Lockheed Martin – P-791 hybrid airship

Peter Lobner, updated 16 June 2023

1. Introduction

Building on Lockheed's hybrid airship design work since the early 1980s, Lockheed Martin continued developing design concepts for semi-buoyant, hybrid airships with lifting body hulls after the two firms merged in 1995.

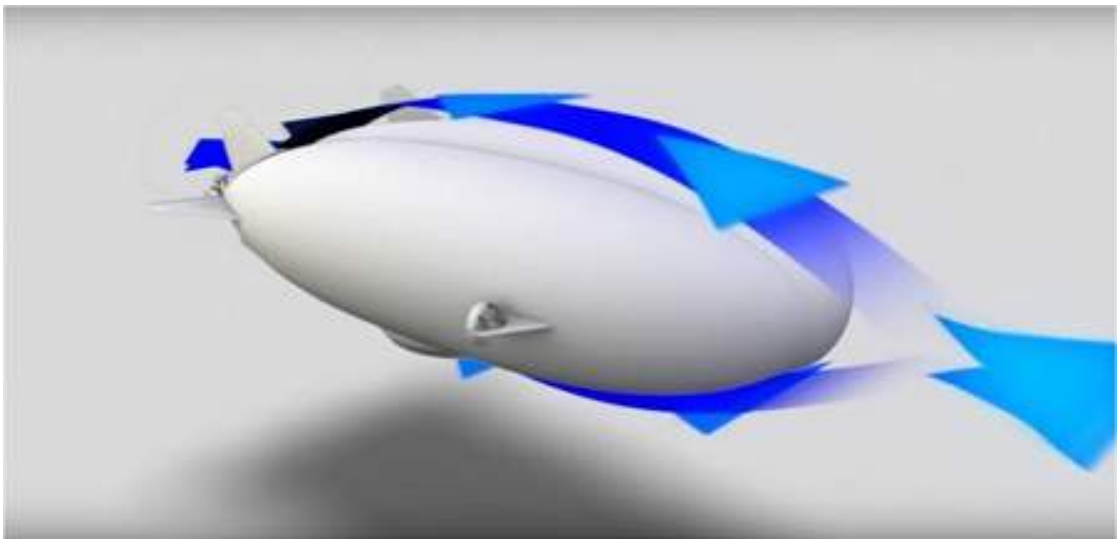
By the 2000s, Lockheed Martin's focus shifted to non-rigid hybrid airships. Lockheed Martin committed internal funding for a project to build a sub-scale, manned, hybrid airship technology demonstrator to validate technologies for use in future full-scale hybrid airships. That sub-scale airship was designed and built at Lockheed Martin's Skunk Works in Palmdale, CA and was designated the P-791. The non-rigid gas envelope was manufactured by TCOM.

In mid-2005, Lockheed Martin and Aeros Aeronautical Systems Corp. (Aeros) were selected as contractors and funded under Phase 1 of the Defense Advanced Research Projects Agency's (DARPA's) Project WALRUS, which sought to develop and demonstrate new technologies and design concepts for a strategic, heavy-lift cargo airship. At the time of the DARPA contract award, work on the Lockheed Martin-funded P-791 hybrid airship already was well advanced. The P-791 flew for the first time in January 2006, about six months after the DARPA contract award. After a short test program, Lockheed Martin and DARPA reported that all flight test objectives were met. The P-791 was placed in storage and has not flown again.

The P-791 technology demonstrator. Source: Screenshot from Lockheed Martin video (2006)

2. The P-791 technology demonstrator

The P-791 is a 120 foot (36.6 meter) long, non-rigid, tri-lobe, semi-buoyant hybrid airship that flies under the combined influence of the aerostatic lift from helium (about 80% of total lift), vectored thrust from propellers, and aerodynamic lift from the hull when in forward flight. The flexible composite fabric hull (the gas envelope) is slightly pressurized (pressure stabilized) to maintain its aerodynamic shape.



The hull of the hybrid airship generates aerodynamic lift in forward flight. Source: Screenshot from Hybrid Enterprises video (2016)

Bow quarter view showing a flank-mounted, two-axis thrust vectoring propeller. Source: Lockheed Martin

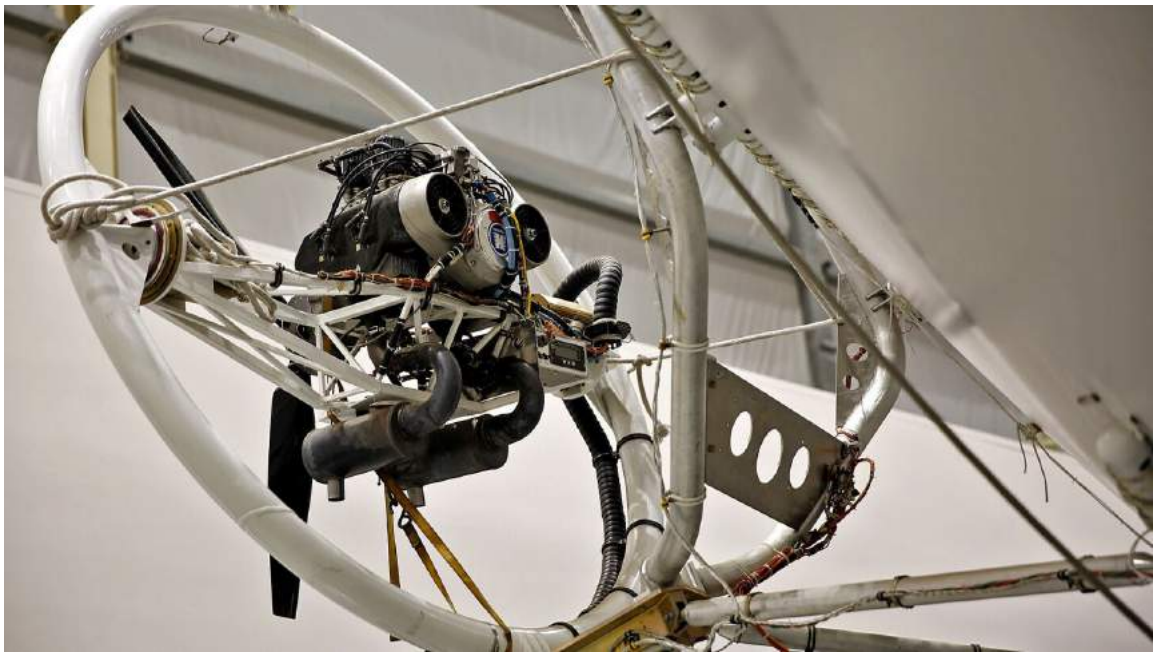
Stern quarter view showing the rear fins and one of two stern thrust vectoring propellers.

Stern view showing the two two-axis thrust vectoring propeller installations & elongated framework that distributes loads into the envelope.
Source, both photos: Al Sieb / Los Angeles Times / TNS

(Above left) Stern quarter view showing the aerodynamic tail surfaces and the two two-axis thrust vectoring stern propeller installations & elongated framework that distributes static & propulsion loads into the envelope. Source: Lockheed Martin

(Above right) One flank two-axis thrust vectoring propeller installation & the supporting framework that distributes static & propulsion loads into the envelope. Source: Lockheed Martin

(Below) Closeup of an engine-driven, flank, thrust vectoring, three-bladed propeller installation. Source: Al Sieb / Los Angeles Times / TNS



Profile view of the P-791 on the ground. Source: Lockheed Martin

Bow view on the ground, showing the tri-lobe hull design, the gondola under the envelope's centerline, and the two forward thrust vectoring propellers. Source: Screenshot from Lockheed Martin video.

General characteristics of the Lockheed Martin P-791

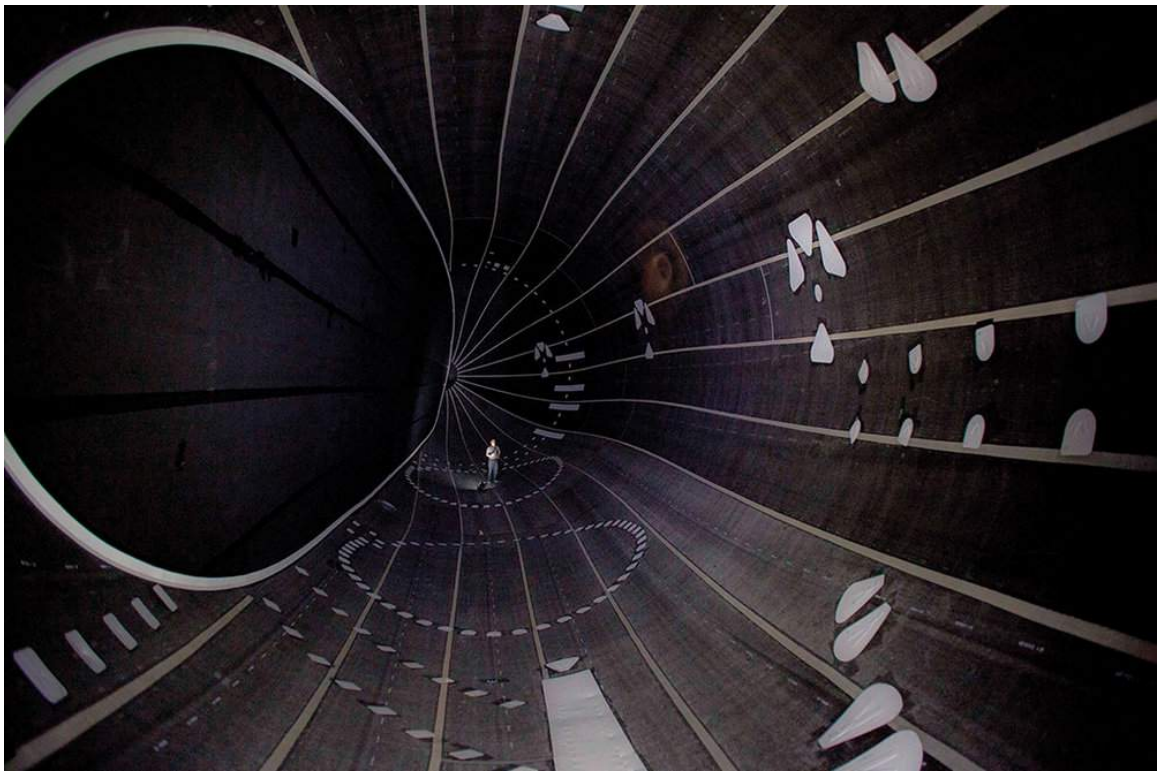
Parameter	**P-791**
Length	120 ft (36.6 m)
Width, max	65 ft (19.8 m)
Height, max	37 ft (11.3 m)
Volume	120,000 ft^3 (3,398 m^3)
Propulsion	4 x diesel engine-driven, thrust vectoring propellers; 2 x forward flank mounted, 2 x tail mounted
Speed, cruise	60 knots
Range	1,500 miles (2,414 km)
Operating altitude	10,000 ft (3,048 m)

The P-791 is designed for short takeoff and landing (STOL) and ground operations at unimproved sites using its air cushion landing system (ACLS). During takeoff and landing and when the P-791 is moving on the ground, the ACLS operates in "lift" mode. The four air cushion pads on the bottom of the airship allow it to float on cushions of air while using the vectored thrust propulsion system to move the airship over almost any type of surface (pavement, unimproved natural surface like dirt, sand, snow or ice or water).

The ACLS fans can be reversed and operated in "suction" mode, which enabled the airship to "grip" a solid surface and remain stationary during ground cargo handling or in windy conditions without the need for ground-based mooring / docking hardware or ballast. Operating the ALCS in suction mode helps compensate for changes in airship gross weight during load exchanges. It may still be necessary to adjust ballast before flight to compensate for the addition or removal of heavy loads.

The P-791 was not designed for vertical takeoff and landing (VTOL) or hover, since flight depends on about 20% of total lift being generated by aerodynamic lift from the hull and/or vectored thrust from the propulsion system.

The four thrust vectoring propulsors were attached directly to the gas envelope. Each is mounted directly to reinforced sections of the gas envelope with mechanical supports that distribute propulsion loads into a broad area of the gas envelope. Inside the gas envelope, two longitudinal catenary curtains (also called "septums") separate the three lobes, carry the loads from the gondola and distribute these loads into the upper surface of the envelope.



Inside the starboard lobe of the gas envelope looking forward.
The oval "septum" separating the starboard and center lobes is at the left.
The two dotted circles on the "floor" mark the ACLS attachment points.
The four short horizontal bars on the forward right side wall make the mounting points for the starboard thrust-vectoring propulsor.
Source: Straightline Aviation gallery.

3. P-791 flight testing

The first flight of the P-791 took place on 31 January 2006 at Lockheed Martin's facility on the Palmdale Air Force Plant 42 in California. This first manned flight was a short circuit of the airport lasting about 5 minutes.

Airship magazine reported that the P-791 flew six times. Lockheed Martin and DARPA reported that all flight test objectives were met. While Lockheed Martin noted that the P-791 was hangered in Palmdale and available to fly again, it never did.

Source: Lockheed Martin

Source: UAS calendar 2017

Source: Lockheed Martin

Source: Screenshot from Daily Motion video (2007)

4. P-791 variant proposed for the U.S. Army's LEMV program

In 2010, Lockheed Martin proposed a scaled-up version of the P-791 for the U.S. Army's Long Endurance Multi-Intelligence Vehicle (LEMV) program. The LEMV was intended to be a medium altitude surveillance platform capable of operating on missions lasting 21 days or more, or carry up to 15,000 lb (6,900 kg) of cargo as far as 2,400 nm (4,440 km).

The Army awarded the LEMV to the team of Hybrid Air Vehicles (HAV) and Northrop Grumman. Their LEMV prototype subsequently was acquired by HAV and became the Airlander 10 hybrid airship prototype.

Lockheed Martin LEMV design concept, with significant changes for the P-791 configuration (i.e., aft flank-mounted propellers, three-pad ACLS)
Source: Lockheed Martin via NAA Noon Balloon (Winter 2009)

Lockheed Martin incorporated technologies validated on the P-791 and updated in the subsequent LEMV competition in the design of their commercial non-rigid hybrid airship designs, the SkyTug and the LMH-1, which are addressed in a separate article.

5. Patent lawsuit

On 18 March 2007, a civil litigation, “Lockheed Martin Corporation v. Jeffery Munk et al.” was filed claiming patent infringement by Jeffrey Munk, Skycat Ltd., and ATG related to their US patents US6880783 and US7040572. The Lockheed Martin P-791 was striking similar to ATG’s SkyKitten technology demonstrator airship and the full-size SkyCat hybrid airship. These hybrid airships use many of the same design concepts, and, at the time, there were some who believed that the two programs were related. The lawsuit was terminated on 16 September 2008 with no declaratory judgment against the defendants.

6. Lockheed Martin’s patents for hybrid airship technology

Lockheed Martin has an extensive portfolio of patents related to hybrid airship technology. Several of the patents awarded in the early 2000s describe features of hybrid airship design concepts that predate, but are applicable to the non-rigid P-791.

- Semi-buoyant airship with pressure stabilized hull generating aerodynamic lift
- Thrust vectoring propulsion system

These patents are addressed in a separate article on the Lockheed Martin semi-rigid Aerocraft (not to be confused with the Aeroscraft trademarked by Worldwide Aeros Corp.).

This section addresses the following Lockheed Martin patents that have a direct bearing on design features found on the non-rigid P-791.

- US 8016229B2 & US 8177161B2 - Retracting air cushioned landing system for air vehicles
- US 8167240B2 & EP 2230173A3 - Systems and methods for buoyancy management in an airship
- US 5333817A - Ballonet system for a lighter-than-air vehicle
- US 7448572B2 - Direct mounted propulsion for non-rigid airships

Patents US 8016229B2 and US 8177161B2 - Retracting air cushioned landing system for air vehicles

US 8016229B2

- Application filed: 7 July 2008
- Patent granted: 13 September 2011
- Available here: https://patents.google.com/patent/US8016229/es

US 8177161B2

- Application filed: 10 June 2011
- Patent granted: 15 May 2012
- Available here: https://patents.google.com/patent/US8177161B2

This patent describes an extendable ACLS with streamlined covers that enclose the retracted (deflated) ACLS units in flight.

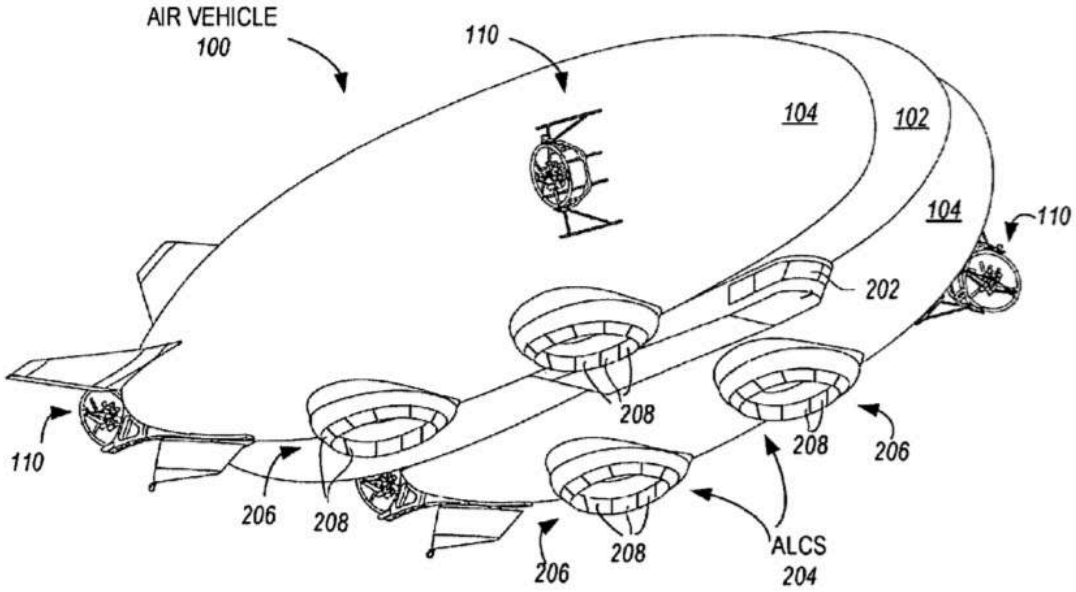


FIG. 2

Fig. 1 shows a hybrid airship resembling the P-791 with ACLS landing pads (206) with finger skirts (208) extended (inflated) and the covers retracted.

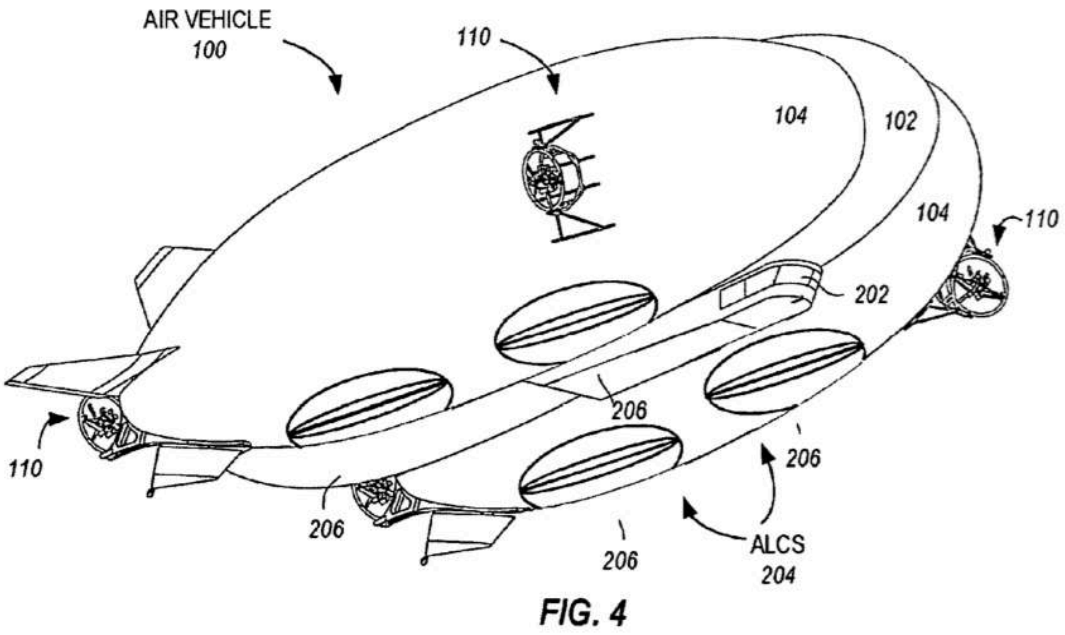


FIG. 4

Fig. 2 shows a hybrid airship with ACLS landing pads retracted (deflated) & the covers deployed.

Patents US 8167240B2 and EP 2230173A3 - Systems and methods for buoyancy management in an airship

US 8167240B2

- Application filed: 13 March 2009
- Patent granted: 1 May 2012
- Available here: https://patents.google.com/patent/US8167240B2/en

EP 2230173A3:

- Application filed: 12 March 2010
- Patent granted: 30 November 2016
- Available here: https://patents.google.com/patent/EP2230173A3/it

These patents describe the operation of the ACLS in five different operating modes and the respective air pressures in the ballonets and the hull in each operating mode.

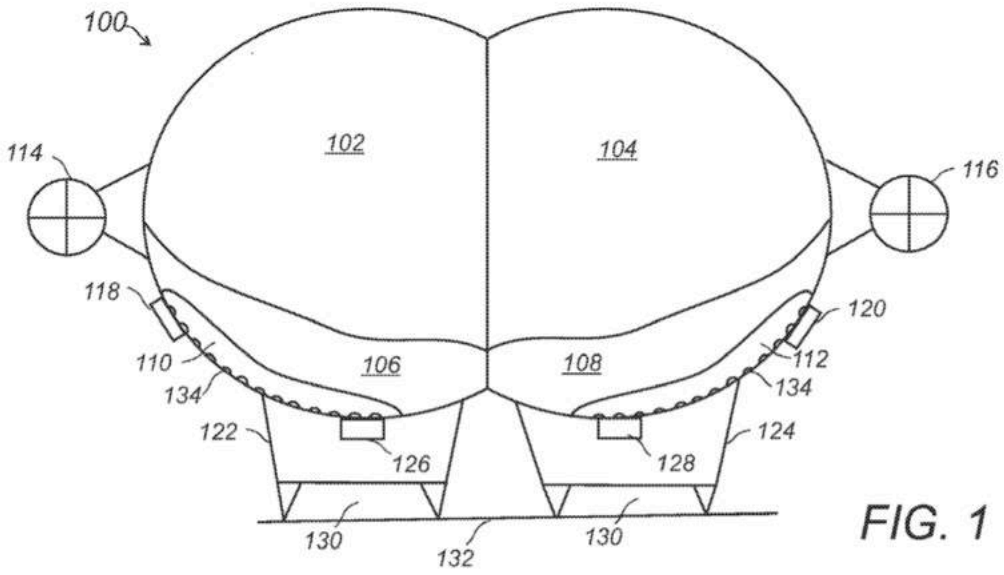


FIG. 1

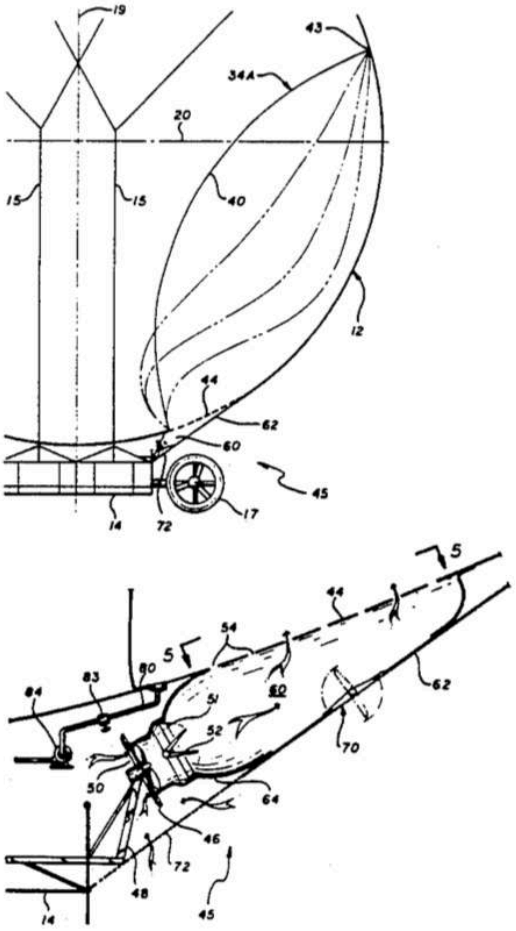
Fig. 1 shows fans (118, 120) suppling higher pressure air via ducts (110, 112) to the ballonets (106, 108) and via control valves (126, 128) into the ACLS chambers (122, 124)

Patent US 5333817A - Ballonet system for a lighter-than-air vehicle

- Application filed: 22 November 1993
- Patent granted: 2 August 1994
- Available here: https://patents.google.com/patent/US5333817A/en

This patent describes an improved ballonet system that has the following attributes:

- It is independent from other systems of the vehicle (including the ACLS).
- The volume of air in each ballonet can be individually varied.
- It provides rapid filling and venting of the individual ballonets.



In a hybrid airship with ballonets installed left and right, and fore and aft, the ballonets can be used individually or collectively to adjust the roll angle and the pitch angle of the airship.

Each ballonet (40) is located along the inner surface of the pressure-stabilized hull (12).

Fan (46) pressurizes the ballonet.

Butterfly valve (70) depressurizes the ballonet.

Patent US 7448572B2 - Direct mounted propulsion for non-rigid airships

- Application filed: 5 October 2005
- Patent granted: 11 November 2008
- Available here: https://patents.google.com/patent/US7448572

The patent describes a means to attach a propulsion system for non-rigid, pressure-stabilized airships directly to a fabric skin and efficiently distribute applied loads into the skin. While patented in connection with an application for a high-altitude airship, the solution applies as well to a hybrid airship with a pressure stabilized hull, like the P-791.

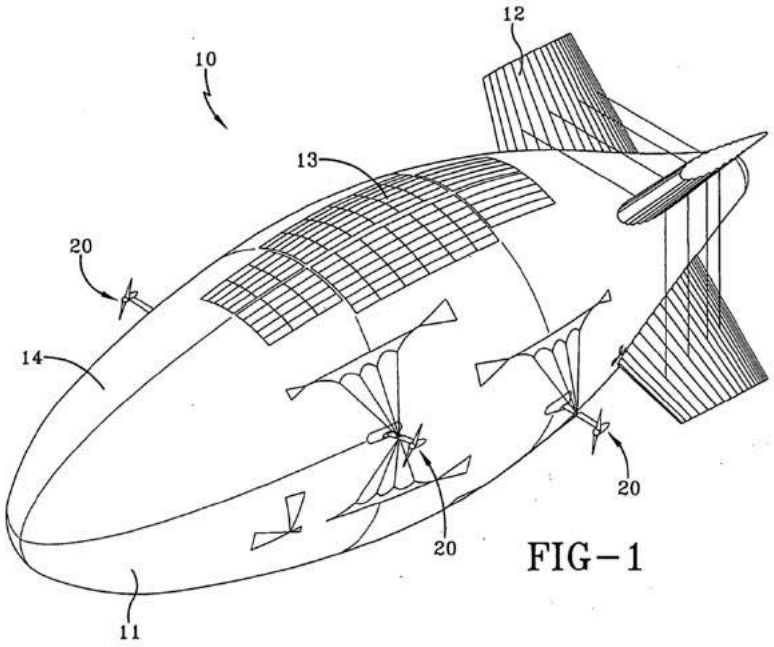


Fig.1 shows a non-rigid airship (10) with propulsors (20) attached to the pressure-stabilized hull (11) with a network of guy cables (60) connected to scalloped fabric mounting assemblies (70) that distribute loads into the hull.

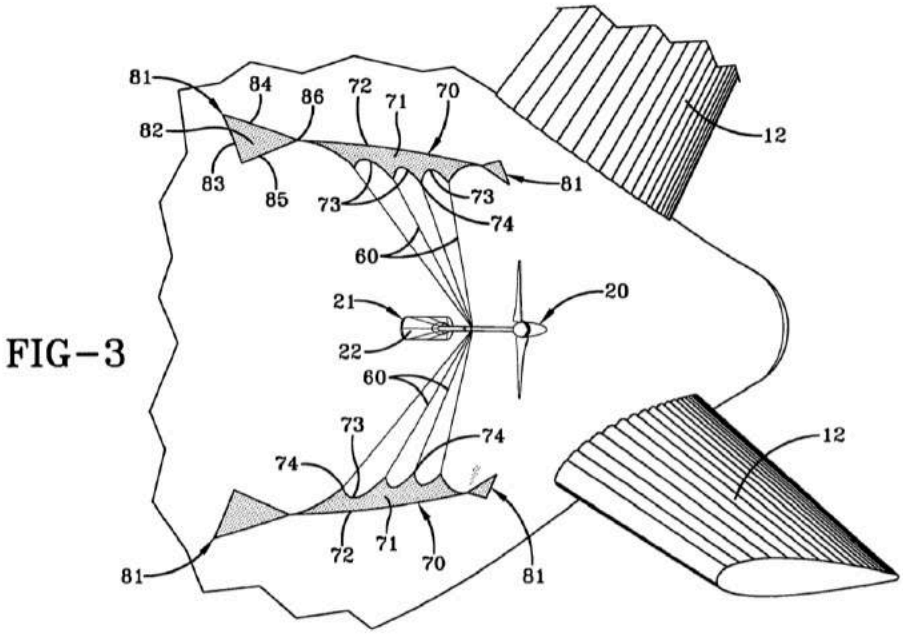


Fig. 3 provides a closer look at the attachment for a single propulsion engine assembly (20), which is mounted at one end of an extension member that is secured to the hull at its base (21, 22). The engine assembly is supported by several guy cables (60) that are fastened to longitudinal scalloped fabric mounting assemblies (70) to distribute the load to a broad area of the hull.

This design also is addressed in European patent EP1772374 B1, "Non-rigid airship with direct mounted propulsion," which was granted on 7 July 2010 and is available here" https://patents.google.com/patent/EP1772374B1/en

7. For more information

- Michael Dornheim, "Lockheed Martin's Secretly Built Airship Makes First Flight," Aviation Week, 5 February 2006: https://web.archive.org/web/20070927013117/http://www.aviationweek.com/aw/generic/story_generic.jsp?channel=awst&id=news/020606p2.xml
- "P-791 hybrid airship project," Military Heat, 18 February 2008: https://military-heat.bubble.ro/91/p791-hybrid-airship-project/
- "New Lockheed airship takes short test flight," Los Angeles Daily News, 15 February 2006: https://www.dailynews.com/2006/02/15/new-lockheed-airship-takes-short-test-flight/
- Trefis Team, "A Comprehensive Look At Lockheed Martin's Hybrid Airships," Forbes, 9 July 2015: https://www.forbes.com/sites/greatspeculations/2015/07/09/a-comprehensive-look-at-lockheed-martins-hybrid-airships/?sh=6eb9dab54c9d

Videos

- "Lockheed P-791," (1:12 minutes, flight test clips), posted by Daily Motion, 2007: https://www.dailymotion.com/video/x4cnc6
- "Lockheed Martin P-791 Hybrid Air Vehicle," (3:32 minutes), posted by DefenseUpdate, 11 June 2015: https://www.youtube.com/watch?v=LZBhs-SrvwI
- "Air Cushion Landing System for Hybrid Airship - Skunk Works," (3:43 min, with details on the design and operation of the P-791 ACLS), posted by MechDesign TV, 12 April 2017: https://www.youtube.com/watch?v=Qi_sJ-k3kRI

Other *Modern Airships* articles

- *Modern Airships - Part 1*: https://lynceans.org/all-posts/modern-airships-part-1/
    - Lockheed Martin - Aerocraft hybrid airship
    - Lockheed Martin - SkyTug and LMH-1 hybrid airships
    - Advanced Technologies Group (ATG) – SkyCat & SkyKitten
    - Hybrid Air Vehicles (HAV) & Northrop Grumman - LEMV
- *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/