

H2 Clipper, Inc.

Peter Lobner, updated 11 October 2022

1. Introduction



H2 Clipper, Inc. was founded in 2011 by Rinaldo Brutoco as a private aerospace development and alternative energy company utilizing existing technologies and innovative composite materials and

manufacturing processes to develop a unique hydrogen-powered dirigible intended to enable the widespread commercialization of hydrogen as a carbon-free alternative fuel source. Brutoco invented and patented many of the key technologies embodied in the H2 Clipper airship and serves as CEO of his firm. The company's headquarters are in Santa Barbara, CA. Their website is here:

<https://h2clipper.com>



H2 Clipper airship general layout, circa 2021.

Source: H2 Clipper, Inc.

The primary mission of the H2 Clipper airship is to establish a "pipeline in the sky™" between hydrogen production sites and distant hydrogen distribution centers and large-scale end users worldwide. The airship uses hydrogen as a lifting gas, as a stored source of energy used by its electric engines for propulsion, and as its

“payload.” The airship is designed for vertical takeoff and landing (VTOL) operations and can operate from remote sites without mooring or dock facilities.

The H2 Clipper is a scaleable rigid airship that can be configured for a variety of manned and unmanned applications other than transporting liquified and gaseous hydrogen. For example:

- Freight transport applications: Low-cost, rapid, intermodal or bulk freight transportation with next-day service even on long-distance routes.
- Telcom / satellite relay applications: Geo-stationary airships at high altitude for long periods as part of a pseudo-satellite network to deliver cellular phone and internet service.
- Relief and humanitarian applications: Rapid delivery of personnel and supplies without dependence on port or airport infrastructure.
- Fighting wild fires, with retardant drops from hovering flight.

Passenger transport applications may be developed later. In carrying out these missions, the H2 Clipper generates zero CO₂ emissions.

H2 Clipper plans to begin construction in mid-2023 of a 40% scale, 400-ft (122-m) long prototype at an existing hangar. The initial flight is expected in 2025. A “greenfield” production facility will be built for the full-scale, 1,000-ft (304-m) long airship, which is expected to be flying late in this decade, with service entry by 2029.

In October 2022, Flight Global reported that “H2 Clipper will seek a maximum of \$50 million from the Series A funding round, and estimates a total requirement of \$250 million to complete development of the prototype aircraft, with ‘significant capital needed’ to scale up for production. On top of the equity investments, the company will seek finance from a variety of sources, including collateralization of assets, state and federal government grants or other incentives, plus customer deposits.”

I am grateful to H2 Clipper Inc. for their thoughtful input for this article.

2. Regulatory issues related to the use of hydrogen lifting gas and deployment of an H2 Clipper airship fleet

The H2 Clipper uses hydrogen as its lifting gas (gaining 10% more lift than from helium) and fuel (for its hydrogen fuel cell), and the airship is designed to transport large quantities of liquified and gaseous hydrogen as cargo.

Aviation regulatory changes will be required to permit the general use of hydrogen lifting gas in commercial airships. In the US, Europe and Canada, the following aviation regulations only allow the use of non-flammable lifting gas:

- FAA ADC: “The lifting gas must be non-flammable.” (4.48)
- TAR: “The lifting gas must be non-flammable, non-toxic and non-irritant.” (TAR 893)
- Canadian Air Regulations: “Hydrogen is not an acceptable lifting gas for use in airships.” (541.7)

The European Union Aviation Safety Agency’s (EASA) proposed Special Conditions published in February 2021 create a new opportunity to use hydrogen lifting gas in Europe:

“If the lifting gas is toxic, irritant or flammable, adequate measures must be taken in design and operation to ensure the safety of the occupants and people on the ground in all envisaged ground and flight conditions.” (SC GAS.2355)

It will be up to the airship manufacturer to demonstrate that their airship meets this Special Condition. The first to do so will be setting an important regulatory precedent for the airship industry.

A technique for preventing hydrogen flammability is described in Russian patent RU2441685C2, “Gas compound used to prevent inflammation and explosion of hydrogen-air mixtures,” which was submitted in 2010 and posted in 2012. This technique yields a product called deactivated hydrogen, which some Russian airship designers are considering for use as an airship lifting gas. You can read the patent at the following link.

<https://patents.google.com/patent/RU2441685C2/en>

H2 Clipper Inc. is developing a subscale prototype with plans to fly this prototype as early as 2025. The first full-sized airship could be flying four - five years later if work underway continues as planned. Part of that progress depends on the FAA developing regulations that permit use of hydrogen in manned, commercial airships in the US, and/or H2 Clipper focusing its early commercial deployments in countries where – like in the EU – applicable regulations are based on the adequacy of measures for assuring safety.

After worldwide regulatory changes are implemented to permit the widespread use of hydrogen in aviation, fleet-scale commercial deployment of H2 Clipper airships could occur.

3. The hydrogen transport Use Case

Robert Shelton, H2 Clipper Vice President for Administration, describes the use case for the H2 Clipper airship as follows:

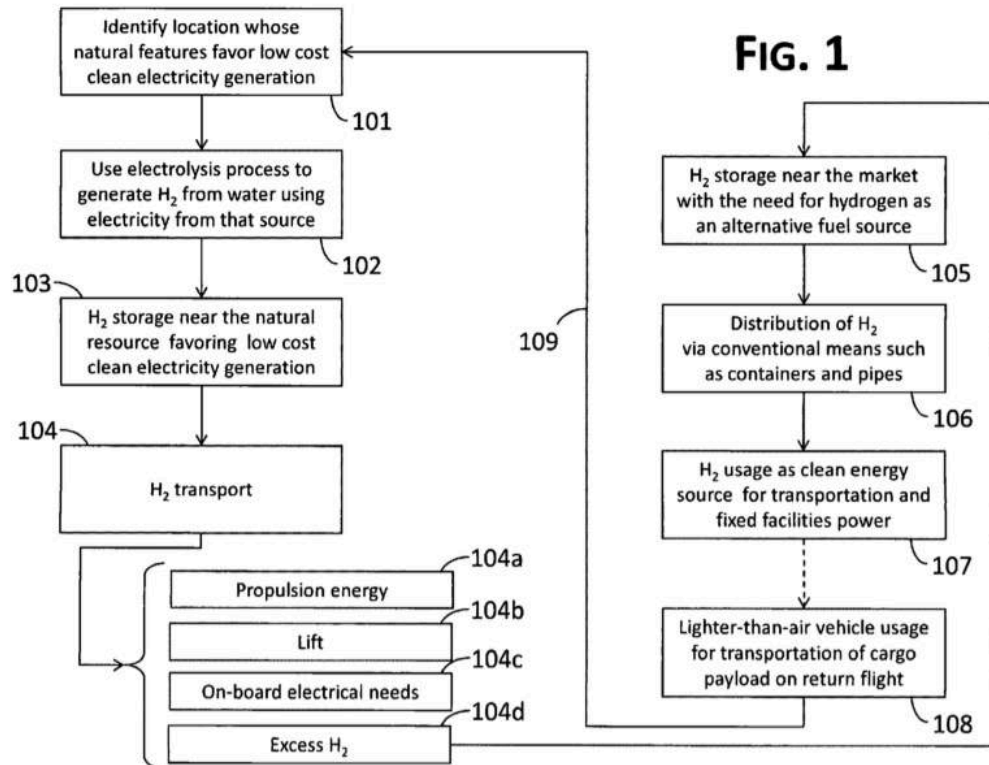
“The H2 Clipper conception arose out of the work that Rinaldo Brutoco had previously done concerning climate change, where in 2008 he co-authored a 500+ page textbook, entitled ‘End of Mideast Oil.’ The book’s first chapter, entitled ‘Titanic Mistake,’ focused on the environmental challenges the world would face if it did not wean itself off the addiction to fossil fuels; and the final chapter focused on the importance of hydrogen as the single best suited alternative.

An early advocate for the goal of a hydrogen economy, Brutoco was confronted with the challenges summarized in the work of Swiss scientists regarding the problems associated with transporting hydrogen using truck, rail, ocean ships and pipeline. After research, he concluded that the best means to overcome these challenges would be through use of an airship; and the system and method of transporting hydrogen via airship forms the basis for H2 Clipper’s first patent (US 8,336,810), filed in 2008 and issued in 2012.

Figure 1 from that patent illustrates the basic conception of flying low cost hydrogen from where renewable resources such as abundant wind, solar, hydro or geothermal conditions make

electricity cost very cheap, to where clean energy is most needed; and on the return flight using the massive volume of the airship to transport traditional cargo and air freight.

To this day, this Use Case, involving hydrogen transport and displacing traditional air freighters, is the principal focus of H2 Clipper.”



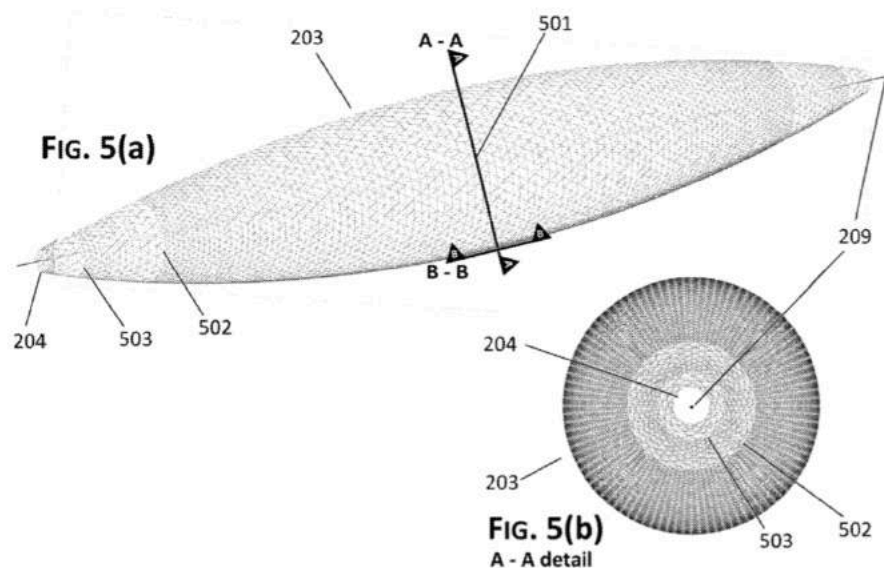
*The hydrogen transport Use Case
Source: Patent US 8,336,810, Fig. 1*

4. H2 Clipper airship design features

With a targeted cruising speed of 175 mph (281.6 kph) and range of 6,000+ miles (9,656+ km), the H2 Clipper airship is a high-speed, multi-mission dirigible that transports hydrogen and uses hydrogen as its lifting gas and primary source of power. Many patents defining features of this airship have been granted, and the company has numerous pending U.S. and International patents. Several key airship features are described in this section.

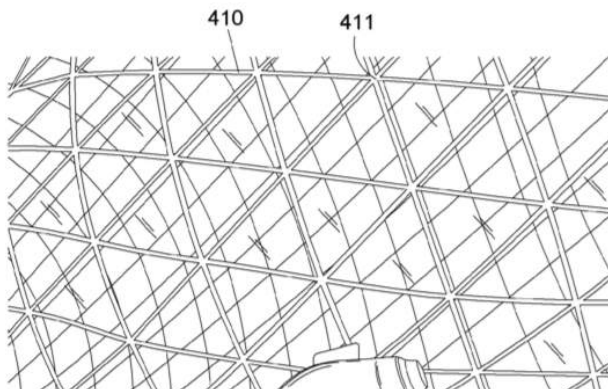
Rigid, geodesic hull structure

Patent US11066145 Figures 5(a) and 5(b) show the primary hull structure, which is a lightweight, composite geodesic exoskeleton (203) with minimal internal structures. This hull design is similar in concept to the geodesic exoskeleton hulls designed for the Lightspeed rigid airship and the Megalifter semi-buoyant aircraft in the mid-1970s. At the midline of the H2 Clipper airship (501), the hull diameter is 150 ft (45.7 m). Nose and tail cones attach to the ends of the exoskeleton (204), where the diameter is about 24.3 ft (7.4 m).



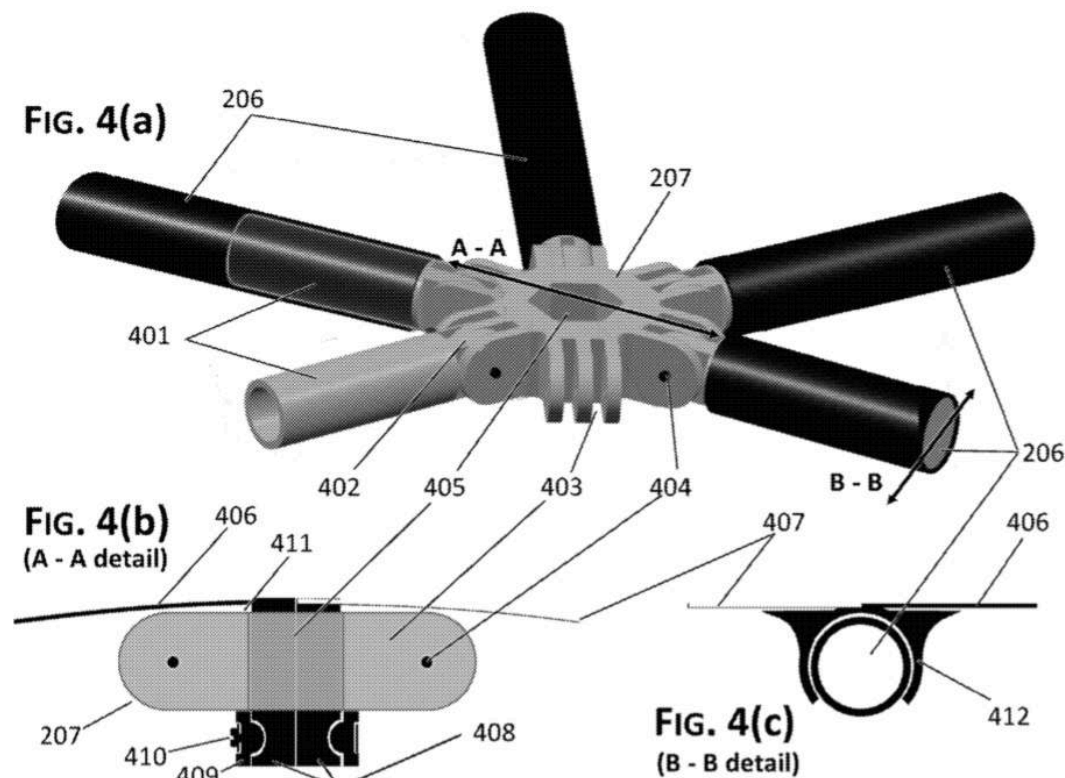
Exoskeleton hull design of the H2 Clipper. Source: Patents US11066145 & US11396356B2, Figures 5(a), (b) (2020 & 2022)

The exoskeleton is designed to support 100% of the structural bearing weight of the craft without internal load-bearing structures.



General form of the geodesic exoskeleton hull, comprising variable-length composite tubes (410) and universal hubs (411). Source: Patent US9102391, Figure 7 (2013)

The exoskeleton hull is made entirely from variable-length composite beams (206), all with a standard diameter. Spoke length ranges from 10 feet (3 m) in the mid-section of the airship to 5 feet (1.5 m) in the smaller-diameter nose and tail sections (from 502 in Figure 5a). The spokes are joined at universal, articulated hubs (207) to form the large-scale geodesic framework of the rigid hull. The use of the variable-length spokes and the articulated hubs enables the connecting angle to change as needed to conform to the local radius of curvature of the hull.

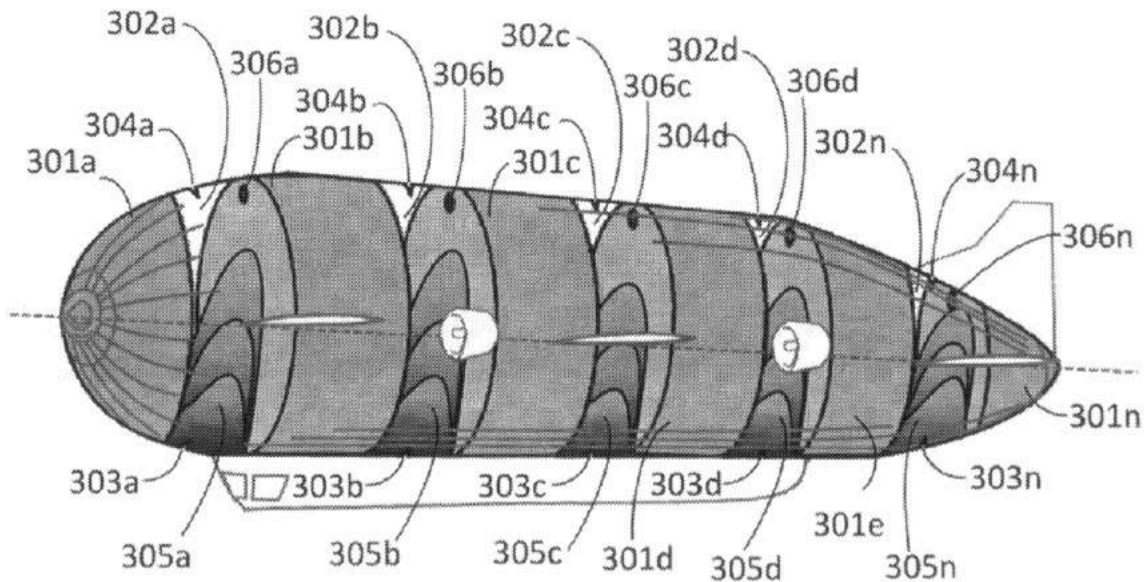


Typical hub configuration joins variable-length spokes (206) at the universal, articulated, central hub (207). Source: Patents US11066145 & US11396356B2, Figures 4(a), (b), (c) (2020 & 2022)

The external skin is made of lightweight composite material, such as bonded aramid fiber coated with PTFE (Polytetrafluoroethylene) to produce a low density and high tensile strength covering with a slick, non-wetting surface that is highly resistant to extreme temperatures (-50°C to $+200^{\circ}\text{C}$), is fire resistant and flame retardant. A flat or curvilinear outer skin panel (406) may include a layer containing thin-film photovoltaic (PV) solar cells (407).

Internal arrangement of gas volumes

Hydrogen storage tanks (301a – n) are high-pressure tanks or other storage devices that carry the pressurized gaseous or liquified hydrogen cargo. These hydrogen storage tanks are distributed along the length of the airship, alternating with air-filled compartments (302a – n) containing expandable hydrogen bladders (305a - 305n).



Generic interior arrangement of the liquified hydrogen transport airship. Source: Patent US8336810, Figure 3

The air-filled compartments (302a – n) are at ambient pressure. The large expandable bladders (305a - 305n) in these compartments can contain variable amounts of hydrogen as needed to provide more or less aerostatic lift. These bladders are managed by a variable buoyancy and trim control system.

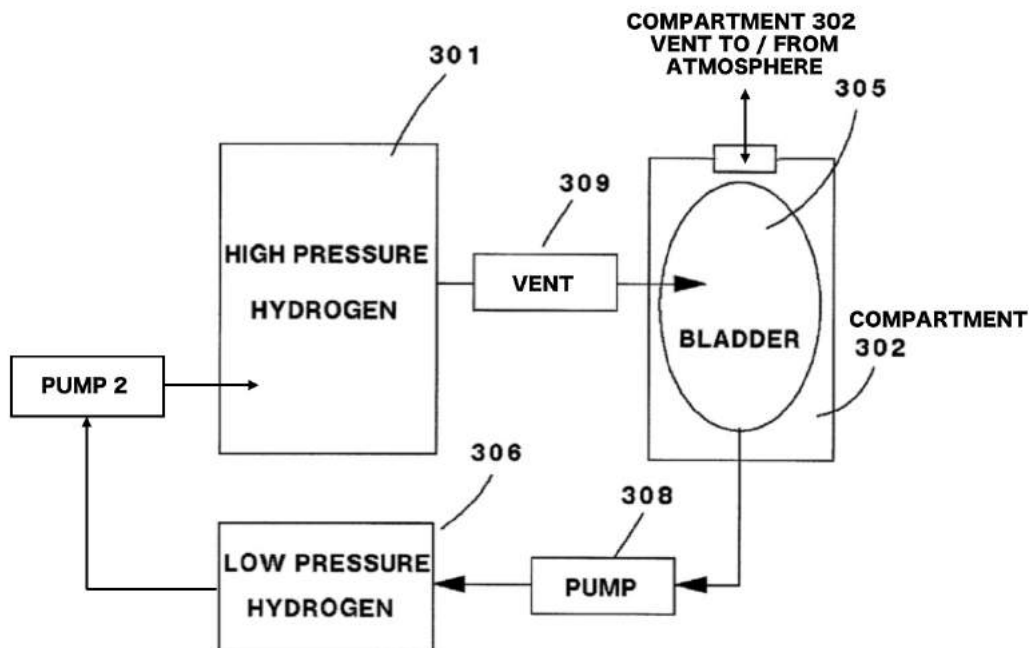
Operation of the variable buoyancy and trim control system

Patent US8336810 provides the following description of airship flight operations:

“The bladder system allows simultaneous control of both lift and fore-aft trim. When the craft is not moving horizontally, adjustment of bladders in different parts of the ship allow trim

control. After the craft acquires a horizontal speed, trim can also be controlled by the airfoils and engine directions.... At altitude and speed, the bladders can be set to achieve approximately neutral buoyancy with trim and with part of the lift then being provided by the structure itself according to aeronautical principles, with trim being almost exclusively controlled by the airfoils and the engine directions. In general, the craftascends and descends at relatively slow horizontal speeds, relying on buoyancy control, and moves at high horizontal speeds at altitude for long distance travel, relying on airfoils and engines for thrust and/or control.”

The general schematic for the variable buoyancy control system is shown in the following diagram, which has been modified from the original patent figure to show additional system features described in the patent text.



Variable buoyancy control system process flow diagram.

Source: adapted from Patent 8336810, Figure 4 (2008) to show Pump 2, as described in the patent.

When additional lift or trim is desired, hydrogen from a high pressure hydrogen tank (301) is vented via a control valve (309) into a particular bladder (305), expanding it into the associated compartment (302). As the bladder expands, air at ambient pressure

is forced out of the compartment and is vented to the atmosphere. The compartment becomes lighter, increasing overall aerostatic lift and possibly affecting trim.

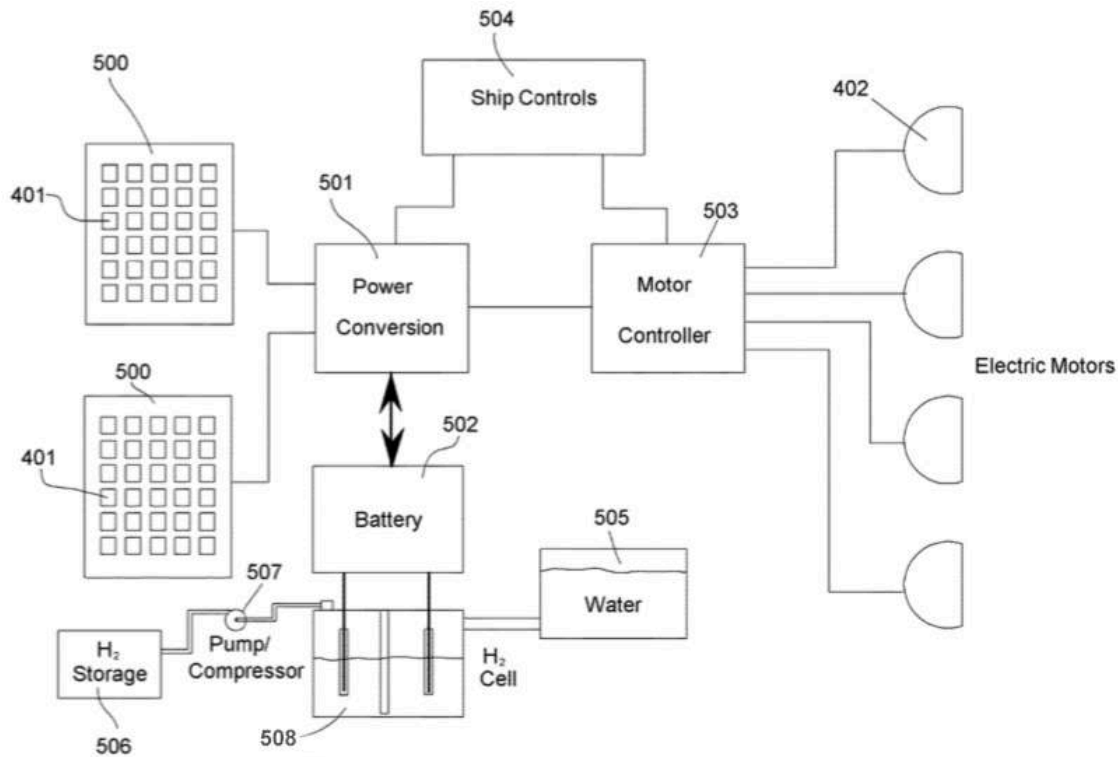
When less lift or trim is desired, a pump (308) draws hydrogen out of a bladder (305), causing the bladder to contract, and delivers it to a low pressure hydrogen tank (306). In this manner, no hydrogen is mixed with air, vented or wasted. The low pressure hydrogen can be saved in the low pressure tank, transferred to another tank, ducted to the engines for use as fuel, or it can be pumped back into the high pressure tank using a second high pressure pump. As a bladder contracts, atmospheric air is drawn in to maintain the compartment (302) at ambient pressure. The compartment becomes heavier, decreasing overall aerostatic lift and possibly affecting trim.

Power conversion system

As described in Patent US10308340, a hybrid battery / photovoltaic system is the primary source of power for the H2 Clipper. Solar panels on the top of the airship (500) charge the battery (501) during daylight hours and supply airship loads.

Excess power production can be used to drive a “hydrogen conversion cell” (508, an electrolyzer) to produce hydrogen and oxygen from water stored on board. The produced hydrogen is stored and the oxygen is vented to atmosphere.

None of the issued H2 Clipper patents propose using hydrogen fuel cells as the primary source of power for the airship. However, that is expected to change. With the huge hydrogen inventory available from the cargo and the lift gas, a hydrogen fuel cell would have an almost inexhaustible, 24/7 supply of reactants (hydrogen and oxygen) for fuel cell generation of electricity to power electric engines, and the solar array would provide supplemental power. Water generated from hydrogen fuel cell operation could be used to augment ballast and/or for trim control.



H2 Clipper hybrid battery / solar photovoltaic power conversion system with a “hydrogen conversion cell” (508, an electrolyzer) for hydrogen production. Source: adapted from Patent US10308340 Fig 6 (2016) to correct the item number of the hydrogen conversion cell (508).

UAV-assisted mooring

While the airship is designed for VTOL operations from remote sites without mooring facilities, two mooring approaches have been developed, one using a mooring tower and one using a docking cradle.

A means for mooring the nose of the airship to a mooring tower was first defined in 2008 in Patent US8336810B2. In patent Figure 2-C, a lightweight guide cable (216) fastened at one end to a reinforced connector (215) at the nose of the airship is carried through a gimbaled attachment (218) at the top of the mooring tower by an unmanned aerial vehicle (UAV, 217). Once the light-weight guide cable is engaged, a larger diameter cable is hauled through the attachment. Then the airship can be hauled in and secured to the

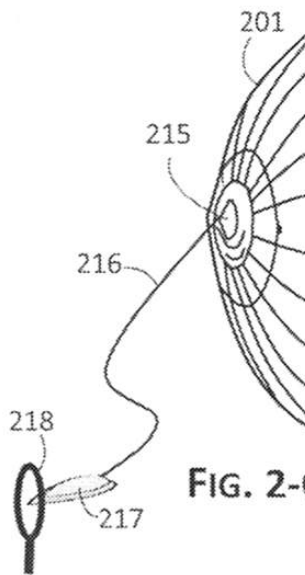


FIG. 2-C

mooring tower. A mooring mast allows the airship to swivel 360° to keep its nose pointed into the wind. The H2 Clipper airship requires an outdoor landing area with a radius of 1,200 feet (366 m) with the mooring mast at the center. A hangar would measure about 1,100 x 165 feet (335 x 50 m).

A small UAV carries a guide cable into a mooring tower catchment. Source: Patent US8336810B2, Figure C-2 (2008)

Patent US11066145 Figures 7(b), 8(a) and 8(b) introduced an alternative approach in 2020 of using UAVs (710) to draw at least two guide cables from the lower part of the hull through two or more ports (710) in a rotating docking cradle (711). The airship is hauled in and secured to the docking cradle, which can rotate 360° to point into the wind or to align the airship for transfer into a hangar (812).

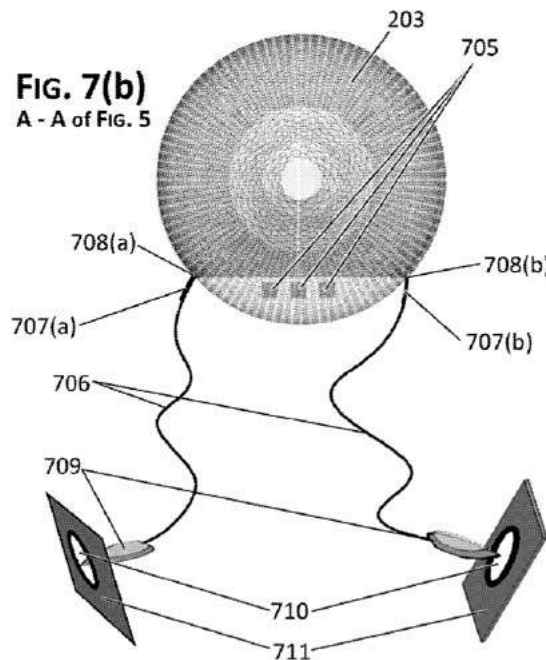
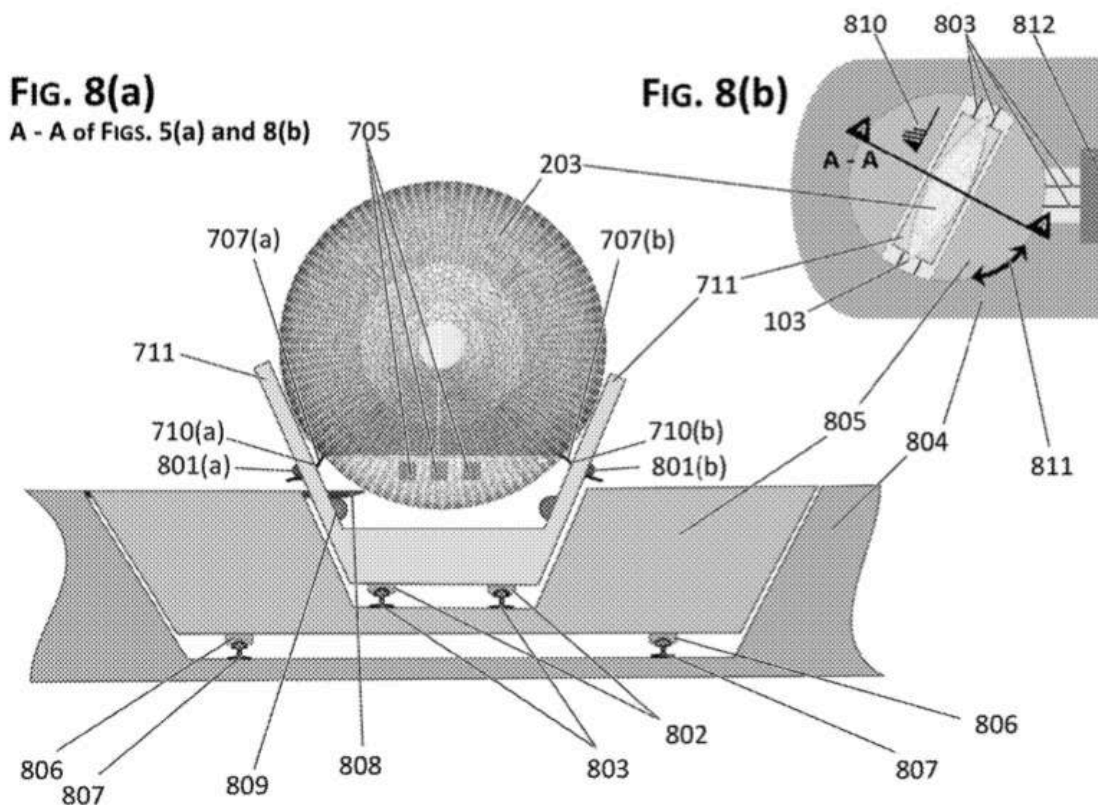


FIG. 7(b)
A - A of FIG. 5

Two small UAVs carry guide cables into two ports on a docking cradle. Source: Patents US11066145 & US11396356B2, Figure 7(b) (2020 & 2022)



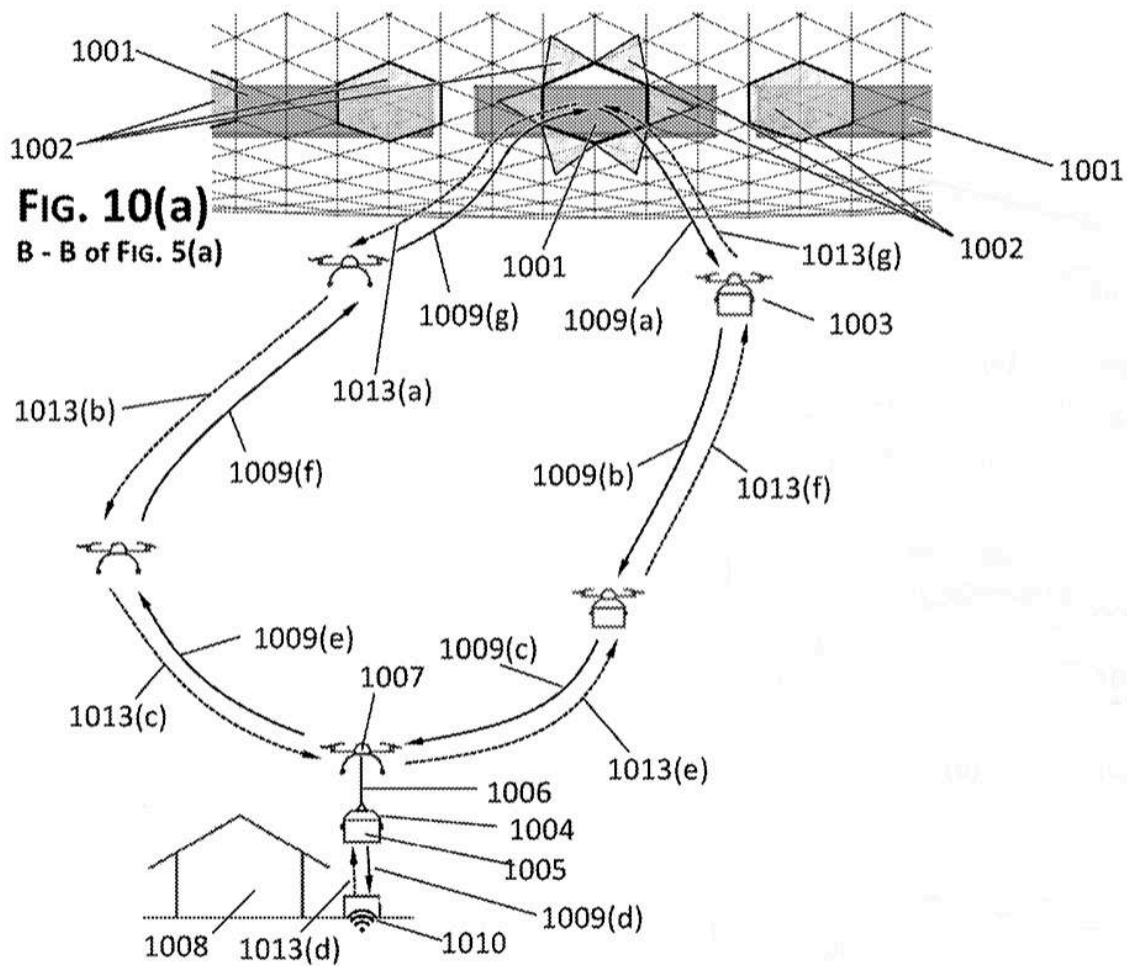
The airship (203) secured in a rotating docking cradle (711) via anchor points (710a & b). Source: Patents US11066145 & US11396356B2, Figures 8(a) & 8(b) (2020 & 2022)

Flying warehouse functionality

The H2 Clipper [is](#) conceived as a multi-mission airship. One potential role is to serve as a flying warehouse.

As described in Patent US11066145B1, the airship could land at a customer's distribution center to load new deliveries and off-load items picked up on the previous flight. Then the airship would deploy on a specified delivery route to make in-flight deliveries and pickups with the aid of cargo UAVs that are launched and recovered from a cargo bay located inside the airship's exoskeleton hull.

Details of the UAV launch and retrieval apparatus are not disclosed in this patent.



Cargo UAVs are launched and recovered from a cargo hold (1001) within the exoskeleton and make deliveries to, and pickups from, customers on the ground. Source: Patents US11066145 & US11396356B2, Figure 10(a) (2020 & 2022)

5. H2 Clipper airship design evolution

The design of the H2 Clipper has evolved since its introduction about a decade ago. The airship design is being developed and managed in a 3-D CAD environment using the Dassault Systemes 3DEXPERIENCE® platform.

H2 Clipper Inc. is developing a subscale prototype airship that completed its preliminary design stage in 2019. Work was expected to start on shop drawings for the subscale prototype in 2022. Rollout and first flight of the prototype could occur as early as 2025.

H2 Clipper Inc. stated that their first full-sized airship could be flying late in this decade, with service entry by 2029 if work underway continues as planned.

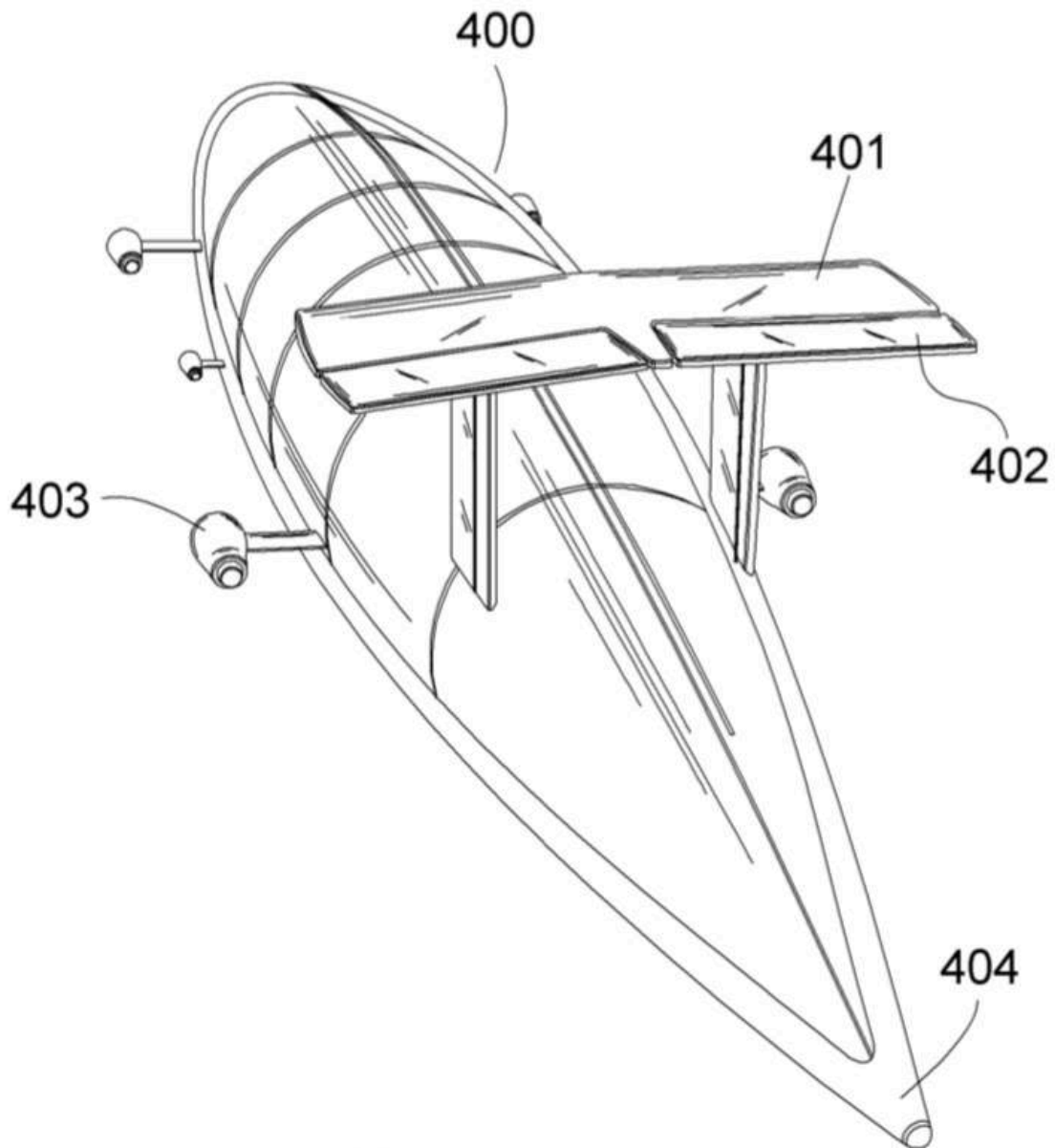
Three H2 Clipper airship design iterations are addressed in this section.

Early H2 Clipper design, circa 2013

From the outset, the H2 Clipper was designed as a scaleable airship that can be mass produced and built in various sized to meet the needs of a specific application. For hydrogen cargo transportation, Patent US11066145 provides the following basic airship parameters:

Parameter	Early H2 Clipper design, circa 2013
Length	1,000 ft (304.8 m)
Diameter, max.	150 ft (45.7 m)
Propulsion	4 x gaseous hydrogen-burning high-bypass turbofan engines
Speed, max.	Greater than 200 mph (322 kph)
Operating altitude	1,000 to 15,000 feet (305 to 4,572 m)
Payload, max.	220 tons (200 metric tons)

The H2 Clipper has a high fineness ratio (length / diameter) of 6.7, which is higher than the LZ 129 Hindenburg, which was 5.95. This streamlined design is intended to help maintain laminar flow over the outer surface of the airship and thereby reduce the drag coefficient.



*Stern quarter view showing the double-T tail assembly (401) with control surfaces (402) and flank-mounted, vectoring high-bypass turbofan engines that burn gaseous hydrogen fuel.
Source: Patent US9102391, Figure 5A (2015)*



*Early design of the H2 Clipper airship shown being moved out of its hangar and taking off vertically from a mooring tower.
Source, both graphics: H2 Clipper, Inc.*



*Vectoring high-bypass ratio turbofan engines
burn gaseous hydrogen fuel.
Source, both graphics: H2 Clipper, Inc.*

Intermediate H2 Clipper design, circa 2020

This intermediate design replaced the flank-mounted, high-bypass ratio turbofan engines with large, vectoring propellers in the same locations.

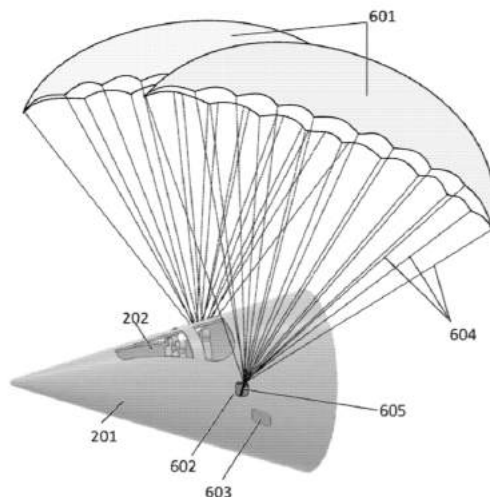


*H2 Clipper profile view. Note the large, flank-mounted propellers.
Source: H2 Clipper, Inc. (circa 2020)*

The geodesic structure of the rigid hull terminates before the highly curved “pointy ends” of the airship. The crew compartment and the tail cone will be separate fabrications that are attached to the ends of the geodesic hull. This provides an opportunity to design a crew compartment that can be separated from the exoskeleton hull during

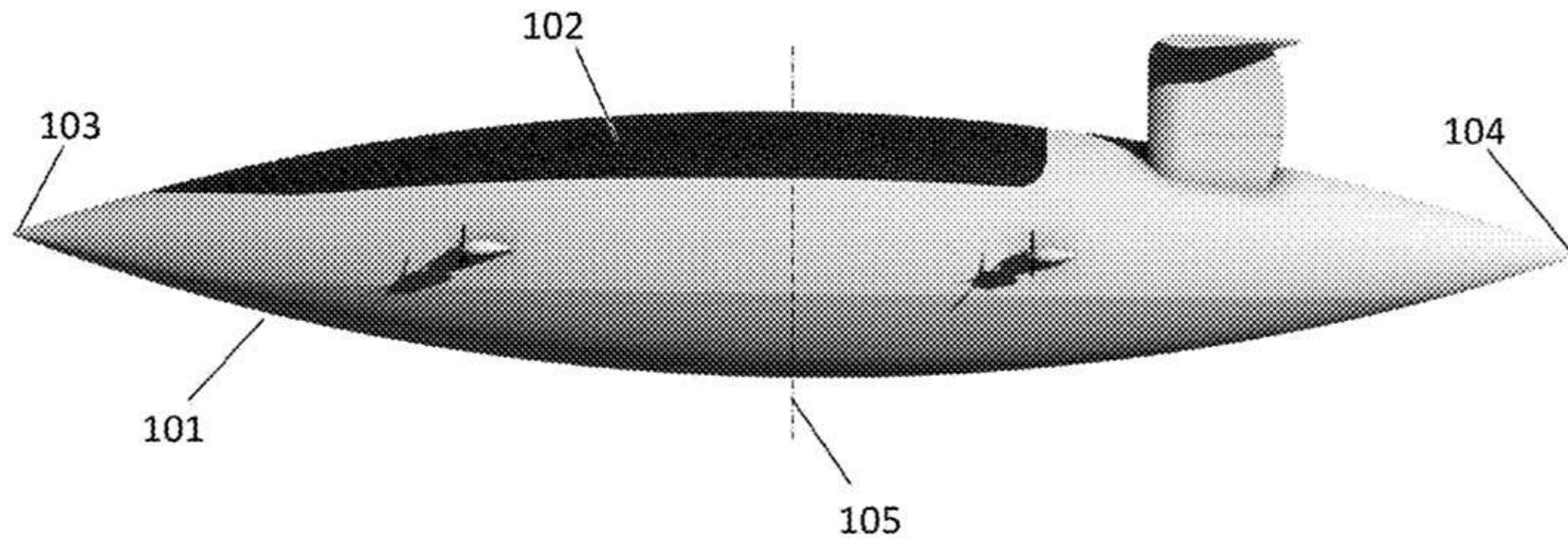
an in-flight emergency, enabling the crew to descend safely with the aid of parachutes.

FIG. 6



*Crew compartment with
parachutes deployed after
separation from the airship.
Source: Patents
US11066145B1 &
US11396356B2, Figure 6
(2020 & 2022)*

FIG. 1



H2 Clipper side view. This patent figure depicts one embodiment of the airship (101), with photovoltaic panels on the top of the hull (102), a 1,000-foot (304.8 meter) long hull between nose (103) and tail (104), and a 150-foot (45.7 meter) maximum diameter at the midpoint (105).

Source: Patent US11396356, Fig. 1 (2022)



H2 Clipper bow quarter view showing the crew compartment at the nose, the flank-mounted propellers and the solar array on top of the hull. Source: H2 Clipper, Inc.

Current H2 Clipper design, circa 2021

The current version of the H2 Clipper airship is a further iteration of the original design, with two notable external refinements: inverted Y-tail control surfaces replace the double T-tail, and a large propeller was added at the stern. H2 Clipper Inc. claims that the airship can deliver goods directly from a factory in China to a distribution center in the US in less than 36 hours or virtually anywhere on the globe in 48 hours, with VTOL at both ends.

General characteristics of the H2 Clipper

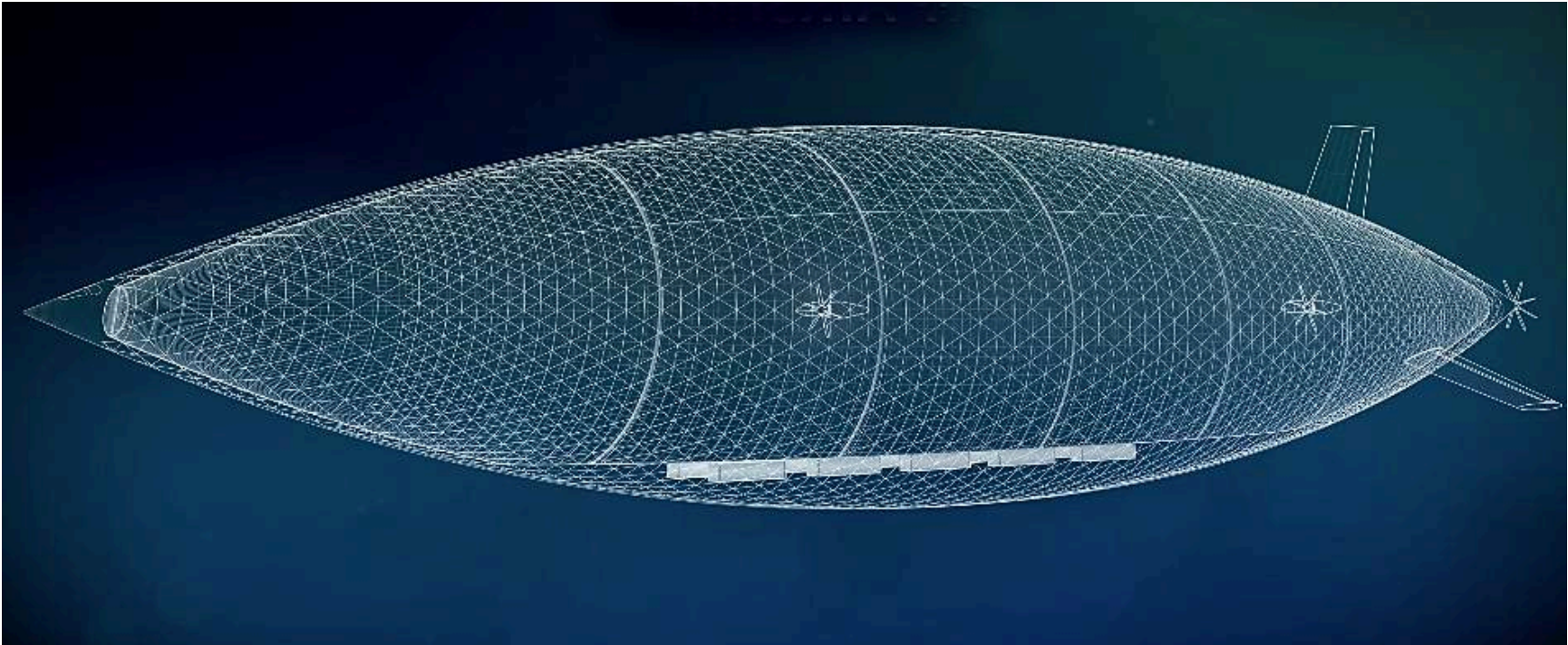
Parameter	Current H2 Clipper design, circa 2021
Type	Conventional, rigid, fixed-volume variable buoyancy, capable of vertical takeoff and landing (VTOL)
Length	1,000 ft (304 m)
Diameter, max.	150 ft (45.7 m)
Lifting gas	Hydrogen
Fuel	Hydrogen
Power source	Hybrid system with hydrogen fuel cell production of energy for propulsion supplemented by a photovoltaic (PV) solar array on the hull
Propulsion	5 x propellers, powered by electric motors: <ul style="list-style-type: none">• 4 x flank-mounted, 6-blade, thrust vectoring props• 1 x stern-mounted 8-blade prop
Total power	33,200 shp (24,757 kW) from the 5 propulsion motors
Speed, max.	<ul style="list-style-type: none">• 175+ mph (280 kph)• 7 to 10 times faster than contemporary cargo ships
Cargo volume	265,000 ft ³ (7,530+ m ³)
Range vs. payload	A function speed: <ul style="list-style-type: none">• 6,000+ miles (5,200+ naut. miles / 9,656+ km) at 175 mph (280 kph) with a 170 ton (340,000 lb / 150,000 kg) payload• 1,000 miles (1,609 km) at 175 mph (280 kph) with a 245 ton payload (490,000 lb / 222,260 kg)• In addition to its hydrogen payload, the airship also has a cargo bay with a capacity for forty-five 20 ft ISO freight container
Estimated cargo transportation cost	About ¼ the cost of a contemporary air freighter: <ul style="list-style-type: none">• < \$0.25/ton-mile for ranges from 1,000 to 6,000 miles (1,609 to 9,656 km) (circa 2021)
Carbon emissions from operation	<ul style="list-style-type: none">• Zero



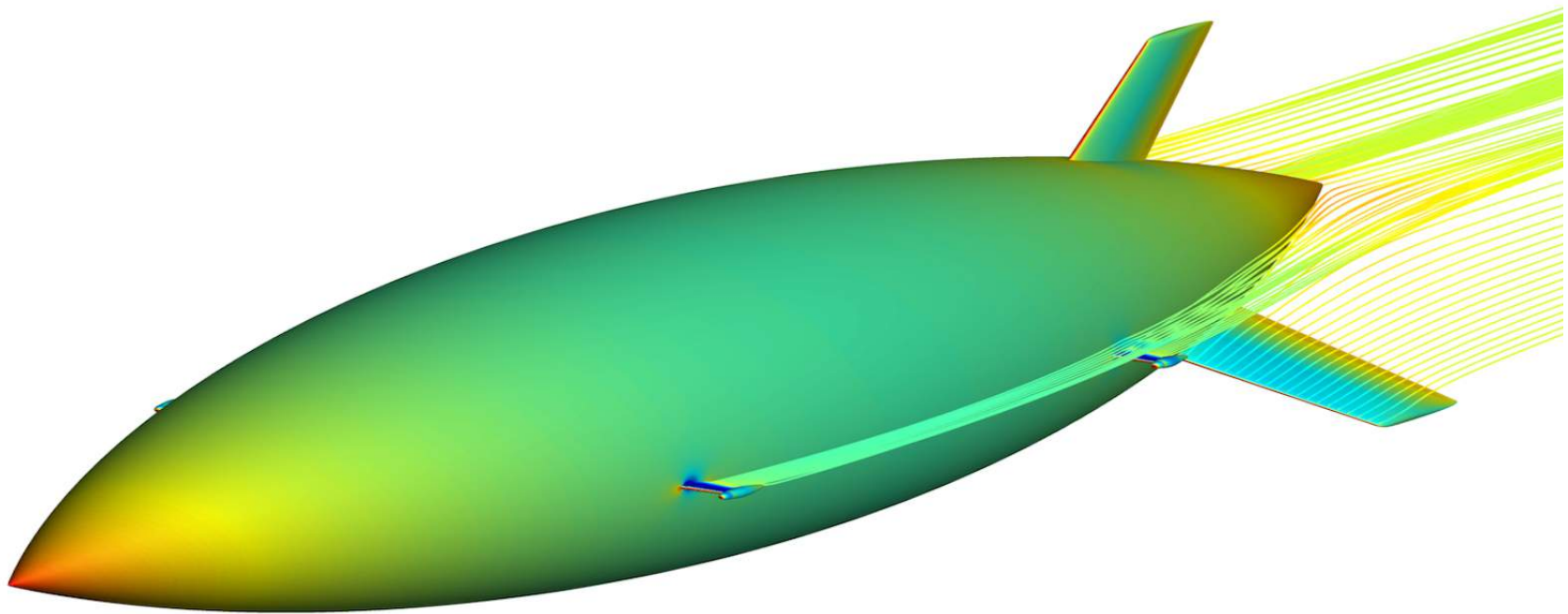
H2 Clipper bow quarter view at takeoff. Source: Screenshot from H2 Clipper, Inc. video (circa 2020)



H2 Clipper bow quarter view. Note the revised tailplanes. Source: H2 Clipper, Inc. (2021)



H2 Clipper bow quarter cut-away view showing the rigid geodesic frame within the smooth external skin, the placement of the flank- and tail-mounted propellers, the inverted-Y tail planes, and the cargo bay along the centerline keel at the bottom of the hull. Source: H2 Clipper, Inc. (2022)



Simulated wind tunnel test using computational fluid dynamic (CFD) analysis illustrates the refined aerodynamic shape of the H2 Clipper's hull, with smooth airflow over the full length of the hull.

Source: H2 Clipper, Inc. (2022)



*H2 Clipper viewed from the bow (top) and stern quarter (middle & bottom). Note the revised tailplanes and tail-mounted propeller.
Source: H2 Clipper, Inc. (circa 2020)*

7. For more information

- M. Sonstegaard, “Airships for transporting highly volatile commodities,” Proceedings of the Interagency Workshop on Lighter than Air Vehicles, NASA-CR-137800, pp. 551 - 562, Doc ID 19760007973, 1 January 1975:
<https://ntrs.nasa.gov/citations/19760007973>
- “H2 Clipper Granted US Patent for “Lighter-Than-Air” Dirigible Design, Advancing the Company’s Mission to Accelerate the Hydrogen Economy,” GlobalNewswire, 30 September 2021:
<https://www.globenewswire.com/en/news-release/2021/09/30/2306300/0/en/H2-Clipper-Granted-U-S-Patent-for-Lighter-Than-Air-Dirigible-Design-Advancing-the-Company-s-Mission-to-Accelerate-the-Hydrogen-Economy.html>
- Jennifer Presley, “Not your grand-daddy’s dirigible: US patent granted for hydrogen-powered airship,” Upstream, 7 October 2021: <https://www.upstreamonline.com/hydrogen/not-your-grand-daddy-s-dirigible-us-patent-granted-for-hydrogen-powered-airship/2-1-1077368>
- Christina Mircea, “H2 Clipper's Disruptive Airship Boasts Insane Specs, Can Carry 340,000 Lb for 6,000 Miles,” autoevolution, 24 June 2022: <https://www.autoevolution.com/news/h2-clipper-s-disruptive-airship-boasts-insane-specs-can-carry-340000-lb-for-6000-miles-192046.html>
- Dominic Perry, “H2 Clipper sails into Series A funding round as prototype production hoves into view,” FlightGlobal, 4 October 2022 : <https://www.flightglobal.com/aerospace/h2-clipper-sails-into-series-a-funding-round-as-prototype-production-hoves-into-view/150418.article>

Videos

- YouTube video, “H2 Clipper Presentation (1st International Hydrogen Aviation Conference Sept. 2020) Updated video,” (20:22 minutes), World Business Academy, posted 18 January 2021: <https://www.youtube.com/watch?v=QLQphjftxF8>
- There are several other video presentations available on the H2 Clipper website at the following link:
<https://h2clipper.com/presentation/#pipeline-in-the-sky>

Patents

- Patent US8336810B2, "System, method and apparatus for widespread commercialization of hydrogen as a carbon-free alternative fuel source," filed 29 October 2008, granted 25 December 2012:
<https://patents.google.com/patent/US8336810B2/en>
- Patent US8820681B2, "Lighter-than-air craft docking system using unmanned flight vehicle," filed 17 December 2012, granted 2 September 2014:
<https://patents.google.com/patent/US8820681B2/en>
- Patent US9102391B2, "Hydrogen lighter-than-air craft structure," filed 3 April 2013, granted 11 August 2015:
<https://patents.google.com/patent/US9102391B2/en>
- Patent US9493223B2, "System, method and apparatus for widespread commercialization of hydrogen as a carbon-free alternative fuel source," filed 4 July 2015, granted 15 November 2016: <https://patents.google.com/patent/US9493223B2/en>
- Patent US10308340B2, "System, method and apparatus for widespread commercialization of hydrogen as a carbon-free alternative fuel source," filed 15 November 2016, granted 4 June 2019:
<https://patents.google.com/patent/US10308340B2/en>
- Patent US11066145B1, "Method and apparatus for lighter-than-air airship with improved structure and delivery system," filed 28 August 2020, granted 20 July 2021:
<https://patents.google.com/patent/US11066145B1/>
- Patent US11396356B2, "Method and apparatus for lighter-than-air airship with improved structure and delivery system," filed 17 June 2021, granted 26 July 2022:
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<https://patents.google.com/patent/US20200385098A1/en>

Other Modern Airships articles

- *Modern Airships - Part 1:* <https://lynceans.org/all-posts/modern-airships-part-1/>
 - LTA Research and Exploration LLC – Pathfinder 1 & 3 (geodesic exoskeleton hull)
 - Megalifter hybrid aircraft (geodesic exoskeleton hull)
 - Shell / Aerospace Developments (AD) - methane gas carrier
 - UPship - 150 meter natural gas carrier
 - Wendel R. Wendel - STAR*FLITE Airship (geodesic exoskeleton hull)
- *Modern Airships - Part 2:* <https://lynceans.org/all-posts/modern-airships-part-2/>
 - Kiev OKBV - Aerostatic fuel transportation system (SATT)
 - Lightspeed USA Inc. (LSI) airships (geodesic exoskeleton hull)
 - Novosibirsk OKB - Natural gas carrier airship
- *Modern Airships - Part 3:* <https://lynceans.org/all-posts/modern-airships-part-3/>