Lockheed Martin – rigid hybrid airships

Peter Lobner, 12 February 2022

1. Introduction

In the 1980s and 1990s, Lockheed Martin was working on several design approaches for semi-buoyant, hybrid airships with lifting body hulls. One design approach involved rigid, semi-buoyant, hybrid airships with lifting body hulls. These rigid, hybrid airships are the subject of this article.

Another approach being developed in approximately the same time period involved semi-rigid, semi-buoyant, hybrid airships with pressure-stabilized fabric lifting body hulls. These airships include the trademarked Aerocraft (not to be confused with the Aeroscraft trademark held by Worldwide Aeros Corp.), the subsequent P-791 technology demonstrator, and the later commercial Sky Tug / LMH-1, which 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 is described in the following 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.

World Intellectual Property Organization (WIPO) application WO1999024315A2, "Partially buoyant aerial vehicle"

- Application filed: 4 November 1998
- Published: 20 May 1999
- Available here: https://patents.google.com/patent/WO1999024315A2/en

This document 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, semi-buoyant Hughes Megalifter 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.

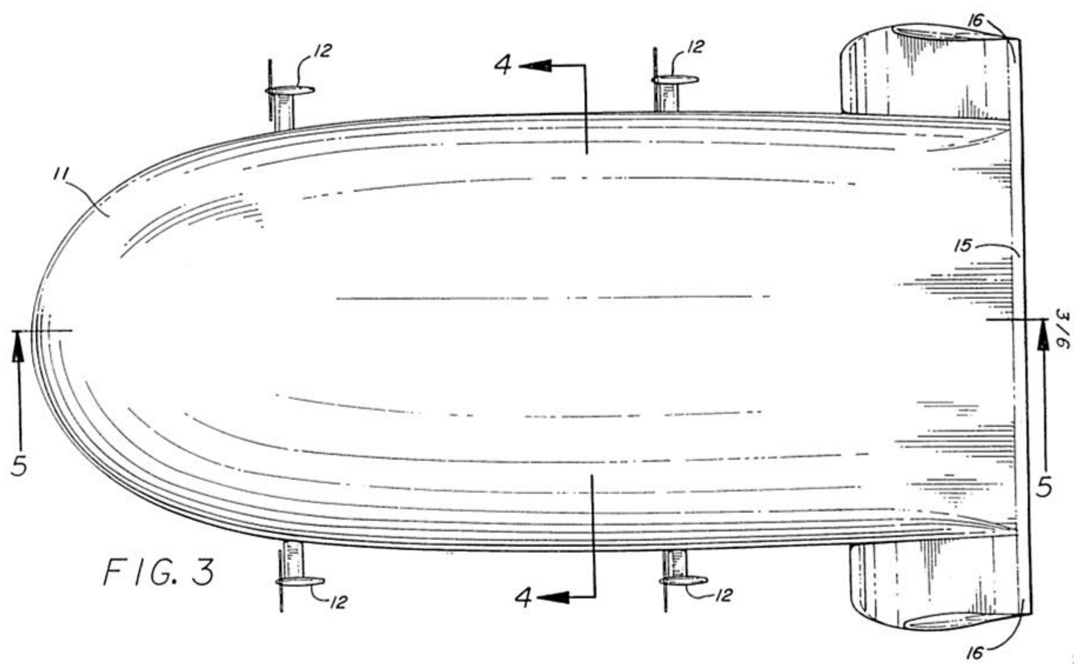


FIG. 3

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

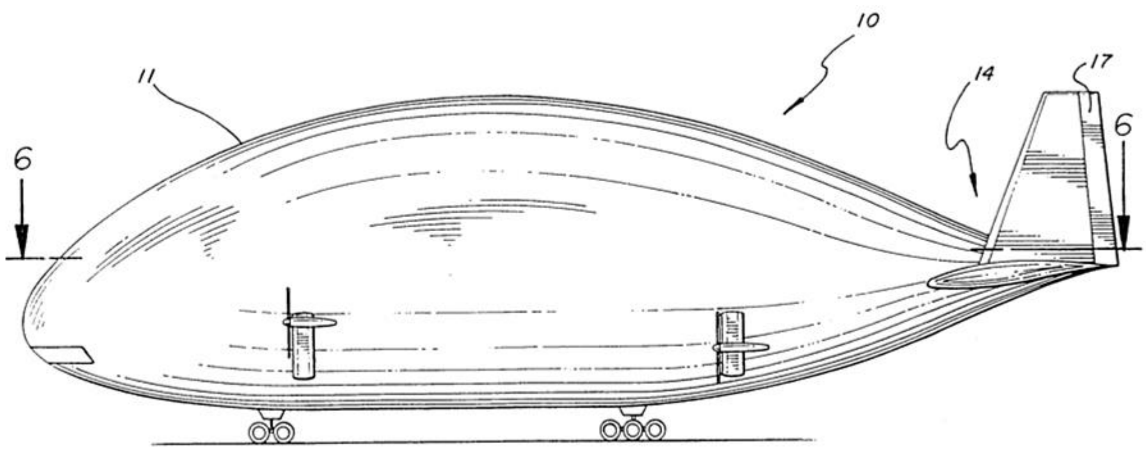


FIG. 2

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.

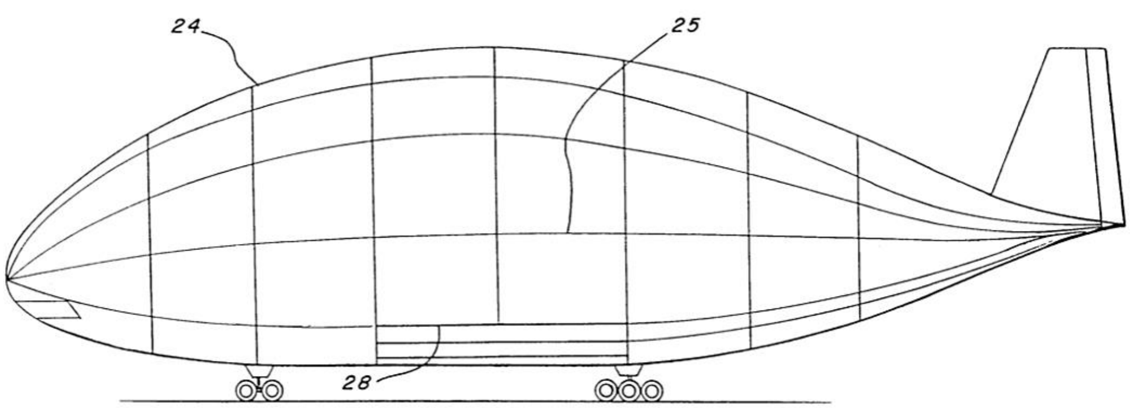


FIG. 5

Profile view of the airship and its outer skin (24) with longitudinal gores (26) over the rigid exoskeleton hull structure. The longitudinal gores illustrate the changing airfoil shape across the broad lifting body hull.

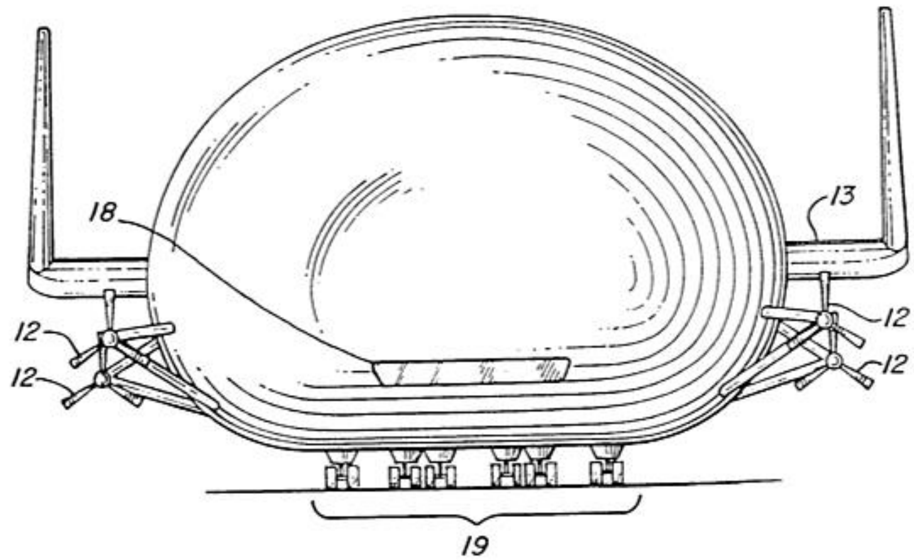


FIG. 1

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

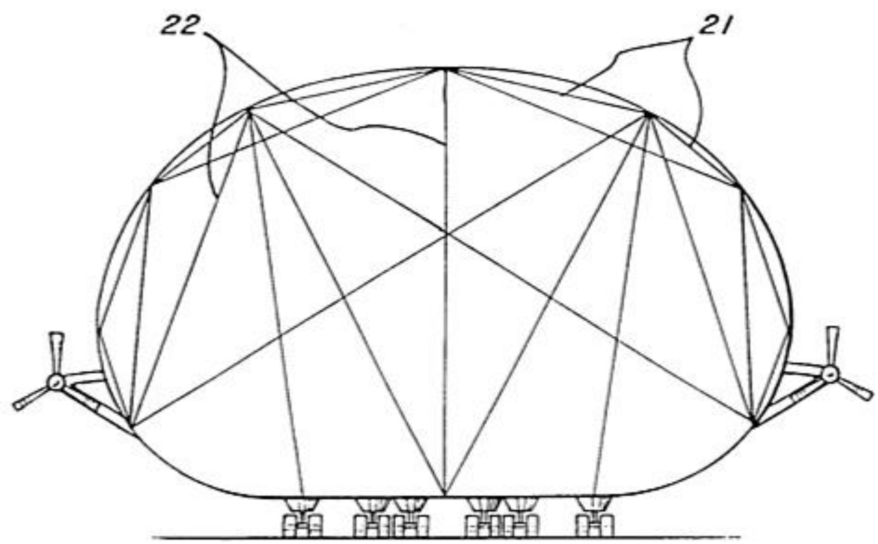


FIG. 4

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, 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

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.

US6164589A, "Centerline landing gear for aerocraft"

- Application filed: 17 May 1999
- Patent granted: 26 December 2000
- Available here: https://patents.google.com/patent/US6164589A/en

This patent describes a rigid, semi-buoyant airship with a deltoid-shaped lifting body hull capable of transporting very large payloads. The rigid, geodesic 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 feet wide runways.

This patent describes an ultra-large airship with 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 the semi-rigid, hybrid Aerocraft. In the case of the semi-rigid Aerocraft, the engines are supported from a truss frame inside the pressure-stabilized gas envelope rather than from the hull itself.

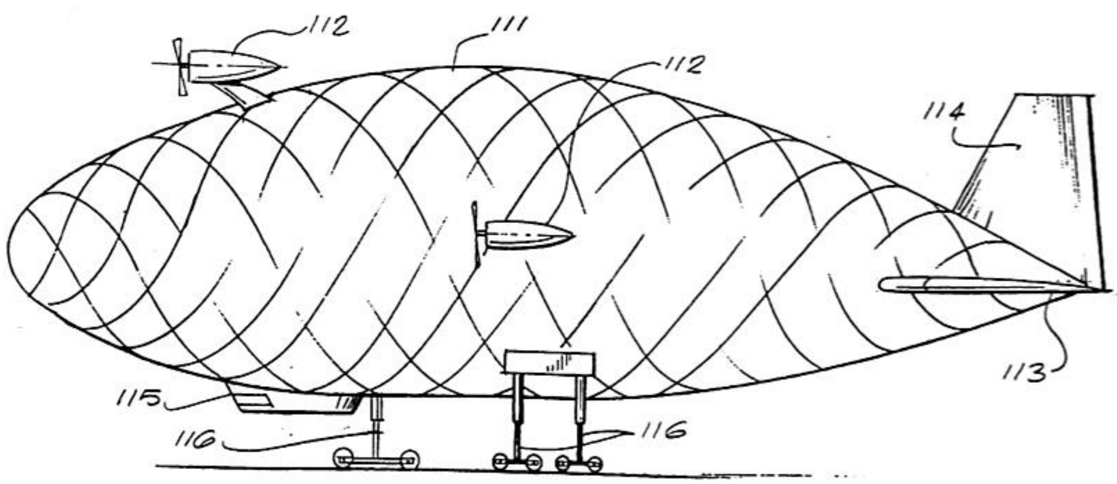


FIG. 1

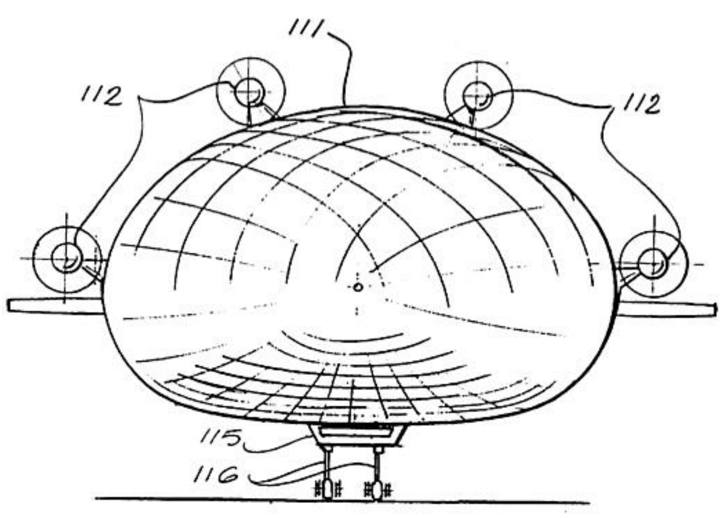


FIG. 2

The profile view (above) and the head-on view (left) 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. Small Rigid Airship (SRA) concept

Predating the work on the ultra-large rigid airships by about a decade, and preceding the Lockheed Martin merger in 1995, Lockheed was developing designs for small rigid airships that were a radical departure from the shape of contemporary non-rigid blimps.

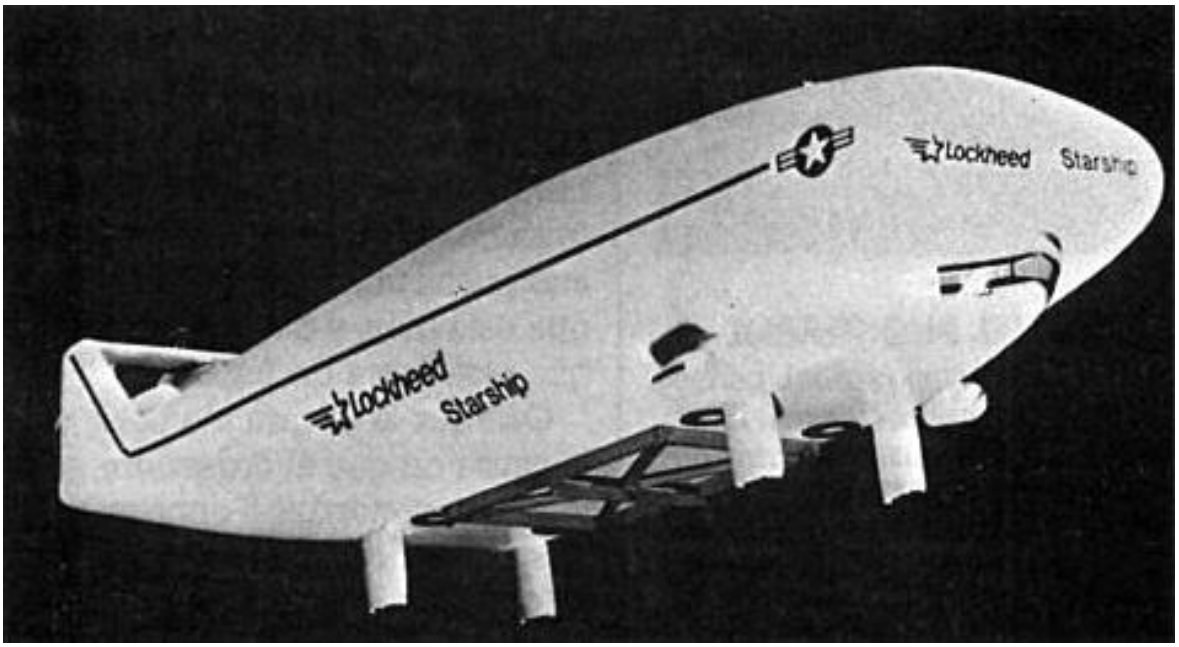
The only information I could find on the SRA is the following post on the Secret Project Forum, which describes an abstract to a 1984 paper written by Roy Gibbens.

> “Can I draw your attention to a Lockheed proposal for a Small Rigid Airship (SRA) going back to 1984. In the introduction to the paper they state, ‘Engineers are no longer restricted to use the classical cigar shapes of the past...Because we can form these new materials to more desirable aerodynamic shapes, we

can now develop the small rigid airship to be a practical vehicle.'

It goes on to say 'These new SRAs will look more like lifting body vehicles than blimps.'

The purpose of the paper was not to propose any particular design for the SRA but to discuss its feasibility. The 'Starship' in their paper is around 160 feet long and 45 feet high. It was to be filled with helium and hot air."



Lockheed SRA Starship model, circa 1984.
Source: Roy Gibbens paper circa 1984 via Secret Project Forum

4. For more information

- "Lockheed SRA" Antonio, Secret Project Forum, 7 September 2008: https://www.secretprojects.co.uk/threads/lockheed-sra.5239/

Other *Modern Airships* articles

- *Modern Airships - Part 1*: https://lynceans.org/all-posts/modern-airships-part-1/
    - Lockheed Martin - Aerocraft hybrid airship
    - Megalifter hybrid aircraft
- *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/