Lockheed Martin - SkyTug and LMH-1 non-rigid hybrid airships

Peter Lobner, updated 16 June 2023

1. Introduction

Building on Lockheed's rigid and semi-rigid 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. That

work became focused in Lockheed Martin's Advanced Development Programs (the Skunk Works) in Palmdale, CA, and produced an extensive series of patents related to large, hybrid airship design.

By the 2000s, Lockheed Martin's focus shifted to non-rigid hybrid airships, with initial designs based on a flattened, ellipsoidal hull with



an Air Cushion Landing System (ACLS) and a large gondola supported under the airship's centerline.

Early Lockheed Martin nonrigid hybrid cargo airship design concept. Lower figure shows an open forward cargo loading ramp on the large gondola, with the cockpit above. Source: Lockheed Martin



Early Lockheed Martin non-rigid hybrid cargo airship design concept. Source: Lockheed Martin

A later design iteration was the 120-foot (36.6-meter) long P-791 technology demonstrator, which implemented a three-lobe, non-rigid gas envelope. It first flew in January 2006 in Palmdale, CA. After a brief six-flight test program, Lockheed Martin and DARPA reported that all test objectives had been met.



Lockheed Martin's P-791 non-rigid hybrid airship technology demonstrator validated technologies for the LMH-1. Source: Lockheed Martin (2006)



Later large non-rigid hybrid airship design, very similar in layout the P-791. Source: Lockheed Martin via Army Sustainment (Nov-Dec 2012)

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 contract to the team of Hybrid Air Vehicles (HAV) and Northrop Grumman.



Lockheed Martin LEMV design concept, with significant changes from 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 SkyTug commercial, non-rigid hybrid airship, which was announced in 2011. Two years later, in 2013, Lockheed Martin rebranded this hybrid airship design as the LMH-1.

On 2014, Lockheed Martin designated Hybrid Enterprises (HE) as their exclusive LMH-1 reseller. HE signed a Letter of Intent (LOI) in March 2016 from the UK firm Straightline Aviation, followed in June 2017 with an LOI from the French firm Hybrid Air Freighters (HAF). In September 2017, Lockheed Martin reported it had LOIs for 24 LMH-1 airships. In 2017, Lockheed Martin announced that the first "float out" of the LMH-1 had slipped to 2019. No "float-out" ever occurred, and in July 2022 it was reported that Lockheed Martin was no longer actively marketing its LMH-1.

On 9 May 2023, Lockheed Martin exited the hybrid airship business, and announced that the business, including intellectual property and related assets, had been transitioned to a newly formed, commercial company called AT² Aerospace. The Lockheed Martin press release reported, "AT² Aerospace, based in Santa Clarita, California, is extending our work to bring hybrid airships to fruition." As portrayed on the AT² Aerospace website (<u>www.at2aero.space</u>) in May 2023, their Z1 hybrid airship appears to be the current incarnation of the former Lockheed Martin LMH-1. AT² Aerospace is addressed in more detail in a separate article.

2. First there was the SkyTug hybrid airship (2011 to 2013)

Less than a year after losing the U.S. Army's LEMV competition in 2010, Lockheed Martin announced in March 2011 that it planned to develop commercial versions to be called SkyTug. The first model would be designed to carry at least 20 tons (18.1 metric tons) of cargo, with future growth versions capable of carrying 50 to several hundred tons of cargo. Lockheed Martin filed a trademark application for the term "SkyTug" on 25 August 2011.



Rendering of the SkyTug hybrid airship. Source: Lockheed Martin via Flight Global (2011)

General characteristics of the Lockheed Martin SkyTug

Parameter	SkyTug
Length	300 ft (91.4 m)
Operating altitude	10,000 ft (3,048 m)
Propulsion	4 x diesel engine-driven, flank-mounted, shrouded, thrust
	vectoring propellers
Speed	80 – 100 knots
Range	1,500 miles (2,414 km)
Payload	Internal cargo bay, slightly larger than the cargo box of
accommodations	the Lockheed Martin C-130 Hercules cargo aircraft.
Payload capacity	20 tons (18.1 metric tons)



SkyTug hybrid airship. Source: Lockheed Martin

SkyTug was being developed under an exclusive agreement with Canadian firm Aviation Capital Enterprises of Calgary, as explained in a 28 March 2011 press release:

"Aviation Capital and its investors will make the hybrid aircraft available to the commercial market. Lockheed Martin will retain rights to the military market. Three variants of the hybrid aircraft ranging in size from 20 tons to several hundred tons will be developed to open transportation pathways to austere locations currently inaccessible to other modes of transport. Delivery of the first experimentally certified Hybrid Aircraft variant is expected in 2012. Although the company has not signed up any firm customers, discussions are ongoing with 'strongly interested parties' in the Middle East, Brazil, Mexico and Canada."

The SkyTug was intended for use as a long-range transport for heavy machinery and equipment for oil and gas rigs drilling in remote Arctic locations. Lockheed Martin claimed the SkyTug could operate in temperatures as low as -68 degrees Fahrenheit (-56 degrees Celsius). Instead of building expensive roads or railways to Arctic drilling sites, the SkyTug would enable equipment and personnel to be delivered by air directly to the site.

The ACLS gave the SkyTug the ability to operate from prepared or unprepared land surfaces, snow, ice and water. When stopped on the ground, the ACLS fans could be reversed to draw a suction and "grip" the ground, which would help stabilize the airship during windy conditions and 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.

According to Aviation Capital, "the fully vertical-takeoff-and-landing (VTOL) capable SkyTug will provide 'greater payload and range at a fraction of the cost of a helicopter.' The larger ships that will follow apparently won't be fully VTOL - they'll require something of a run-up on the ground to generate dynamic lift and get airborne, rather as an airplane does." Evidently, the VTOL version was to have proportionally more powerful vectored thrust engines to provide the needed propulsive lift for VTOL operations, while the larger versions would have had short takeoff and landing (STOL) performance typically associated with hybrid airships.

The exclusive business arrangement between Lockheed Martin and Aviation Capital appears to have lapsed in 2013, after which the SkyTug trademark was abandoned and Lockheed Martin re-branded its commercial hybrid airship as the LMH-1.

3. The LMH-1 airship (2013 to 2023)

By 2013, reference to SkyTug had disappeared as Lockheed Martin re-branded their large commercial hybrid airship as the LMH-1. Like the P-791, the LMH-1 would generate about 80% of its total lift from helium buoyancy and the balance from direct lift from vectored thrust engines and, in forward flight, from aerodynamic lift generated by the lifting-body fuselage.



LMH-1 concept drawing, profile view.



LMH-1 concept drawing, bow quarter view. Source, both graphics: Lockheed Martin



Overhead view of an LMH-1.



LMH-1 general arrangement. Source, both graphics: Lockheed Martin

General characteristics of the Lockheed Martin LMH-1

Parameter	LMH-1
Length, overall	276 ft (84.1 m)
Length, gondola	150 ft (45.7 m)
Width, max.	157 ft (47.9 m)
Height, max	75 ft (22.9 m)
Envelope type	Tri-lobe, pressure stabilized, Vectran fabric
Volume	 About 1,285,000 ft³ (36,387 m³)
	 About 10x the volume of the P-791
Propulsion	4 x 310 shp diesel-engine driven, flank-mounted,
	thrust vectoring, 3-bladed, 9-ft (2.7-m) diameter,
	variable pitch propellers
Speed, cruise	60 knots
Payload, max	Up to 23.5 tons (47,000 lb, 21 metric tons)
Fuel capacity	5 tons (10,000 lb, 4.5 metric tons, 5,400 liters)
STOL space	At full load: 2,400 feet (732 meters) of clear space
requirement	
Operating altitude	10,000 ft (3,048 m)
Range	1,400 nautical miles (2,593 km), at a cruise speed of
	60 knots with a 20 ton (18.1 metric ton) payload
Crew & passenger	2 cockpit crew
accommodations	Up to 19 passengers
Payload	• Internal cargo bay: 10 x 10 x 60 feet (3 x 3 x 18.3 m)
accommodations	Truck height cargo deck
	• Long loads can be handled with the aft cargo door left open in flight.

A digital fly-by-wire flight control system, derived from the F-35 fighter, coordinates the operation of the throttles, the aerodynamic control surfaces on the four tail fins, and the orientation and blade pitch of the four, flank-mounted, vectorable propellers. Flight control laws were optimized for the various flight modes: takeoff / landing, cruise, and the transitions between these modes.

As a hybrid airship, the LMH-1 is designed for STOL operations using its ACLS during takeoff and landing runs and for maneuvering on the ground. For STOL takeoffs at full load, the LMH-1 requires about 2,400 feet (732 meters) of clear space, which needs to be free of large obstacles, but does not need to be paved. When lightly loaded, the STOL field requirements are shorter, and, when very lightly loaded, an LMH-1 may be able to takeoff and land vertically.





LMH-1 unloading cargo on the ground from its truck bed height aft cargo door. Source: Lockheed Martin & Hybrid Enterprises (2017)

The tri-lobe gas envelope is made of Kevlar fabric and has three sideby-side internal chambers that are separated by two catenary curtains (also called "septums") along the longitudinal seam lines between the chambers. The catenary curtains support the gondola and its contents and transfer and distribute that load into the upper surfaces of the envelope. Maintenance of the airship's large fabric envelope is aided by an automated, self-propelled instrument called the SPIDER (Self-Propelled Instruments for Damage Evaluation and Repair), which was



developed at the Lockheed Martin Skunk Works to inspect the envelope, find and then repair pinhole leaks. Straightline Aviation explains: "The SPIDER consists of two magnetically attached halves, one that sits on the outside of the airship, while the other clings to it

from the inside. Using a set of bright LED lights and a camera, the SPIDER can automatically spot pinhole leaks, and then reposition itself to patch them. Photos of before and after the hole is patched, are sent to a central server for further human inspection, but that adds minimal time to the mostly automated inspection process." A team of five to six SPIDERS, each traveling about 2 miles (1.6 km) per day, could inspect the 80,000 ft³ (7,432 m³) LMH-1 gas envelope in about five days. SPIDER is shown in operation in a 2016 Lockheed Martin video: <u>https://www.youtube.com/watch?v=86EAzvXrESg</u>



A team of three small SPIDER robots inspect the gas envelope of Lockheed Martin's P-791 hybrid airship for pinhole. Source: Lockheed Martin via IEEE Spectrum (2011)



LMH-1 gondola forward sections: Flight Deck & Accommodation Bay. Note the forward ACLS unit under the gondola. Source: Lockheed Martin (2016)



LMH-1 gondola interior layout. Note that 8 passengers are seated in the Flight Deck area and 11 more can be seated in the Accommodation Bay with galley and lavatory. Source: Hybrid Enterprises & Lockheed Martin (2017)



LMH-1 Flight Deck for a crew of two.



Glass cockpit arrangement. Source, both photos: Lockheed Martin (2016)



LMH-1 passenger seating in the Flight Deck area (forward of partition) and in the Accommodation Bay (aft of partition).



View forward from the Accommodation Bay. Source, both photos: Lockheed Martin (2016)



Walkway in the LMH-1 Fuel Bay (aka Equipment Bay) between the accommodation bay and the cargo bay, contains the diesel engines and associated fuel tanks.



LMH-1 Cargo Bay contains cargo tie-downs and a strengthened deck capable of taking heavy construction vehicles and bulldozers. Source, both photos: Lockheed Martin (2016)



Rendering of an LMH-1 unloading cargo on a remote beach. Source: Lockheed Martin



Rendering of an LMH-1 on the ground at a remote desert industrial site. Source, both graphics: Lockheed Martin via Hybrid Air Freighters (HAF)



Rendering of an LMH-1 in flight above the Arctic, stern quarter view.



Rendering of an LMH-1 in low-level flight, bow quarter view. Source, both graphics: Lockheed Martin via BBC (November 2019)

4. Other LMH-1 variants

"Safari" passenger / tourism hybrid airship concept, circa 2015

The Safari version of the LMH-1 is a passenger airship that can be configured for short-haul scheduled service, low-altitude sightseeing, or as a small luxury cruise ship for longer airborne tours. Behind the cockpit / crew compartment is a large triangular gondola with panoramic windows. Relative to a cargo-carrying LMH-1, the Safari is lightly loaded. ACLS landing pads have been deleted in favor of landing legs, indicating this variant is capable of VTOL operation.



LMH-1 "Safari" concept in quiet, low-level flight.



LMH-1 "Safari" concept after landing on three retractable landing legs. Source, both graphics: Lockheed Martin via Straightline Aviation gallery.



LMH-1 "Safari" concept in flight.



LMH-1 "Safari" concept viewed from astern, showing the triangular shape of the large passenger gondola, with rear viewing decks on two levels. Source, both graphics: Lockheed Martin via Straightline Aviation gallery.

LMH-1 humanitarian medical airship concept, circa 2016: Straightline Aviation & RAD-AID Collaboration

Straightline Aviation and RAD-AID partnered in 2016 to develop a medical airship program based on the LMH-1. Working with a network of medical equipment suppliers, they designed mobile medical facility modules that could fit in the LMH-1 cargo bay for transport to regions that required medical services but lacked the transportation infrastructure for delivery by other means.



LMH-1 in RAD-AID livery on the ground at a remote, undeveloped landing site.





(Above) Example layout of a 10 x 10 x 60 foot (3 x 3 x 18.3 meter) multi-purpose medical service module. (Left) Example of three small selfcontained medical modules. Source, three graphics: Straightline Aviation gallery.

5. Orders for Lockheed Martin's LMH-1 hybrid airship

Since 2014, Atlanta-based Hybrid Enterprises

HYBRID

ENTERPRISES

(<u>https://www.facebook.com/HybridHE/</u>) has served as the exclusive reseller of the LMH-1 and has accepted orders at a price of about \$40

million USD plus an additional \$350,000 for a full charge of helium. This purchase price is more than for a fixed-wing

Hercules transport (\$12 – \$30 million). However, the hybrid airship is expected to have lower operating and maintenance costs, can takeoff and land on unimproved surfaces, requires minimal ground support equipment and can stay aloft for days if needed.

In March 2016, the UK firm Straightline Aviation Ltd.

(https://www.straightlineaviation.com) signed a Letter of Intent with Hybrid Enterprises valued at \$480 million for 12 LMH-1s. You can watch a 2018 video, "Straightline Aviation Hybrid Airship," that describes their plans to use the LMH-1 to

serve remote areas in Alaska and other areas, at the following link: <u>https://www.youtube.com/watch?v=Ix8KP3IU3Sw</u>



Rendering of LMH-1 in Straightline Aviation livery. Source: Anchorage Daily News (2016)

The Paris-based logistics firm Hybrid Air Freighters (HAF) (<u>http://www.hybridairfreighters.com</u>) was created by a team of experts



in air transport and logistic and describes itself as
 "particularly well placed to design and implement the most appropriate and the most efficient transport
 solutions based on the Lockheed Martin Hybrid Airship (LMH).... HAF will offer new solutions that

address in priority the unmet or poorly covered remote transportation needs." In June 2017, HAF signed a Letter of Intent with Hybrid Enterprises to purchase up to 12 LMH-1 airships at a total value of approximately \$500 million.



Rendering of LMH-1 in Hybrid Air Freighters livery. Source: HAF (2017)

In September 2017, Lockheed Martin reported it had Letters of Intent for 24 LMH-1 airships.

6. FAA type certification of Lockheed Martin's LMZ1M (LMH-1) hybrid airship

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.

Lockheed Martin was in this uphill battle with the U.S. Federal Aviation Administration (FAA) for more than a decade.

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

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, the FAA's Seattle Aircraft Certification Office, approved Lockheed's project-specific certification plan for the LMZ1M (LMH-1). In their 17 November 2015 press release, Lockheed Martin announced:

"Given that Hybrid Airships did not fit within existing FAA regulations, the team worked to create a new set of criteria allowing non rigid hybrid airships to safely operate in a commercial capacity. Transport Canada was also involved in the development of this criteria to ensure it included safety concerns unique to Canada."

"Lockheed Martin and the FAA have been working together for more than a decade to define the criteria to certify Hybrid Airships for the Transport Category. This criteria was approved by the FAA in April 2013. Following that approval, the team has been developing the project specific certification plan over the past two years, which details how it will accomplish everything outlined in the Hybrid Certification Criteria."

"Earlier this year Lockheed Martin along with Hybrid Enterprises LLC kicked off sales for the 20 ton variety of the Hybrid Airship. They are on track to deliver operational airships as early as 2018."

There is nothing on the FAA public webpage for docket FAA-2013-0550 that provides details of the certification dialog between the FAA and Lockheed Martin or the status of the type certification effort.

7. Lockheed Martin's vision beyond the LMH-1

Lockheed expected that the basic LMH-1 design could be scaled up to carry much heavier cargo. After LMH-1, Lockheed Martin had plans to build a larger LMH-2 90-ton cargo hybrid airship that would be more competitive with trucking and rail transport in remote areas. Plans also included a future 500-ton LMH-3 cargo airship.



- Regional cargo transport
- 3,000+ nm range
- Take-off & land from unimproved fields or water
- Lower operating costs (similar to fixed wing)

117' tall

- Global cargo transport
- 6,000+ nm range
- Very large cargo hold
- Containerized freight mover
- Take-off & land from unimproved land or sea
- Lowest operating cost



423' long, 242' wide

500 Ton: 742' long, 394' wide 202' tall

Growth versions of the LMH-1. In the bottom figures, cargo bay dimensions are listed above the airship image, and airship dimensions are listed below. Source: Hybrid Enterprises & Lockheed Martin (2017)

8. Lockheed Martin 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 SkyTug and LMH-1.

- Semi-buoyant airship with pressure stabilized hull generating aerodynamic lift
- Thrust vectoring propulsion system
- Retracting air cushioned landing system for air vehicles
- Systems and methods for buoyancy management in an airship
- Ballonet system for a lighter-than-air vehicle (with ACLS)
- Direct mounted propulsion for non-rigid airships

These patents are addressed in separate articles on the Lockheed Martin semi-rigid Aerocraft (not to be confused with the Aeroscraft trademarked by Worldwide Aeros Corp.) and the non-rigid P-791 technology demonstrator.

This section addresses one additional Lockheed Martin patent that has a direct bearing on design features found on the SkyTug and LMH-1.

Patent US 8783602B2 - System and method for furling an air cushion landing system

- Application filed: 17 April 2012
- Patent granted: 22 July 2014
- Available here: <u>https://patents.google.com/patent/US8783602</u>

The patent describes a furling system that creates a streamlined cover for a deployable air cushion landing system while the airship is in flight. The three landing pad ACLS in the patent is similar to the layout found on the SkyTug and LMH-1.







FIG. 2



Fig.1 shows a hybrid airship (10) resembling the LMH-1 with the ACLS extended (18 forward & 16 aft) and the aft furling system (50) stowed.

Fig. 2 provides a closer look at an extended (inflated) aft ACLS landing pad (16), which comprises an inflatable pad (22) and an inflatable finger skirt (24). The retracted furling system covers are stowed under fairings (26A & 26B).
Furling system deployment and retraction are accomplished with a system of cables (30A & 30B) and pulleys (28A & 28B).

Fig. 3 shows the aft ACLS retracted (deflated) and the furling system deployed, with covers (32A, 32B) drawn out of their respective fairings (26A & 26B) and positioned over the ACLS, forming a flush surface with the hull (12)

9. Passing the baton to AT² Aerospace

In a July 2022 article for AINonline in connection with the Farnborough Air Show, Chris Pocock reported that Lockheed Martin was no longer actively marketing its LMH-1 hybrid airship. Lockheed Martin's operating partner, Straightline Aviation, told AIN that it remains active in the airship market and was interested in Lockheed Martin's hybrid airship technology.

Less than a year later, on 9 May 2023, Lockheed Martin announced



that it had exited the hybrid airship business, transitioning that business, including intellectual property and related assets, to a newly formed, commercial company called AT² Aerospace.

As portrayed on the AT² Aerospace website (<u>www.at2aero.space</u>) in May 2023, their Z1 hybrid airship appears to be the current incarnation of the former Lockheed Martin LMH-1. Details are presented in my separate article on AT² Aerospace.

As of May 2023, the former Lockheed Martin hybrid airship website (<u>https://www.lockheedmartin.com/en-us/products/hybrid-airship.html</u>) has been taken down, as has the former Hybrid Enterprises website (<u>http://www.hybridhe.com</u>). Hybrid Enterprises still maintains a Facebook presence (<u>https://www.facebook.com/HybridHE/</u>) with historical LMH-1 content. Their last new entry was in September 2017.

10. For more information

SkyTug (2011 to 2013)

- Stephen Trimple, "Skunk Works P-791 airship revived as civil cargo-lifter," FlightGlobal, 23 March 2011: <u>https://www.flightglobal.com/skunk-works-p-791-airship-revived-as-civil-cargo-lifter/99025.article</u>
- "Canadian Company Buys Commercial Rights for SkyTug from Lockheed Martin," 28 March 2011: <u>https://www.uasvision.com/2011/03/28/canadian-company-</u> <u>buys-commercial-rights-for-skytug-from-lockheed-martin/</u>

- Lewis Page, "Airship 'Sky Tugs' ordered from Lockheed for Canadian oilfields," TheRegister.com, 28 March 2011: <u>https://www.theregister.com/2011/03/28/p791_ordered_for_can</u> <u>adian_oilsands/</u>
- "Recent Development Efforts for Military Airships," Pub. No. 4239, Congressional Budget Office, November 2011: <u>https://www.cbo.gov/sites/default/files/cbofiles/attachments/11-01-Airships.pdf</u>
- "Enter the SkyTug," How It Works, 11 February 2012: https://www.howitworksdaily.com/enter-the-skytug/

LMH-1 (2013 to 2023)

- Colin Clark, "Lockheed Hands Off Hybrid Airship To Commercial Reseller," Breaking Defense, 16 June 2015: <u>https://breakingdefense.com/2015/06/lockheed-hands-off-hybrid-airship-to-commercial-reseller/</u>
- FAA Notice, "Airworthiness Criteria: Proposed Airship Design Criteria for Lockheed Martin Aeronautics Model LMZ1M Airship," 25 June 2013: <u>https://www.federalregister.gov/documents/2013/06/25/2013-15056/airworthiness-criteria-proposed-airship-design-criteriafor-lockheed-martin-aeronautics-model-Imz1m
 </u>
- Trefis team, "A Comprehensive Look At Lockheed Martin's Hybrid Airships," Forbes, 9 July 2015: <u>https://www.forbes.com/sites/greatspeculations/2015/07/09/a-comprehensive-look-at-lockheed-martins-hybrid-airships/?sh=1bcc6974c9dc</u>
- "Lockheed Martin Hybrid Airship Certification Plan for Commercial Transport Approved by the FAA," Lockheed Martin via CISION PR Newswire, 17 November 2015: <u>https://www.prnewswire.com/news-releases/lockheed-martinhybrid-airship-certification-plan-for-commercial-transportapproved-by-the-faa-300179764.html</u>
- James Drew, "Lockheed venture lifts off with LOI for 12 hybrid airships," FlightGlobal, 30 March 2016: <u>https://www.flightglobal.com/lockheed-venture-lifts-off-with-loifor-12-hybrid-airships/120141.article</u>
- Jane Wells, "Lockheed has liftoff: Sells new airships in \$480M

deal," CNBC, 30 March 2016:

https://www.cnbc.com/2016/03/29/lockheed-has-liftoff-sellsnew-airships-in-480m-deal.html

- Guy Norris, "Up Close: Lockheed Martin's LMH-1 Hybrid Airship," Aviation Week Network, 30 March 2016: <u>https://aviationweek.com/aerospace/close-lockheed-martins-Imh-1-hybrid-airship</u>
- Evan Ackerman, "How Lockheed Martin's SPIDER Blimp-Fixing Robot Works - Pinholes are a big problem for blimps, so Lockheed Martin built a swarm of robots to find and fix them," IEEE Spectrum, 1 August 2016: <u>https://spectrum.ieee.org/howlockheed-martin-spider-blimp-fixing-robot-works</u>
- Andrew Toopf, "Canadian rare earths mine to transport ore using airships," Mining dot com, 22 November 2016: <u>http://www.mining.com/canadian-rare-earths-mine-transport-ore-using-airships/</u>
- "Hybrid Air Freighters Signs Letter of Intent to Purchase Lockheed Martin Hybrid Airships," Hybrid Enterprises via CISION, 20 June 2017: <u>https://www.prnewswire.com/newsreleases/hybrid-air-freighters-signs-letter-of-intent-to-purchaselockheed-martin-hybrid-airships-300474933.html</u>
- Howard Slutsken, "LMH-1 airship "float out" pushed to 2019," Skiesmag.com, 22 September 2017: <u>https://www.skiesmag.com/news/lmh-1-airship-float-pushed-2019/</u>
- Hybrid Enterprises & Lockheed Martin presentation at the 9th Global Humanitarian Aviation Conference & Exhibition, 11 – 13 October 2017: http://appualghac.com/images/presentations/original/2017/10/5

http://annualghac.com/images/presentations/original/2017/10/5 9e09fbb8990877500977.pdf

- "Hybrid Air Freighters partners with Columbia Helicopters," HAF, 20 September 2018: <u>http://www.hybridairfreighters.com/hybrid-air-freighters-partners-with-columbia-helicopters/</u>
- "Proposal for Humanitarian Medical Airship Program: RAD-AID Straightline Aviation Collaboration," issuu, 24 March 2020: <u>https://issuu.com/straightlineaviation/docs/rad-aid_straightline_humanitarian_aid_airship_summ</u>

Transfer of hybrid airship business to AT² Aerospace (2023)

- Chris Pocock, "Hybrid Air Vehicles Executes a Slow Takeoff," AlNonline, 15 July 2022: <u>https://www.ainonline.com/aviation-news/air-transport/2022-07-15/hybrid-airships-make-slow-takeoff</u>
- "Hybrid Airship Enters The Transfer Portal," Lockheed Martin press release, 9 May 2023: <u>https://news.lockheedmartin.com/2023-05-09-Hybrid-Airship-Enters-the-Transfer-Portal</u>
- "Lockheed Martin Forms New Company Around Hybrid Airship Efforts," Manufacturing Net, 10 May 2023: <u>https://www.manufacturing.net/aerospace/news/22861518/lock</u> heed-martin-forms-new-company-around-hybrid-airship-efforts

<u>Videos</u>

- "Hybrid Airship: No Roads, No Problem," (1:42 min), posted by Hybrid Enterprises, 3 February, 2016: <u>https://www.youtube.com/watch?v=oA_wUrpO5NI&t=6s</u>
- "Skunk Works' SPIDER: Self-Propelled Instrument for Airship Damage Evaluation and Repair," posted by Lockheed Martin, 26 July 2016: <u>https://www.youtube.com/watch?v=86EAzvXrESg</u>
- "Hybrid Lift," (0:28 min), posted by Hybrid Enterprises, 30 August 2016: https://www.youtube.com/watch?v=vmpULiiWtKE&t=12s
- "ACLS," (0:41 min), posted by Hybrid Enterprises, 30 August 2016: <u>https://www.youtube.com/watch?v=-GCpnBx4mD8&t=7s</u>
- "Not Just a Propeller: Digital flight controls bring high tech to the Hybrid Airship," (2:47 min), posted by Hybrid Enterprises, 7 March 2017: https://www.youtube.com/watch?v=wOlbp9kGtZc&t=159s
- "Hybrid Airship," (4:48 min), posted by Straightline Aviation Limited, 14 November 2018: <u>https://www.youtube.com/watch?v=wPRCX7CMJql&t=3s</u>
- "Hybrid Airship Ground Handling," (4:42 min), posted by Straightline Aviation Limited, 18 April 2019: <u>https://www.youtube.com/watch?v=7i-pKuJThHA</u>

Other Modern Airships articles

- Modern Airships Part 1: <u>https://lynceans.org/all-posts/modern-airships-part-1/</u>
 - Lockheed Martin Rigid hybrid airships
 - Lockheed Martin Aerocraft semi-rigid hybrid airship
 - DARPA Project WALRUS
 - Lockheed Martin P-791 non-rigid hybrid airship
 - AT² Aerospace Z-1 non-rigid hybrid airship
 - Hybrid Air Vehicles (HAV) Airlander 10 non-rigid hybrid airship
 - Advanced Technologies Group (ATG) SkyCat & SkyKitten
- Modern Airships Part 2: <u>https://lynceans.org/all-posts/modern-airships-part-2/</u>
- Modern Airships Part 3: <u>https://lynceans.org/all-posts/modern-airships-part-3/</u>