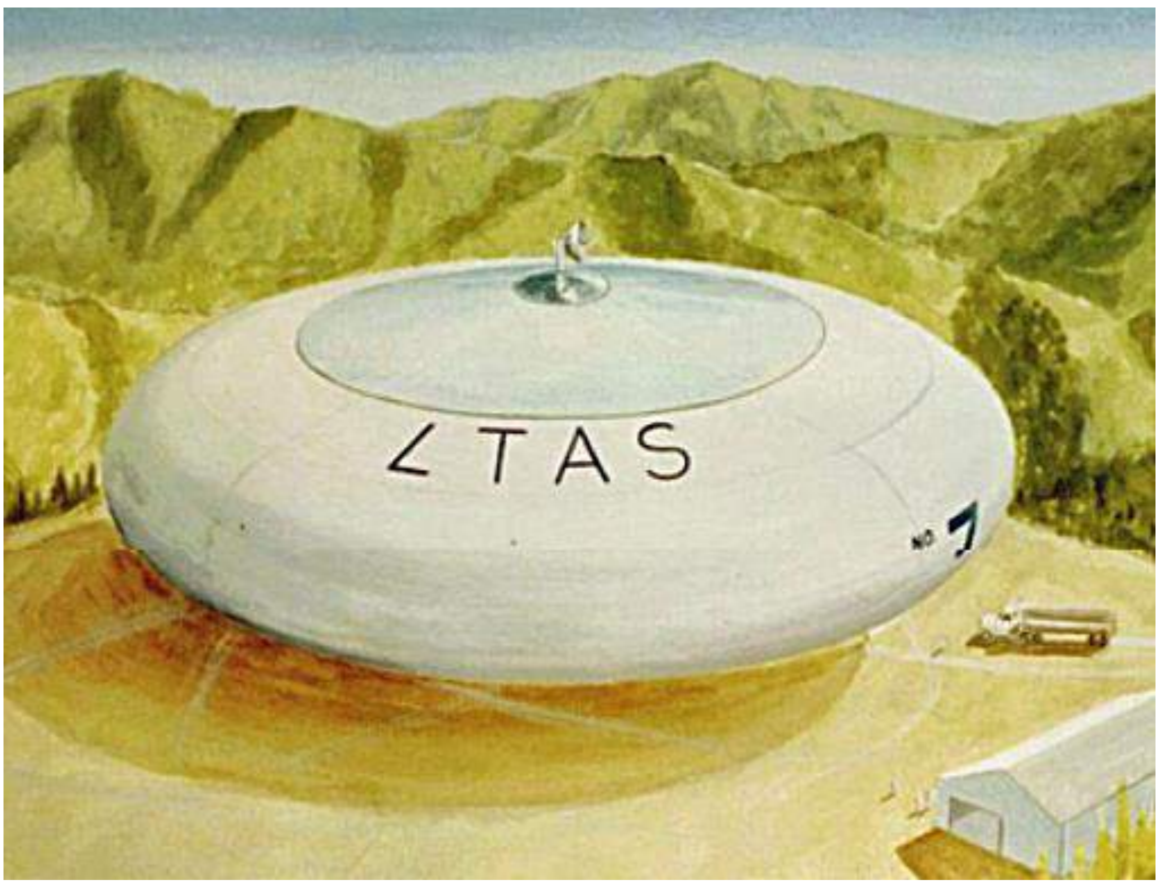
Walden Aerospace / LTAS - Lenticular, toroidal, variable buoyancy airships

Peter Lobner, updated 17 March 2024

1. Introduction

In 1976, Michael K. Walden founded Lighter Than Air Solar (LTAS) Corp. in Nevada. Walden served as Chief Technology Officer (CTO) and was responsible for the lenticular, toroidal hull design that became a characteristic feature of LTAS airships. He also was the inventor of active aerostatic buoyancy control, which LTAS referred to as density controlled buoyancy (DCB), and related technologies incorporated in LTAS toroidal airship designs.



One of Walden's early designs for a lenticular, toroidal airship with a DCB system, circa 1980. Source: LTAS / Walden Aerospace

From the mid-1970s to the mid-1980s, LTAS developed and flew a series of subscale airships, known as the XEM-1, XEM-2 and XEM-3, which were designed by Walden to demonstrate important features of his airship designs. Notable milestones include:

- XEM-1: 1974 – 76, rigid hull, solar powered, first demonstration on an airship of hybrid ionic airflow electro-kinetic propulsion
- XEM-2: 1978, solar powered, stayed aloft for more than three months
- XEM-3: 1980, first lenticular airship with a full composite hull and a DCB system

From 1977 to 1990, Walden collaborated with Mario Sánchez-Roldan, the founder the Mexican airship manufacturing company SPACIAL S.A., in the design and development of a series of airships with lenticular, rigid, geodesic space frame hulls. The result of the collaboration included the subscale XEM-4 rigid, lenticular airship demonstrator and the full-scale SPACIAL MLA-32-B, which first flew in June 1989, when it became the first modern, manned rigid airship to fly in 50 years. This collaboration also validated Walden's geodesic hull design codes, which were used in LTAS airship designs.

In 1997, the firm gained its first investors and the corporate name was changed to LTAS / CAMBOT LLC to reflect their plans to develop a remotely controlled high altitude platform (HAP) known as the CAMBOT. Robert Ellingwood became president of this firm.

In 2003, the firm was rebranded as LTAS Holdings LLC and LTAS International LLC. LTAS Holdings was the assignee for Michael Walden's patents and licensed the use of this intellectual property (IP). LTAS International was a licensee for applications of the IP. Also, in 2003, a group of foreign investors provided funding to develop and build a large-scale DCB prototype airship, which originally was intended to be the 30-XB / Technology Demonstrator, and later was designated simply as TD1 and TD2.

Michael Walden left LTAS Holdings and LTAS International in 2005. The LTAS firms moved offshore in 2015 and shortly thereafter went out of business without flying a full-scale airship.

After leaving LTAS in 2005, Michael Walden founded Walden Aerospace where he is the President and CTO, building on the creative legacy of his work with the former LTAS firms.

Michael Walden and the LTAS firms developed and demonstrated an impressive range of technologies and design concepts for lighter-than-air (LTA) craft, including:

- Rigid, geodesic airships; most with a characteristic lenticular, toroidal, “infinite edge” aeroshell; SPACIAL MLA-32-B was the first modern, manned rigid airship to fly in 50 years.
- First fully-functional solar-powered aircraft (XEM-1) flight in 1977.
- Fixed-volume, active buoyancy control system for airships (aka variable-buoyancy control, density controlled buoyancy).

THE ORIGINAL INVENTORS OF ACTIVE AEROSTATIC BUOYANCY CONTROL FOR AIRSHIPS

WALDEN AIRSHIPS

- Mass Transfer Unit (MTU) for non-aerodynamic airship pitch and roll stability control and center-of-gravity (CG) control
- High-altitude platform (HAP) functioning as a stratospheric communications pseudo-satellite with high-speed laser communications links among nearby HAPs to form a high-speed regional or national communications network
- Electro-kinetically (EK) propelled airships
- Variable buoyancy propelled hybrid airships / aircraft
- Hybrid near-space and low Earth orbit LTA vehicles

The Walden Aerospace website moved to the Internet Archive's WayBack Machine in May 2023, at the following link: https://web.archive.org/web/20180809061812/http:/www.walden-aerospace.com/HOME.html

Source: Walden Aerospace

In this article, we'll take a look at the fixed-volume, variable buoyancy DCB airship development work undertaken by Michael Walden and LTAS. This is a complex story that I've organized as follows:

- Section 2: Patent applications and patents granted for density controlled buoyancy (DCB, aka "variable buoyancy control") and non-aerodynamic airship stability and CG control.
- Section 3: Subscale airship demonstrators (1974 - 2007)
- Section 4: Walden's collaboration with Mexican firm SPACIAL
- Section 5: Walden's lenticular, toroidal, DCB airship design concepts, starting with a "generic" design and examining the following specific design concepts: T-90 Tourer, the Coast Guard 222-PAD and 30-XB, T-280, and the Sub-Orbital Solar collection & Communications Station (S.O.S.C.S)
- Section 6: Walden's non-toroidal DCB airship designs

See the following separate articles describing Michael Walden's other distinctly different airship prototypes and design concepts:

- **Electro-kinetically propelled airships**: XEM-1 and EK-1 subscale proof-of-concept demonstrators, and the MK-4 EK panel airship and MK-5 Big Black Delta (BBD) design concepts: https://lynceans.org/wp-content/uploads/2021/04/Walden-LTAS_EK-propelled-airships.pdf
- **Variable buoyancy propelled airships**: HY-SOAR B.A.T. and the VAMPIRE around-the-world flyer design concepts: https://lynceans.org/wp-content/uploads/2021/04/Walden-LTAS_VB-propelled-airships_R1-converted.pdf
- **Exotic hybrid airships**: LTA-1701-D entertainment airship, I-Fleet combat airships, hybrid rocket / airship W.A.V.E.S., Earth Station One high altitude habitat and Silver Dart shuttle, and airship applications for low Earth orbit missions: https://lynceans.org/wp-content/uploads/2021/05/Walden-LTAS_Exotic-hybrid-airships.pdf

I am grateful to Michael Walden for his thoughtful input for this series of articles.

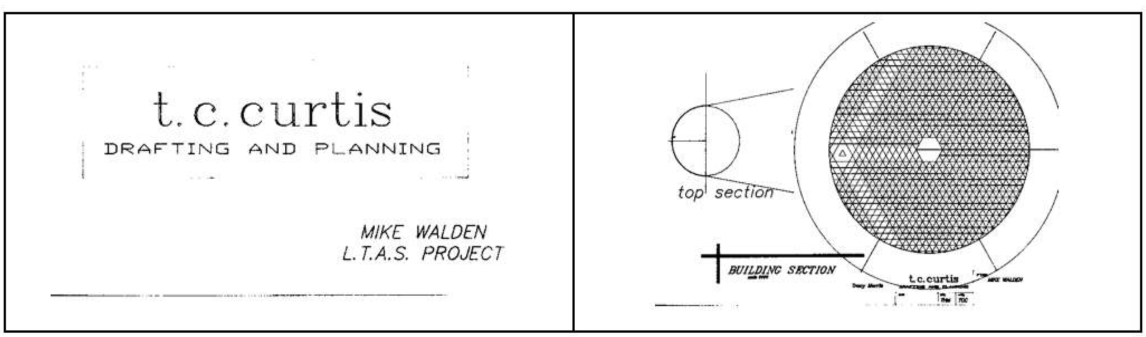
2. Michael Walden and LTAS Patent Applications

<u>The 1979 patent application</u>

On 22 October 1979, Michael Walden filed a single patent application related to the following lighter-than-air (LTA) technologies (US Patent & Trademark Office filing receipt serial number 06/059.977):

- Structures and designs for rigid LTA hulls:
    - Plastic expanded foam and fiberglass or metallized sandwich material
    - Rigid sheet plastic and strut material
    - LTA hull design concepts employing these materials
- Solar power conversion system and related solar powered propulsion system for use on LTA craft
- Constant volume, variable density lift gas control unit and associated control system for LTA craft [aka a density controlled buoyancy (DCB) system]
- Ionic air flow electro-kinetic (IAF/EK) engines for use on rigid LTA craft

The lenticular, toroidal, “infinite edge” hull form with a geodesic, composite aeroshell and a DCB active aerostatic lift control system, as described in the 1979 application, have become characteristic features in many of Walden’s subsequent airship designs.



Lenticular, toroidal, “infinite edge” hull design showing the geodesic structure and the toroidal rim tube, circa early 1980s. Source: LTAS / Walden Aerospace

No patents resulted from this initial filing. Instead, the USPTO advised Walden & LTAS to submit a separate patent application for each technology.

It was not until 2003 that LTAS Holdings LLC filed new individual patent applications for the following inventions that were represented in the original 1979 application:

- Density controlled buoyancy (DCB) system
- Lenticular airship with central fairing
- Mass transfer unit (MTU) for airship stability control

The resulting patents issued between 2007 and 2009 all originally listed Michael Walden as the inventor. LTAS Holdings LLC arranged to have the name of George Heaven Jr. added as an "inventor" even though he made no contribution to the development of the intellectual property in these patents. An overview of each of these patents is provided in the following sections.

LTAS Holdings LLC did not file new individual patent applications for the following:

- Structures and designs for rigid LTA hulls
- Solar power conversion system and related solar powered propulsion system for use on LTA craft
- IAF / EK engines for use on LTA craft

By about 2012, all of the recently issued patents had lapsed after LTAS Holdings LLC failed to pay patent maintenance fees. These patents now are in the public domain and free for anyone to use.

Active density controlled buoyancy (DCB) system

Walden's density controlled buoyancy (DCB) system (another name for a fixed volume, variable buoyancy control system) is at the heart of most of his airship designs developed since the early 1970s. This invention is described in several US and international patents, which provide numerous examples ("various embodiments") of how DCB can be implemented in the design of an airship, including:

- Moving helium lift gas between a pressurized tank and atmospheric pressure lift gas cells to alter buoyancy by causing atmospheric pressure air ballonets to expand or contract and thereby change the mass of air carried by the airship.
- Charging atmospheric air to a pressurized tank or discharging the pressurized air back to the atmosphere to change the mass of air ballast carried by the airship.

The US patent process for this invention was not completed until 2 January 2007, when a patent was granted as US2006/0065777A1, "Systems for actively controlling the aerostatic lift of an airship." You can read this patent here:
https://patents.google.com/patent/US20060065777A1/en

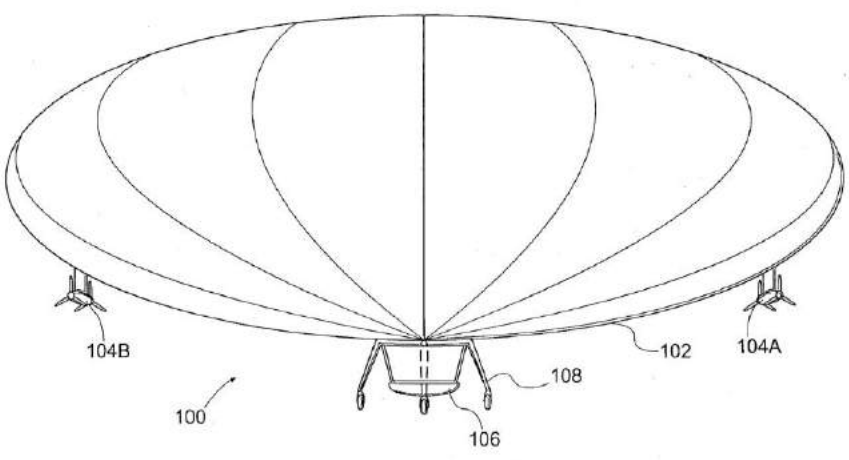


Fig. 1

Legend: *The airship (100), fixed volume hull (102), propulsion engines (104), gondola (106), landing gear (108)*

Generic exterior configuration of a lenticular, toroidal DCB airship.
Source: US US2006/0065777A1

Operation of the DCB system is quite simple. The process for moving helium lift gas back and forth between a pressurized tank and an atmospheric pressure lift gas cell is shown in the following Figures 4A and 4B from the patent and is described below.

Michael Walden estimates that the DCB can provide a rate of ascent of over 2,000 feet per minute. DCB descent rate is limited by pump size and is about 1,000 feet per minute. No helium is lost during these venting and compressing cycles.

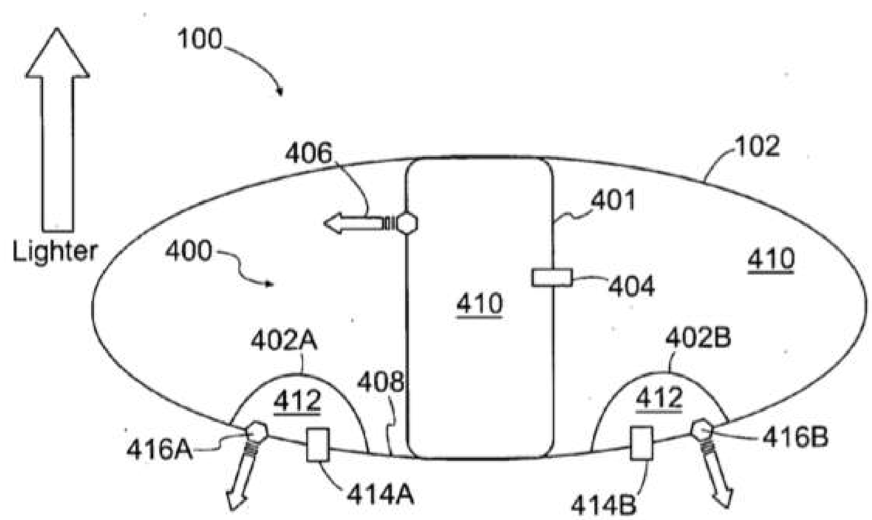


Fig. 4A

In Figure 4A, the aerostatic lift of a fixed-volume airship (102) is increased by venting helium (410) from a fixed-volume pressure tank (401) via a helium control valve (406) into an atmospheric pressure helium cell (400). As more helium gas enters the helium cell, heavier air (412) is forced out of the ballonets (402, also known as "displacement change bags") and is discharged to the atmosphere via vent valves (416). The total mass of the airship decreases as the heavier air is displaced and there is a corresponding increase in buoyancy. Very little power is needed for operating the helium control valve (406), which also can be operated with a manual actuator.

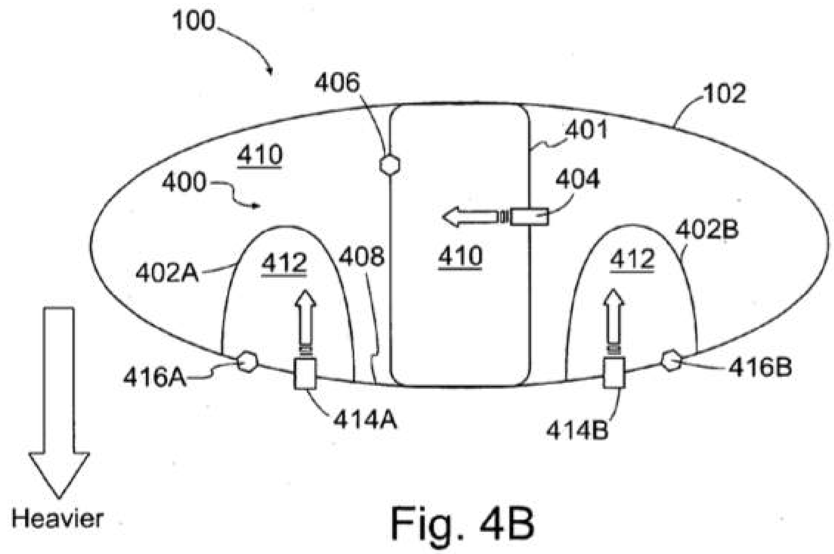


Fig. 4B

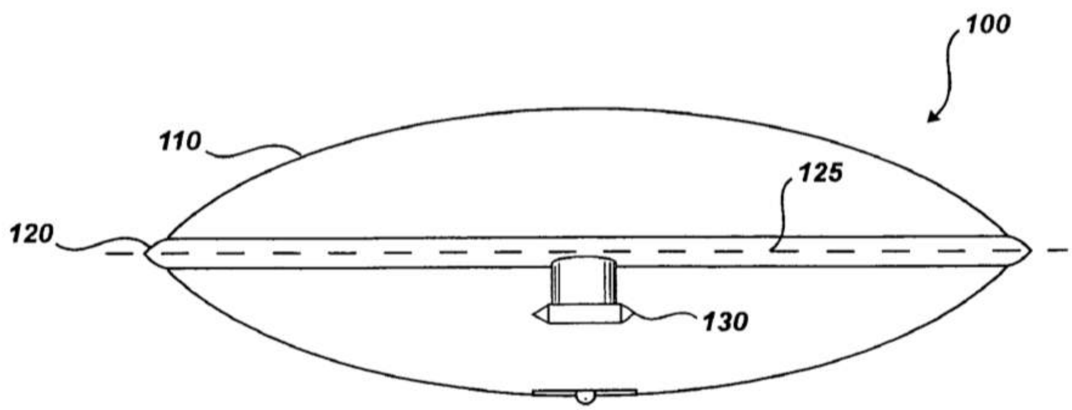
In Figure 4B, the aerostatic lift of a fixed-volume airship (102) is decreased when helium from the atmospheric pressure helium cell (400) is compressed by pump (404) and discharged into the smaller fixed-volume pressure tank (401). As the helium is transferred, the ballonet volumes (402) expand as fans (414) add heavier atmospheric air (412). The total mass of the airship increases as the heavier air is added to the ballonets and there is a corresponding decrease in buoyancy. Power is needed for operating ballonet fans and for compressing some helium from the atmospheric pressure helium cells and returning it the fixed-volume pressure tank (401).

Related patents and web links (where available) are listed below.

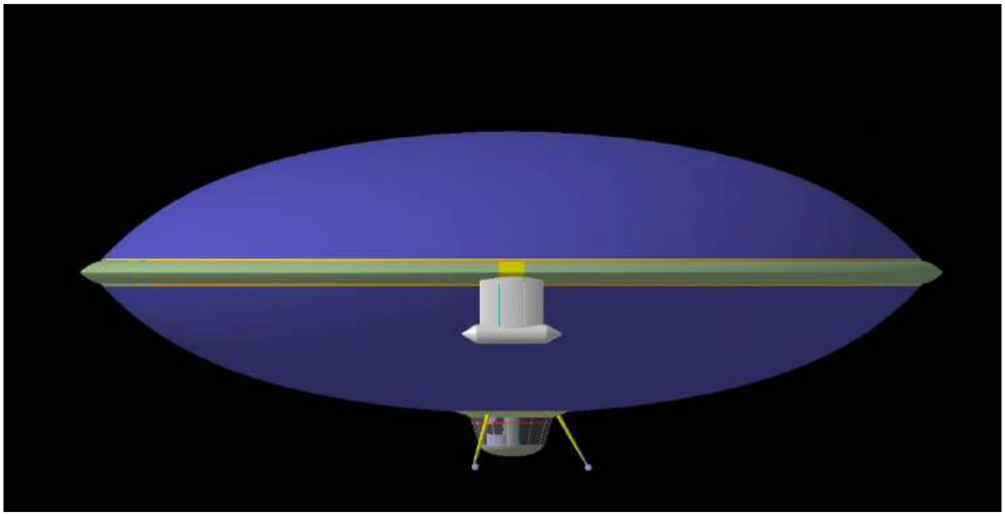
- US7156342B2, granted 2 January 2007: https://patents.google.com/patent/US7156342B2/en
- US7487936B2, granted 10 February 2009: https://patents.google.com/patent/US7487936B2/en
- US2008/0135678A1, granted 10 February 2009: https://patents.google.com/patent/US20080135678A1/en
- WO2006/137880A2, published 28 December 2006: https://patents.google.com/patent/WO2006137880A2/en?oq=airship+toroidal+ininventor:Michael+ininventor:Walden
- WO2008/051638A3, published 2 May 2008: https://patentimages.storage.googleapis.com/5d/ae/2b/d4fcf61ada983c/WO2008051638A3.pdf
- EP1802525, TW 095109971 and CN 200580040456

Lenticular airship central fairing to reduce lift and instability

Patent US 7490794B2, "Airship having a central fairing to act as a stall strip to reduce lift," granted on 17 February 2009, defines a means to control the dynamic lift generated by the flow of air over a lenticular hull. This airflow is a problem because it creates an instability that becomes more pronounced at higher airspeeds. One solution defined in the patent is to add a protruding fairing around the leading edge (the equator) of a lenticular airship. The fairing may have a triangular shape or a semi-circular shape or any other shape capable of disrupting the flow of air over the hull. The result is a hull shape as shown in the following patent diagram:



Side view of a lenticular airship (100) with a rigid aeroshell (110) and a central fairing (120) along the equator of the airship (125), with propulsion units (130) attached. Source: Patent US 7490794B2



Artist's rendering of a lenticular airship with a central fairing. Source: Walden Aerospace

You can read this patent here:
https://patents.google.com/patent/US7490794

The central fairing provides a convenient space for installing the mass transfer unit (MTU) for pitch and roll stability control, which is described next.

Mass Transfer Unit (MTU) for airship stability control

Starting in the 1970s, Michael Walden invented and later patented several methods for controlling an airship's pitch and roll in flight by moving masses to control the airship's center of gravity relative to its center of pressure. This approach provides pitch and roll stability without requiring movable aerodynamic surfaces or vectoring thrusters.

The US patent process for this invention was not completed until 6 March 2007, when a patent was granted as US 7185848B2, "Mass transfer system for stabilizing an airship and other vehicles subject to pitch and roll moments." You can read this patent here:
https://patents.google.com/patent/US7185848/en

One method described in this patent uses a track-based mass transfer system installed around the equator of Walden's characteristic lenticular airship hull. The space occupied by the MTU also satisfies the need for a central fairing to act as a stall strip to reduce lift and improve stability.

The general arrangement of this mass transfer system (400) is shown in patent Figures 4, which is a top view with four track quadrants (402, 404, 406 and 408) running around the periphery of the airship. Each track quadrant contains one movable mass transfer unit (410, 412, 414 and 416). Figure 5 is a vertical edge view at the equator showing a single mass transfer unit (600) that rides within the track pathway (602). In this particular example, the airship's integrated control system positions the mass transfer unit in each quadrant in response to pitch and roll commands. Other track-based configurations of this system are possible.

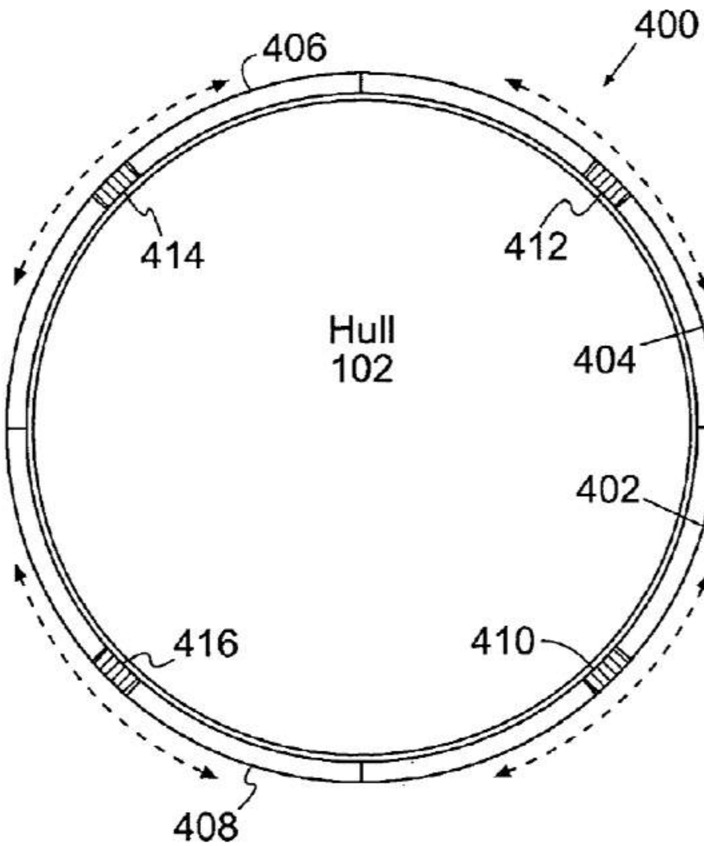


Fig. 4

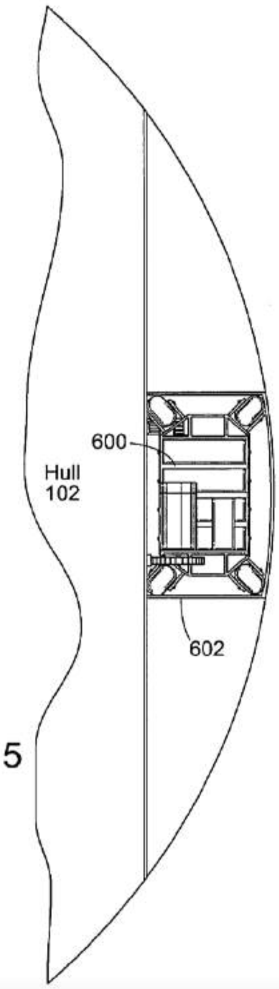
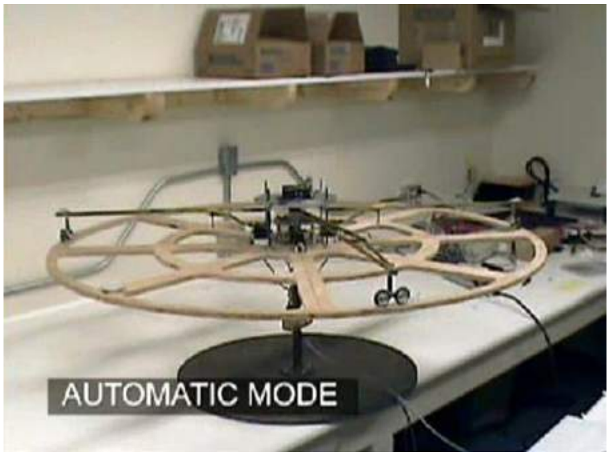


Fig. 5

A subscale bench test unit was built and tested in 2003 to validate this approach for airship pitch and roll control.

This was followed in 2004 with the development and testing of a larger MTU demonstration track and subsequent flight testing in 2007 on the Technology Demonstrator 2 (TD-2) airship.

The 2004 MTU bench test model was designed to demonstrate the operation of a working MTU model and flight control software for holding an airship level or at any operator-selected angle.



The bench test model represents the toroidal track around which the MTUs travel to rapidly implement pitch and roll commands and to stabilize a toroidal airship without using aerodynamic control surfaces for those purposes.

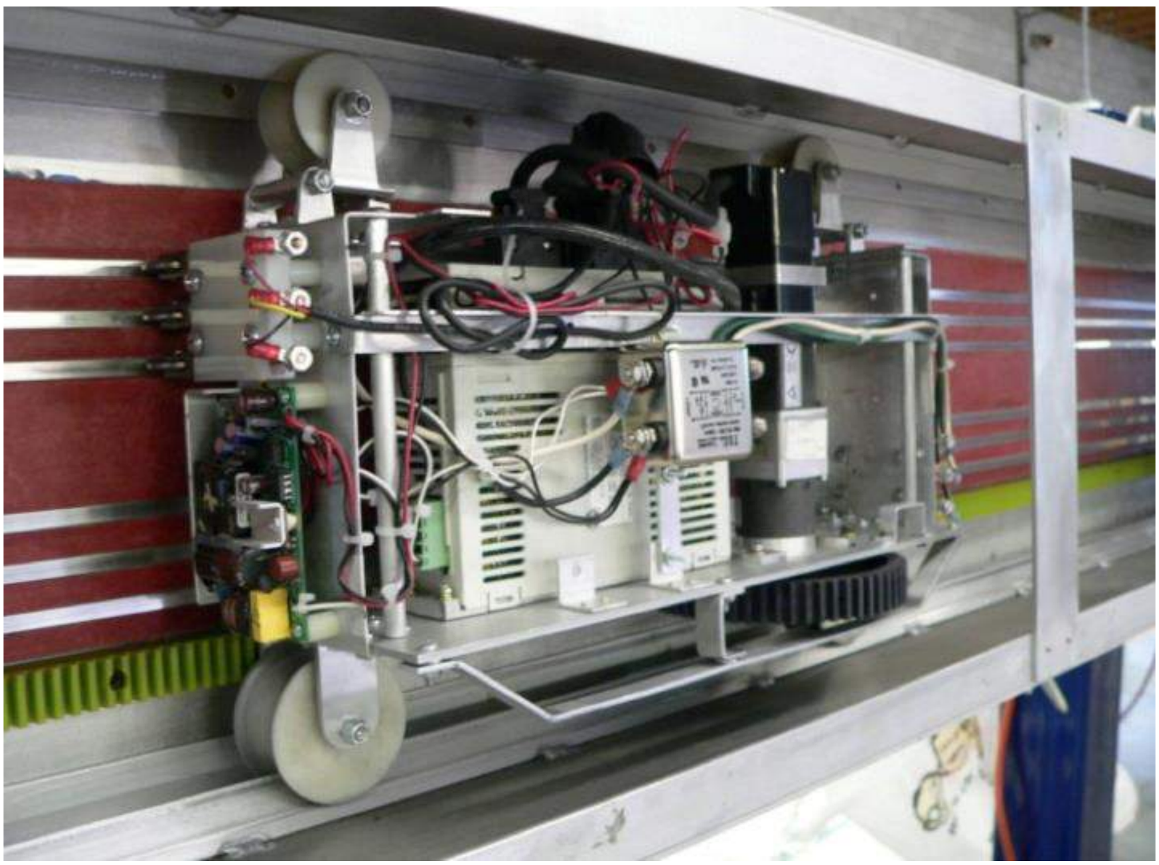
In steady-state flight, the MTU will automatically respond to instantaneous changes in pitch and roll (i.e., from turbulence) and maintain a level attitude during all flight modes (i.e., cruise, hover) and at all operating altitudes.

Here the MTU is responding to a command input from the joystick and has banked the airship.

Source, three images: Michael Walden / Walden Aerospace

You can watch a short video of Michael Walden's bench test model in operation here: https://lynceans.org/wp-content/uploads/2022/10/Walden_Tabletop-StabilityDiscV7.mp4

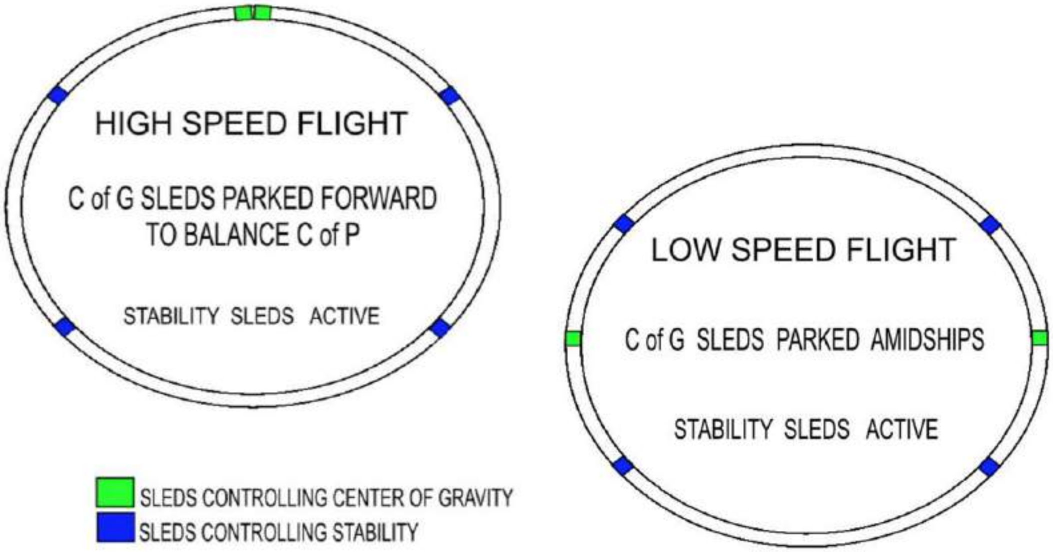
MTU demonstration track segment.



2004 close-up of one MTU demonstration sled installed in the test track.
Source, both photos: Michael Walden / Walden Aerospace

The subscale TD-2 technology demonstrator airship had a flight-weight DCB system and an MTU sled ring housing around the aeroshell equator. The MTU sleds for the TD2 weighed 7 pounds (3.2 kg) each, with the total system sled mass being 28 pounds (27 kg), less than 3% of airship's mass.

TD-2 showing the black equatorial MTU housing.
*Source: LTAS / Walden Aerospace (*circa 2007)



Examples of MTU sled positioning as a function of airspeed.
Source: LTAS / Walden Aerospace

Patent US 7185848B2 describes other mass transfer methods for controlling airship pitch and roll, including the one shown in patent Figure 13, which distributes fluid as needed from a central reservoir to four trim tanks at the periphery of the airship.

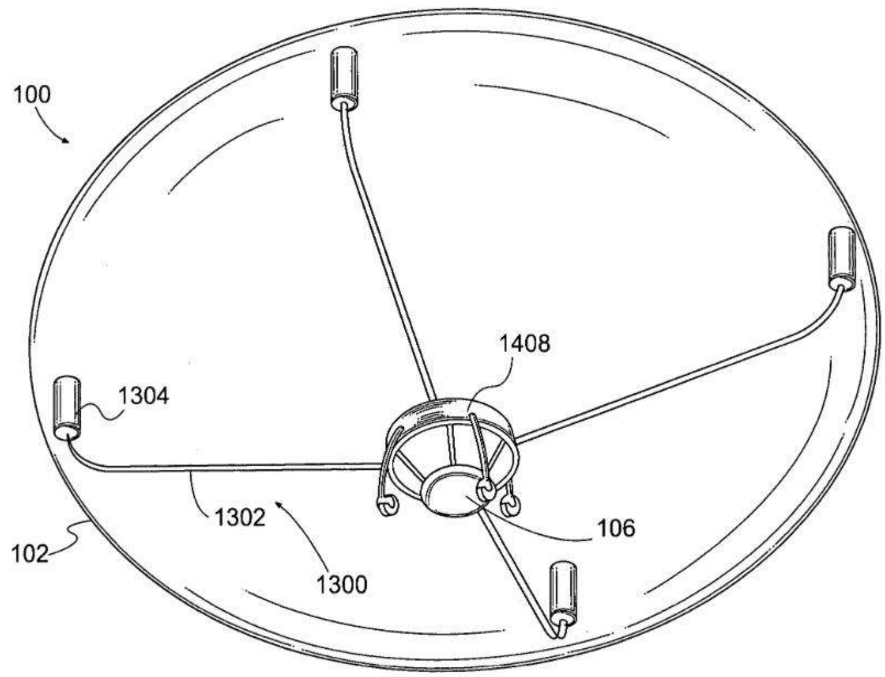


Fig. 13

Related patents and web links (where available) are listed below.

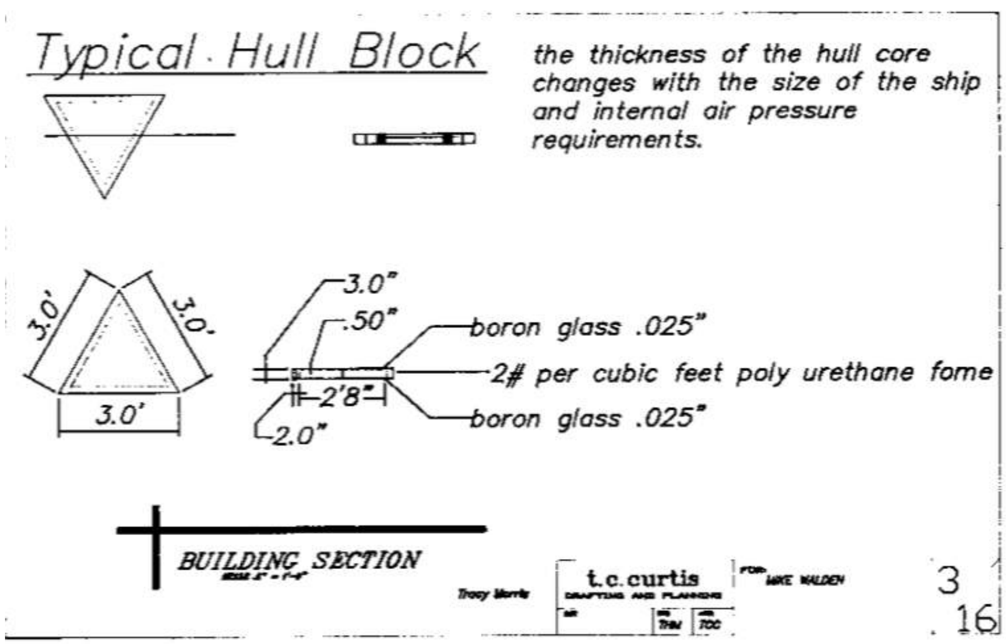
- US2006/0060695A1, granted 6 March 2007: https://patents.google.com/patent/US20060060695/en
- US7350749B2, granted 1 April 2008: https://patents.google.com/patent/US7350749/en
- US7878449B2, granted 1 February 2011: https://patents.google.com/patent/US7878449B2/en
- US 2008/0164370, granted 1 February 2011: https://patents.google.com/patent/US20080164370
- WO2006/085919, published 17 August 2006: https://patentscope.wipo.int/search/en/detail.jsf?docId=WO2006085919
- Additional patents EP 1758788, TW 095109972 and CN 200580017735

Structures for rigid LTA hulls

Michael Walden's original 1979 patent application included details for a novel lightweight, composite, rigid, geodesic structure that would form the structural framework the airship and the aeroshell. No patent resulted from the original 1979 application and LTAS Holdings LLC did not file a new individual patent application for LTA hull structures in 2003 when it re-filed several other individual patent applications. Nonetheless, this section provides an overview of the original geodesic rigid hull design concept that became a feature of later Walden and LTAS airship designs.

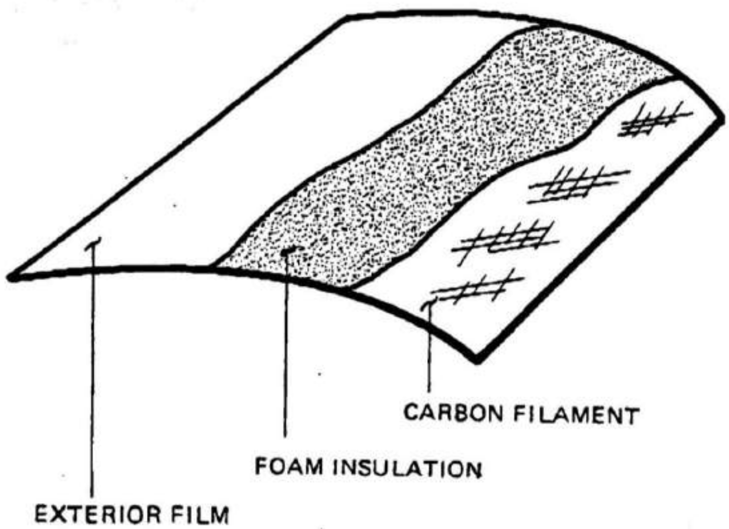
The composite geodesic panel aeroshell is a strong, distributed, load strut system with a smooth aerodynamic exterior surface. This type of aeroshell allows for a more robust and higher speed vehicle that is able to take the aerodynamic loads of high-speed flight and the internal pressure changes inherent in the operation of the DCB system. The rigid aeroshell also allows for the distribution of cargo and propulsion loads over a vast majority of the hull surface, eliminating point loads and weak spots inherent in conventional rigid and non-rigid airship designs.

This type of aeroshell requires only a few types of standardized, modular panels (hull blocks) to complete the geodesic structure.

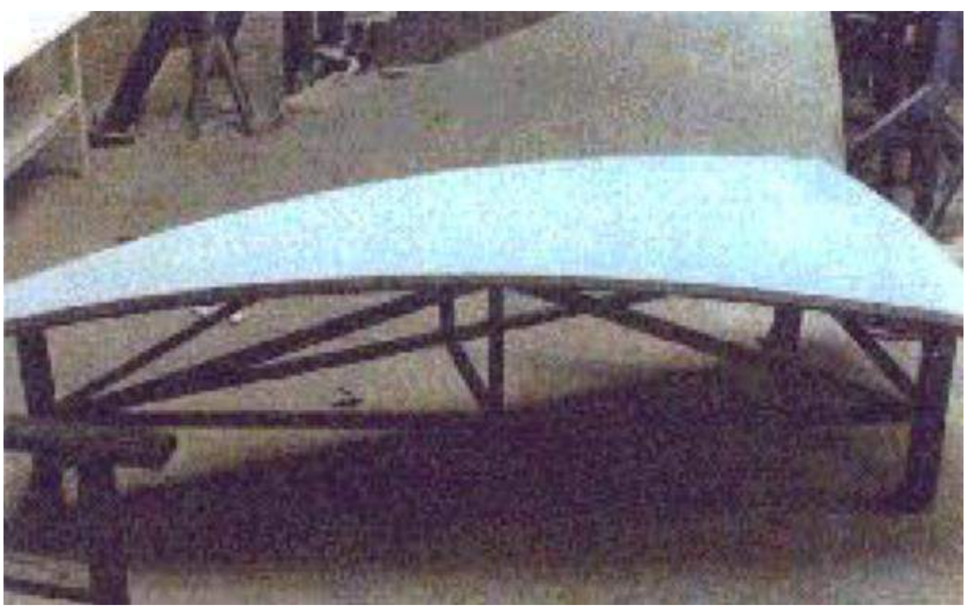


Source: LTAS / Walden Aerospace

The use of the standardized hull blocks simplifies aeroshell scaling and reduces the cost and time of construction. Individual panels can be replaced, thereby simplifying maintenance and improving the overall durability of the aeroshell. Panel face materials can be selected for ship service environments. For example, thin film solar panels can be installed across the top of the aeroshell while other materials can be selected for the sides and bottom of the aeroshell. One face material described in the original patent application is shown below.



Source: LTAS / Walden Aerospace



A rigid hull block. Source: LTAS / Walden Aerospace

An assembled rigid, geodesic aeroshell panel.
Source: LTAS / Walden Aerospace

Regarding the rigid monocoque aeroshell, Michael Walden reported:

- "These boron glass and polyurethane foam core sandwich panels include a molded-in geodesic rib structure. Besides being light, strong, and eliminating a tubular frame structure and gas cells, this structure is almost transparent to most types of detection equipment, and has very good thermal insulation properties for providing constant lift gas temperatures."
- The structural panels are pre-formed, and hull construction should be rapid and fairly simple. Construction time for a 120-foot (36.6-meter) diameter rigid airship (i.e., the LTAS Tourer-90 airship) was estimated to be 6 to 8 months.
- The rigid monocoque hull keeps its form with the internal lifting gas volume at atmospheric pressure or at a slight superpressure (slight positive pressure inside).

Walden developed the SIZ computer code to establish the displacement sizing of an airship and the corresponding strut lengths and geodesic design for the rigid frame structure. This design process was validated in the 1980s in the designs of the full-size SPACIAL MLA-24-A, -32-A and -32-B rigid airships, which all had a geodesic hull framework.

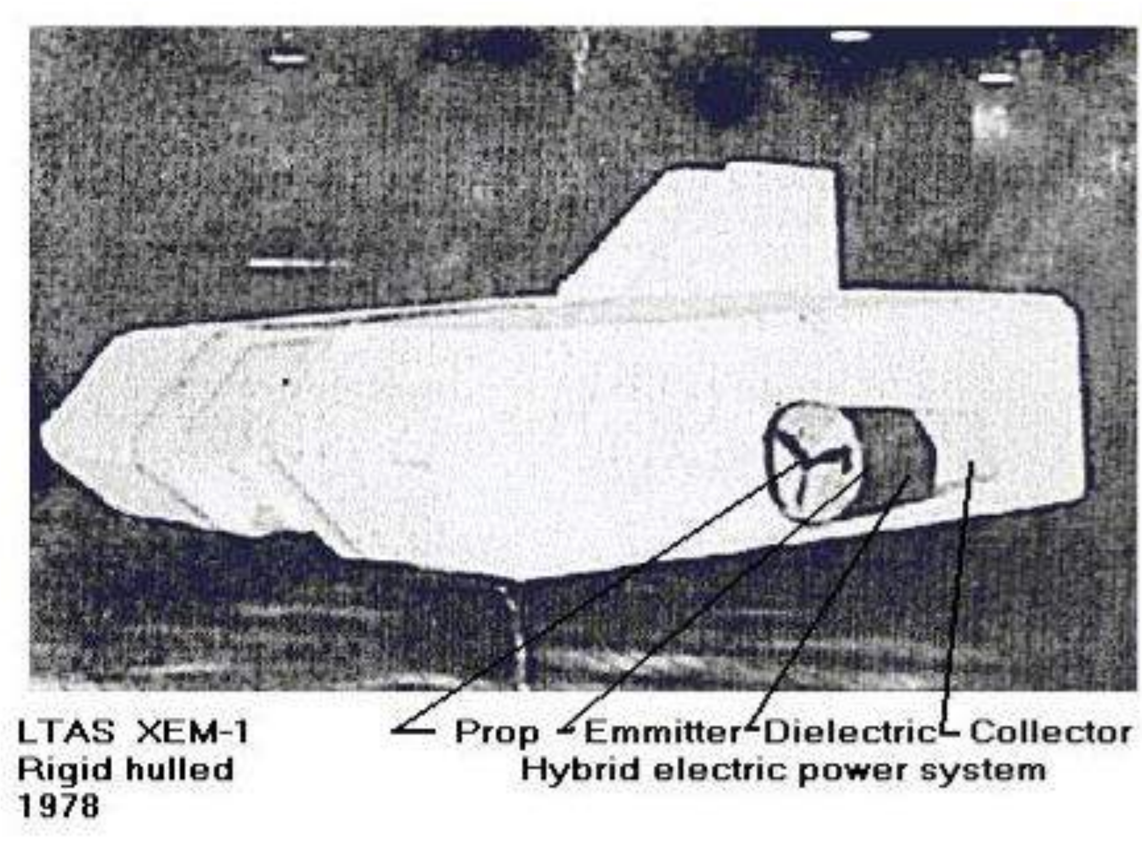
Walden estimated that the lenticular hull form is 9% to 14% lighter per volume than a conventional elliptical or cylindrical rigid hull. The elimination of aerodynamic fins and their support structures provides another 3% to 4% savings when replaced by Walden’s Mass Transfer Unit (MTU) for stability control. Walden reported that this 12% to 17% airship mass savings enabled the DCB (variable buoyancy control system), which adds about 10% of the mass of the airship, to be implemented without having to increase lift volume or reduce payload relative to a conventional airship.

3. The subscale airship demonstrators (1974 – 2007)

For more than 30 years, Walden and LTAS developed and tested a broad range of subscale demonstrator airships to validate design features and develop performance parameters for these features. Following is a chronological synopsis of these test vehicles.

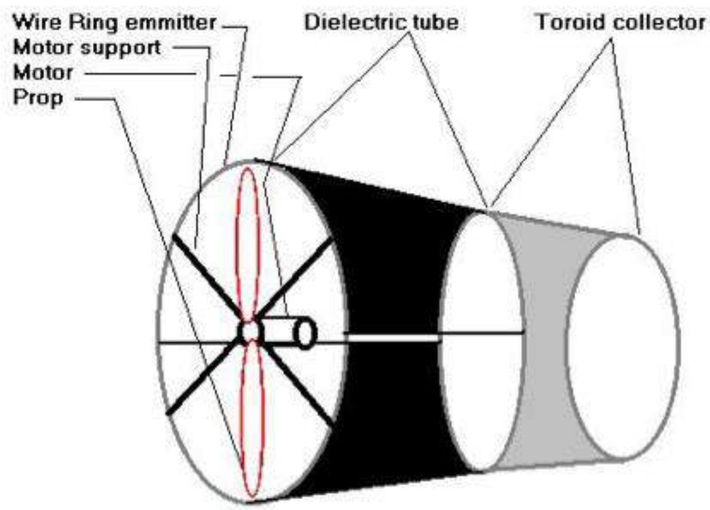
XEM-1 (1974 to 1977)

The XEM-1 was built in 1974 as a subscale proof-of-concept demonstrator for a solar-powered airship with a rigid, composite (foam laminate) hull and an ionic airflow electro-kinetic (IAF/EK) propulsion system. It measured 6 ft (1.8 m) long, 4 ft (1.2 m) wide and 2.5 ft (0.76 m) tall with a gas volume of 60 ft^3 (1.7 m^3), gross lift of 3.0 lb (1.4 kg) and gross weight 2.2 lb (0.8 kg).



XEM-1 general arrangement. Source: LTAS / Walden Aerospace

The MK-1 IAF/EK ducts on the sides of the airship model had 10 inch (3.9 cm) “bent tip” propellers and were a little over 1 foot (4.7 cm) long. The solar power system generated 7 watts of power, which enabled a maximum speed of 4 mph (6.4 kph) with the IAF/EK propulsion system.



MK-1 ionic IAF/ EK drive. Source: LTAS / Walden Aerospace.

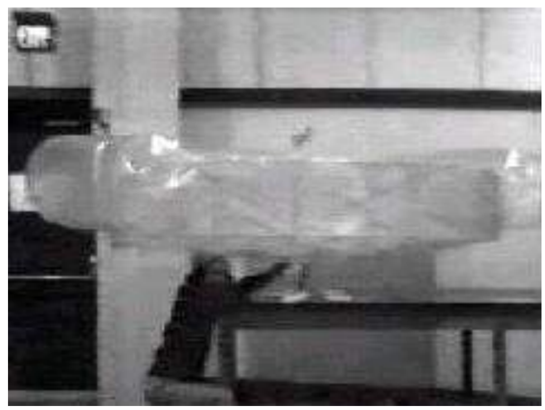
Walden reports, “We flew the first fully solar powered rigid airship (the XEM-1) in 1974, followed by a US Department of Defense and Department of Energy flight demonstration in August 1977”…. “ DoD was interested in his work to the extent that some of it is still classified despite requests for the information to become freely available.”

Walden credits the XEM-1 with being the first fully self-contained air vehicle to fly with a hybrid ionic airflow electro-kinetic propulsion system. This small airship also demonstrated the feasibility of a rigid, composite, monocoque aeroshell, which became a common feature on many later Walden / LTAS airships.

XEM-2 (1978)

The XEM-2 was a subscale, rigid, remotely-controlled, lenticular airship designed to demonstrate the feasibility of long-duration, solar-powered airship flight. It measured 8 ft (2.4 m) in diameter and 2.5 ft (0.76 m) in height, with a gas volume of 120 ft^3 (3.4 m^3), a gross lift of 6 lb (2.7 kg) and a gross weight of 4.2 lb (1.9 kg). Solar panels on the top of the hull provided 10 watts of power. Small electric motor-driven thrust vectoring ducted fans under the hull enabled a maximum speed of 6 mph (9.7 kph).

On its longest flight, the XEM-2 stayed aloft at an altitude of 15 ft (4.6 m) for three months and three days, from 15 February to 18 May 1978. At that time, that was an unofficial flight duration record. Very slow lift gas cell leakage into the outer hull required “topping off” the lift gas cell about once a week. The XEM-2 remained airborne during this operation.



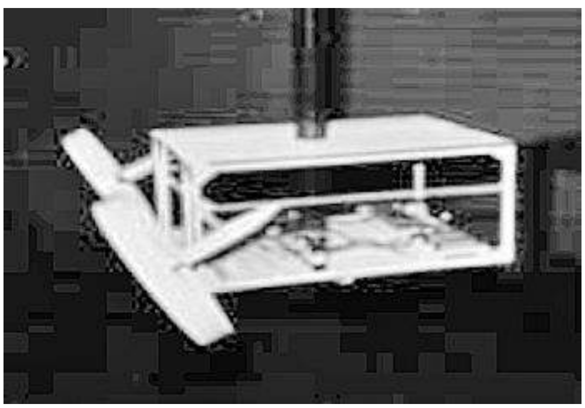
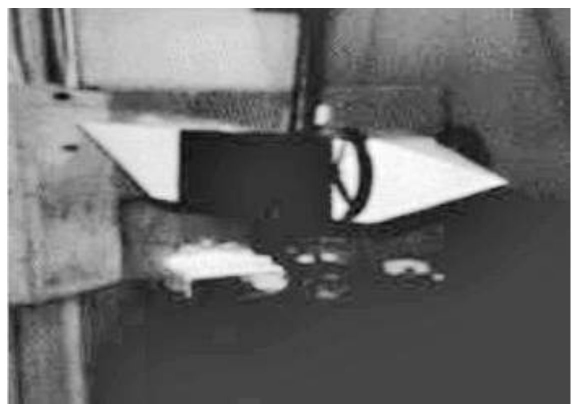
LTAS XEM-2 subscale solar powered airship showing gas cell and internal frame structure (left), which was later covered with a foam laminate rigid outer hull. Note the person under the hull (right). Source: LTAS / Walden Aerospace

XEM-3 (1979 - 1980)

This was the first flying model airship with a lenticular, rigid, composite, monocoque hull and a density controlled buoyancy (DCB) system. The rigid, foam laminate hull also served as the lifting gas envelope. There were no gas cells within the hull.

The XEM-3 measured 12 ft (3.7 m) in diameter, 4.5 ft (2 m) in height, with a volume of 450 ft^3 (12.7 m^3), a gross lift of 25 lb (11.3 kg), and a gross weight of 10 lb (4.5 kg). Solar panels on the top of the hull generated 40 watts of power, with energy storage in a motorcycle battery.

Two thrust-vectoring, electric motor-driven ducted fans attached to the gondola enabled a maximum speed of 16 mph (25.7 kph). The DCB pump and airship electronics also were housed in the gondola.

Two views of the XEM-3 gondola (shown under construction) with ducted props vectored downward (left) and in the horizontal cruise position (right). Source: LTAS / Walden Aerospace

The free-flying, remotely-controlled XEM-3 was flown from 1979 to 1980.

Michael Walden reported: “Development of the XEM-3 was supported by the Stratosphere casino. After testing, it was delivered to the casino. An inexperienced worker attempted to fill the hull without opening the pressure relief valve (as instructed) using a high pressure tank, causing the hull to split along one of its seams (in a loud explosive report)... the casino declined to rebuild it.”

XEM-4 (1981 - 1990)

XEM-4 was a remotely controlled, subscale, rigid airship model with a fabric covered geodesic frame hull and an internal lift gas cell. It did not have Walden's DCB system. The XEM-4 was designed by Mario Sánchez-Roldan and Michael Walden and was built by Roldan's company SPACIAL in 1981 to support development of a series of full-scale, lenticular, rigid, geodesic hull, conventional airships in Mexico. These were the SPACIAL MLA-24-A, -32-A and -32-B airships.

The XEM-4 measured 19 ft (5.8 m) in diameter, 6 ft (1.8 m) in height, with a gas volume of 800 ft^3 (22.6 m^3) and a gross weight of 30 lb (13.6 kg). The airship had a gross lift of 40 lb (18.1 kg) at the 7,300 ft (2,225 m) elevation of SPACIAL's facility in Lake Toluca, Mexico.

Two petrol-powered engines driving shrouded, thrust-vectoring propellers were attached under the rigid hull, flanking the gondola. The XEM-4 demonstrated fully-aerobatic flight and was capable of a maximum speed of more than 40 mph (64 kph).

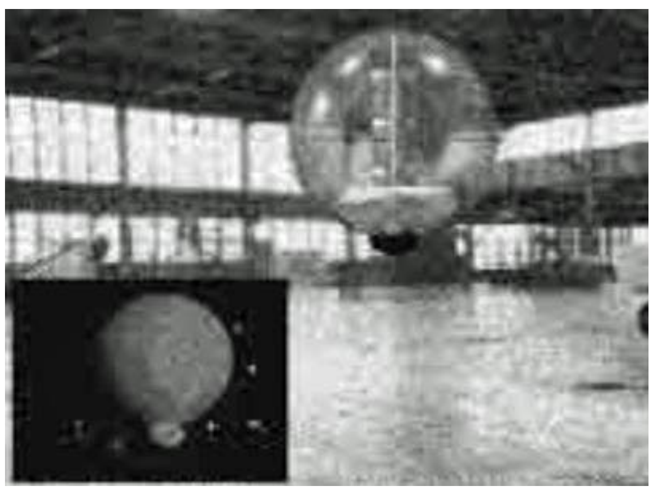
The XEM-4 subscale test model with the full-size SPACIAL MLA-32-B in the background, circa late-1980s. Note the similar triangular geodesic design of the rigid framework of the XEM-4 and MLA-32-B. Source: Walden Aerospace

DCB test unit (late 1980s)

In the 1980s, LTAS developed a larger DCB test unit with a spheroid hull to develop DCB system sizing and performance parameters. Walden reported,

> "Based on our SIZ-2 airship sizing and performance software we expect the average mass of the DCB system that can modify total lift by 25% to 30% is between 10% and 15% of gross lift. In the mid-1990s, a NASA 'GAINS technology development program' built a crude near duplicate of this same demonstrator making three test flights and confirming the LTAS power and mass figures."

Based on the LTAS and NASA tests, it is expected that the DCB system can produce a 25% change in gross lift in 5 minutes.

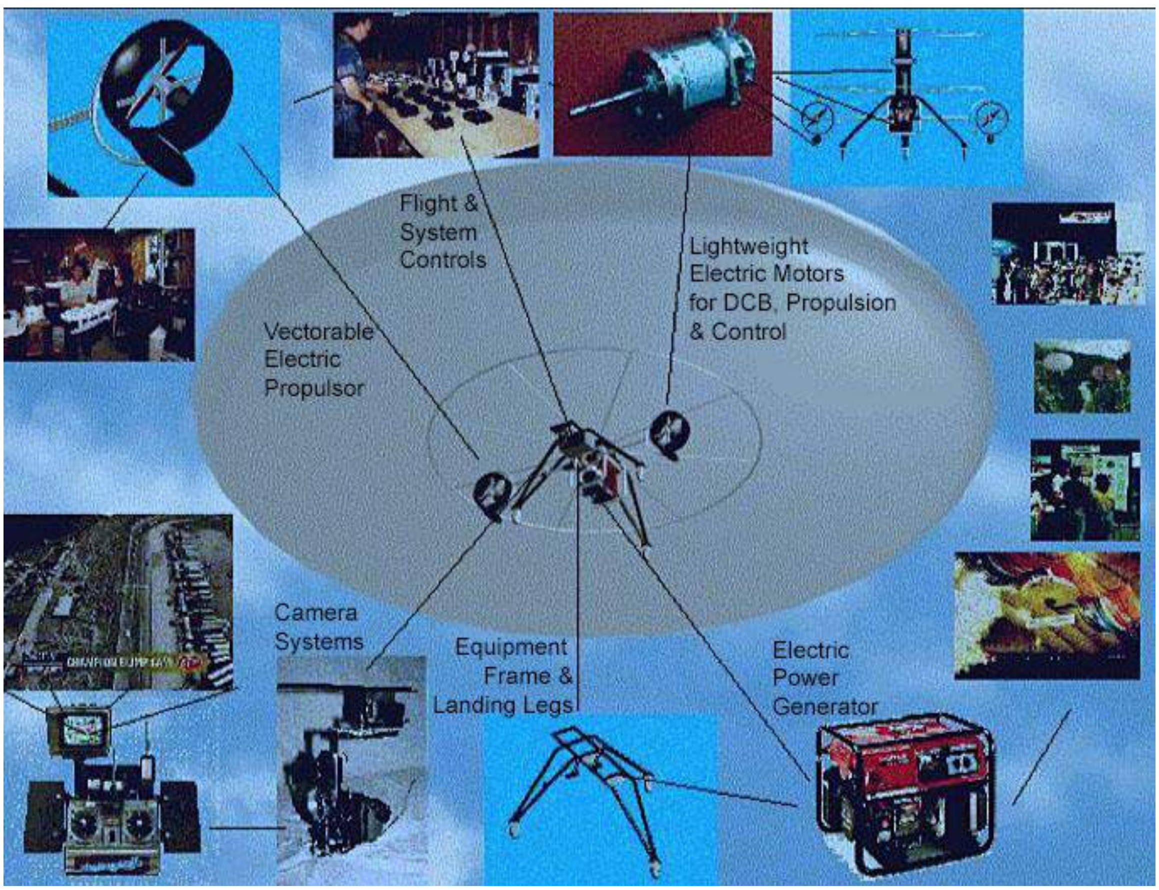


1980s LTAS DCB demonstrator and the very similar
1990s NASA GAINS demonstrator (see insert). Source: NASA

CAMBOT remotely-controlled LTA camera platform (1997)

In 1997, the newly renamed firm, LTAS / CAMBOT LLC, was focused on the development of an unmanned high altitude platform (HAP) known as the CAMBOT. A subscale, 2.5 m (8 ft) diameter, superpressure, proof-of-concept CAMBOT demonstrator first flew in 2001, followed in August 2003 by the first flight of the 3.3 m (10 ft) diameter CAMBOT II. Designs for a full-scale CAMBOT were developed, but the airship did not enter production.

Flight of the 2.5 m (8 ft) diameter, remotely piloted, subscale CAMBOT proof-of-concept vehicle, circa 2001. Source: LTAS / Walden Aerospace



General arrangement of a full-scale CAMBOT and its associated subsystems. Source: adapted from LTAS / Walden Aerospace

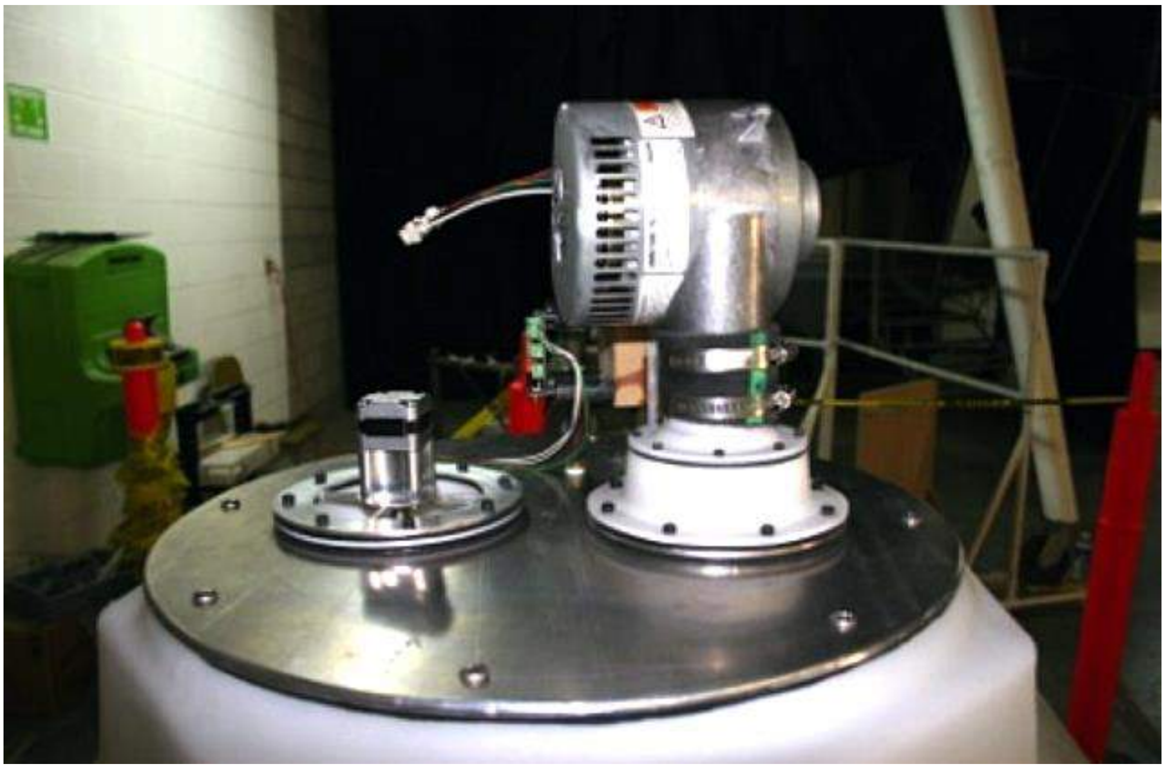
EK-1 skin-integrated electro-kinetic (EK) drive airship (2003)

In June 2003, LTAS rented a hangar at the Boulder City, NV airport to build and fly a remotely controlled, self-powered, skin-integrated EK drive model airship that became known as the EK-1. Testing the EK-1 was concluded in early August 2003 after demonstrating the technology to National Institute for Discovery Science (NIDS) board members.

EK-1 in flight. Source: LTAS / Walden Aerospace

DCB pressure cell bench test (2005)

In 2005, LTAS demonstrated the operation of the DCB system in a bench test that included a helium compressor (pump), helium release valve and a high-pressure helium storage tank that were sized for the Technology Demonstrator (TD-1, TD-2) airship.



DCB bench test unit. Source: LTAS / Walden Aerospace

The bench test unit demonstrated that it could change the aerostatic lift of a small-scale test volume by about +/- 5 pounds (2.3 kg).

Pressure test model (2005)

A subscale pressure test model was designed and built to optimize the distribution pattern and size of the baffles in the air chambers used to keep the airship floating level during DCB volume changes. It also was designed to test the pressure limits of the Vectran fiber reinforced hull material.

The pressure test model was designed to take up to 3.5 PSI of superpressure and was charged / volume changed using a compressed air pump and relief valve / pressure gage. This allowed for different amounts of air to be put into the air cells, changing the helium volume / air mass ratio and thus aerostatic lift. The DCB pressure test flight model was flown indoors.

2005 pressure test flight model tethered indoors.
Source: LTAS / Walden Aerospace

The pressure test model embodied the lenticular airship design described in Walden's patent US2006/0065777A1, "Systems for actively controlling the aerostatic lift of an airship."

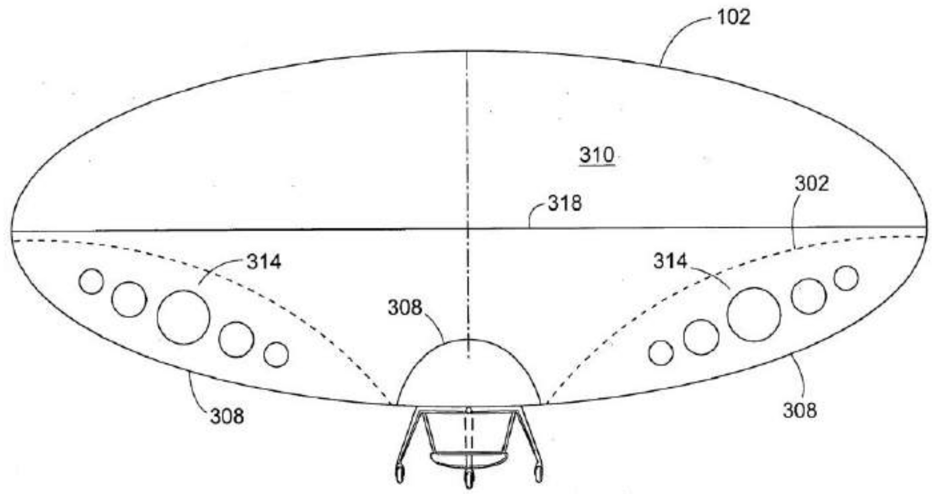


Fig. 3C

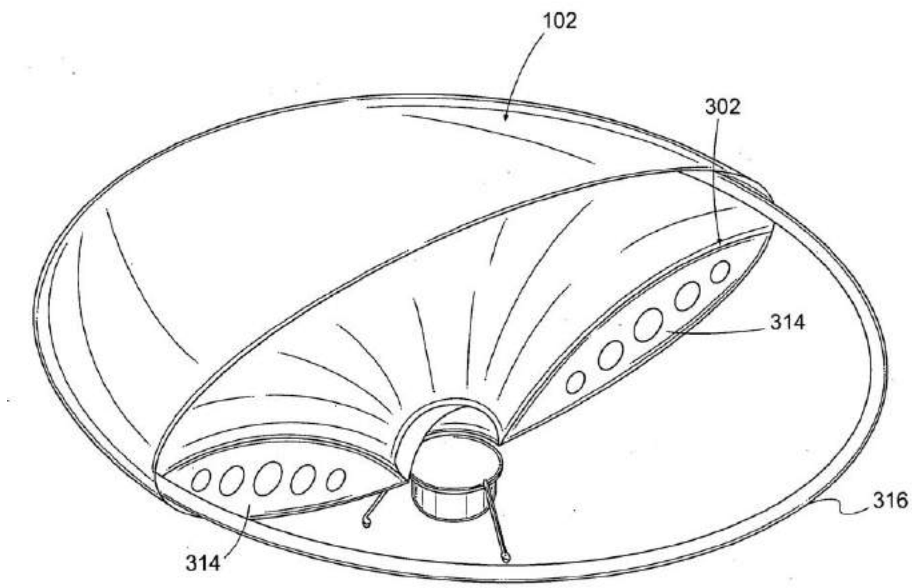


Fig. 3D

Legend: Hull (102), flexible compartment (302), bottom surface (308), lifting gas (310), baffles(314), equatorial ring (316)

Propeller drive control test model (2005)

This small-scale test vehicle had two sets of electric motor-driven propellers mounted on opposite sides of the equatorial ridge of the toroidal airship. The basic configuration of the airship is shown in the following photo. Yaw control is provided at low speeds and hover by differential and reverse thrust from the motors / propellers. At high speeds, yaw control is provided by differentially opening drag rudders on the struts supporting the propellers.

Michael Walden with the propeller drive control test model, circa 2005.

Struts attach the fixed propeller units to the equatorial structure of the airship. Source, both graphics: LTAS / Walden Aerospace

TD-1 / TD-2 Technology Demonstration flight test vehicle (2006 to 2010)

In 2003, a group of foreign investors provided funding to develop and build a large-scale, DCB prototype airship, which originally was intended to be the 30-XB / Technology Demonstrator.

LTAS built a large-scale technology demonstrator (TD) airship known as TD-1 (and later TD-2) to demonstrate the DCB, mass transfer unit (MTU) and advanced propulsion technologies. It was completed after Michael Walden left LTAS in 2005. The TD vehicle had a hull diameter of about 70 feet (20 meters) with a total volume of about 45,000 cubic feet (1,274 cubic meters), which should have provided a gross lift of about 2,000 pounds (907 kg) and a payload capacity of slightly over 500 pounds (227 kg).

This LTAS development work was funded by investors. Several of the key technologies identified in the Defense Advanced Projects Research Agency's (DARPA's) Project Walrus already were included in the TD design. While LTAS submitted a Project Walrus proposal to DARPA in 2004, the firm was not invited to participate in the Phase 1 study contracts, which were awarded to Lockheed and Aeros in mid-2005.

Photo likely showing a TD inside the Bolder City, NV airport hangar rented by LTAS on 19 July 2007, during delivery of helium tanks. Source: LTAS / Walden Aerospace

TD with the MTU track ready to be installed, circa 2007.
Source: LTAS / Walden Aerospace

TD with MTU cover being installed, circa 2007.
Source: LTAS / Walden Aerospace

In 2007, TD-2, with flight-weight DCB and MTU demonstration systems installed, conducted float tests and system tests inside the hangar to demonstrate its basic control capabilities. Portions of these tests are shown in the following two short LTAS videos:

- Pitch controls: https://lynceans.org/wp-content/uploads/2022/10/Walden_MTU_pitching_the_TD2.mp4
- Stability recovery: https://lynceans.org/wp-content/uploads/2022/10/Walden_MTU-stability-recovery-hanger-test.mp4

The tests appear to have validated Walden's MTU as a viable pitch / stability control system for lenticular airships.

The TD-2 may have been flight tested outdoors, but no records of such tests have been found. The TD was not developed further into a flying prototype airship.

Artist's concept drawing of the TD vehicle ready for takeoff, circa 2007. Source: Walden Aerospace

Artist's concept drawings of the TD vehicle in flight, circa 2007.
Source, both graphics: Walden Aerospace

4. Michael Walden’s airship collaboration with SPACIAL S.A.

Starting in 1977, Michael Walden collaborated with Mario Sánchez-Roldan and his airship manufacturing company SPACIAL S.A., located near Lake Toluca, Mexico, to develop a series of full-size, rigid frame, conventional airships. These airships did not include a DCB system or a composite aeroshell as found in other Walden designs. In this collaboration, Sánchez-Roldan was the main designer and engineer. Michael Walden’s primary role was as co-designer of the geodesic rigid framework for the airship’s hull. Walden used his SIZ-3 computer code for establishing the displacement sizing of the airship and the corresponding strut lengths and geodesic design of the frame. SPACIAL financed the design, construction and flight testing of the MLA-series airships and the XEM-4 sub-scale model. No funding was provided by LTAS.

MLA-24-A

The first product of this collaboration was Walden’s 1979 geodesic rigid frame design for SPACIAL’s first airship, the MLA-24-A. SPACIAL’s work on this 24 meter (79 foot) diameter airship started in about 1976, with Michael Walden first becoming engaged in 1977. Work continued until May 1985 when a windstorm destroyed the nearly completed airship and damaged the SPACIAL workshops, all models, and much of the nearby airport. The MLA-24-A was not rebuilt.

XEM-4

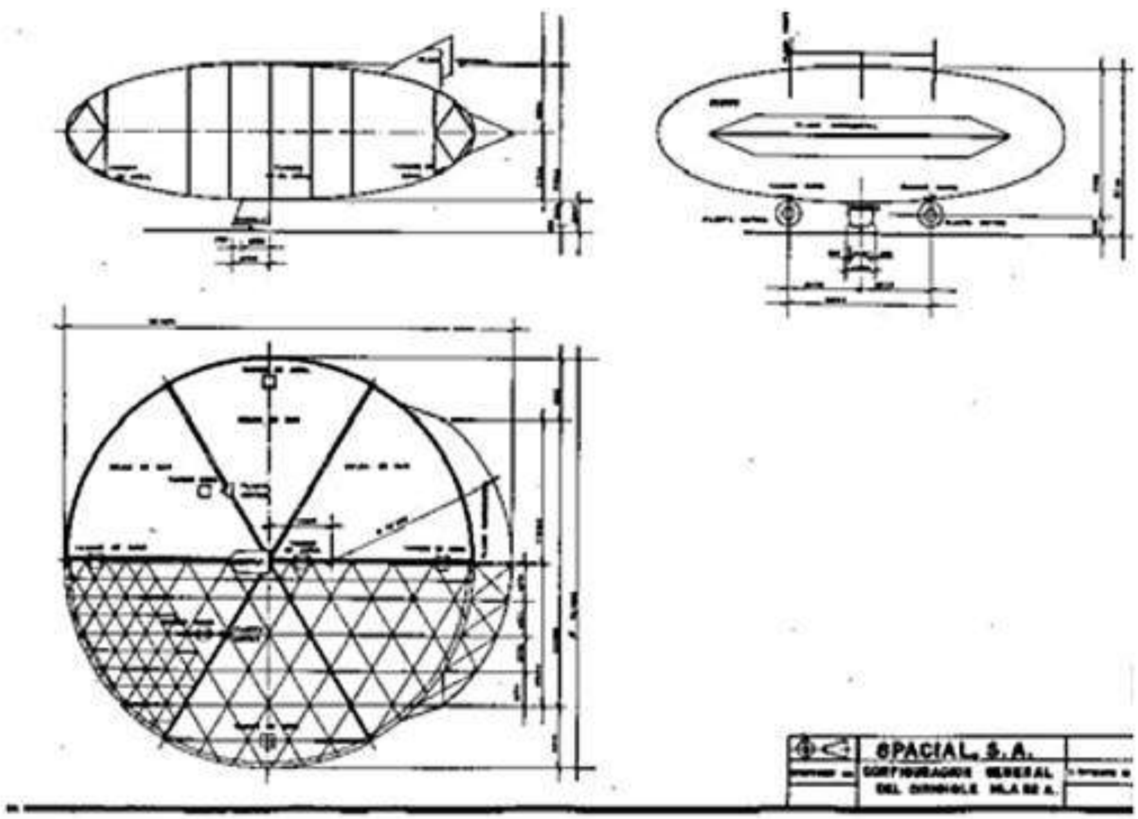
The next collaboration product in 1981 was the XEM-4 remotely controlled, subscale, rigid airship test model, which was described previously. This flying model was used to validate the designs of the MLA-24-A and the subsequent MLA-32-A and MLA-32-B.

MLA-32-A

This scaled-up 32 meter (105 foot) diameter rigid airship was completed in early 1988. It was designed to carry a payload of 3.2 metric ton (3.5 tons) / 20 passengers. In February 1988, after breaking away from its mooring and ground crew on a gusty day, the completed MLA-32-A made a two-hour unplanned, unmanned first flight, reaching an altitude of nearly 6,096 meters (20,000 feet) ASL. The flight ended after a lift gas cell ruptured, leading to a hard landing that damaged the gondola.

MLA-32-B

Repairs to the MLA-32-A were initiated in 1988 and the updated airship, with several important design changes, was renamed the MLA-32-B.



SPACIAL three-view drawing of the MLA-32-B. Note the geodesic frame design in the top view. Also note the "beaver-tail" extension at the stern of the rigid hull. Source: Walden Aerospace

The first manned flight took place on 24 June 1989, when the SPACIAL MLA-32-B became the first new manned rigid airship to fly in over 50 years. The MLA-32-B also was the first large lenticular airship to make a successful flight. These milestones were key results of the collaboration between Mario Sánchez-Roldan and Michael Walden.

A short video clip of the MLA-32-B first flight is included in a 1997 Las Vegas TV Channel 3 interview with Michael Walden.

The MLA-32-B made daily flights for a week during the 1990 World Cup soccer finals in Mexico City, advertising a Mexican potato chip company and being seen by millions of people.

On its last flight in 1990, the MLA-32-B had an engine problem and was forced to make an emergency landing in an open field occupied by Aztec farmers, who attacked and destroyed the airship.

Stern quarter view of the rigid, lenticular MLA-32-B on the ground, under the control of its ground crew. Source: Walden Aerospace

Sanchez-Roldan died in a car accident a month later. Walden's collaboration with SPACIAL ended at about that time.

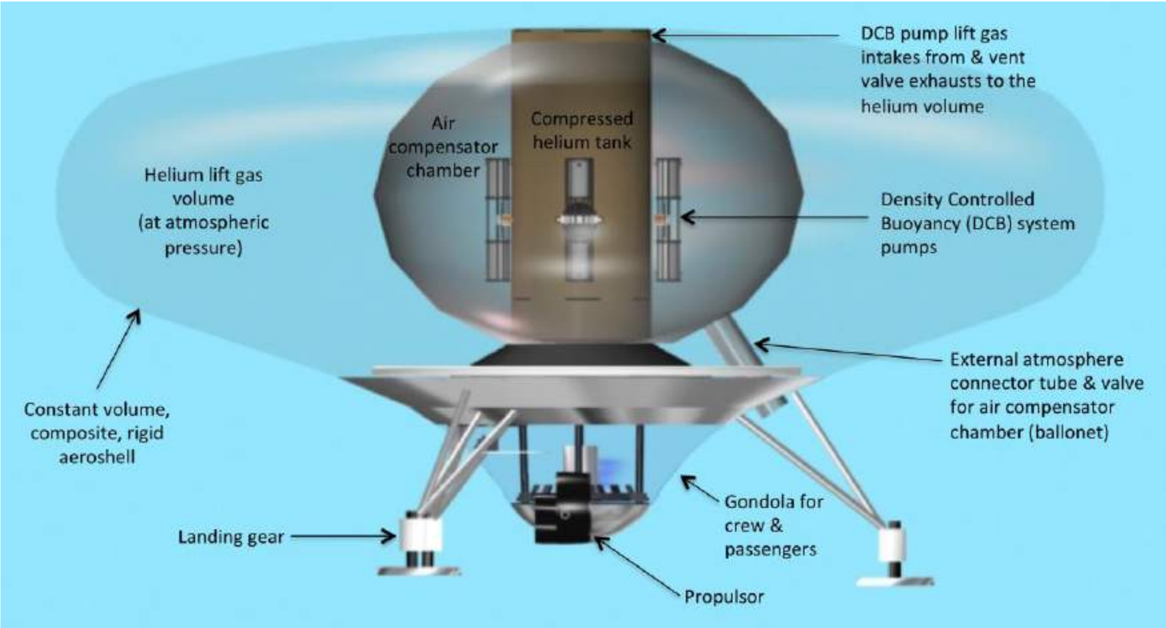
The collaboration helped validate the SIZ airship design code and some of the lenticular, rigid hull design features favored by Walden / LTAS. The SPACIAL airships were about 80% of the size envisioned by Walden / LTAS for their own T-90 Tourer airship that was proposed for Grand Canyon tourism.

See my separate article on SPACIAL airships for more information on the sub-scale XEM-3 and their full-scale airships.

5. Michael Walden's lenticular toroidal DCB airship design concepts

The generic lenticular DCB airship

The generic design of Walden's characteristic rigid, lenticular, "infinite edge" toroidal airship is shown in the following cut-away diagram.



Cross-sectional view of the generic lenticular infinite edge toroidal airship. Source: Adapted from Walden Aerospace

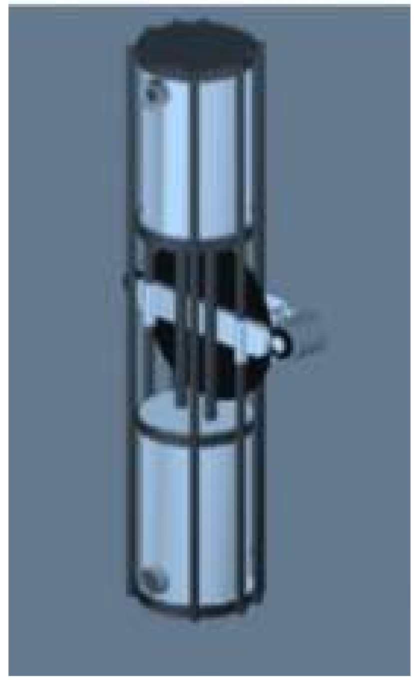
The piloting station and passenger accommodations are in the gondola under the broad, composite, rigid aeroshell. The lenticular airship design presents a uniform cross-section to the wind from all directions, making it insensitive to changing wind direction and simplifying airship handling. This feature is particularly important during precision vertical takeoff and landing (VTOL) operations.

The density-controlled buoyancy (DCB) system enables the airship's VTOL capability. The DCB is housed entirely within the aeroshell and consists of the helium lift gas cells (light blue), the air compensator chamber (light grey) that functions as a ballonet and draws air from and vents air to the atmosphere, the compressed helium tank (in the center), and the helium pressure control components (pumps and valves) attached to the tank.

Artist's rendering of the generic lenticular, toroidal,
infinite edge airship in flight.

Artist's rendering of the generic lenticular, toroidal, infinite edge airship
after an unsupported landing at a remote site.
Source, both graphics: LTAS / Walden Aerospace

With the DCB system, ascent rate is limited by helium vent valve sizing and can be at over 2,000 feet per minute. Descent is limited by helium pump capacity and is expected to be about 1,000 feet per minute. These are DCB-only rates and do not include any contributions from a vectored thrust propulsion system. The DCB positive displacement pumps have a lightweight composite construction and operate at a relatively low RPM. As shown in the cross-section of the generic airship (above), there are several pump modules installed around the central compressed helium tank. An individual pump module is shown in the graphic on the right.



DCB pump. Source: LTAS / Walden Aerospace

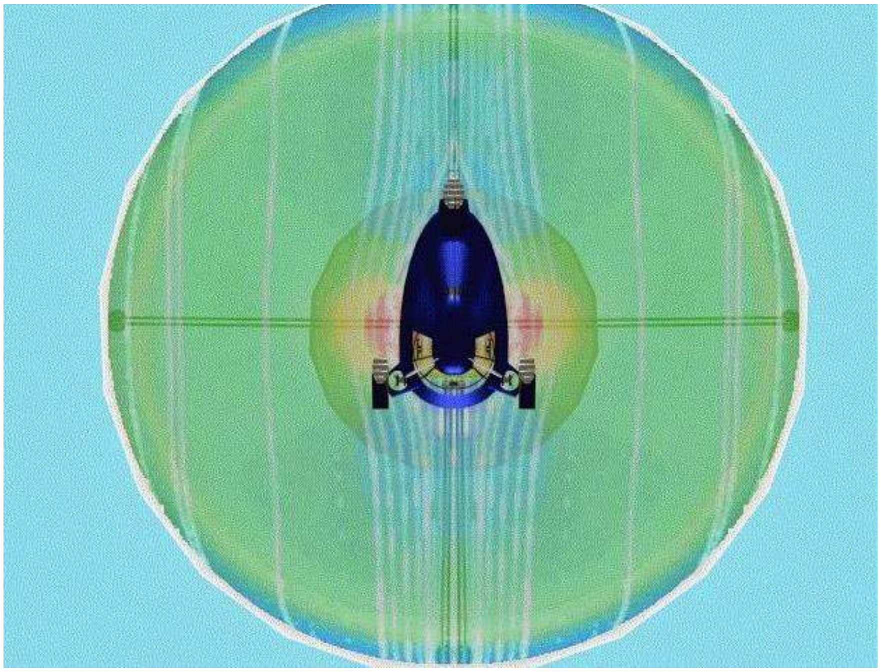
Thrust vectoring propulsors can be installed on the aeroshell or gondola in a variety of locations. In the cross-section of the generic airship (above), the propulsors are attached to the base of the gondola. Other design concepts show propulsors mounted at or near the equator (rim) of the aeroshell.

Thin film solar panels can be installed on about 75% of the top of the rigid aeroshell to supply electric power for an all-solar power system or as part of a hybrid solar-electric power system. Unlike conventional airships with cylindrical hull forms, the lenticular hull form has a relatively flat top surface that enables the same amount of power to be generated regardless of the direction of flight relative to the sun.

With certain operational restrictions, the solar array can provide sufficient power for an airship to operate indefinitely in a solar power only mode. For example, the 1982 LTAS 222-PAD airship design concept with a 200-foot (61 m) diameter solar array was capable of generating a maximum of 440 kilowatts of electric power, enabling a solar-only cruise speed of 46 knots. Higher speeds were possible with supplementary power from a hybrid electric power system.

The aerodynamic characteristics of the rigid, toroidal, infinite edge aeroshell were validated in wind tunnel tests and computational fluid dynamics (CFD) analysis.

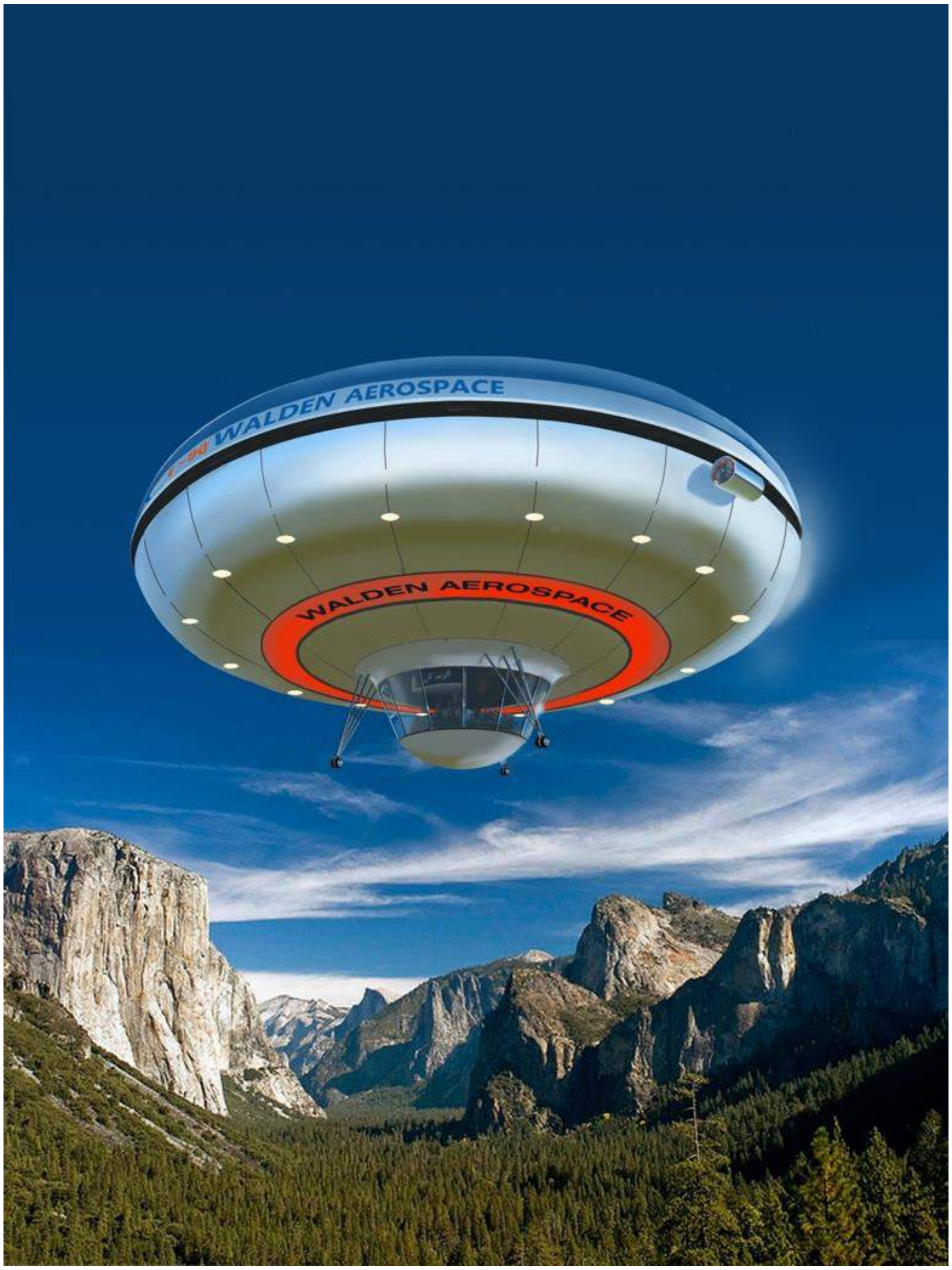
Wind tunnel model circa 2004.



One view from CFD model circa 2004, showing the airship gondola and hull viewed from below. Source, both graphics: LTAS / Walden Aerospace

The T-90 Tourer

Development of the T-90 with DCB began in 1990. This is a 120-foot (36.6-meter) diameter, 56-foot (17-meter) high, rigid, lenticular airship. The carbon fiber and composite aeroshell has a volume of 508,000 cubic feet (14,385 cubic meters) and an estimated service life of 10 – 15 years. The T-90 has a gross payload capacity of 9,000 pounds (4,082 kg) and is intended primarily for sightseeing tourism with a 24-passenger capacity plus crew.



Source: LTAS / Walden Aerospace

The two-level gondola, with large 360° panoramic windows, carries passengers on the lower level, with a two-person piloting station on the upper level.

Operating altitude is 1,000 – 10,000 feet (305 – 3,050 m) at a cruise speed of 40 – 60 knots, propelled by two 300 bhp (224 kW) electric propulsors mounted at the rim of the toroidal hull. The hybrid power system uses solar power from thin-film panels on the top surface of the hull, supplemented by two 300 bhp (224 kW) biodiesel engines.

Two-level gondola configuration. Source: LTAS / Walden Aerospace

The Las Vegas Sun ran a two part article on 7 June 1997 and 9 June 1997 reporting favorably on Michael Walden's airship design and an LTAS proposal to operate a solar-powered, all-electric, quiet T-90 airship on scenic tours over the Grand Canyon. You can watch a short (2:12 min) Las Vegas TV Channel 3 video interview with Michael Walden from the same period here: https://lynceans.org/wp-content/uploads/2022/10/Video-interview-with-Michael-Walden-circa-1997.mp4

Walden prepared a comparative economic analysis of the T-90 Tourer in his 2002 paper, "A Comparison of Modern Airship Designs for the Aero / Eco Tourism Market." In that paper, Walden noted that the T-90's rigid geodesic hull design had been validated on the SPACIAL MLA-32-B airship, which flew in Mexico in the 1980s. The MLA-32-B had a payload of 3.2 tons (20 passengers) with a hull that was 80% of the size of a T-90. While the T-90 is only a modest scale-up from the MLA-32-B, it offers major technical advancements through the use of composite rigid hull panels, a DCB active aerostatic lift control system and an MTU stability control system.

The design of the T-90 Tourer, circa 2003, is shown in the following two photos of a small static display model.

Source, three photos: LTAS / Walden Aerospace

The 222-PAD and 30-XB

In 1982, LTAS evaluated designs for a USCG Patrol Airship Demonstrator (PAD) capable of carrying a gross payload of 30,000 pounds (13,608 kg) and sized for an operating altitude of 11,000 feet (3.3 km). The USCG PAD missions included border patrol, fisheries patrol, drug interdiction and naval fleet support / anti-submarine warfare (ASW) / airborne early warning (AEW). LTAS determined that a conventional non-rigid airship with those capabilities would have an estimated length of 456 feet (139 m) and a diameter of 114 feet (34.7 m), and also determined that there were no previous airship designs that could accomplish this mission.

The USCG requested that LTAS submit a proposal for a new design that would meet or exceed the PAD mission parameters. The result was the LTAS 222-PAD, which had a lenticular, rigid, composite hull, a DCB system, an internal gondola and multi-axis thrusters. With a diameter of 222 feet (67.7 m) and a height of 60 feet (18.3 m), the 222-PAD was sized between the T-90 Tourer and the T-280. The 200-foot (61 m) diameter solar array on the top of the rigid aeroshell was capable of generating a maximum of 440 kilowatts of electric power, enabling a solar cruise speed of 46 knots. Speeds of more than 90 knots were possible with supplementary power from a hybrid electric power system. This LTAS design is described in more detail here: https://lynceans.org/wp-content/uploads/2020/12/Walden_30-XB-and-222-PAD.pdf

The USCG did not award a contract for a 222-PAD airship. In the 1990's, LTAS submitted a more advanced, smaller airship design to the USCG. This was the 30-XB.

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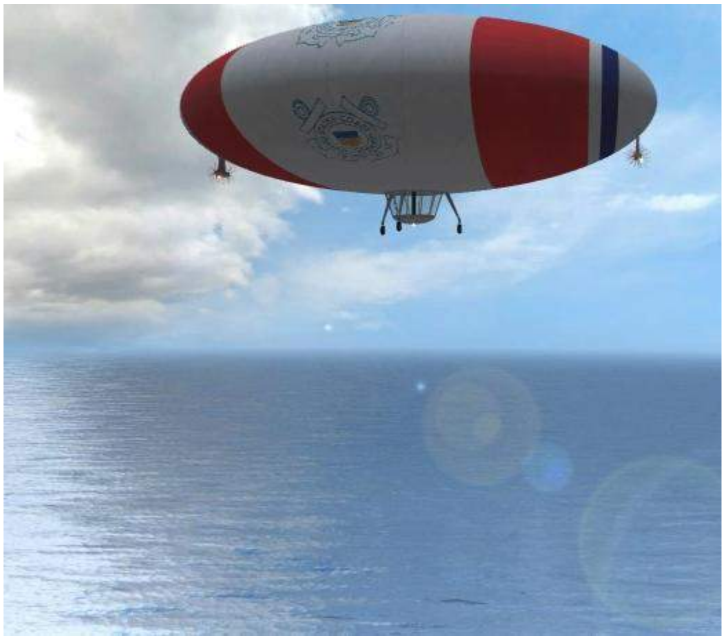
Artist's concept of a 1982 USCG 222-PAD design. Source: LTAS / Walden Aerospace



Development of the 30-XB with DCB began in 1995, in parallel with the T-90 Tourer, and continued until about 2004.

The 98-foot (30-meter) diameter 30-XB was designed with a 5 ton (10,000 lb, 4,536 kg) payload capacity and accommodations for a crew of 2 to 6 persons on patrol missions and for airship pilot training.

These artist concept drawings show the 30-XB in a US Coast Guard color scheme. Note the external gondola under the aeroshell and two electric propulsors mounted under the rim of the rigid hull.

Source, both graphics: LTAS / Walden Aerospace

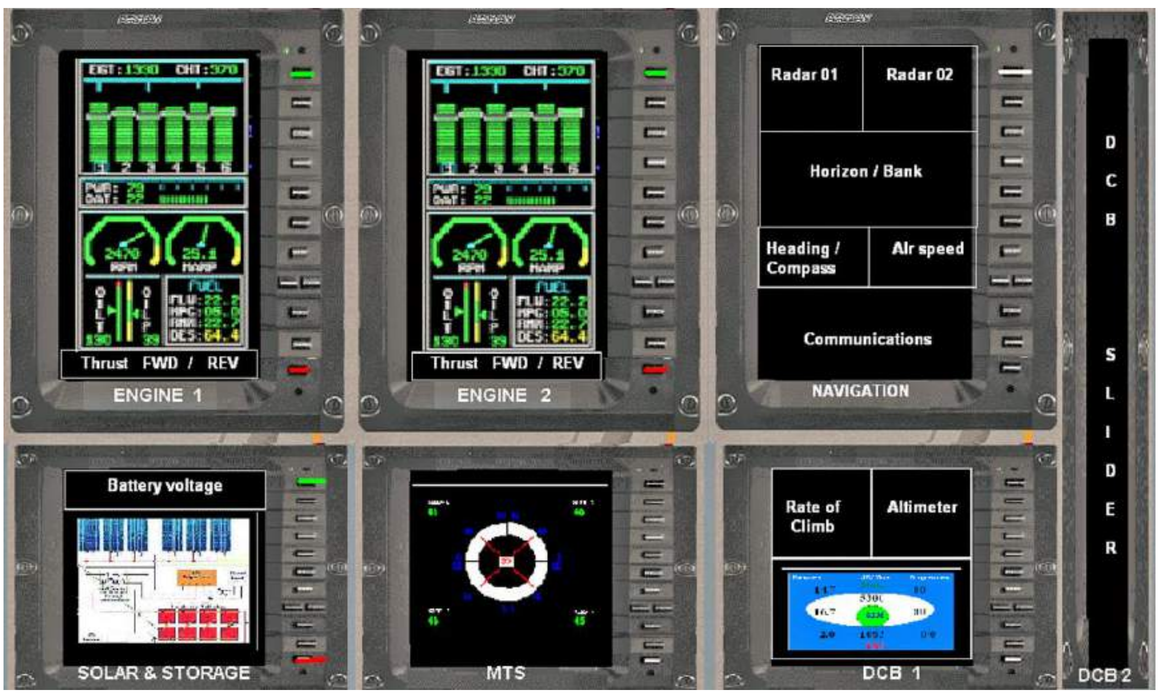
The 30-XB cruise speed on solar power alone was faster than a USCG cutter and, at a cruising altitude of 5,000 to 10,000 feet (1,524 to 3,048 meters), the airship’s search range to the horizon was much greater. On a normal patrol, the 30-XB could search nearly three times the ocean area of a cutter. If hybrid propulsion were used to supplement solar power, the 30-XB could operate at higher speeds and cover larger areas.

General arrangement of the 30-XB gondola, circa 2004.

Model of 30-XB gondola, circa 2004.
Source, both graphics: LTAS / Walden Aerospace

A full-scale 30-XB gondola and a flight simulator were built to help validate the design. There were plans to mount the gondola on the LTAS Technology Demonstrator (TD-1 / TD-2) airship. The USCG did not award a contract for development of the 30-XB.

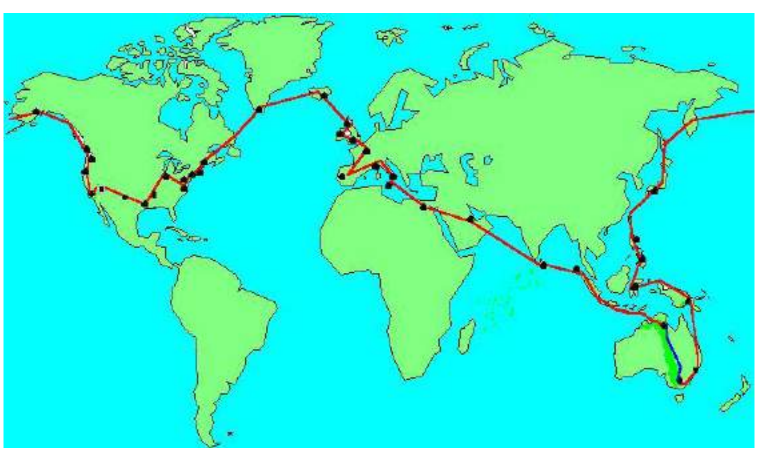

Left: Full size six-person 30-XB static test gondola, circa 2004.
Right: 30-XB co-pilot station showing the side stick controller.



30-XB control panel in the flight simulator. Note the displays for the density controlled buoyancy (DCB) system, mass transfer system (MTS) for pitch & roll stability, and solar & battery storage system.
Source, three graphics: LTAS / Walden Aerospace

Artist's concept of a USCG 30-XB in flight.
Source: LTAS / Walden Aerospace

The 30-XB was intended to fly during the Solar Challenge in Australia with the goal of participating in a solar airship race. In addition, the first round-the-world tour with a solar-powered airship was planned: The Solar Saucer Tour. LTAS did not participate in the Challenge or conduct the Tour.

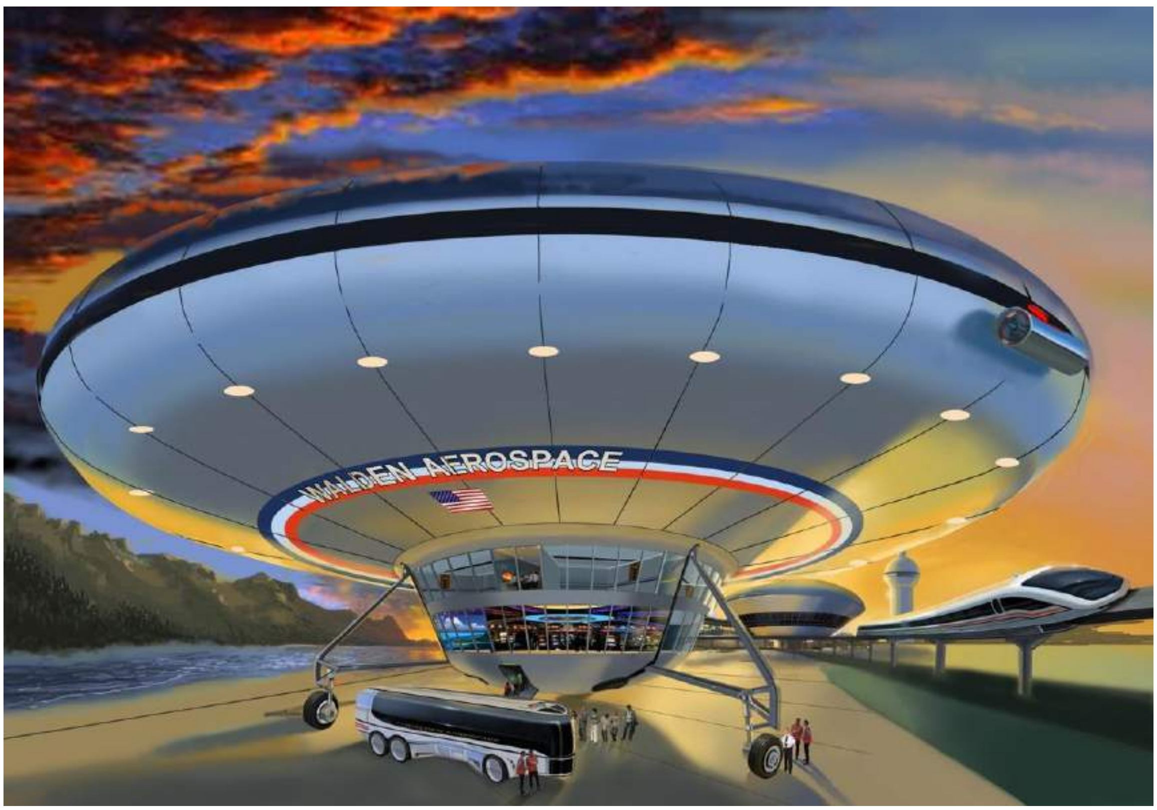


LTAS Solar Tour map. Source: LTAS / Walden Aerospace

The T-280

Development of the T-280 with DCB began in 1996. The 280 foot (85 meter) diameter T-280 is more than double that of the T-90, with a larger gross payload capacity of 39 tons and longer range.

As with the T-90, the hybrid power system uses solar power from thin-film panels on the top surface of the hull, supplemented by two biodiesel engines as needed. Propulsion is provided by two 300 bhp (224 kW) electric propulsors mounted at the rim of the toroidal hull.

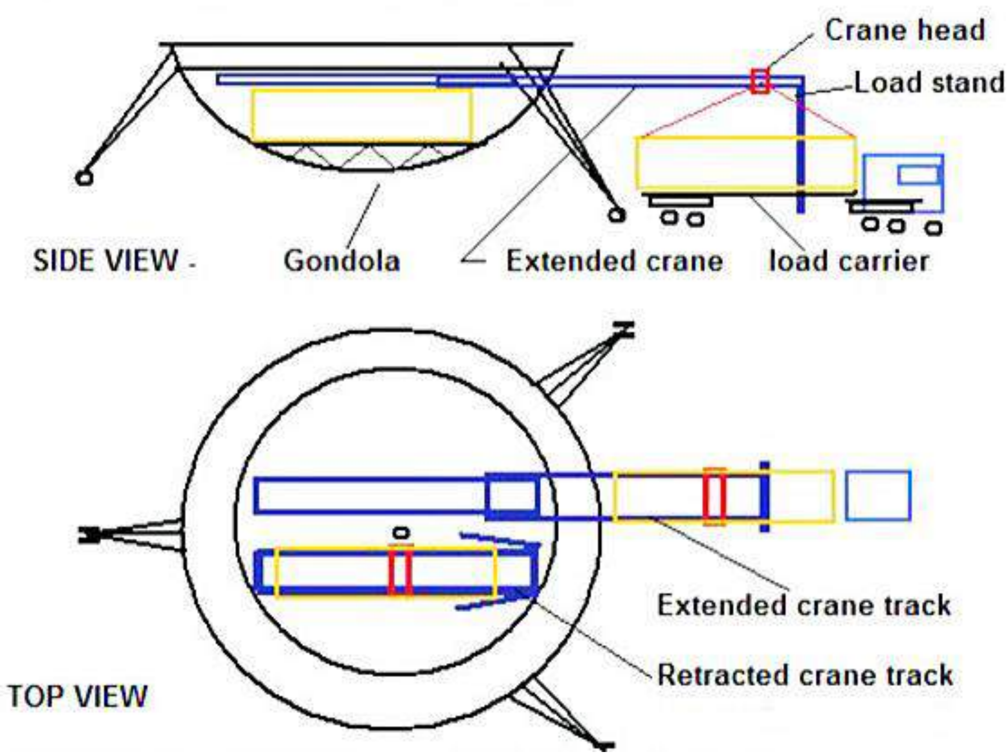


Rendering of a T-280 boarding passengers.
Source: LTAS / Walden Aerospace

The gondola can be configured for day tours with 100 - 150 passengers plus 15 flight and cabin crew, or for mixed use with cargo containers and fewer passengers.

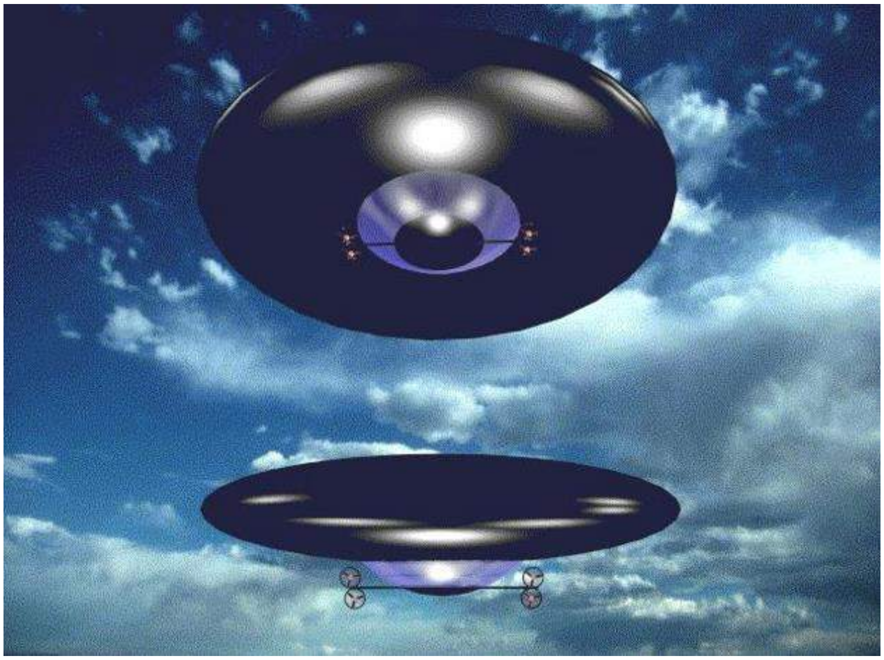
The gondola also can be configured for high-end luxury excursions or as a corporate or personal airship yacht.

Rendering of a T-280 in flight.
Source: LTAS / Walden Aerospace



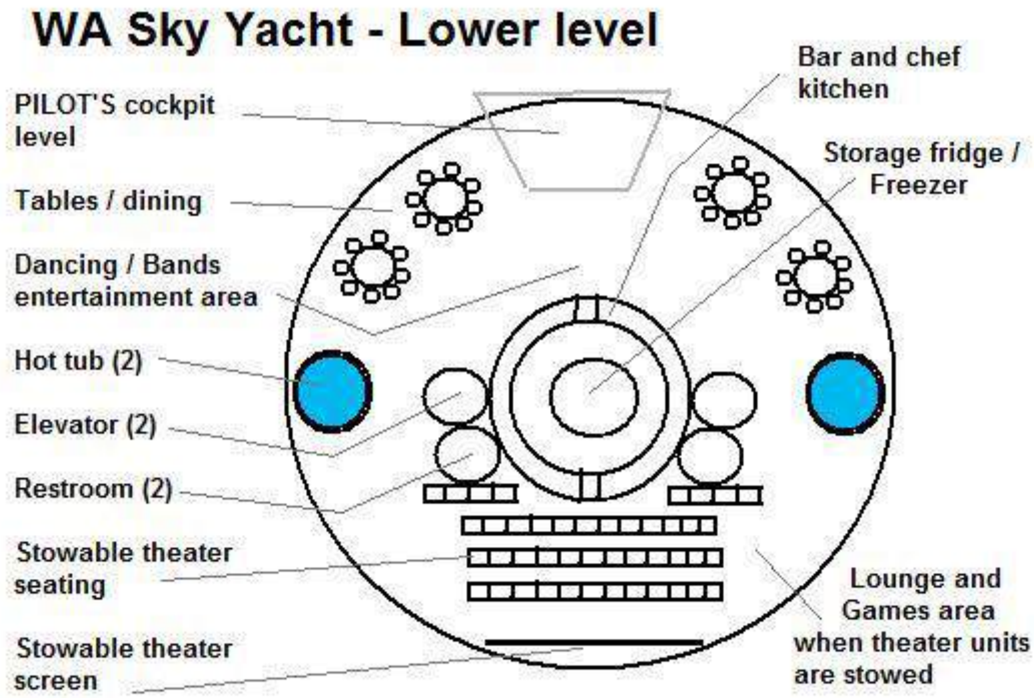
Containerized cargo handling concept for a cargo version of the T-280.
Source, both graphics: Walden Aerospace

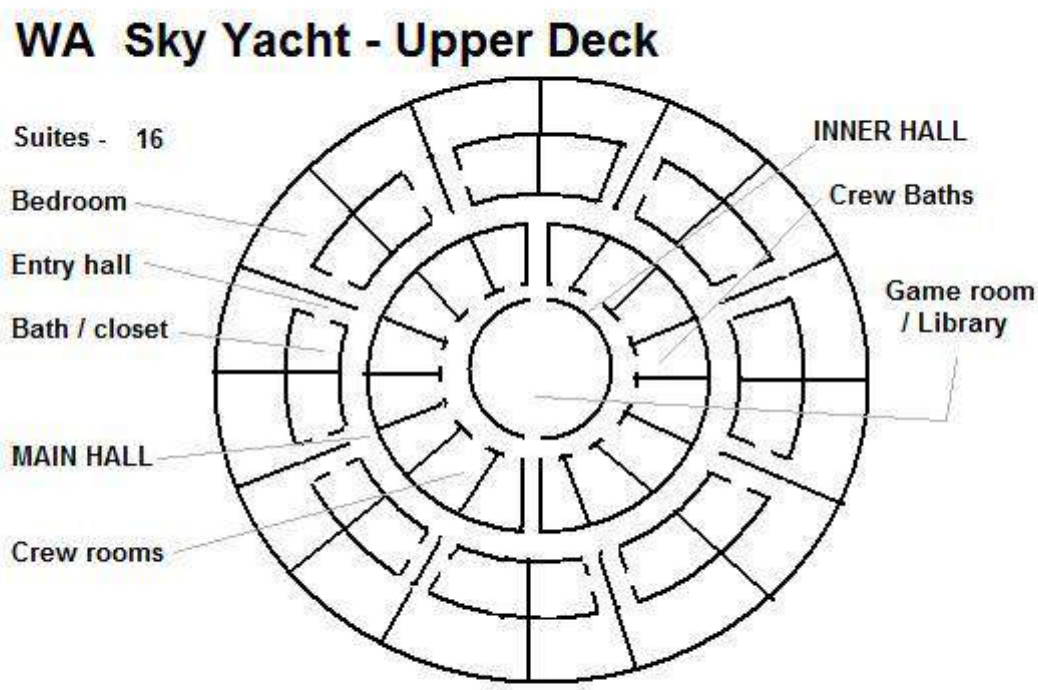
By 2001, the Tourer T-280 configuration had evolved to the 30-ton payload “Club Ship” design shown below. It was intended as a sky yacht for evening / overnight trips with high-end entertainment. The two deck gondola provided public spaces and the crew cockpit on the lower level, with passengers staterooms and crew accommodations on the upper level.



“Club Ship” general arrangement, circa 2004.

“Club Ship” interior concept for luxury entertainment.
Source, both graphics: LTAS / Walden Aerospace





"Club Ship" interior deck layout concept.
Source, both graphics: LTAS / Walden Aerospace

The Sub-Orbital Solar collection and Communications Station (S.O.S.C.S.)

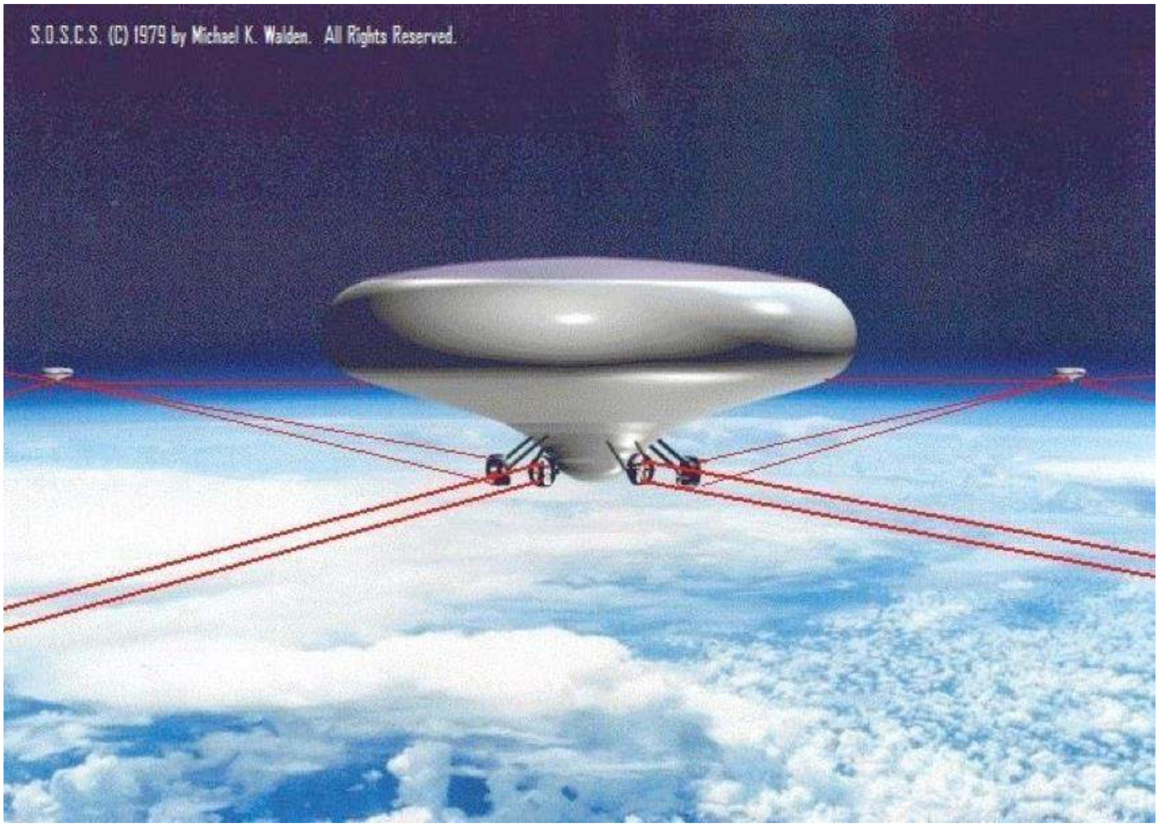
S.O.S.C.S. is an unmanned, geostationary, stratospheric, solar powered high altitude platform station (HAPS). Development started in the early 1970s based on Walden's characteristic lenticular airship design and DCB system.

S.O.S.C.S. is designed to operate on long-duration missions at altitudes between 100,000 to 120,000 feet (18.9 to 22.7 miles, 30.5 to 36.6 km), which is well above the prevailing jet stream, which usually is in the 5 to 9 mile (8 to 15 km) altitude range. S.O.S.C.S. would operate above the altitude of most other HAPS, which typically are designed to operate in the 65,000 to 75,000 foot (12.3 to 14.2 miles, 19.8 – 22.9 km) altitude range. This gives one S.O.S.C.S. HAPS a service footprint that is more than 1.5 times larger in diameter and 2.3 times larger in area that competing HAPS concepts. This gives S.O.S.C.S. a significant advantage in establishing regional or national high-speed data and voice networks with fewer HAPS.

At its operating altitude, the S.O.S.C.S. HAPS can perform a wide variety of missions for many different user communities. For example, it can serve as a communications platform that provides a variety of regional communications services that traditionally have been provided by terrestrial systems or orbital spacecraft.

In this role, the S.O.S.C.S. can deliver the following types of services:

- Regular regional communications and data services, particularly for remote areas that are poorly served by existing broadcast and broadband service providers.
- Emergency regional communications and data services that can be rapidly deployed to replace or supplement terrestrial systems disabled by a severe natural event (i.e., hurricane or earthquake).
- Broad area or nationwide communications and data services, enabled by electronically linking a distributed network of S.O.S.C.S. airships.



Artist's concept circa 1979 of S.O.S.C.S. stations at high altitude.
The red lines represent line-of-sight laser optical data links among distant S.O.S.C.S. stations operating as part of an integrated communications network.
Source: LTAS / Walden Aerospace

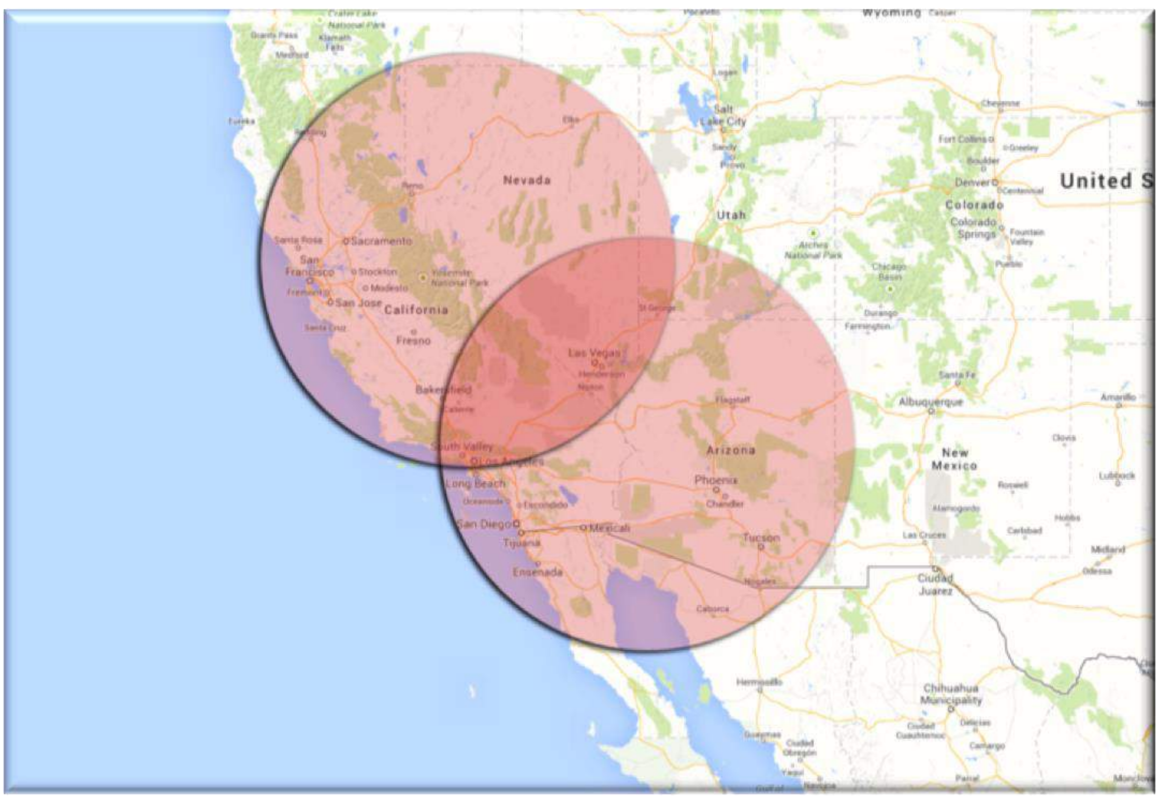
This airship concept has a rigid, lenticular aeroshell with a 600-foot (183-meter) diameter and 250-foot (72-meter) height at the center of the hull, not including payload antenna arrays that may be deployed in flight.

At low altitudes, S.O.S.C.S. uses conventional propulsion, like the T-280 airship. At very high-altitudes, where propellers become ineffective, S.O.S.C.S. will use an ionic airflow electro-kinetic (IAF/EK) propulsion system that is well suited for station keeping in the very low-density air. The S.O.S.C.S. EK propulsion system builds on experience with EK systems demonstrated by LTAS during subscale airship test flights.

The S.O.S.C.S. airship has an integrated control system for managing the systems for DCB (buoyancy control), MTU (pitch and roll stability control) and propulsion (precise geo-stationary positioning).

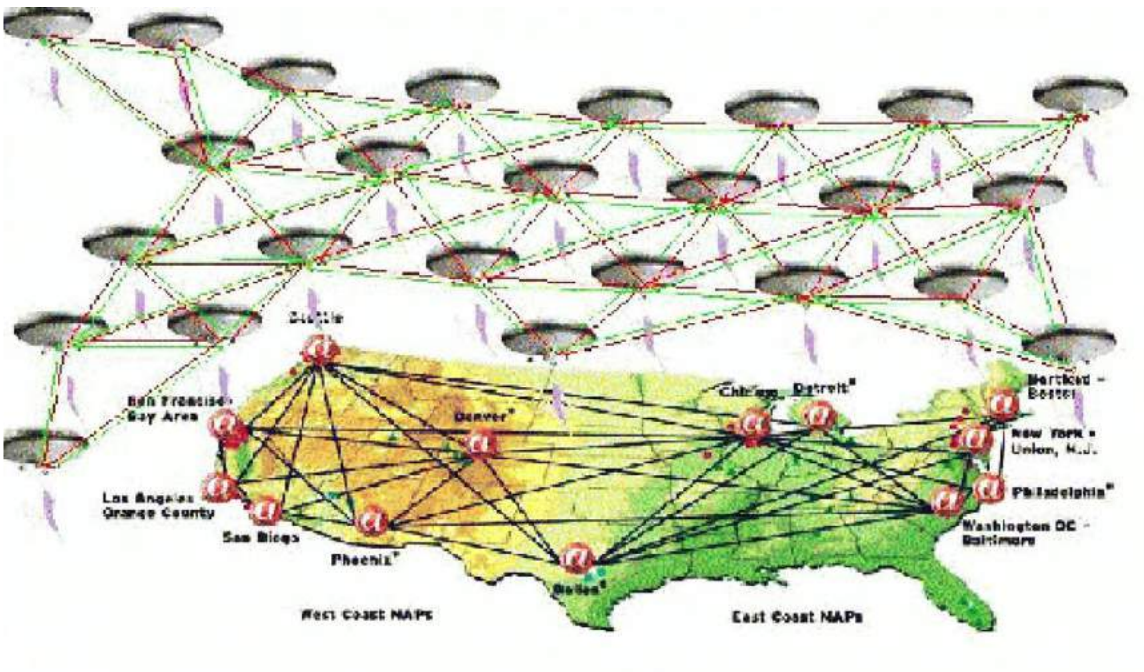
With space for about 226,200 square feet (20,015 square meters) of thin film solar cells (about 80% of the top surface), S.O.S.C.S. generates power to supply the platform house loads and customer-provided on-board system loads and charge the batteries that provide continuity of electrical service during hours of darkness. Peak generating capacity at high altitude is expected to be about 4 megawatts, which is about 2.5 times greater than the generating capacity of a similar solar array at sea level.

A S.O.S.C.S. airship operating at high altitude has a useful communications line-of-sight diameter of 600 miles (966 km). Walden claims two S.O.S.C.S. airships operating at high altitude can provide communications coverage for the entire state of California and most of Nevada and Arizona, as shown in the following map



Two S.O.S.C.S. could serve southern California, Nevada and most of Arizona. Source: LTAS / Walden Aerospace

About 25 S.O.S.C.S. airships could provide communications and data service for the U.S. lower 48 states. S.O.S.C.S. is designed to accommodate the transceiver hardware for any communications provider.



25 S.O.S.C.S. could form a network serving the U.S. lower 48 states.
Source: LTAS / Walden Aerospace

Relative to terrestrial communications systems, S.O.S.C.S. offers the following advantages:

- Lower environmental impact:
    - Much wider area of coverage than terrestrial antennas. This greatly reduces or eliminates the need for ground-based facilities, landline cables and other equipment, particularly in remote areas.

- Improved system performance:
    - Higher signal angle of incidence results in lower signal interference from terrestrial “clutter” that may preclude reliable service in some hilly or mountainous areas.
    - Fewer switch points in the end-to-end signal path decrease system latency.

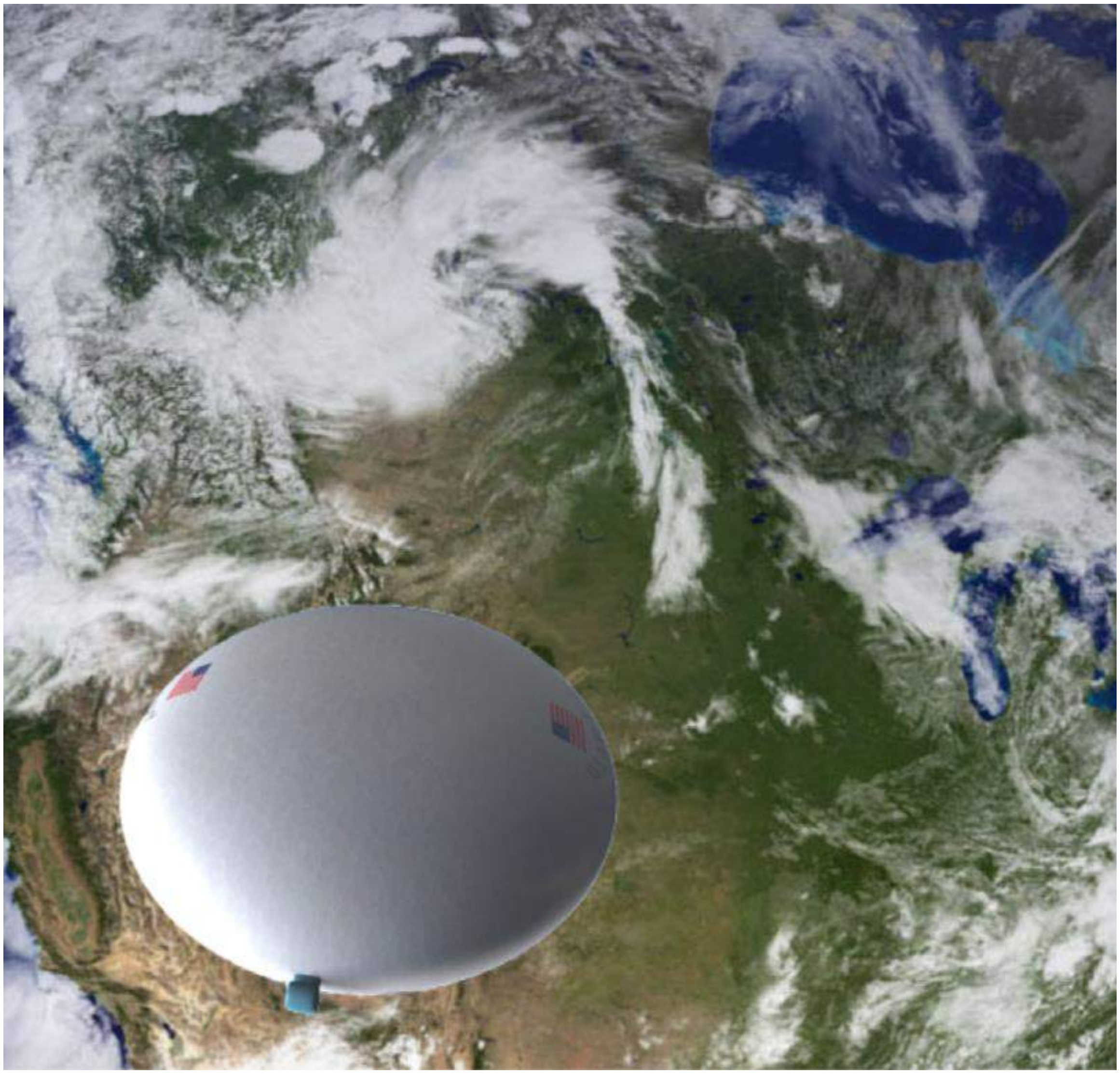
- Lower cost for delivering a uniform level of service to all customers:
    - Ease of deployment and better coverage within a prescribed service area greatly impacts the cost to deliver a uniform level of service, particularly in remote areas where the cost to complete the terrestrial “last mile” of connectivity to a customer can be very high.

Relative to orbital communications systems, S.O.S.C.S. offers the following advantages:

- One S.O.S.C.S. platform is about one-tenth the cost of a large communications satellite. Many countries would only need a few S.O.S.C.S. airships to deliver nationwide service.
- More transceiver power is available than in spacecraft-based systems. This should enable direct broadcast systems to deliver better performance to their customers.
- Lower propagation delays than in spacecraft-based systems operating at much higher altitudes.
- The airship can periodically return to base for maintenance / technical update / repair and then return to service. Maintenance of orbital spacecraft is much more problematic.

In developing countries without a national communications and data infrastructure, S.O.S.C.S. offers a means to deploy a national infrastructure quickly and at modest cost.

At an airship estimated unit price of about $80 million, it would cost about $160 million for regional communications coverage throughout California, and about $1.36 billion for coverage of the U.S. lower 48 states. Those amounts do not include ground stations, spare airships, or periodic maintenance.

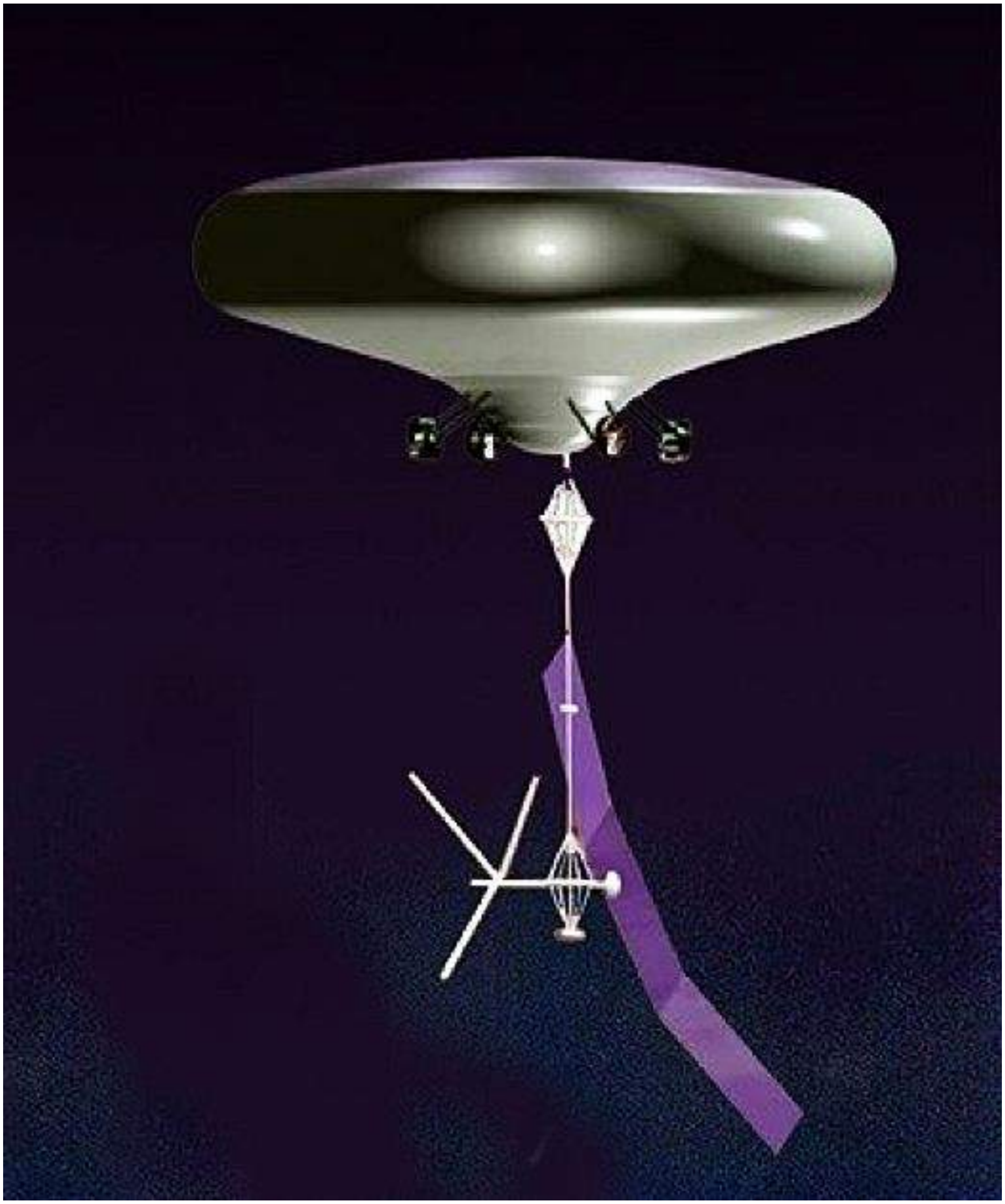


Rendering of S.O.S.C.S. at high altitude. Source: LTAS / Walden Aerospace

The S.O.S.C.S. airship can be configured for a variety of other missions, such as: geospatial remote sensing and mapping, weather monitoring, environmental and resource monitoring, and maritime surveillance / search and rescue.

On 9 September 2008, patent US 7424040B2 , “Communications Systems and Methods for Transmitting Data in Parallel Over Multiple Channels,” was granted to LTAS Holdings, LLC, with Michael Walden listed as the inventor. This patent describes a type of frequency division multiple access (FDMA) wireless communication system that achieves high data transfer rates and provides error correction of the cyclic redundancy check (CRC) packet without retransmission of the data. This type of communication system is applicable to S.O.S.C.S.

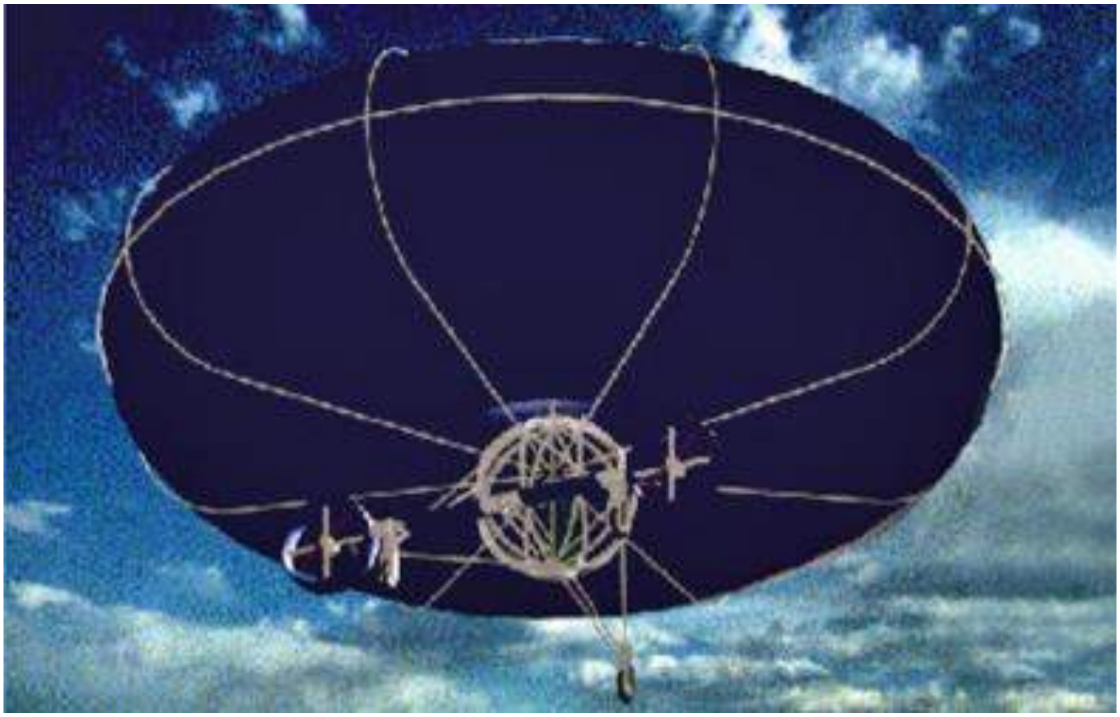
You can read this patent here:
https://patents.google.com/patent/US7424040



Rendering of S.O.S.C.S. with a deployed antenna array.
Source: LTAS / Walden Aerospace

Ultralight toroidal DCB airship design concept

Michael Walden developed an ultralight toroidal airship design concept in the 1997 to 1998 time frame and presented the concept at the LTAS booth at a NASA open house. This ultralight DCB airship had a black, flexible composite shell with an external tube frame supporting a transparent globe gondola with two cantilevered, shrouded propellers and a three-point landing gear.



General arrangement of Walden's ultralight toroidal airship.
Source: Walden Aerospace

As described in [FAA Advisory Circular AC 103-7, "The Ultralight Vehicles,"]() the basic characteristics of an ultralight vehicle are the following:

- Single-occupancy by a pilot who has assumed all responsibility for his/her personal safety. There can be no provisions for a second occupant.
- The pilots is not required to have training or previous experience prior to the operation of an ultralight vehicle.
- The vehicle is used for sport or recreational purposes only. It cannot be used for aerial advertising, aerial chemical application (i.e., crop spraying), aerial surveying or patrolling, or carrying parcels for hire.
- The vehicle is not subject to Federal aircraft certification and maintenance standards. If the vehicle has received an airworthiness certificate, it cannot be operated as an ultralight.
- A powered ultralight airship must comply with the following design parameters:
    - Empty weight of less than 254 pounds (115.2 kg)
    - Fuel capacity not exceeding 5 U.S. gallons (18.9 liters)
    - Airspeed at full power not exceeding 55 knots (63.3 mph, 101.9 kph) in level flight

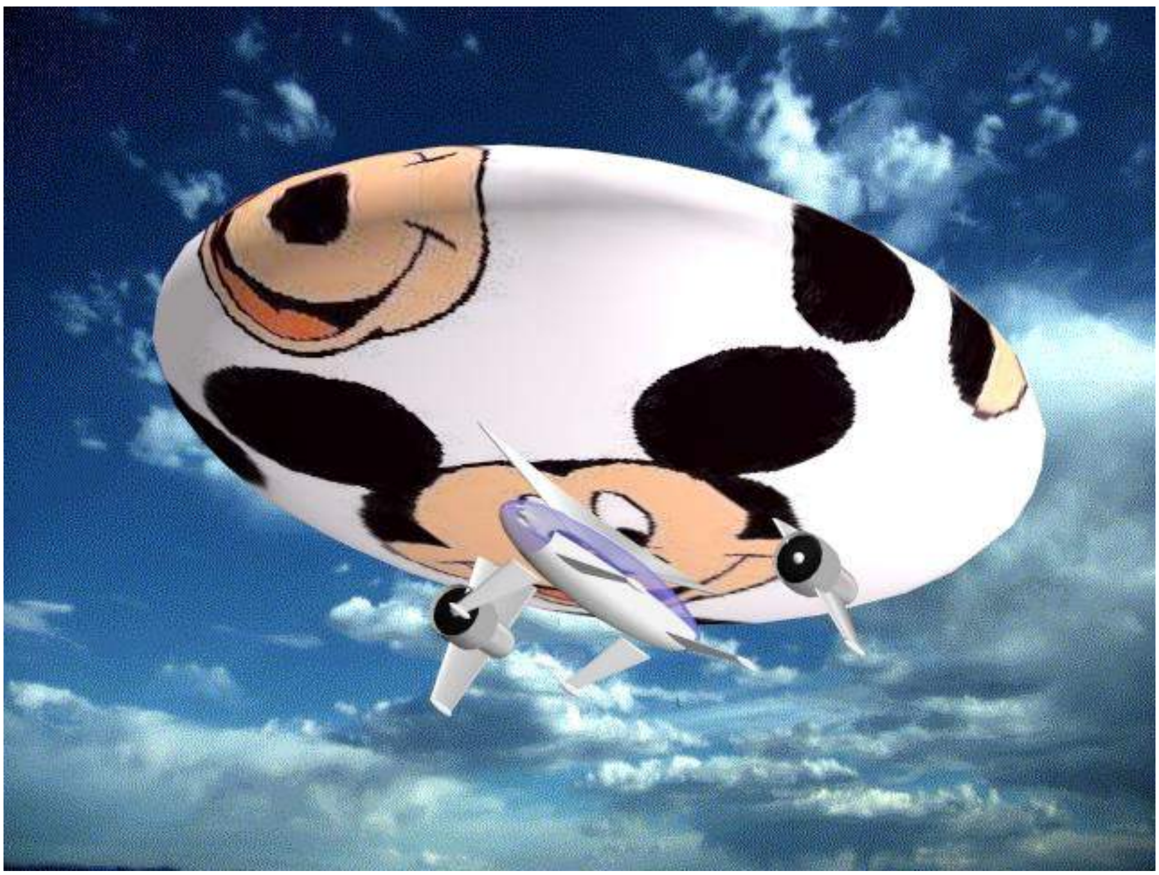
“Canopy Trek” toroidal DCB airship (non-ultralight)

Walden also developed a design concept for a similar, but larger DCB airship with a translucent, flexible, composite toroidal hull that could carry 2 or 3 persons in a transparent sphere gondola, which could be lowered down into a tree canopy for close-up views of plants and wildlife while protecting the occupants and keeping the main airship safely above the canopy.

Canopy Trek airships.
Source: Walden Aerospace

Intercity passenger transport

This design concept merged Walden’s signature rigid, toroidal, DCB hull design with a suspended aerodynamic gondola configured for carrying passengers on relatively short intercity routes.



Source: Walden Aerospace

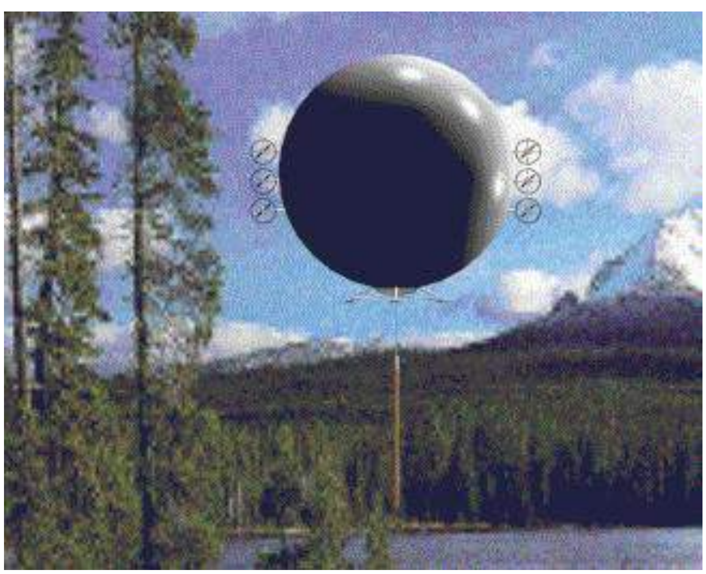
6. Examples of Michael Walden's non-toroidal DCB airship design concepts

Michael Walden also developed design concepts for several non-toroidal airships that employed his DCB system. Several of these design concepts are described in this section.

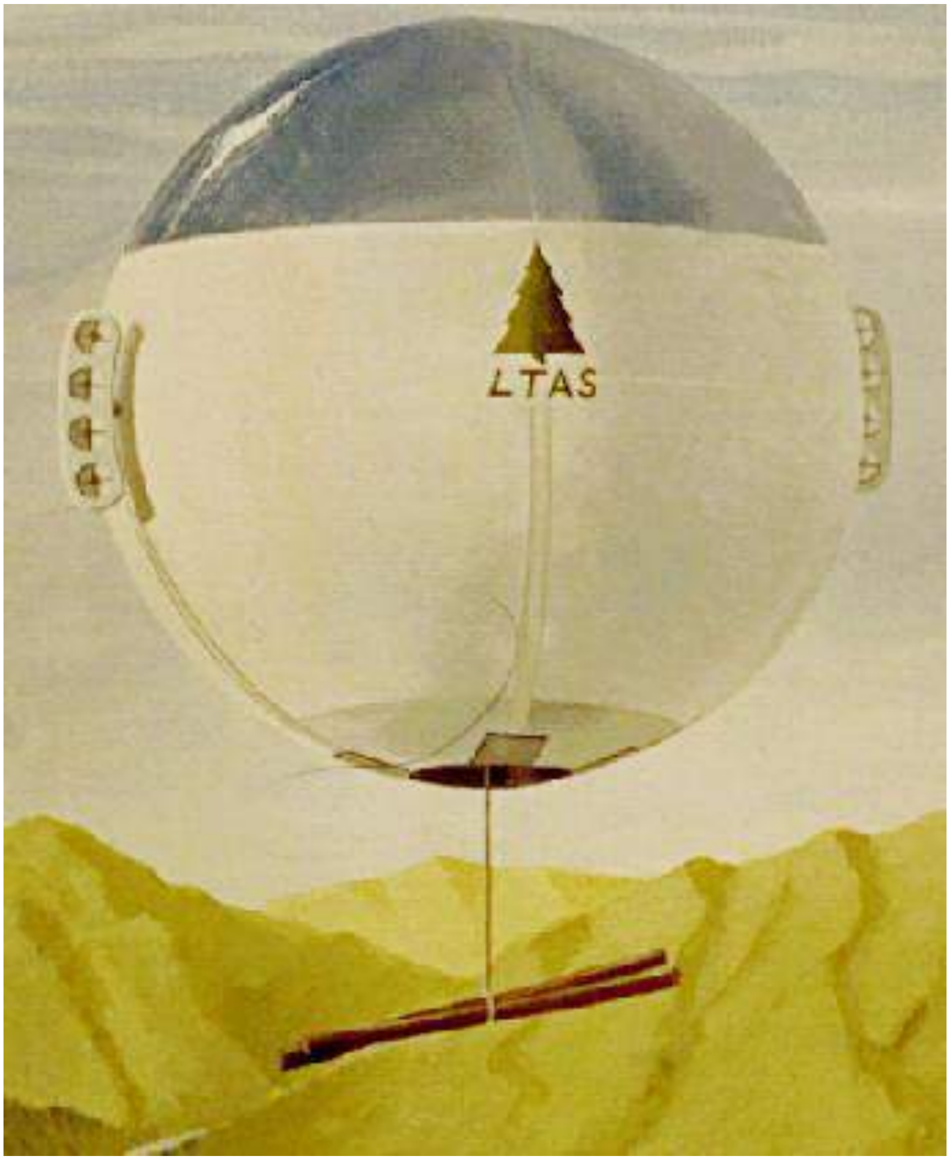
Spherical heavy lift airship

In the 1980s, LTAS designed a DCB test unit with a spheroid hull capable of modifying its total lift by 25% to 30%. Subsequently, Michael Walden developed a design concept with a similar spheroid hull for a commercial heavy lift application for logging. The general arrangement of this airship is shown below.

In 2002, CargoLifter AG used their spherical CL75 AC AirCrane heavy-lift, unpowered aerostat to demonstrate a load exchange in which a 55 metric tons cargo was exchanged with about 55 cubic meters (1,766 cubic feet, 14,530 US gallons) of water ballast received from, or discharged to, tanker trucks on the ground. In contrast, Walden's DCB heavy lifter would compress or release helium lift gas within the gas envelope to manage the static buoyancy of the airship throughout a load exchange. No external ballast exchange is required, greatly simplifying operations, particularly in remote areas.



Artist's concept of the spherical heavy lifter with DCB. Source: LTAS / Walden Aerospace



Artist's concept of the spherical heavy lifter with DCB.
Source: LTAS / Walden Aerospace

Twin hull yacht

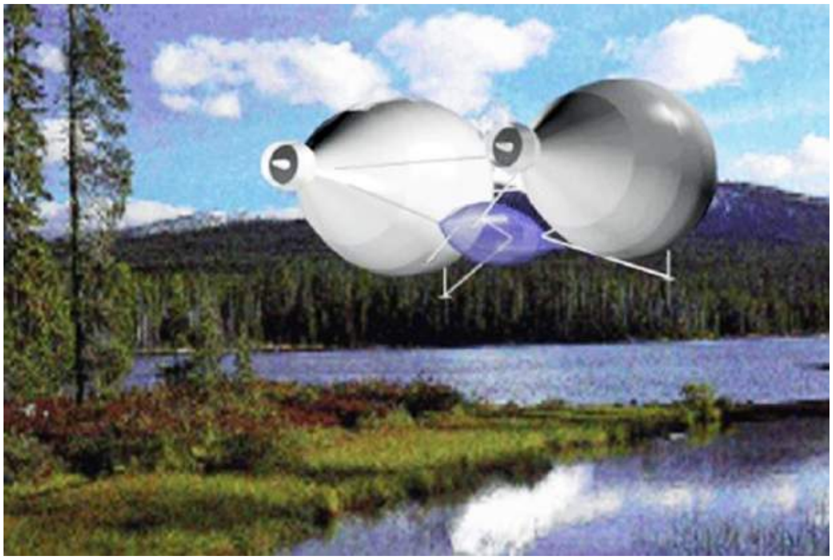
The twin hull yacht is a modest size DCB airship with multi-axis vectoring propellers mounted fore and aft on an airfoil-shaped truss structure between the two hulls. The gondola for passengers and cargo is suspended under the centerline of the truss structure.

This basic hull configuration is generally similar to the 2002 design of the Elettra Twin Flyer hybrid airship designed by the Italian firm Nautilus S.p.A and Politecnico di Torino.

Artists' concept of the twin-hull yacht with DCB.
Source, both graphics: LTAS / Walden Aerospace

Twin-hull firefighting airship

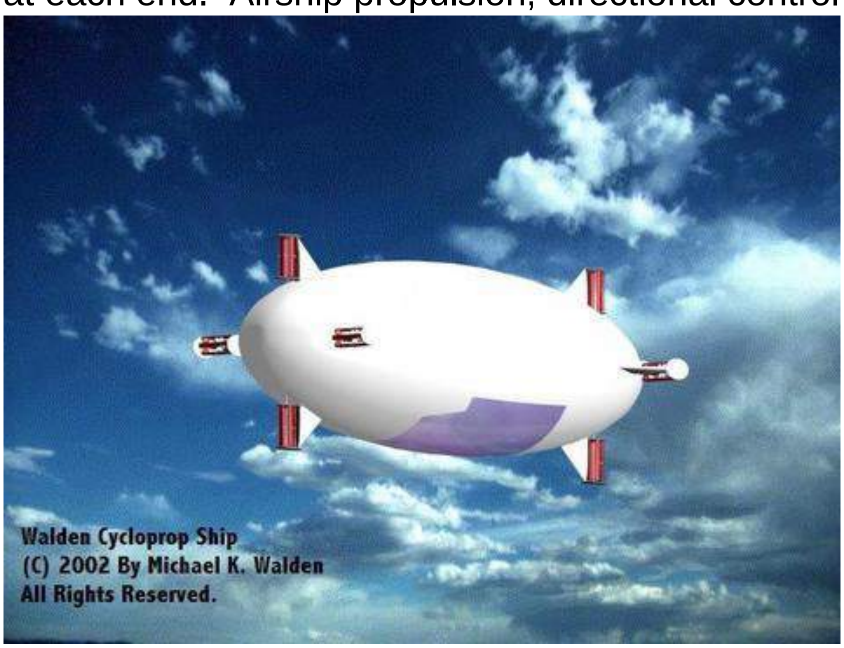
The twin hull firefighting airship is another modest size DCB airship concept with a truss structure between the two hulls supporting a streamlined central gondola. The airship would be able to replenish its water supply from lakes or other nearby bodies of water and then return quickly to fight the fire.



Artists' concept of the twin-hull firefighting airship with DCB. Source: LTAS / Walden Aerospace

Single ellipsoidal hull, cycloidal thruster airship (2002)

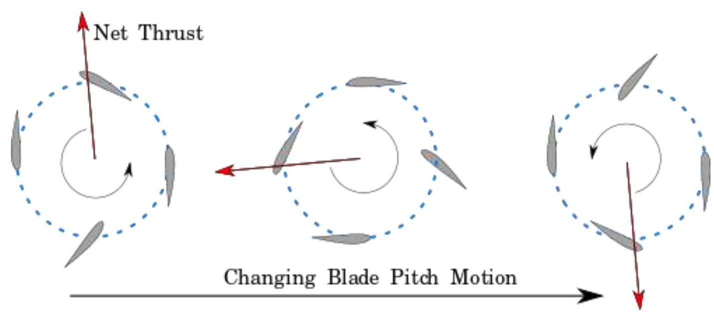
This 2002 airship design concept has a single, streamlined, symmetric ellipsoidal, rigid hull with four cycloidal propellers mounted at each end. Airship propulsion, directional control on all axes (pitch, roll & yaw), and precise geo-positioning are accomplished through the coordinated operation of the cycloidal propellers.



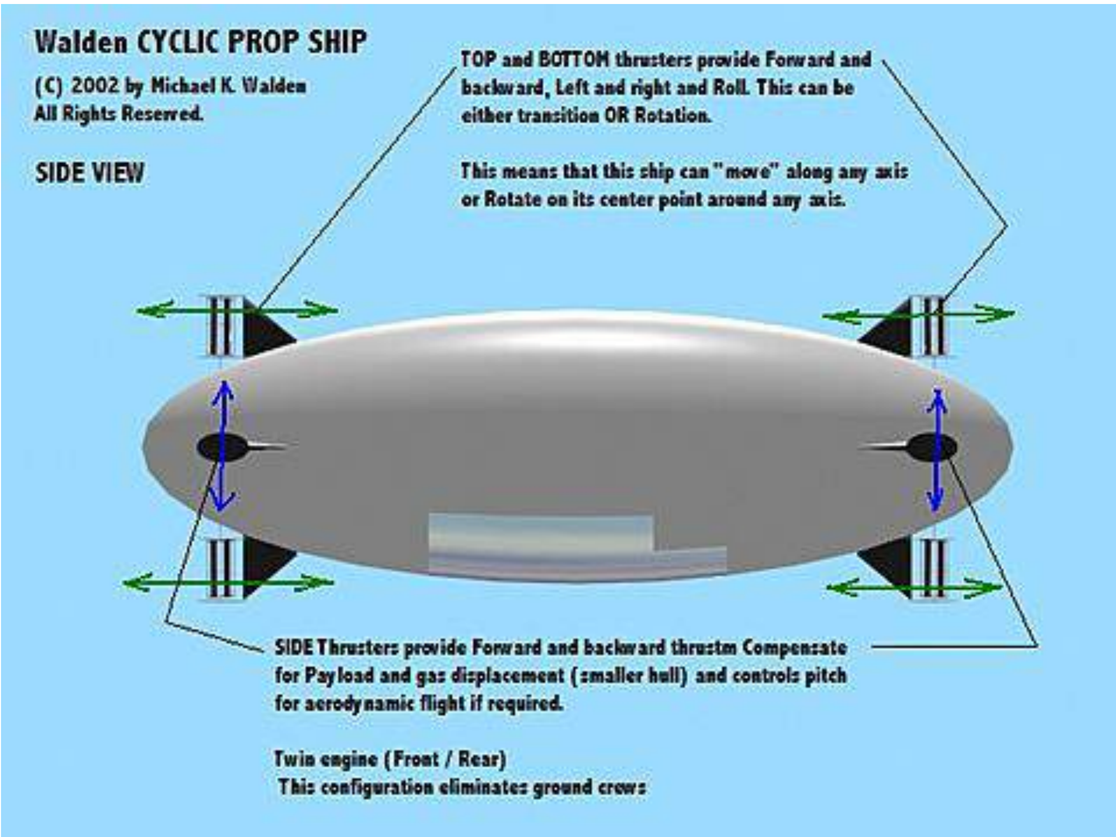
Source: LTAS / Walden Aerospace

This airship was designed for Arctic conditions. The short hull, with its highly curved top surface, is designed to minimize snow / ice buildup.

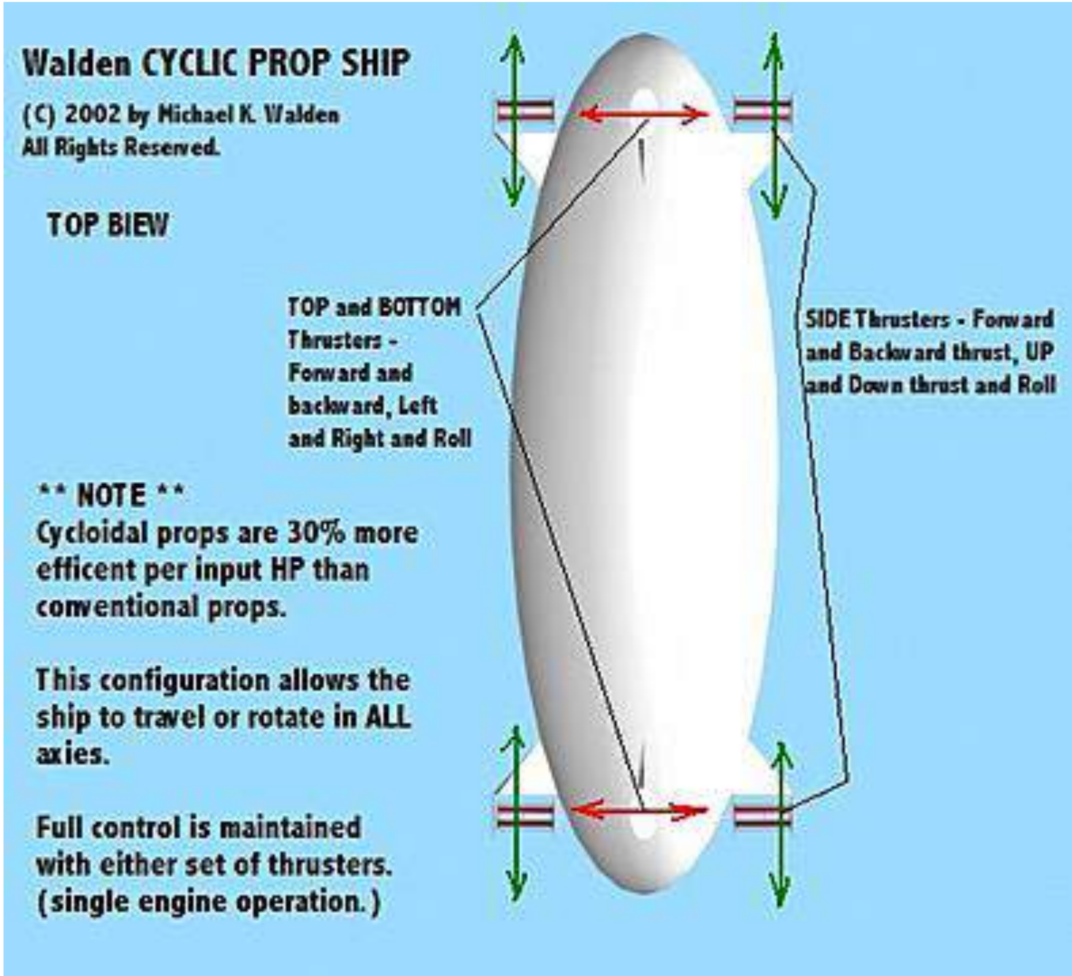
The cycloidal propellers can produce instantaneous thrust in any direction perpendicular to their axis of rotation. This is accomplished by adjusting propeller blade pitch, as shown in the following diagram.



A cycloidal propeller delivers vectored thrust in any direction by changing its blade pitch angles. Source: Wikipedia



Side view, general arrangement of Walden's cycloidal propeller airship with DCB. Source: LTAS / Walden Aerospace (2002)



Top view, general arrangement of Walden's cycloidal propeller airship with DCB. Source: LTAS / Walden Aerospace (2002)

With fast-acting, easily modulated thrust vector controls, the DCB buoyancy control system enables precision hovering and maneuvering for cargo off-loading and on-loading while hovering, with no need for a ballast exchange. Cargo also can be transferred after landing on the ground,

The cycloidal propellers are expected to be about 30% more efficient than conventional propellers and enable flight control to be maintained without aerodynamic control surfaces commonly found on airships. As a result, this airship is expected to have lower operating / shipping costs than conventional airships.

7. For more information

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- Michael K. Walden, “Walden Aerospace Patented Advanced Technologies for Variable Buoyancy, composite Aero-shell Vehicles,” (no longer “Confidential & Proprietary”): https://lynceans.org/wp-content/uploads/2020/12/Walden-Aerospace-Advanced-Technologies.pdf

- Achmed A. W. Khammas has written an historical overview of Michael Walden and LTAS. You'll find that article translated from German to English here: https://lynceans.org/wp-content/uploads/2020/12/Khammas_Book-of-Synergy_Walden-LTAS-histoy.pdf
  The original article in German is in Teil C (Part C) of *Buch der Synergie*, which you will find at the following link: http://www.buch-der-synergie.de/c_neu_html/c_11_17_solarluftschiffe_01.htm
- Charles Luffman, "LTA Solutions - A Lighter-than-air Aircraft Design/Engineering Practice - Lenticular Airships An Exposition," LTA Solutions, 7 May 2015: https://docplayer.net/64482432-Lta-solutions-a-lighter-than-air-aircraft-design-engineering-practice-page-1-of-16-lenticular-airships-an-exposition.html

Videos

- Las Vegas TV Channel 3 video interview with Michael Walden, (2:12 min), circa 1997: https://lynceans.org/wp-content/uploads/2022/10/Video-interview-with-Michael-Walden-circa-1997.mp4
- MTU bench test model in operation, (1:34 min), LTAS, circa 2002: https://lynceans.org/wp-content/uploads/2022/10/Walden_Tabletop-StabilityDiscV7.mp4
- Technology Demonstrator flight-weight MTU pitch control test, LTAS, (0:24 min), circa 2007: https://lynceans.org/wp-content/uploads/2022/10/Walden_MTU_pitching_the_TD2.mp4
- Technology Demonstrator flight-weight MTU stability recovery test, (0:14 min), LTAS, circa 2007: https://lynceans.org/wp-content/uploads/2022/10/Walden_MTU-stability-recovery-hanger-test.mp4

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- *Modern Airships - Part 2*: https://lynceans.org/all-posts/modern-airships-part-2/
  - Walden Aerospace / LTAS - Electro-kinetic (EK) propulsion airships
  - Walden Aerospace / LTAS - Variable Buoyancy Propelled Airships / Aircraft
- *Modern Airships - Part 3*: https://lynceans.org/all-posts/modern-airships-part-3/
  - Aquarian Airships
  - Walden Aerospace / LTAS - Exotic Hybrid Airship Concepts