Lockheed Martin – Ultra-large, rigid, semi-buoyant hybrid airships

Peter Lobner, updated 30 August 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 was a small rigid airship (SRA) that was similar in size, but was a radical departure from the designs of contemporary non-rigid blimps. This work, led by Lockheed engineer Roy P. Gibbens, was introduced in July 1983. This SRA, with a flattened ellipsoidal, lifting body hull resembling many later hybrid airship designs, became known as the Lockheed Starship.

Lockheed Corp. and Martin Marietta merged in 1995 to form Lockheed Martin Corp. Building on the prior airship experience of both firms, Lockheed Martin continued developing a variety of advanced airship designs. One design concept was the ultra-large, rigid, semi-buoyant, hybrid airship, which is the subject of this article.

Another design concepts being developed in the 1990s was the semi-rigid, semi-buoyant, hybrid airship with a pressure-stabilized, fabric, lifting body hull. These airships include Lockheed Martin's trademarked Aerocraft (not to be confused with the "Aeroscraft" trademark held by Worldwide Aeros Corp.). By the early 2000s, Lockheed Martin's focus had shifted to non-rigid, semi-buoyant, hybrid airships, as embodied in their P-791 technology demonstrator, which flew in 2006, and their commercial Sky Tug / LMH-1 designs.

Lockheed's SRA Starship and Lockheed Martin's semi-rigid Aerocraft and their later non-rigid P-791 and Sky Tug / LMH-1 hybrid airship designs are the subjects of separate articles.

2. Ultra-large rigid hybrid airship concepts

Lockheed Martin's basic design approaches for ultra-large, rigid, hybrid airships are described in two patents from the late 1990s. In these patents, Lockheed Martin refers to the rigid, semi-buoyant airship as an "aerocraft." None were ever built.

2.1 Ultra-large rigid hybrid airship with tensioned frame & longeron hull

World Intellectual Property Organization (WIPO) application WO1999024315A2, which was published in 1999, describes the design of an ultra large, semi-buoyant, aerial vehicle that is capable of carrying up to 1,000,000 pounds (500 tons / 454 metric tons) of cargo for a distance of up to 4,000 nautical miles (7,408 km), or at least 10,000 nautical miles (18,520 km) without cargo, before landing or needing to refuel.

This huge, rigid hybrid airship is comprised of a broad lifting body hull that has a longitudinal cross-section resembling a thick airfoil. The rigid, geodesic, transverse hull structural frames are held in tension by a network of non-metallic cables inside the hull. Longerons connect the transverse frames and define internal compartments that contain the flexible lifting gas cells that are installed above and around a large, rigid cargo bay. An external, multi-layer fabric "skin" covers the exoskeleton hull to define a smooth aerodynamic shape. Propulsion equipment and aerodynamic flight control surfaces are attached directly to the rigid hull.

The contemporary, Hughes Megalifter semi-buoyant aircraft generates the majority of its aerodynamic lift from wings attached to an aerodynamically shaped fuselage. In contrast, the Lockheed Martin ultra-large rigid hybrid airship has no wings and generates the majority of its aerodynamic lift from the airfoil shaped lifting body hull plus a small amount of lift from the horizontal tail fins.

The general layout of this airship is shown in patent Figures 1 to 4.

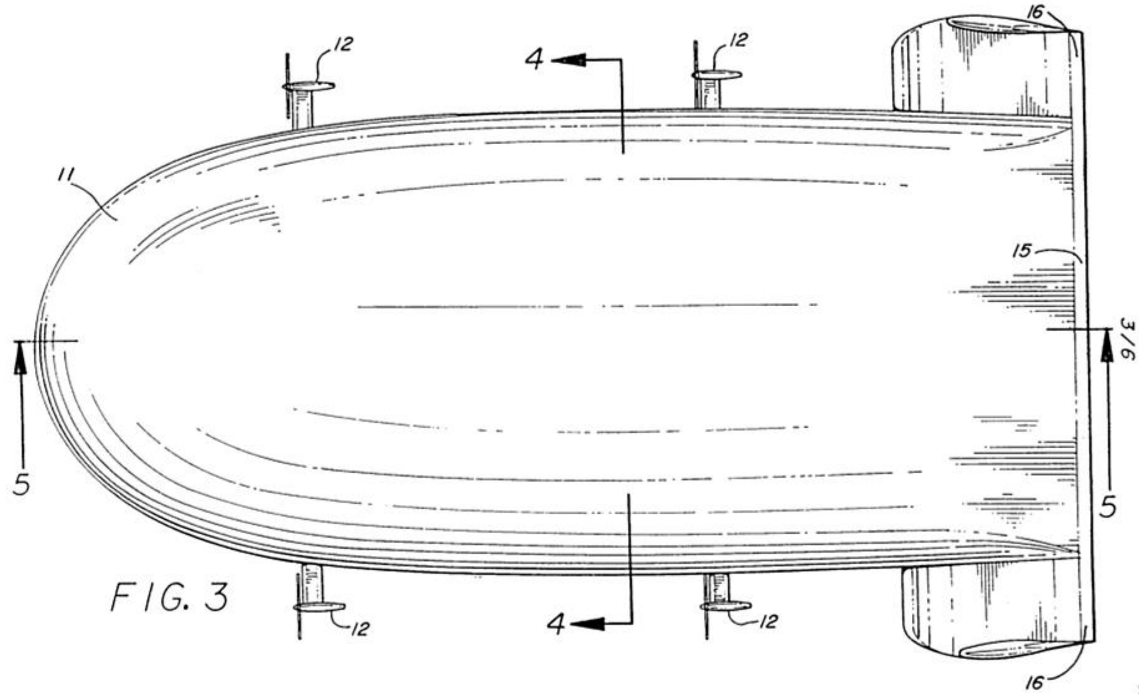

FIG. 3

Overhead view of the airship showing the placement of the thrust vectoring engines (12), trailing edge body flap (15) & ailerons (16).

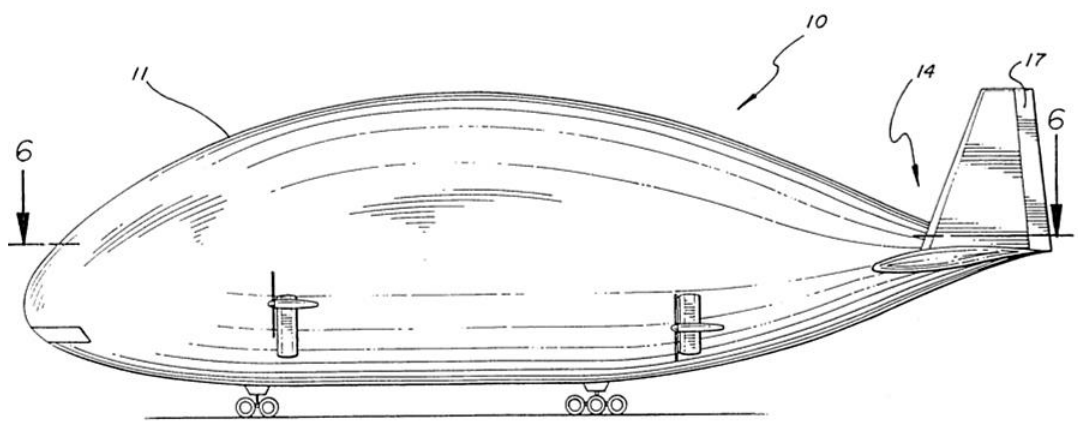

FIG. 2

Profile view of the airship (10) with a lifting body hull (11) with a pair of vertical fins (14), each having a rudder (17) for aerodynamic control.

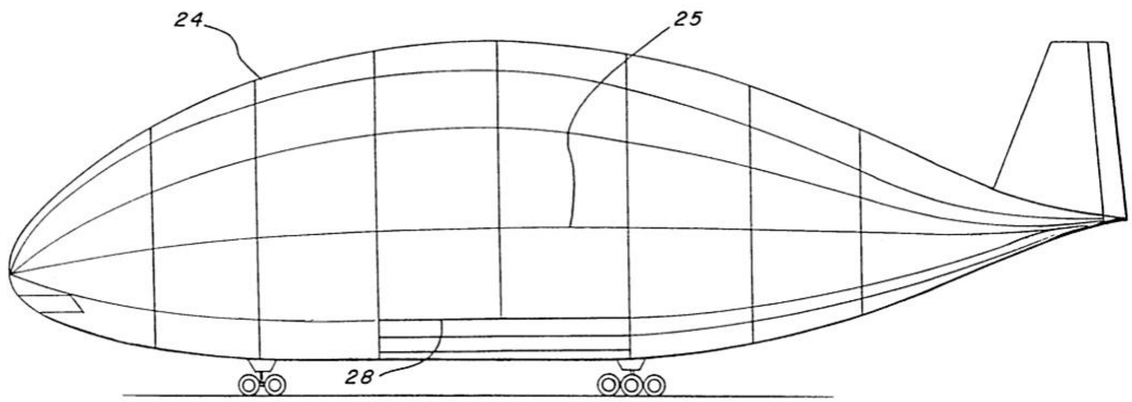

FIG. 5

Profile view of the airship and its outer skin (24) with longitudinal gores (25) over the rigid exoskeleton hull structure. The longitudinal gores illustrate the changing airfoil shape across the broad lifting body hull.

Vehicle trim is managed by transferring helium lift gas between the bow and stern lift gas cells or by transferring fuel between fuel tanks.

At full load, the airship can operate from a conventional 10,000 ft (3,048 m) runway. The airship is capable of executing short takeoff and landing (STOL) with a reduced payload. It could execute vertical takeoff and landing (VTOL) with a further reduction of payload and/or fuel. Propulsive lift and control during STOL and VTOL operations are achievable by a combination of engine throttle position and thrust vector angle.

The business case for this type of rigid, hybrid airship is based on the notion that the cost of airborne transport vehicles can be reduced significantly by designing for lower speed and altitude, and using buoyant lift to replace the aerodynamic lift produced by wings, which are expensive to build. The size of the hybrid airship and its associated payload capacity must be large enough to compensate for a cruise speed that is much slower than contemporary winged transport aircraft.

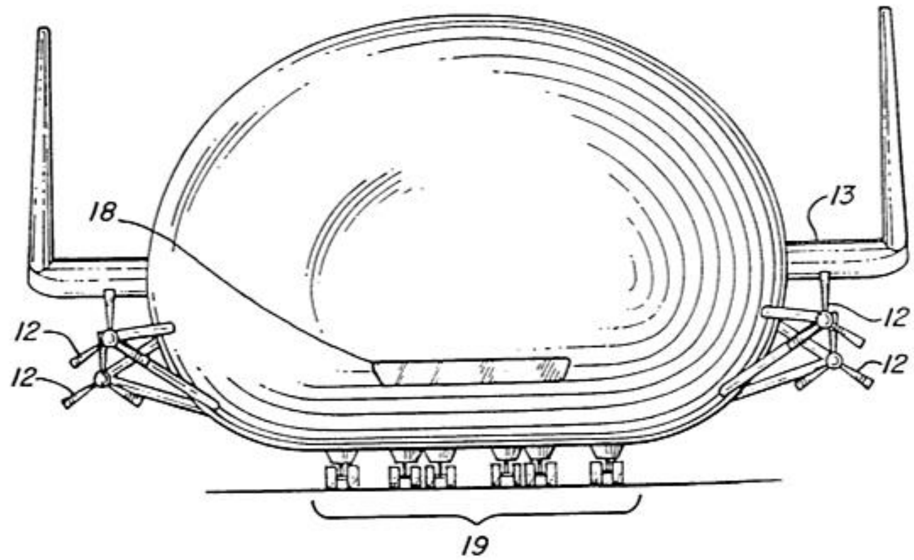

FIG. 1

Bow-on view showing placement of the crew cockpit (18),
thrust vectoring engines (12), tailplane (13) and conventional landing gear (19)

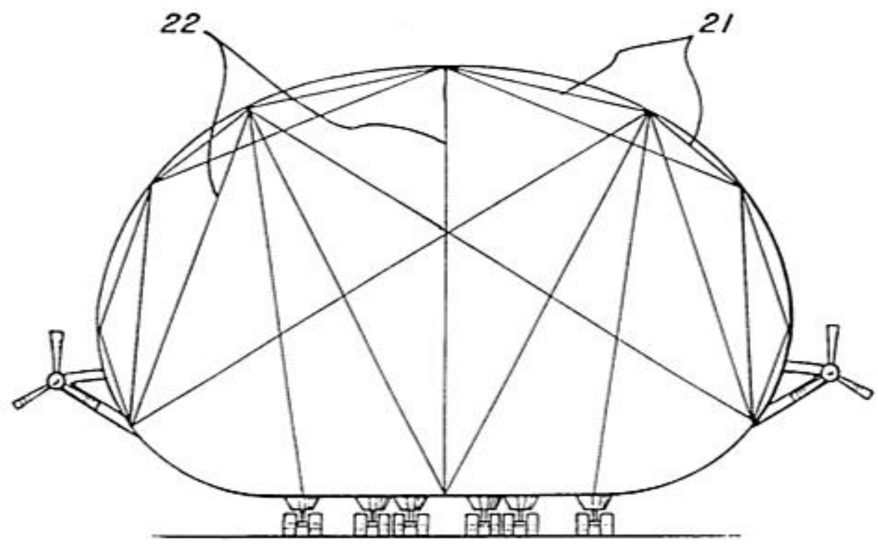

FIG. 4

Transverse cross-section view through the forward set of engines
showing the geodesic frame structural members (21) and the network
of guy cables (22) that maintain the frame structure in tension.

WO1999024315A2 includes the following representative design parameters for this ultra-large, rigid, semi-buoyant, hybrid airship.

General characteristics of the ultra-large rigid airship

Parameter	**WO1999024315A2 ultra-large rigid airship**
Length	780 ft (237.7 m)
Width	480 ft (146.3 m)
Height	220 ft (67.1 m)
Volume	30,000,000 ft^3 (848,505 m^3)
Takeoff mass at full load	About 1,500 tons (1,361 metric tons), split almost equally among empty weight, fuel weight & payload weight
Aerostatic lift	About 750 tons (680 metric tons, about ½ of takeoff mass at full load)
Payload, max	500 tons (454 metric tons), carried internally
Payload bay dimensions	• Preferably about 250 feet long x 260 feet wide (76.2 x 79.2 m) along the bottom of the airship & aligned with the center-of-gravity • Strengthened floor to support heavy loads • Ro-Ro (fore and aft) cargo handling
Propulsion	• 4 or more turboprop engines installed in tandem along the sides of the airship • Each engine drives a large shrouded fan or multi-bladed propeller 50 – 60 ft (15.2 – 18.3 m) in diameter and capable of pitch thrust vectoring from -110º to +110º
Aerodynamic controls	Vertical fins with rudders, horizontal fins with ailerons, and trailing edge body flaps
Landing gear	• Conventional, 36 wheels, 100 ft (30.5 m) track to limit runway loading to current limits for large fixed-wing aircraft. • Weight on landing gear at full load: 750 tons (680 metric tons)
Takeoff distance, full load	< 10,000 ft (3,048 m)
Speed, cruise	150 knots (278 kph)
Altitude, cruise	4,000 ft (1,219 m)
Altitude, pressure	5,000 ft (1,524 m), or higher with a reduced payload and reduced helium charge)
Range	4,000 nautical miles (7,408 km) with 500 ton (454 metric ton) cargo, or at least 10,000 nautical miles (18,520 km) without cargo

2.2 Ultra-large rigid hybrid airship with helical exoskeleton hull

Patent US6164589A, which was granted and assigned to Lockheed Martin in 1999, describes a rigid, semi-buoyant airship with a deltoid-shaped lifting body hull capable of transporting very large payloads. The rigid, helical exoskeleton hull structure provides a large internal volume for the lifting gas cells and cargo bay. Aerodynamic surfaces, propulsion engines and landing gear are all supported directly from the rigid hull structure. This patent also describes a landing gear configuration that would allow such an ultra-large airship to operate on typical Class VI 200-foot (61-meter) wide runways.

This ultra-large airship described in this patent has general dimensions that are very similar to the airship described in WO1999024315A2.

Like the Hughes Megalifter, the rigid hull structure of this Lockheed Martin design is an exoskeleton consisting of a web of tension members helically wrapped around the fuselage, as shown in patent Figure 1. Aerodynamic control surfaces consist of horizontal stabilizers (113) and a vertical stabilizer with a rudder (114). Four engines (112) are supported from the rigid exoskeleton hull in locations that are very similar to those on Lockheed Martin’s semi-rigid, hybrid Aerocraft design. In the case of the semi-rigid Aerocraft, the engines are supported from a truss frame inside a pressure-stabilized gas envelope rather than from the exterior rigid hull itself.

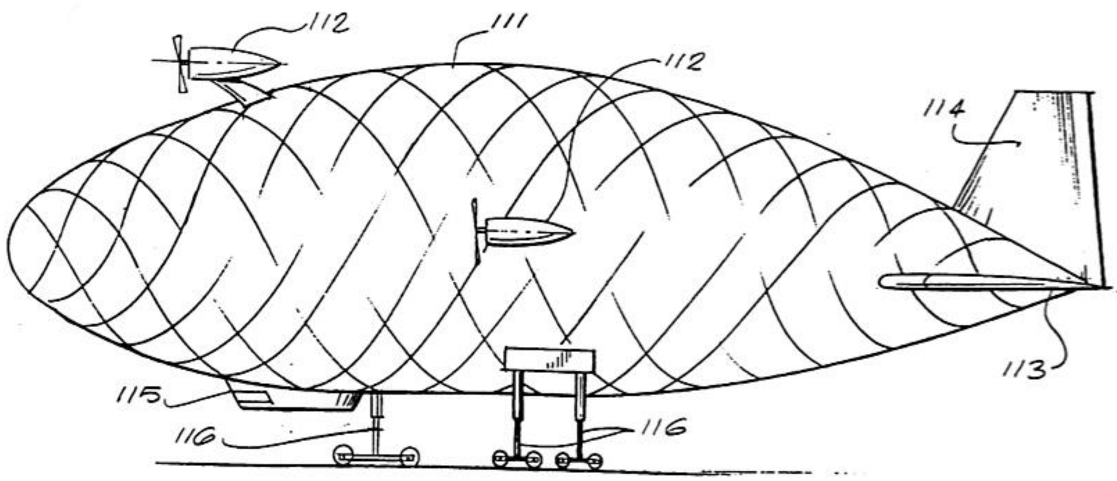

FIG. 1

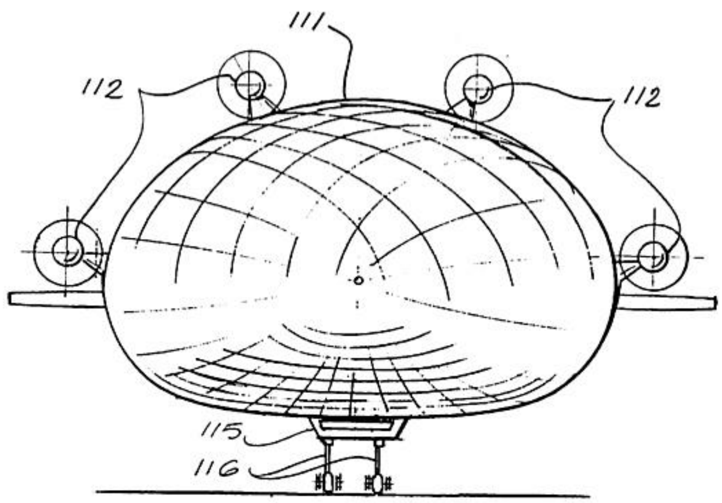

FIG. 2

The above profile and head-on views show the broad airfoil shape of the lifting body hull (111), an outline of the helical exoskeleton, and the placement of the engines (112), crew cockpit (115), landing gear (116) and aerodynamic surfaces (113, 114).

The airship has a center of buoyancy that is well above the center of gravity, producing a stabilizing pendulum effect. In flight, this improves control on the pitch and rolls axes. However, on the ground, this can create a unique handling problem. The patent notes:

> "The pendulum stabilizing effect of the vehicle requires relatively large roll excursions to generate significant restoring moments. The vehicle will roll back and forth during taxi and runway operations, and must be aided with an active propulsion control system to provide active roll control when combined with tire friction to prevent the vehicle being blown downwind."

A buoyancy management system is used to ensure that the vehicle is sufficiently heavy to land with adequate control during adverse weather conditions.

In certain lightly loaded conditions, the airship is capable of STOL and VTOL operations. The thrust vectoring engines can provide dynamic lift during STOL and VTOL operations by controlling engine throttle position and thrust vector angle, which can be varied in pitch from about -110° to +110°.

The large cargo bay floor is strengthened to enable roll-on / roll-off (Ro-Ro) cargo operations with heavy and large volume cargoes.

3. For more information

Patents

- World Intellectual Property Organization (WIPO) application WO1999024315A2, "Partially buoyant aerial vehicle," Inventors: Edsel R. Glasgow & Grant E. Carichner; Filed: 4 November 1998 by Lockheed Martin Corp.; Published: 20 May 1999: https://patents.google.com/patent/WO1999024315A2/en
- US6164589A, "Centerline landing gear for aerocraft," Inventor: John Kalisz; Filed: 17 May 1999; Granted: 26 December 2000; Assigned to Lockheed Martin Corp.: https://patents.google.com/patent/US6164589A/en

Other *Modern Airships* articles

- *Modern Airships - Part 1*: https://lynceans.org/all-posts/modern-airships-part-1/
  - Aereon Corp - Dynairships
  - Goodyear Aerospace Corp. - Dynastat hybrid airships

    - Megalifter - Semi-buoyant hybrid aircraft
    - Ohio Airships - Dynalifter semi-buoyant hybrid aircraft
    - Roy P. Gibbins - AirLighter small rigid airship (SRA)
    - Lockheed Corp. - Starship small rigid airship (SRA)
    - Lockheed Martin - Aerocraft semi-rigid hybrid airship
    - Lockheed Martin - P791 non-rigid hybrid airship
    - Lockheed Martin - SkyTug & LMH-1 non-rigid hybrid airships
- *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/