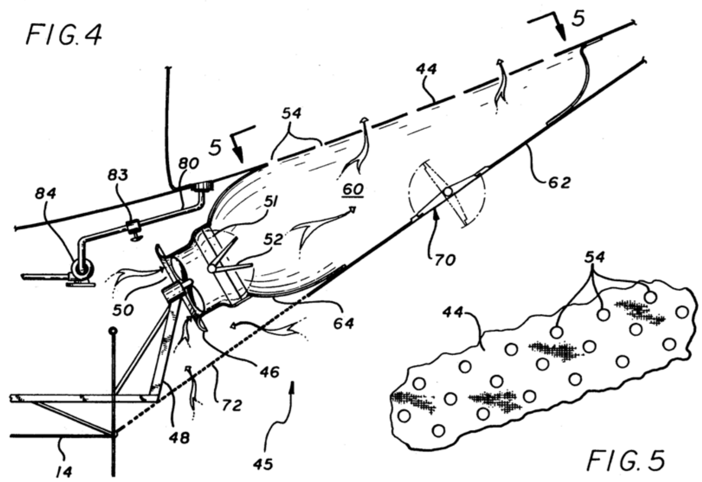
A ballonet pressurization system supplies each ballonet with pressurized air as needed. One or more fans draw ambient air and discharge at a positive pressure into air distribution manifolds that connect via flexible tubing to the individual ballonets. When the fans are OFF, check valves in the outlet ports of the fans prevent higher pressure air in the ballonets and manifolds from flowing back through the inlet ports of the fans and discharging to the ambient atmosphere.

A ballonet venting system, preferably in the form of one or more butterfly valves, is mounted on the manifolds for venting the interior of the ballonets directly to the ambient atmosphere.

The ballonet system includes a means to drain the ballonets of liquids that may collect therein (i.e., from water vapor condensation). The system has a drain tube connected to the bottom of the ballonet, an isolation valve mounted in the drain tube, and a pump to periodically drain the ballonet.



Above: Transverse view of envelope & ballonet at Section 3-3.
Below: Ballonet fan & vent details.



Legend

Non-rigid gas envelope (12), cargo compartment suspension system (catenaries, 15), airship vertical axis (19), representative ballonet (34A), flexible sheet forming the interior wall of a ballonet (40) and sealed around its periphery (43) to the inner wall of the gas envelope. Ballonet pressurization system (45), with fan (46) discharging through a check valve (52) into a duct supplying air to the ballonets (60) through a porous membrane (44 & 54), and ballonet vent to atmosphere via butterfly valve (70). Source, both graphics: Patent US5333817

4. Propulsion system

The basic thrust vectoring propulsion system

Patent US5449129A describes a thrust-vectoring propulsion system that provides cruise propulsion and precise maneuvering control at low speed and altitude when the airship is in the vicinity of its docking station. The patent applies to both rigid and non-rigid airships.

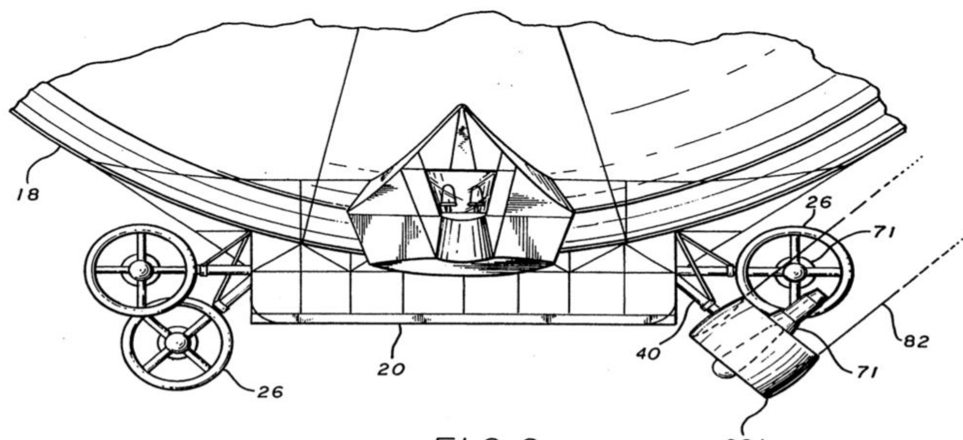


FIG. 2

Note propulsor 26A is shown rotated 90° relative to the orientation of the other three propulsors. Its downward-canted pylon (40) results in the propulsor's slipstream (82) avoiding the airship's (18) gas envelope. Source: Patent US5449129A, Figure 2.

The propulsion systems consists of multiple "thrust producing" propulsors (i.e., fan, ducted fan, propeller, or ducted propeller) located in equal numbers on either side of the airship. The patent notes that ducted fans or propellers are preferred from a safety standpoint, for if there is a blade failure, the duct wall would prevent the blade from possibly ripping open the gas envelope. Additionally, between the two favored types of propulsors, ducted propellers are preferred because of their higher efficiency at the low cruise speeds typical of airships.

The propulsors are mounted at the ends of pylons that extend outward from the vehicle, perpendicular to the airship's longitudinal axis. For Lockheed's semi-rigid cargo airship design, the pylons are attached to and supported from the sides of the rigid keel structure. This places the propulsors below the gas envelope and relatively close to the ground, which improves their accessibility for maintenance, repair and removal.

Each propulsor is rotatably mounted on the free end of its pylon, enabling an automated flight control system to independently position each propulsor and modulate its thrust as needed for a specific flight condition. For example, during vertical takeoff and landing (VTOL) operations and during hover, the propulsors may be aligned vertically to generate dynamic lift forces (up / down, fore / aft), enable the flight control system to dynamically manage gust response and precisely position the airship over the landing platform. After takeoff, the propulsors would be gradually transitioned to a horizontal alignment to accelerate the airship to cruise speed.

The slipstream from propulsors positioned along the flanks of the rigid keel will not impinge on the cargo airship's gas envelope during horizontal flight or during VTOL flight with downward-directed thrust. If upward-directed thrust is needed (i.e., for managing the airship in a lightly loaded condition), a downward-canted pylon could be used to direct the upward thrust from a propulsor diagonally away from the airship's gas envelope, as shown in Patent US5449129A Figure 2.

<u>Use of a reversible thrust ducted fan</u>

Patent US5516061A describes the design of a reversible thrust shrouded fan propulsor that could be used in a thrust-vectoring propulsion system as described previously in Patent US5449129A. A problem encountered during reverse thrust operation is that air must flow into the former exhaust end of the duct, which is not designed to serve as an efficient air intake. Patent US5516061A offers the following solution for this problem:

> "In general terms, the shroud includes a system for increasing the efficiency of the exhaust nozzle when acting as an inlet duct when the fan is providing reverse thrust. The system comprising a plurality of auxiliary inlet duct systems spaced about the circumference of the exhaust nozzle in proximity to the rear end thereof, the auxiliary inlet duct systems extending from the exterior surface of the exhaust nozzle to the interior surface thereof. The auxiliary inlet duct systems are movable

from a closed position to an open position wherein air can be drawn from the exterior surface of the exhaust nozzle to the interior thereof when the fan is providing reversed thrust.”

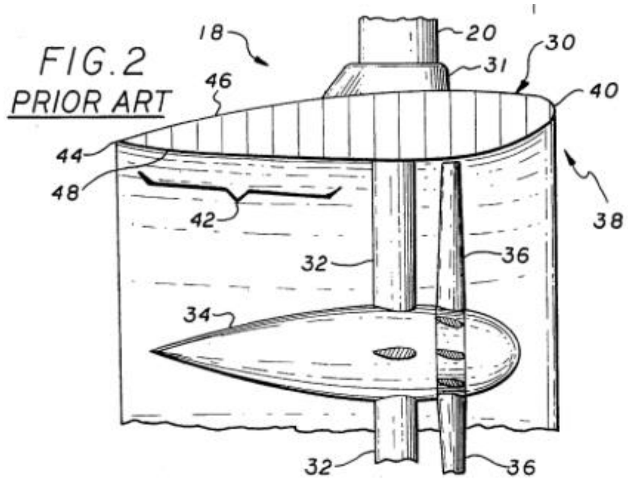


FIG. 2 is partial cross-sectional view of a conventional shrouded fan operating on a low speed vehicle such as the lighter-than-air vehicle.

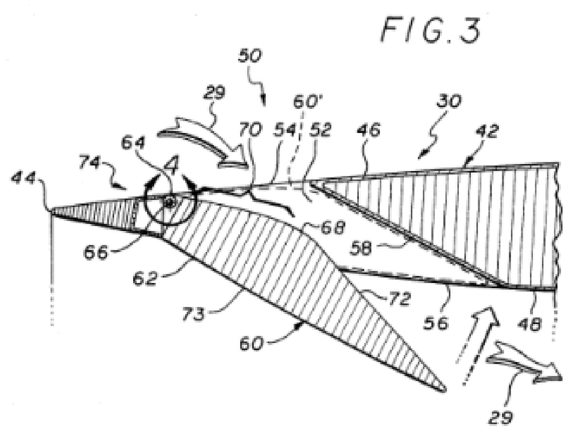


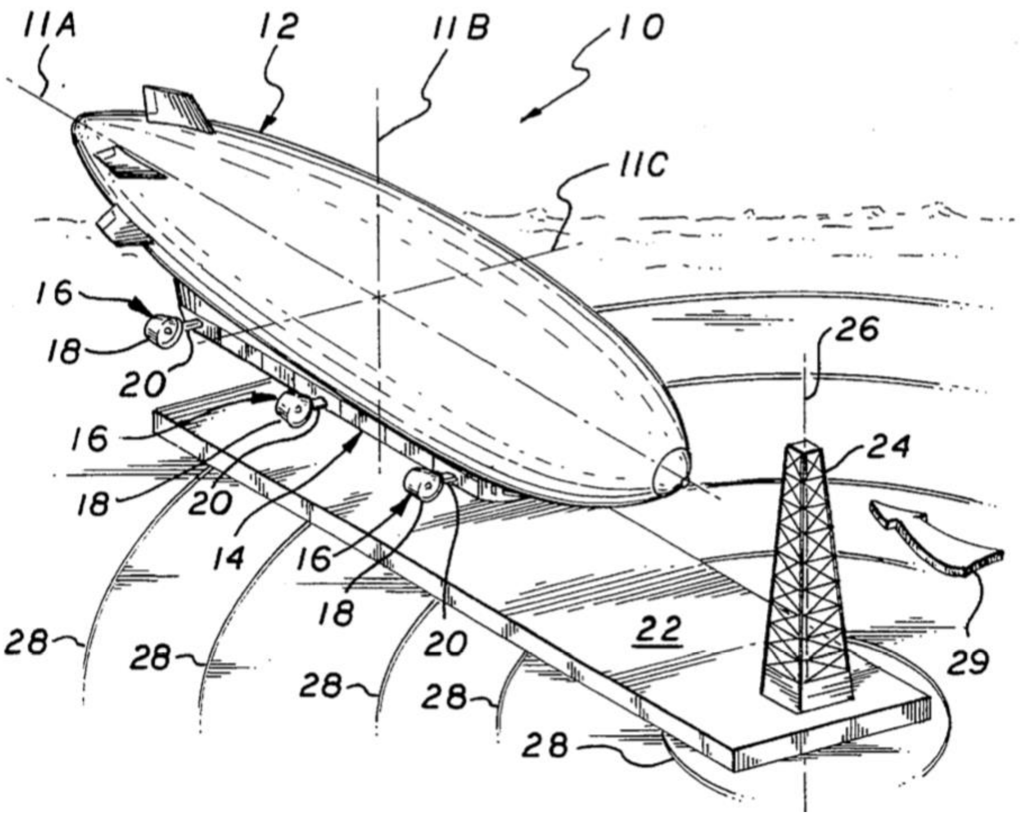
FIG. 3 is a cross-sectional view of the exhaust end of shroud shown in FIG. 2 modified to incorporate an auxiliary inlet duct system for increasing the efficiency of the exhaust nozzle when acting as an inlet duct when the fan is providing reverse thrust. Source, both graphics: Patent US5516061A

The use of a reversible thrust ducted fan eliminates the need to mechanically rotate the entire propulsor through 180° to direct its thrust in the opposite direction. This significantly improves the responsiveness of the propulsion system to inputs from the flight control system.

5. Mooring & cargo handling systems

The airship was designed for fixed base operation, with a mooring tower and a rotating platform to keep the airship pointed into the wind while it is on the ground. Side-loading cargo bays are installed like a set of very large enclosed transverse trays in the rigid keel. Cargo is loaded from one side and unloaded from the opposite side to reduce cargo handling congestion on the docking platform and to better manage the load transfer process while the airship is docked.

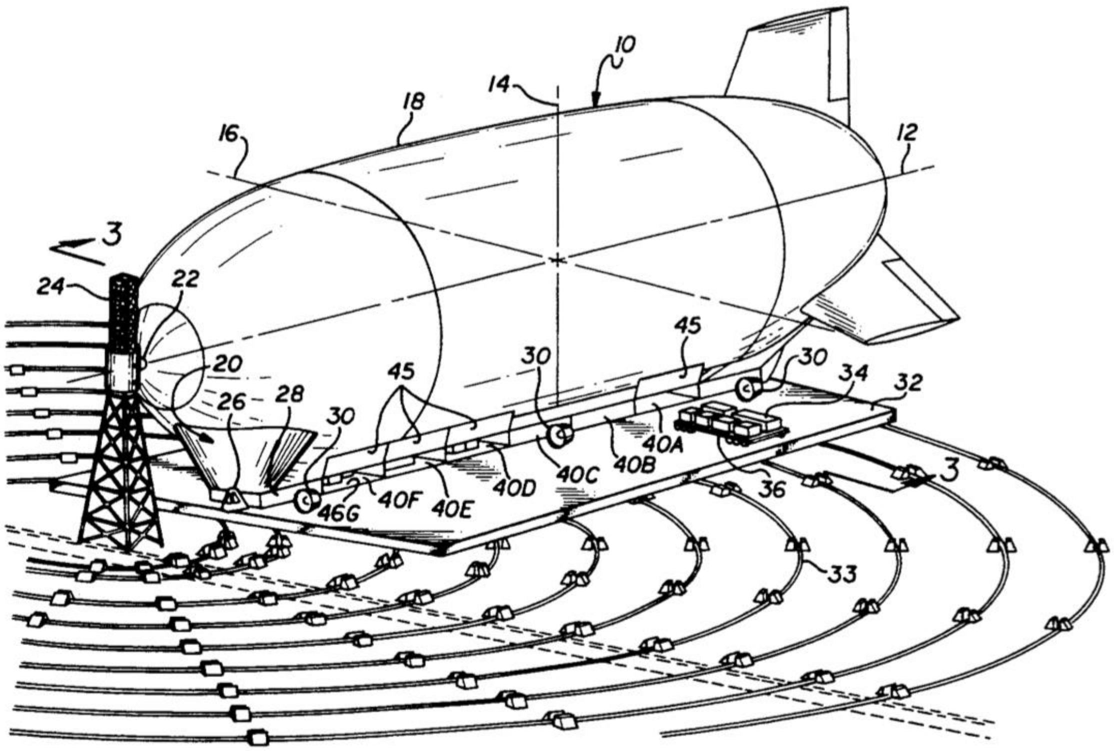
FIG. 1



Legend

Lighter-than-air vehicle (10) with longitudinal axis (11A), vertical axis (11B) and lateral axis (11C), is comprised of a non-rigid gasbag (12), a gondola (14), and a propulsion system (16) comprised of shrouded fans (18), each mounted via a rotating pylon (20) to the gondola. The rotating pylons provide thrust vector control for the shrouded fans. The docking platform (22) can rotate thru 360º about vertical axis (26) on circular tracks (28) to align the platform and airship into the wind (29) while the airship is docked at the mooring tower (24).

Perspective view of the airship approaching its mooring platform.
Source: Patent US5516061, Fig. 1



Legend

Lighter-than-air vehicle (18) with longitudinal axis (12), vertical axis (14) and lateral axis (16), is comprised of a non-rigid gasbag (18), a piloting station (26), a gondola (28) and a propulsion system comprised of shrouded fans (30) installed along the flanks of the gondola. Also along the flanks of the gondola, a series of cargo doors (45) open vertically to provide access to transverse cargo bays (40A to 40G) that are designed to carry palletized cargo in the rigid keel.
The docking platform (32) can rotate thru 360º about a vertical axis on circular tracks (33) to align the platform and airship into the wind while the airship is docked at the mooring tower (24).

Perspective view of docked airship during cargo handling.
Source: Patent US5346162, Fig. 1

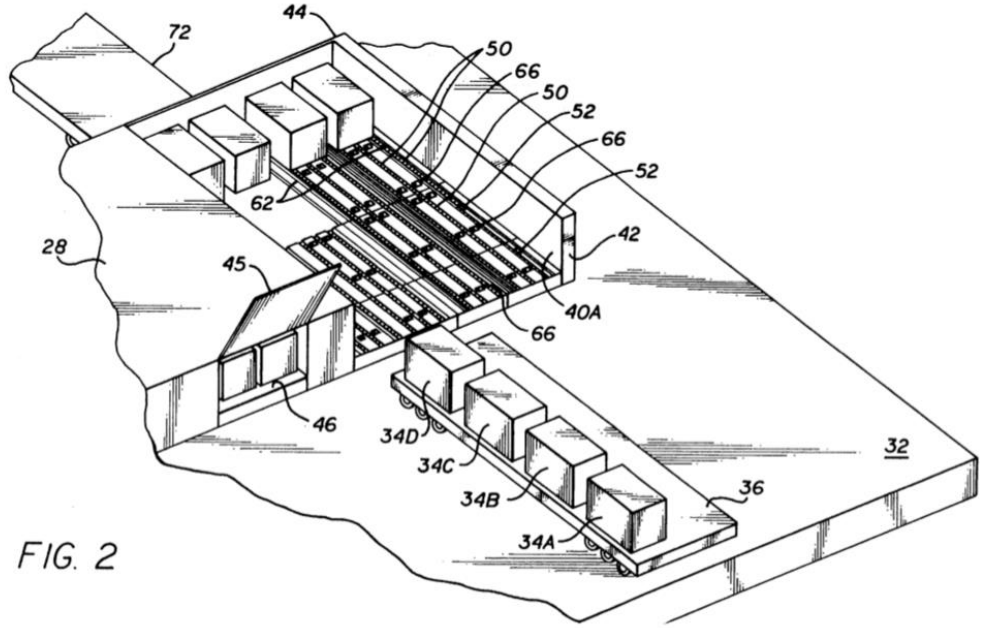
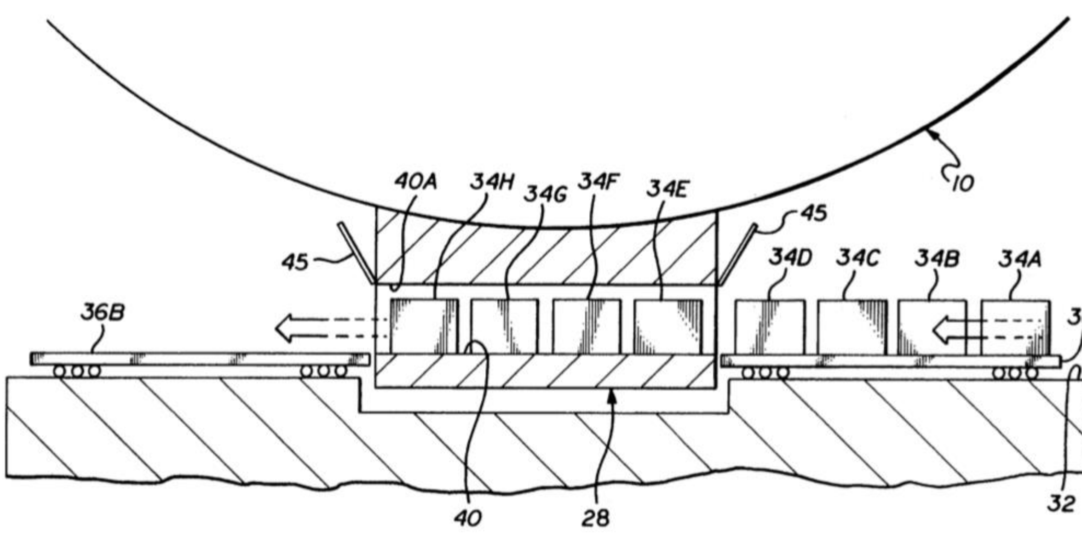


FIG. 2

Perspective view of a representative airship transverse cargo bay (40A), with cargo door (45) open and incoming palletized cargo (34A to 34D) positioned on a cargo cart (36) on the docking platform (32).
Source: Patent US5346162, Fig. 2



Airship (10) is moored on the docking platform (32). Outgoing palletized cargo is removed from the left and placed on a cargo cart (36B), and incoming palletized cargo on another cargo cart (36A) is ready to be loaded from the right.
Source: Patent US5346162, Fig. 3

6. For more information

Patents

- USD358575, “Lighter-Than-Air Vehicle,” (ornamental design for lighter-than-air vehicle), Inventors: Edsel R. Glasgow, Mark H. Wexler & Robert R. Cuccias; Filed 19 September 1994; Granted: 14 May 1996; Assigned to Lockheed Martin Corporation: https://patents.google.com/patent/USD358575S/en
- US5333817, "Ballonet System For A Lighter-Than-Air Vehicle,” Inventors: John B. Kalisz & Mark H. Wexler; Filed: 22 November 1993, Granted: 2 August 1994; Assigned to Lockheed Martin Corporation: https://patents.google.com/patent/US5333817A/en
- US5346162A, "A Cargo Compartment For A Lighter-Than-Air Vehicle,” Inventors: Robert G. Belie & Leland M. Nicolai, Filed: 8 November 1993; Granted: 13 September 1994; Assigned to Lockheed Martin Corporation: https://patents.google.com/patent/US5346162A/en
- US5368256A, “Propulsion system for a lighter-than-air vehicle,” Inventors: John B. Kalisz & David E. Carlile; Filed: 19 August 1993; Granted: 29 November 1994; Assigned to Lockheed Martin Corporation: https://patents.google.com/patent/US5368256A/en
- US5449129A, “Propulsion system for a lighter-than-air vehicle,” Inventors: David E. Carlile & Mark H. Wexler; Filed: 18 February 1994; Granted: 12 September 1995; Assigned to Lockheed Martin Corporation: https://patents.google.com/patent/US5449129A/en
- US5516061A, “Shroud for reversible thrust fan,” Inventor: Edsel R. Glasgow; Filed 19 September 1994; Granted: 23 May 1995: Assigned to Lockheed Martin Corporation: https://patents.google.com/patent/US5516061A/en

Other *Modern Airships* articles

- *Modern Airships - Part 1*: https://lynceans.org/all-posts/modern-airships-part-1/
    - CargoLifter - CL160
- *Modern Airships - Part 2*: https://lynceans.org/all-posts/modern-airships-part-2/
    - Augur RosAeroSystems (RAS) airships – DZ-N1 large rigid airship

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