Roy P. Gibbens – AirLighter and cycloidal propellers

Peter Lobner, 27 October 2023

1. Introduction

In the early 1980s, the Lockheed-Georgia Company (a division of Lockheed Corporation) developed a design concept for a small rigid airship (SRA), which was similar in size to, but a radical departure from, contemporary non-rigid blimps. Known as the Starship, the SRA incorporated several novel design features, including a rigid hull, a lifting body hull shape and two lifting gases; helium and hot air.

Starship SRA development work was led by Lockheed engineer Roy P. Gibbens, who worked at the Lockheed plant in Meridian, Mississippi from 1983 to July 1990 and first publicly described the SRA in a July 1983 paper. Lockheed never built the Starship SRA.

After his retirement from Lockheed in 1990, Gibbens continued developing the Starship SRA design concept, rebranded as the "AirLighter," at his new firm, Gibbens & Associates, in Meridian, Mississippi. He introduced the AirLighter, in 1991 and noted that the term "lighter" means "the transportation of goods," which seemed a better fit for the airship than "Starship."

AirLighter. Source: Roy P. Gibbens (1991)

While Gibbens was an early proponent of small, rigid hull airships with lifting body hull shapes (commonly known today as “hybrid” airships), he stated,

> “The key to airship success is not in their shape, but how controllable is the airship……..The reason airships are not in general use today is not the burning of the Hindenburg, but the lack of control. In order for airships to become commercially acceptable, they must be controllable at all times.”

This philosophy led Gibbens to explore the use of cycloidal propellers in airships. He developed, flight tested and promoted the use of cycloidal propellers as an effective solution to airship controllability, particularly at low speeds and during hover.

Integrating cycloidal propellers with the AirLighter cargo airship led Gibbens to his streamlined AirLighter 2 design concept with no aerodynamic control surfaces.

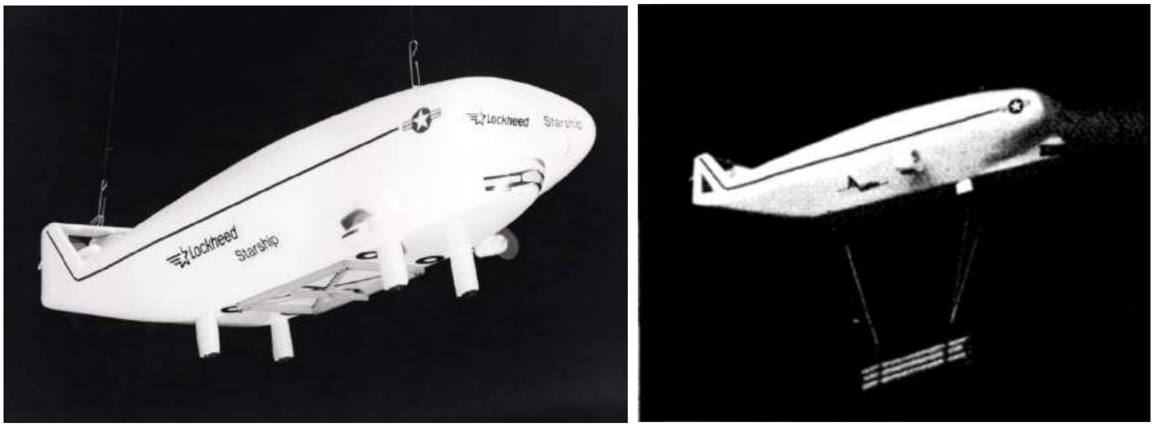
AirLighter 2. Source: Roy P. Gibbens (1991)

Gibbens & Associates was one of several firms that sponsored the University of Virginia (UVA) Charlottesville Solar Airship Program in the 1990s.

Roy Powell Gibbens passed away in Meridian, Mississippi on 20 February 2013. His AirLighter and AirLighter 2 airships remained as design concepts. His work on cycloidal propellers demonstrated how these novel devices can be integrated with modern airships to resolve age-old airship controllability issues. The author is grateful to his daughter, Sue Henderson, for generously providing access to his files.

2. Design concept for the AirLighter

The AirLighter was an evolutionary development of the Lockheed Starship SRA designed by Roy P. Gibbens in the early 1980s. Their shared heritage is evident in the following photos.



Models of a Starship SRA (left) and an AirLighter (right). Source: Roy P. Gibbens

Like the Starship SRA, the AirLighter was a rigid, variable buoyancy, hybrid airship that generated its aerostatic lift from the combined effects of a fixed mass of helium lift gas and a variable mass of hot air. With helium alone the airship was semi-buoyant (heavier-than-air). Buoyancy was managed by controlling the heating and venting of air in “hot air compartments” within the hull.

This buoyancy control concept was developed and applied in the 1700s in hybrid balloons designed by Jean-François Pilâtre de Rozière. Such “Rozière” balloons have separate chambers for a non-heated lift gas (hydrogen or helium) and a heated lift gas (air).

This class of airship, known as a hybrid thermal airship, includes 1980s contemporary design concepts and flying prototypes from the UK firm Thermo-Skyships Ltd. (TSL, 1972 to 1982) and the Soviet firm Design Bureau "Thermoplan" (mid-1980s to 1992), as well as several other firms in later decades.

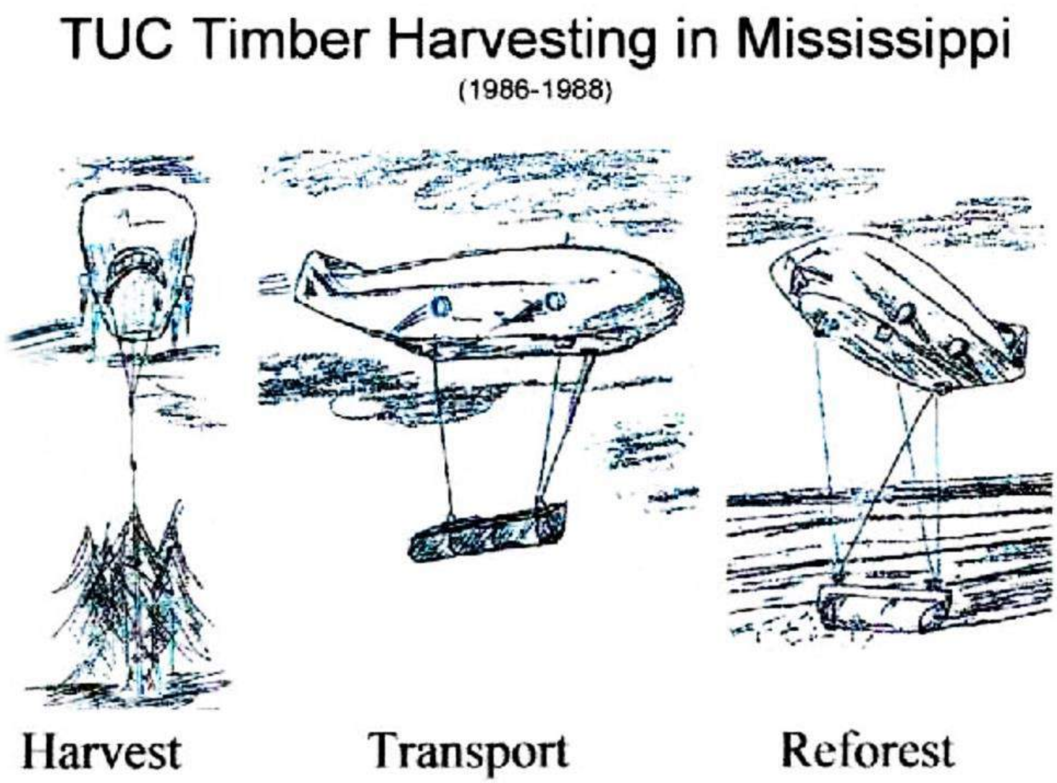
Other Starship SRA features carried over in the AirLighter include:

- “Hard shell” rigid hull; stronger than blimp fabric hulls and not subject to tearing

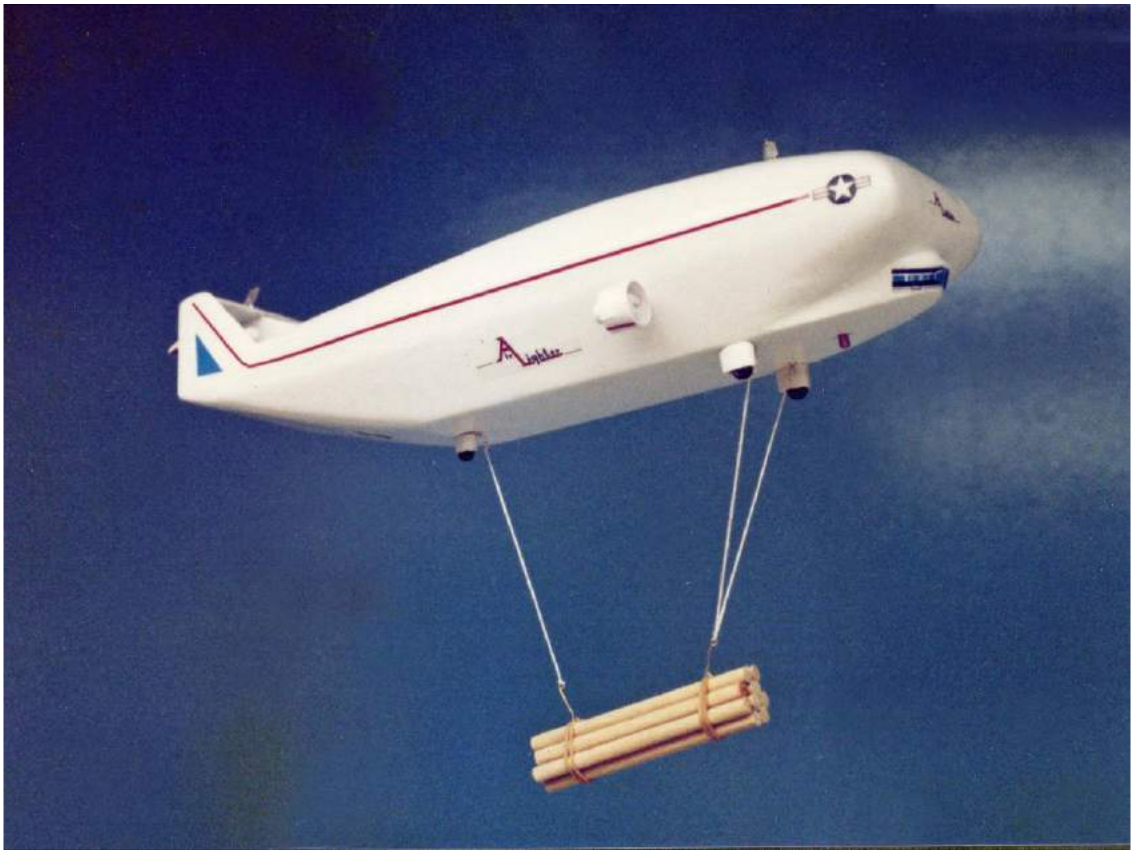
- Lifting body hull shape to provide aerodynamic lift in flight
- Vertical takeoff and landing (VTOL) & hovering with good low-speed airship control
- Simple ground handling
- Maximum airspeed above 100 knots

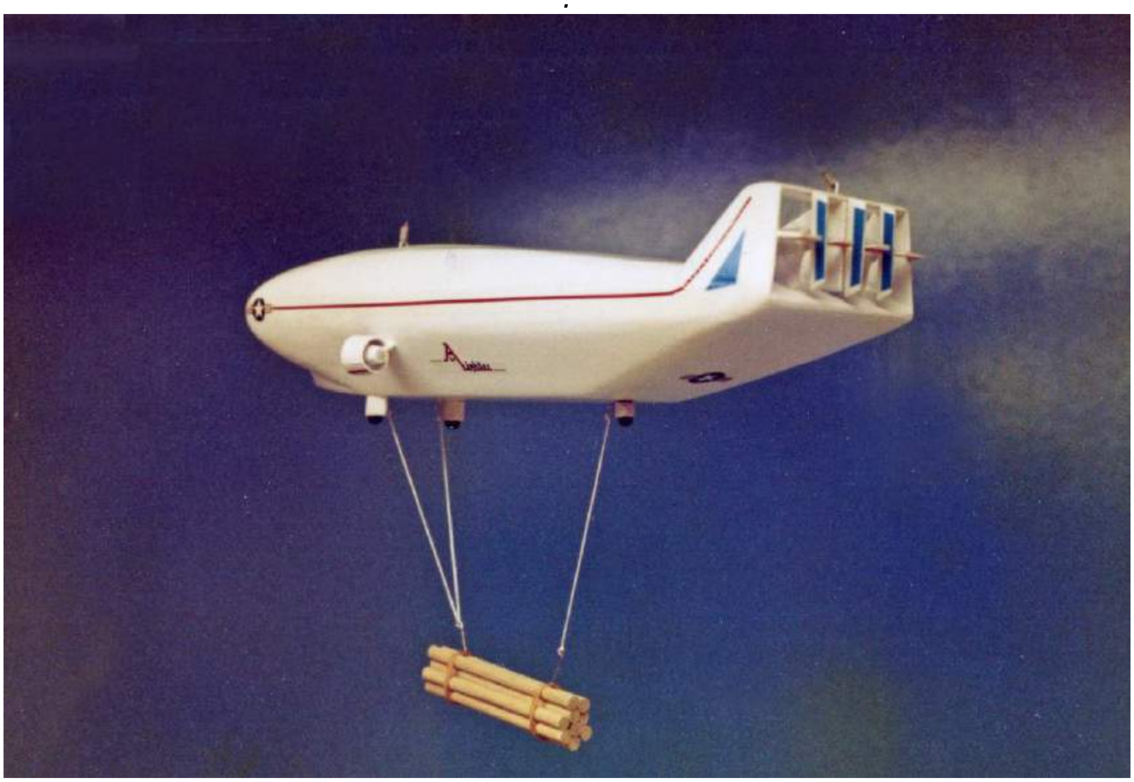
Notable external features that distinguish the AirLighter from the Starship SRA are larger, shrouded forward maneuvering engines, shorter tricycle landing gear, and no sign of the extendable cargo space frame used on the Starship SRA to carry external loads.

The AirLighter could be configured for a variety of applications, such as short-haul cargo transport, logging and sky yacht for corporate or personal transport. Gibbens noted, “Logging airships will be a special breed as they will require additional lift engines for additional thrust while transporting the logs. The engines will be at idle or off when not loaded. Additional larger airships will be required to transport the logs from the staging area to the mill.”

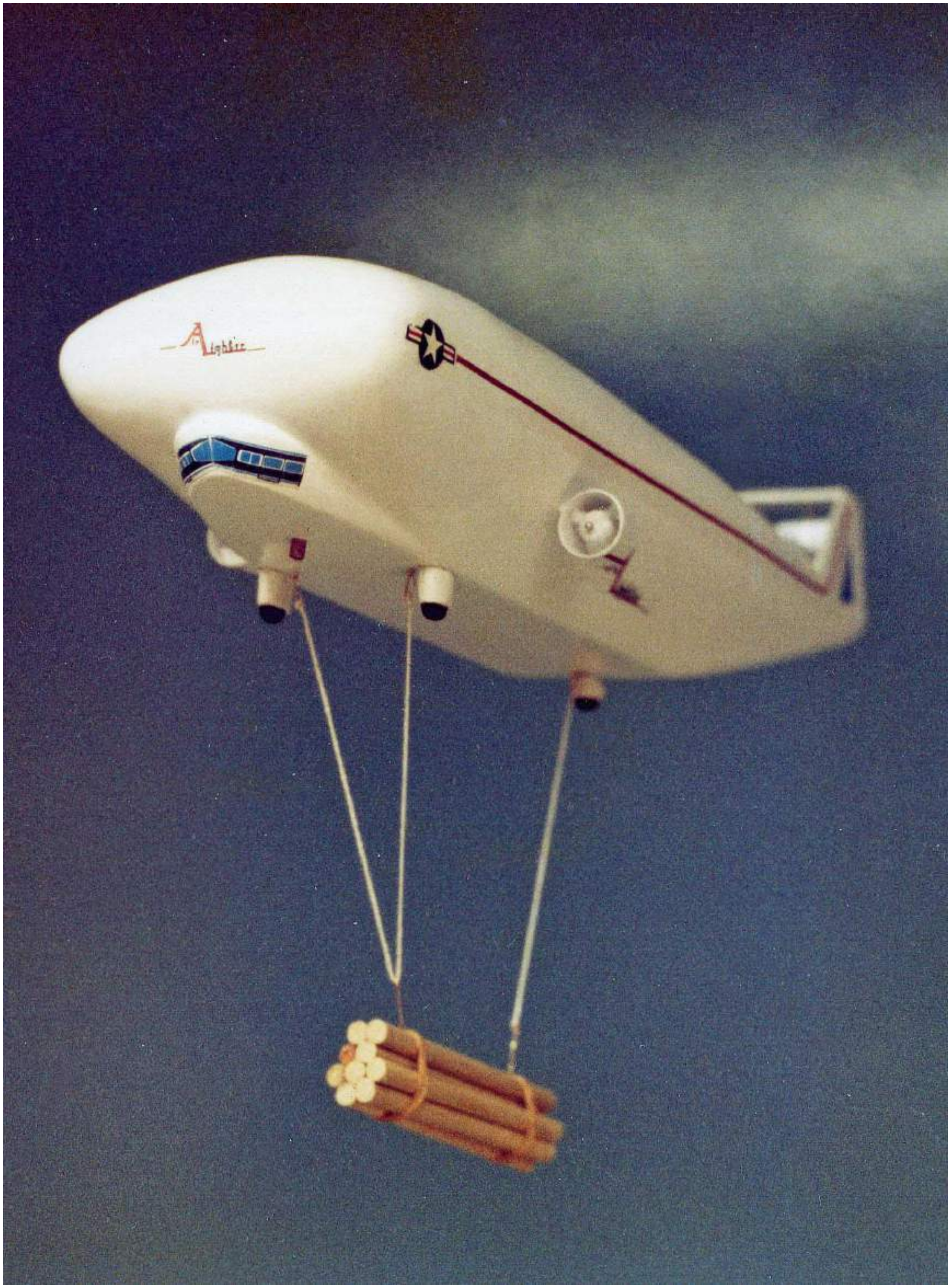


Timber industry harvesting and replanting applications for the AirLighter airship. Source: Roy P. Gibbens (2011)

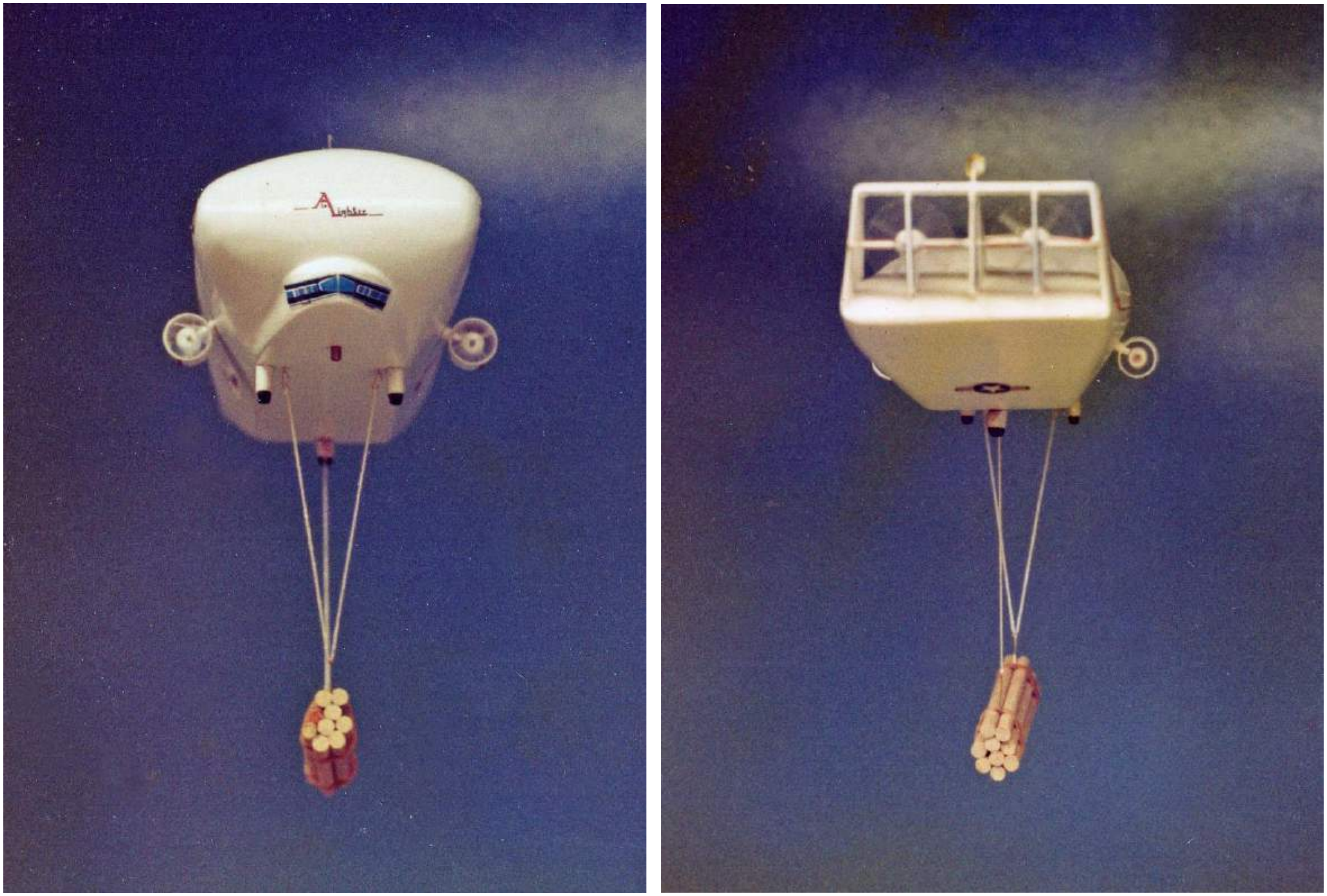




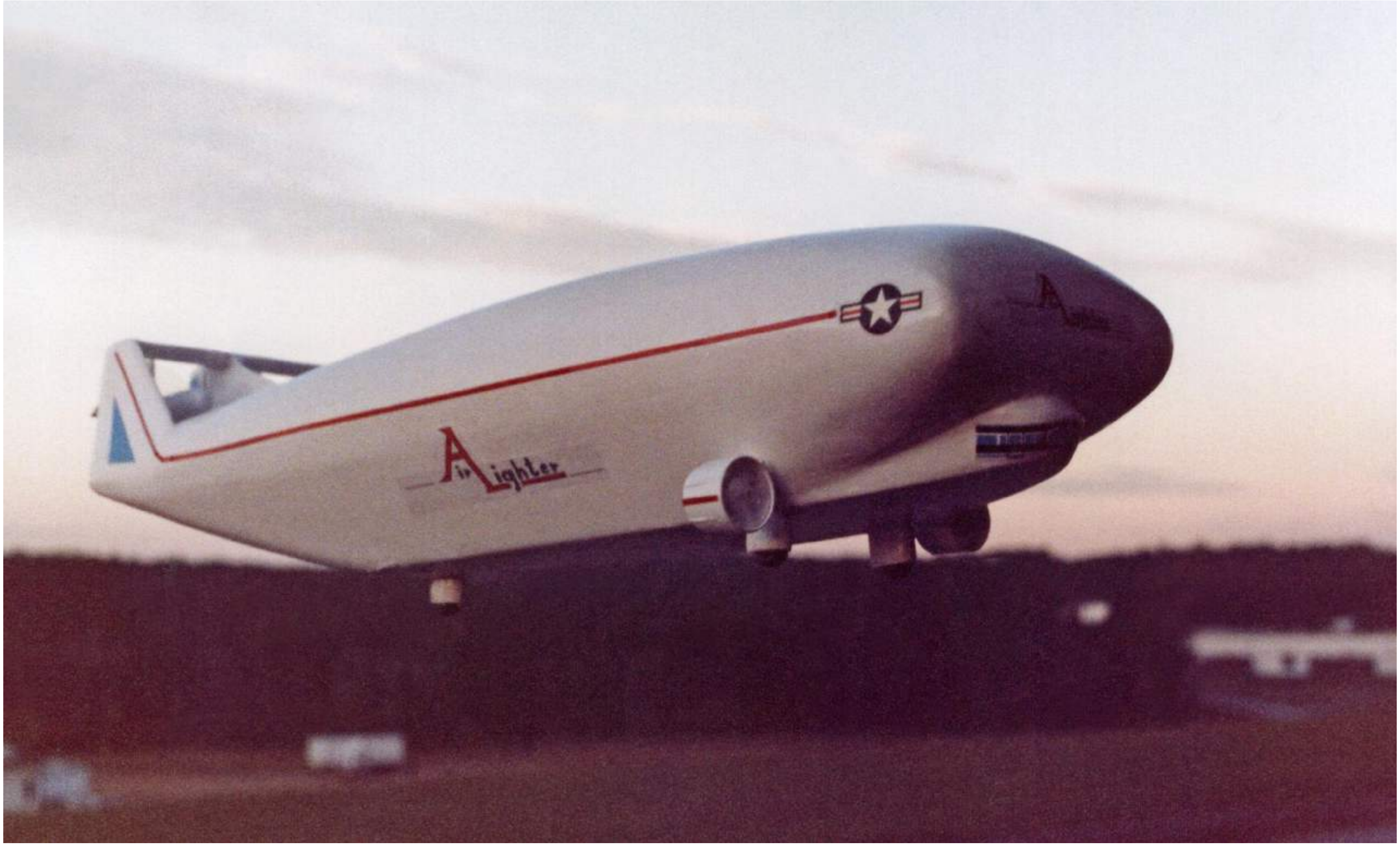
Model of Roy P. Gibbens' AirLighter hauling logs.
Source, both photos: Gibbens and Associates, circa 1991



Model of Roy P. Gibbens' AirLighter hauling logs.
Source: Gibbens and Associates, circa 1991



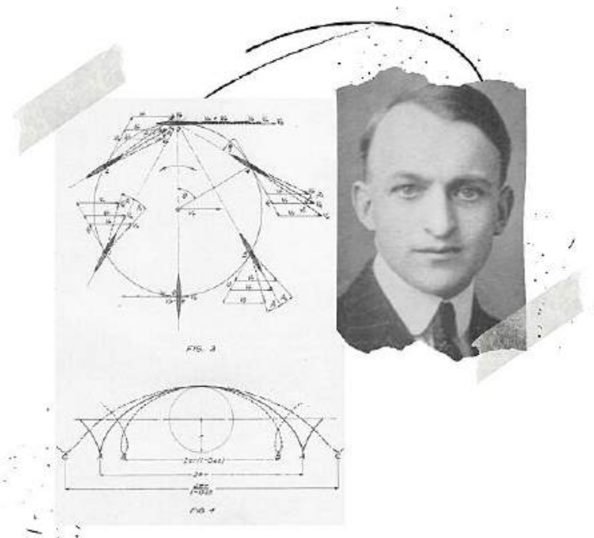
Model of Roy P. Gibbens' AirLighter hauling logs, bow view (left) & stern view (right).
Source, both photos: Gibbens and Associates, circa 1991



Rendering of AirLighter. Notable external changes from the Starship SRA include larger, shrouded forward maneuvering engines, shorter tricycle landing gear, and no sign of the extendable cargo space frame used on the Starship SRA to carry external loads. Source: Roy P. Gibbens, circa 1991

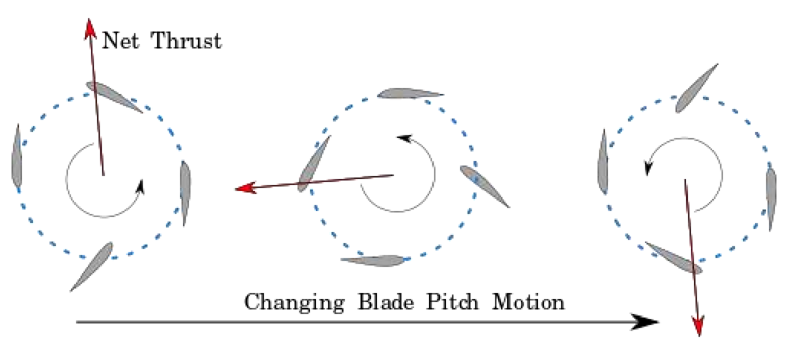
3. Cycloidal propeller development and testing

The concept for the cycloidal propeller was developed in 1921 by Frederick Kirsten based on his observations of the flight of birds, in particular, the cycloidal motion that their wings make during each flapping cycle.



Frederick Kirsten and his mathematical renderings of cycloidal motion.
Source: University of Washington, College of Engineering, Dept. of Aeronautics & Astronautics

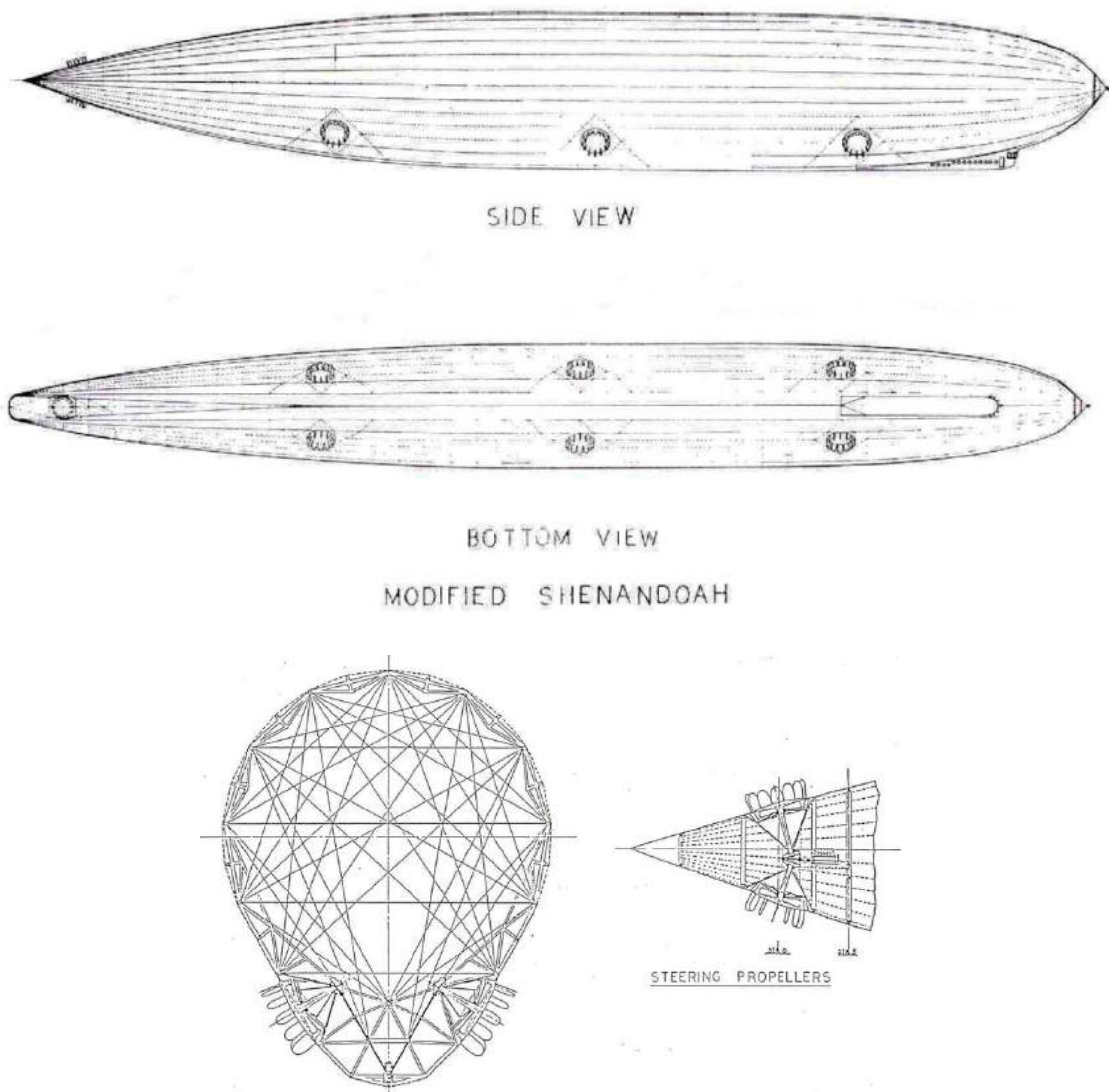
A cycloidal propeller can produce instantaneous thrust in any direction perpendicular to its axis of rotation. This is accomplished by adjusting individual propeller blade pitch, as shown in the following diagram:



A cycloidal propeller delivers vectored thrust perpendicular to its axis of rotation by changing its blade pitch angles. Source: Wikipedia

Kristen first built a 10.23 inch (26 cm) model of a cycloidal propeller and tested it in the wind tunnel at the University of Washington in 1921 with very favorable results. Larger propellers were tested to measure performance variables more accurately over a broad range of conditions, yielding up to 12.6 pounds thrust /shaft horsepower.

Boeing invested in cycloidal propeller development for both aerial and marine applications. Based on the good results obtained from the experimental aerial propellers, the U.S. Navy planned to install eight Kirsten-Boeing cycloidal propellers on the 207.5 m (680.8 ft) long *USS Shenandoah* (ZR-1) airship for flight testing. Unlike Kirsten's experimental propellers, the outer rim was left off, so the blades projected directly from the hub into the open air. Unfortunately, *USS Shenandoah* crashed in September 1925 before the planned installation could be done.



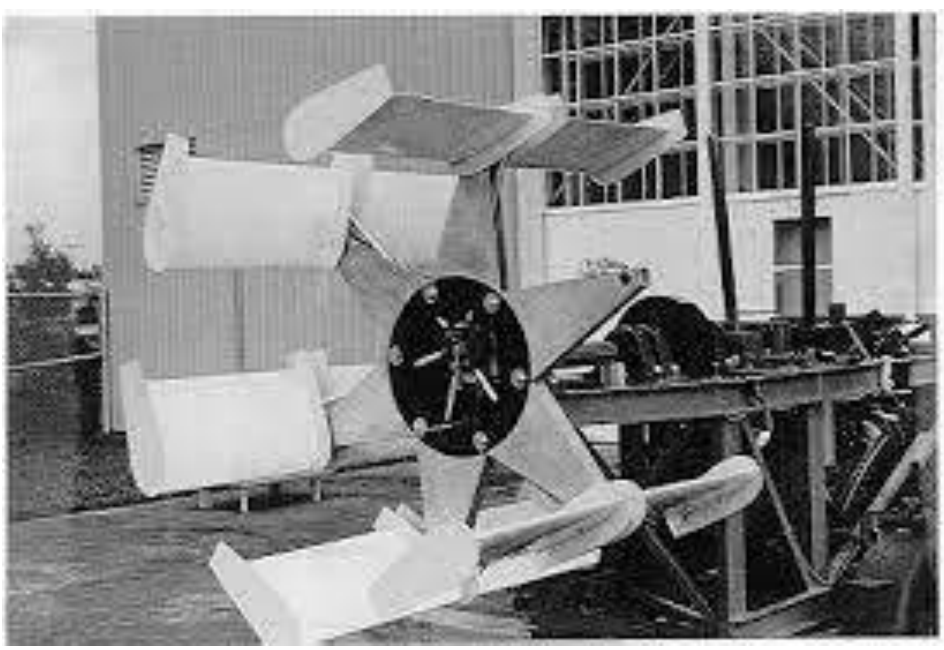
Proposed cycloidal propeller modification of the USS Shenandoah (ZR-1), with six flank-mounted Kirsten-Boeing propellers and two tail-mounted propellers for steering control. Aerodynamic control surfaces were removed.
Source: NACA TM-351 (1926) via Roy P. Gibbens (1990 Hobbs prize submittal)

In 1934, John B. Wheatley and Ray Windley tested a four-bladed cycloidal propeller with a diameter and wingspan of 8 feet (2.44 m) at NACA Langley, Virginia. This propeller reportedly produced up to 12.5 pounds thrust /shaft horsepower, in very close agreement with Kristen's results a decade earlier.

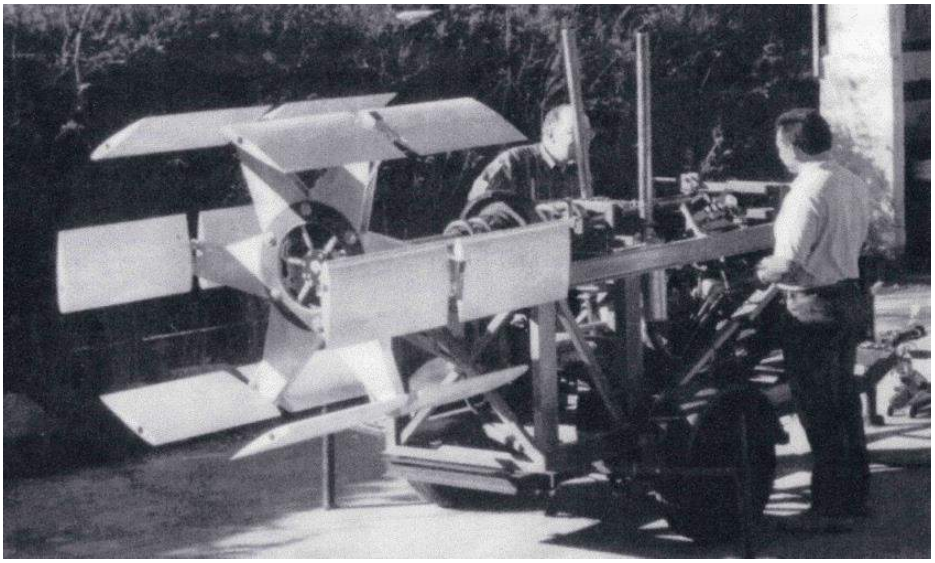
Aerial cycloidal propeller development at Bosch Aerospace

In November 1997, the U.S. Department of Defense issued a Request for Proposal (RFP) for a novel propulsion unit for a remotely piloted aircraft that did not require rotors, tilt-rotors or vectored thrusters. James Boschma, of Bosch Aerospace in Huntsville, Alabama, submitted a proposal using a Curtate cycloidal propeller, which was selected because it provides the best hover performance and excellent flight performance up to speeds up to about 120 knots. In May 1998, the Naval Air Warfare Center - Aircraft Division, Patuxent River, Maryland awarded Bosch Aerospace a Phase I (six month) SBIR (Small Business Innovative Research) contract to build and test a full-scale prototype Curtate cycloidal propeller. Roy P. Gibbens served as a consultant to Bosch Aerospace on this project.

On 31 October 1998, Bosch Aerospace became the first company in more than 50 years to build and run an aircraft cycloidal propeller. Their 4-foot (1.2-m) diameter, six-bladed prototype cycloidal propeller is shown in the following photos.

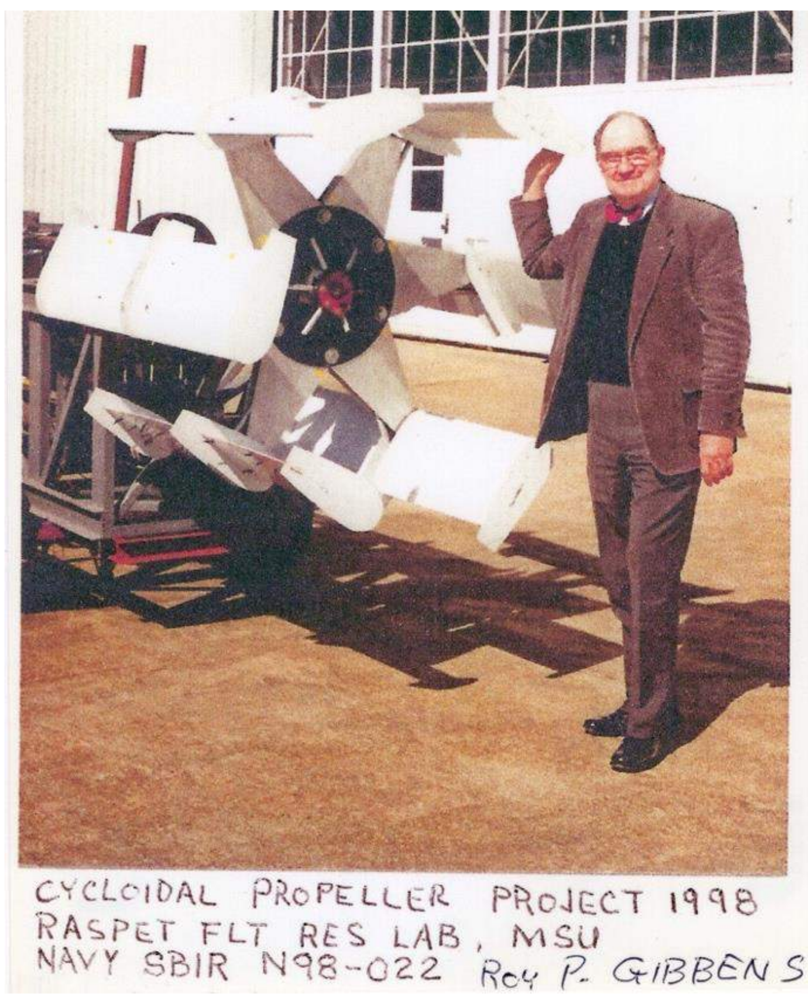


Bosch Aerospace prototype six-bladed cycloidal propeller. Source: Roy P. Gibbens



Bosch Aerospace prototype six-bladed cycloidal propeller. Source: Roy P. Gibbens

Gibbens reported, “Following the first start in Huntsville, AL, the propeller was transported to the Raspet Flight Research Center at Mississippi State University (MSU) in Starkville, MS. Qualifying test were run and approved by the Navy and a follow-on SBIR (contract) was awarded for further testing. Under the new SBIR, the metal blades were replaced with composite blades. Extensive testing was accomplished under the direction of Mr. Boschma and the Raspet director, Dr. Bennett.”

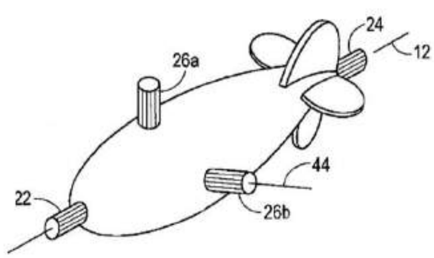


In their November 1998 Final Report, Bosch Aerospace provided the following summary of their test results:

> “The cycloidal propeller tests were designed to accomplish two major goals, to measure thrust, and to assess thrust vector capability…….”
>
> “Thrust measurements were taken at various RPMs in two orientations, 90° up, and then 90° down from horizontal. Vector assessment was made throughout the 360° arc. Downward thrust was approximately 20% below projections. Upward thrust in lower RPM ranges was 3% above projections. However, as RPM increased thrust decreased to the 20% below projections level. Reduced data showed that thrust varied from approximately 10.88 lb/Hp at low RPM, to 8.4 lb/Hp at high RPM.”

Bosch Aerospace built a test airship with three cycloidal propellers, however, project funds were cut in 1998 and it never flew. Nonetheless, the project demonstrated the high thrust / horsepower and 360° thrust vectoring performance of the cycloidal propeller as well as its low noise characteristics and responsiveness to rapid control changes.

Years after its cycloidal propeller development program ended, Bosch Aerospace’s parent, Information Systems Laboratories (ISL), was granted patent US7264202 B2 for a “tri-cycloidal airship,” which used cycloidal propellers to provide propulsion and control on all three flight axes (pitch, roll, yaw). Callum Sullivan, the Bosch Aerospace design engineer, was listed as the inventor and the patent was assigned initially to ISL. In 2011, the patent was reassigned to Boschma Research Inc.



Legend: *Cycloidal propulsive units (22, 24 & 26), longitudinal axis (12), transverse horizontal axis (44), Transverse vertical axis not shown.*

Bosch Aerospace cycloidal propeller airship concept. Source: Adapted from Patent US 7264202 B2 Fig 1

Comparison of cycloidal propeller and modern rotary wing aircraft performance

The Bosch Aerospace prototype cycloidal propeller thrust results were somewhat lower than the results obtained by Frederick Kirsten in the 1920s and by John E. Wheatley at NACA Langley in 1935. Bosch Aerospace noted that, “However, to this day no rotary-winged aircraft has been developed that can match the efficiency of a cycloidal propeller. The latest in VTOL aircraft, the V-22 Osprey, falls well *below* the closest rival to cycloidal systems, the MD-500 helicopter.”

The following chart from the Bosch Aerospace Final Report shows the large margins by which the cycloidal propeller test results by Bosch (1998) and NACA (Wheatley, 1935) exceed the thrust / horsepower performance of modern rotary wing aircraft.

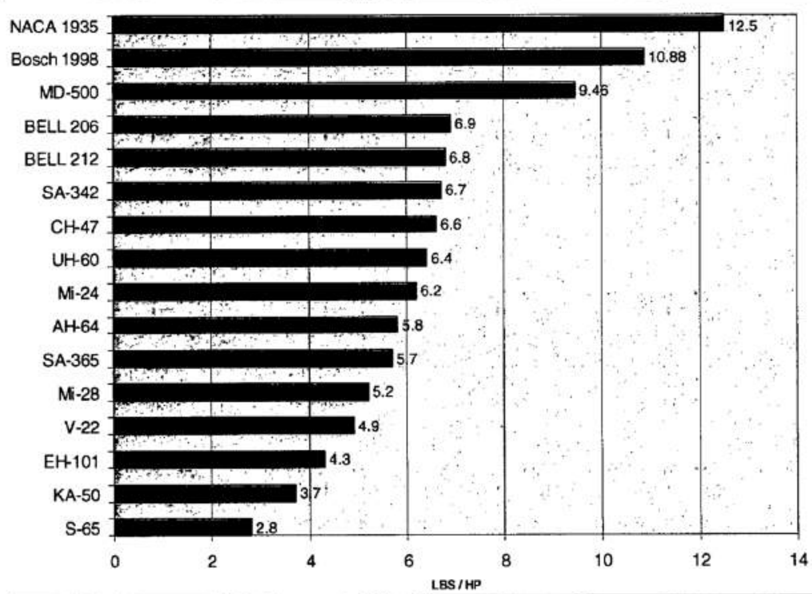


Figure 1. Thrust Comparison Chart

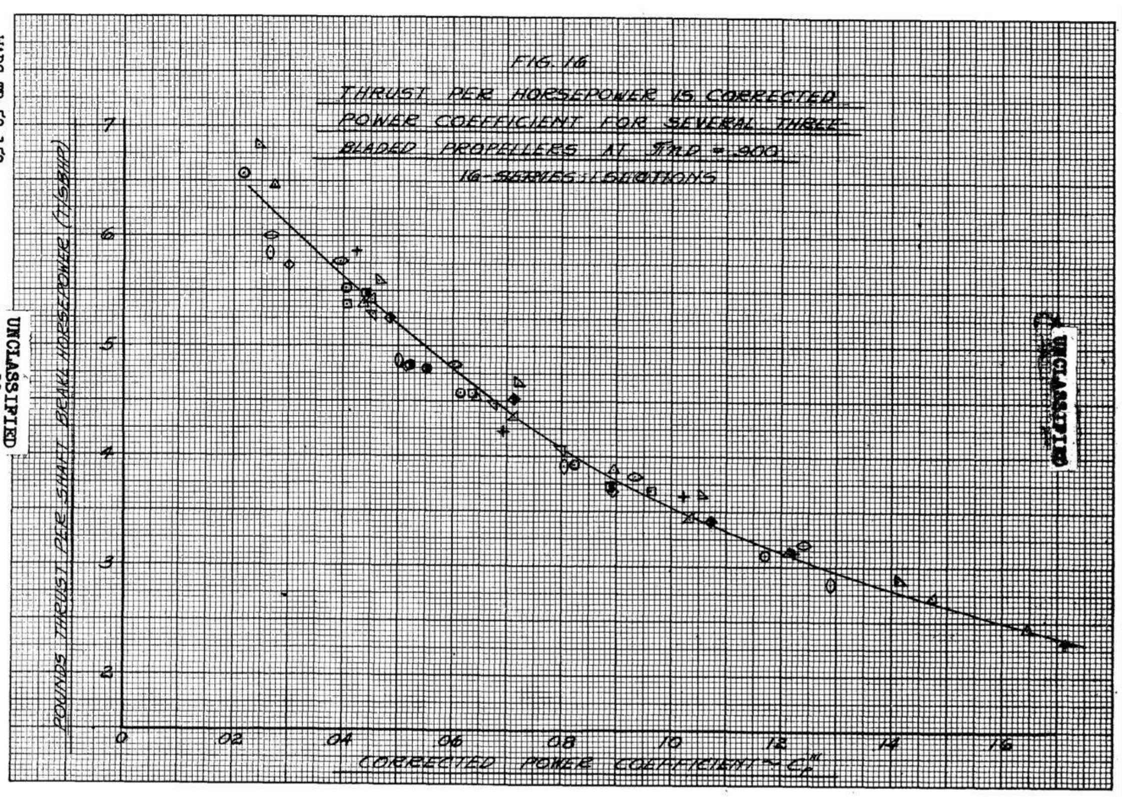
This chart provides a comparison to wind tunnel data from cycloidal propellers and a selection of the most modern rotary winged aircraft in service in the world today including many Soviet-built machines. (data from Jane's All the World Aircraft)

2 BOSCH AEROSPACE, INC./5635 FINAL REPORT

Comparison of cycloidal propeller and screw-type aviation propeller performance

The above cycloidal propeller thrust / horsepower performance statistics can be compared with similar results for conventional propellers at zero airspeed. Such propellers are commonly used on airship in main propulsion applications, which may include various installations with a thrust vectoring capability.

The comparative propeller data were developed in 1952 by Wright Air Development Center and documented in their report WADC Technical Report 52-152, “Propeller Performance at Zero Forward Speed.” This WADC report includes thrust per shaft horsepower graphs for 2-, 3-, 4-, 6-, and 8-bladed (dual 4-bladed) propellers. Representative results for a 3-bladed propeller are shown in the following chart.



Thrust per Horsepower vs. corrected power coefficient for several three-bladed propellers. Source: WADC Technical Report 52-152, Fig. 16

The Y-axis of the above chart is “Pounds Thrust Per Shaft Brake Horsepower” and ranges from a maximum value of 6.5 to a low of 2.5 pounds thrust/shp. Other propellers were in a similar thrust / horsepower range, generally topping out at less than 7 lb thrust / horsepower.

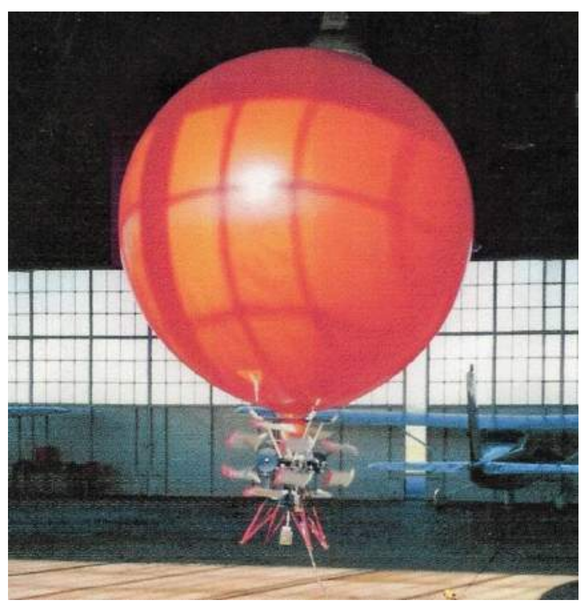
Recall that the Bosch Aerospace 1998 cycloidal propeller tests recorded a maximum 10.88 pounds thrust / horsepower.

Cycloidal propeller development by Gibbens & Associates

After the Bosch Aerospace program ended, Roy P. Gibbens' firm, Gibbens and Associates, started in 2000 to design and test cycloidal propeller systems, which they referred to as Horizontal Axis Propellers (HAPs).

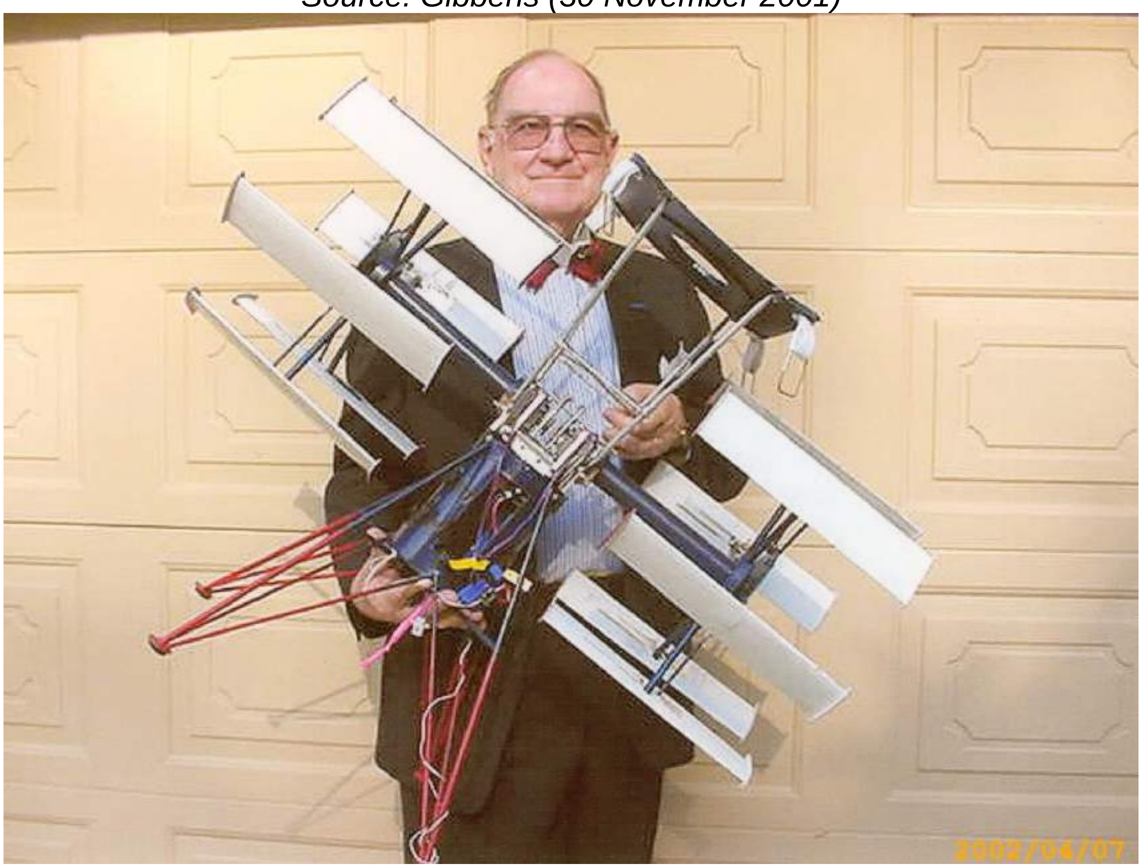
Their first test device was a radio-controlled, small, six-bladed cycloidal propeller mounted on a free rotating horizontal arm to demonstrate the ability to rapidly change direction and hover. Later, using an articulated rotating arm, it was possible to demonstrate control in both the horizontal and vertical planes.

The first free-flying test vehicle was a radio-controlled test rig comprised of a 7-foot (2.1-meter) diameter balloon carrying a flight unit with two, six-bladed, 1-foot (0.3-m) diameter, electric motor-driven cycloidal propellers. Gibbens reported that, during the first indoor tests on 4 December 2000, this flying test rig responded rapidly to controls, hovering, flying backward, forward, making turns and elevation changes. Gibbens noted, "The flights were made in the Historic Key Brothers Hangar at Key Field, Meridian, MS, and were the 'first' actual flights of any aircraft controlled completely by horizontal axis propellers."



Flight unit under 7 ft (2.1 m) balloon. Source: Gibbens (23 November 2001)

Source: Gibbens (30 November 2001)



Roy P. Gibbens and his cycloidal propeller test rig. Source: Gibbens (2001)

Following these successful indoor flights, the propellers were taken to the UK, where they were installed on a modified 23 foot (7 m) Airspeed Airships radio-controlled blimp designed by Nigel Wells, likely an AS-300. The airship was modified by removing the two original conventional propellers and installing two horizontally-mounted cycloidal propellers cantilevered transversely from the gondola. Fight tests in the UK in 2001 demonstrated that the airship was fully controllable with the two horizontal axis cycloidal propellers cantilevered transversely from the gondola.

A 7 m (23 ft) Airspeed Airships blimp, likely an AS-300, adapted for testing cycloidal propellers. Source: Roy Gibbens (2011)

Following the successful UK test flights, the airship was then shipped to the U.S. for further modifications and flight tests at Gibbens' facility in MS. Gibbens reported on these tests:

> "The upper tail fins/rudders were removed and the lower controls were locked in place, acting only as directional fins. The controls were adjusted to allow the propellers to be 'cross

controlled' and make the airship turn without the use of the rudders. The airship made turns with only two propellers on the gondola. Quicker turns could have been made with an additional propeller mounted on the aft end of the airship."

You can watch a short 2002 video showing with an introduction to Gibbens' cycloidal propeller design and an indoor flight test of this airship here.

23-foot (7-m) long, remote controlled, helium blimp manufactured by Airspeed Airships and adapted for cycloidal propeller testing by Roy P. Gibbens. Note that the upper tail fins have been removed. Source: Gibbens (photo 2001)

Cycloidal propeller installation on a remotely-controlled blimp.
Source: Roy P. Gibbens DARPA white paper, circa 2008

4. Design concept for the AirLighter 2

In a 2009 paper, Roy P. Gibbens explained the origin of his AirLighter 2 design concept:

> “My 1983 AIAA paper proposed an ‘aerodynamic’ shaped ‘Small Rigid Airship’ formed using high strength composites. If designing this airship today, we would remove the ‘vectored thrusters’ and all the complicated (and heavy) tail control system and replace them with a ‘horizontal axis propeller control system,’ (cycloidal propellers), which would be lighter and more efficient.”

> “The (AirLighter 2) airship is a semi-buoyant aircraft that derives much of its lifting power through a lighter-than-air (LTA) gas (non-flammable helium), aerodynamic lift from the shape of the aircraft and its propulsion system.”

After this transformation, the resulting rigid, hybrid airship became known as the AirLighter 2. It apparently dispensed with the two lifting gas (helium and hot air) system used in the Lockheed Starship SRA and the original Gibbens and Associates AirLighter design concepts.

Regarding the use of cycloidal propellers, Gibbens noted in 1990:

> "Using the cycloidal propellers gives instantaneous directional control in any direction and even allows the ship to rotate 360° while hovering. The airship can power itself up with a heavy load or power down to a precise landing position even when light. With these new capabilities the airship will become a useful asset within the transportation system. They will become the cargo ships of the world as they will be able to service any geographical location and without the need of an airport."

With GPS input, the airship's flight control computer could precisely position and hold the airship at an assigned altitude, geolocation and heading. The rapid response of the cycloidal propellers would be big asset for maintaining airship stability during gusty conditions.

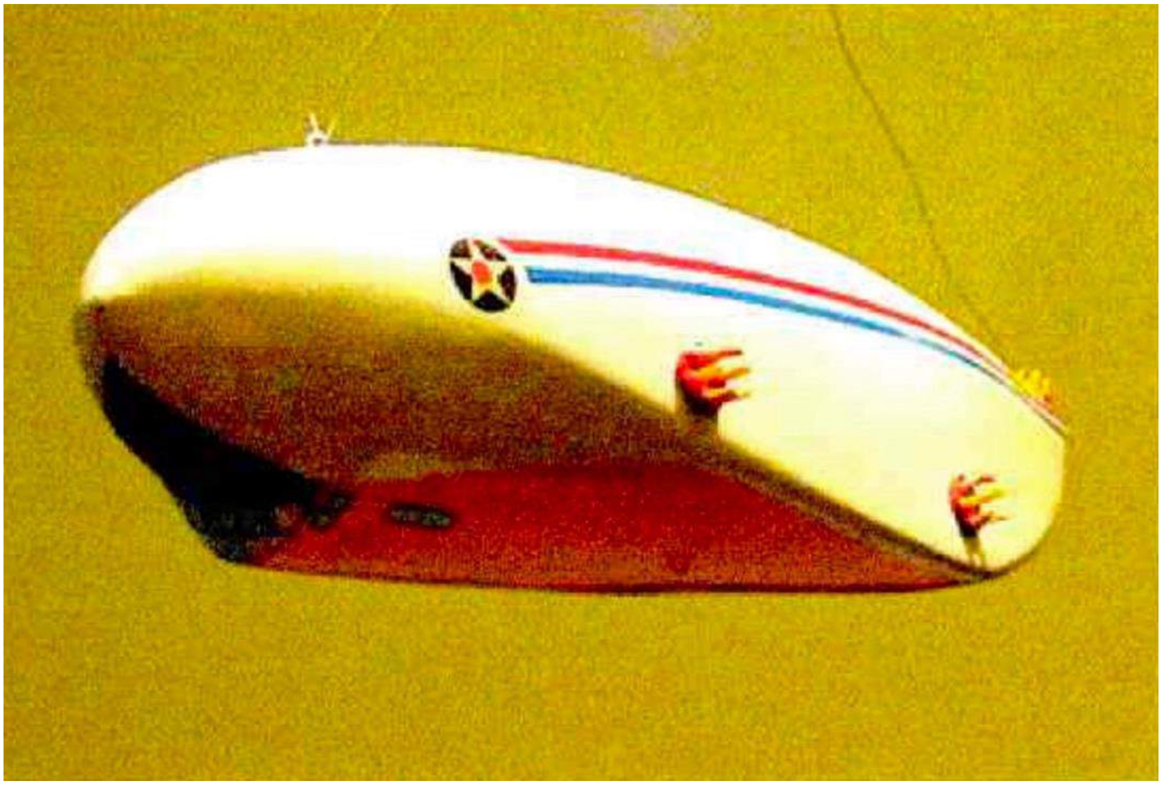
As implemented in his design concept for the AirLighter 2, five cycloidal propellers, two along each flank of the airship and one atop the tail, would propel the airship at cruise speed and enable precise maneuvering at low speed, during hover and VTOL without aerodynamic stabilizing fins or control surfaces.

- All five of the AirLighter 2's cycloidal propellers could be employed for cruise propulsion or braking (fore and aft thrust).
- The four flank-mounted cycloidal propellers also could provide almost instantaneous 360◦ of vertically vectored thrust to enable precise lift control during VTOL, hover and airborne load exchanges. Differential controls enable these cycloidal propellers to accurately respond to fine pitch, roll and yaw commands.
- The tail mounted cycloidal propeller also could provide an almost instantaneous 360◦ of horizontally vectored thrust to accurately respond to yaw commands.

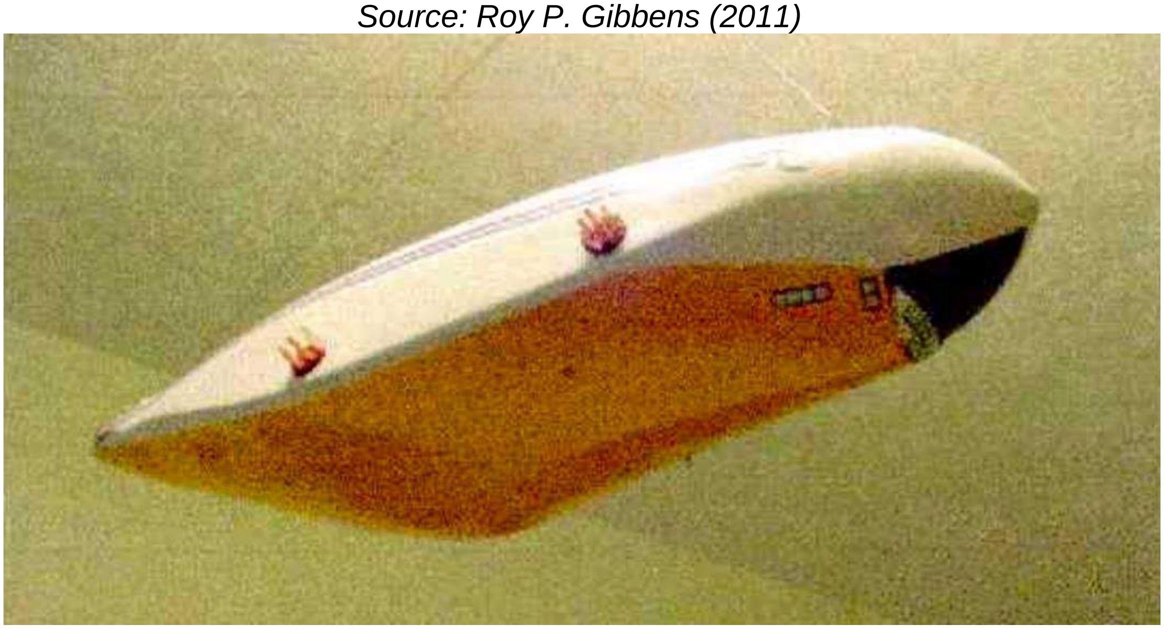
AirLighter 2 model bow overhead view showing two flank-mounted cycloidal propellers and one more aft, atop the tail for precise low-speed directional control. Source: Roy P. Gibbens (2003)

The AirLighter 2 was designed for longer-range cargo missions than the original AirLighter, with a family of airships sized for payloads from 30 to 200+ tons (27 to 181+ metric tons). Gibbens explained its intended role as follows:

> "The Airship will fill a niche between ocean vessels and the airplane in transporting goods and passengers as it is much faster than a boat and can carry goods too bulky for an airplane at a reasonable price. Goods transported by airship will bypass seaports and fly point-to-point, thus eliminating several transfer points of goods. Eliminating the high cost associated with dockside storage and ground transportation will reduce loss and damage of goods."
>
> "Modern airship (the AirLighter 2), with five de-rated turbo-shaft engines or perhaps even solar-powered electric motors (driving cycloidal propellers), will be capable of unrefueled flights half-way around the world."



AirLighter 2 model, bow quarter view showing the two flank cycloidal propellers. Source: Roy P. Gibbens (2011)

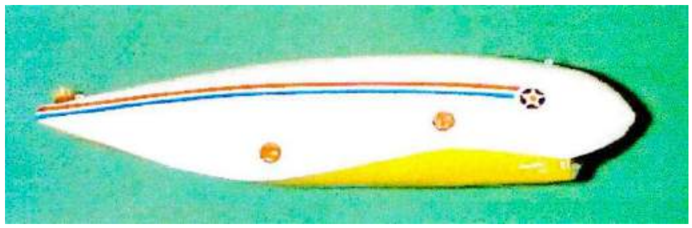


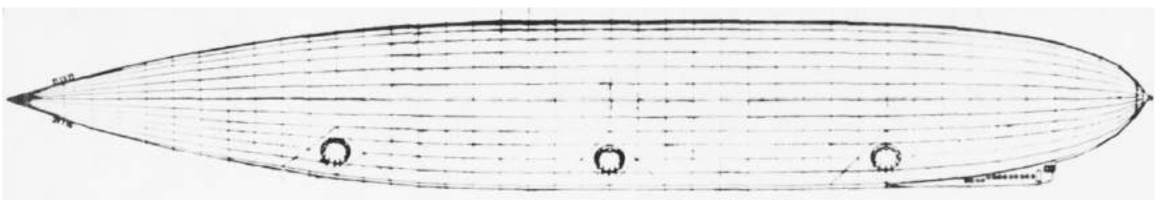
AirLighter 2 model, view from below showing the two flank cycloidal propellers. Source: Roy P. Gibbens (2011)

Development of the AirLighter 2 did not continue after Roy P. Gibbens passed away in 2013.

Comparison of AirLighter 2 with the planned modified *USS Shenandoah* (ZR-1)

The general layout of cycloidal propellers on Gibbens' AirLighter 2 was quite similar to the layout planned in the 1920s by the U.S. Navy for installation on the larger, modified *USS Shenandoah* (ZR-1). Both have multiple, flank-mounted cycloidal main propulsion propellers and stern mounted steering propeller(s).





(Top) AirLighter 2 model side view showing the two flank-mounted cycloidal main propulsion propellers and the single tail-mounted (top only) steering propeller. Source: Roy P. Gibbens (2009).
(Bottom) USS Shenandoah (NOT TO SCALE) with three flank-mounted cycloidal main propulsion propellers and two tail-mounted (top and bottom) steering propellers. Source: NACA TM-361 (1926)

The planned installation of Kirsten-Boeing cycloidal propellers on the *USS Shenandoah* is described in NACA Technical Memorandum No. 351, dated February 2026. In addition to information on the installation of the cycloidal propellers, this Tech Memo also describes the operation of the modified *USS Shenandoah* and opportunities for optimizing a future similar airship, such as the AirLighter 2.

> "There were six main propellers thus designed, with their axes at an angle of 30 to the horizontal plane. With these propellers it is possible to so adjust the thrust as to produce forward and backward and upward and downward motions of the airship. The two rear propellers lie in the vertical plane and replace the customary rudders. These propellers increase the forward

thrust in straight-ahead flight. …….. it is worth noting that all the driving shafts, struts, supports and engines have been put inside the hull. This arrangement necessitates the use of incombustible lifting gas, e.g., helium. The gasbags are inflated only just enough to lift the airship to the desired pressure height. If, after a long flight, the airship gets too light from the consumption of the fuel, its ascent can be arrested by the proper adjustment of the propellers.

In practice, the airship will be supplied with only enough gas to lift one-half of the fuel required for the trip, the balance of the lift required during the first half of the journey being supplied by the propellers . The possibility of controlling the airship in the vertical direction by means of the propellers renders it unnecessary to valve the very valuable helium gas in order to bring the ship down. For the same reason, the heavy and cumbersome devices for recovering ballast water from the exhaust gases of the engines can be eliminated. In regard to the ballast and trim difficulties, the airship can be kept on an even keel at all times, since the thrust of any propeller can be changed instantly to any direction required to counteract any tendency of the ship to rise or fall. The limits of this possibility naturally depend on the magnitude of the available propeller thrust. In this case, the propellers were designed for a thrust of about 1,800 pounds each, making a total thrust of about 10,800 pounds for the six main propellers.

Since the control of an airship equipped with the Kirsten-Boeing propellers is independent of the flight speed and has, through the action of the propellers, very great “rudder-forces” at its disposal, the hull can be made shorter and more compact for a given gas capacity, and the airship can be made stronger with the same weight of material. The attendance (crew complement) of the airship is likewise greatly simplified, due to the fact that the engines always revolve in the same direction, regardless of the direction of the thrust. In ordinary maneuvers, it is not necessary to stop the engines or disconnect any couplings, even when it is desired to bring the ship to a complete stop. The direction of the thrust of all the propellers can be controlled by one man through simple mechanical and

> electrical devices located in the pilot house. The installation of an automatic control is entirely feasible.
>
> The total weight of an airship equipped with Kirsten-Boeing propellers will be less than that of one equipped with the conventional screw propellers. The weight of the steering gear, power cars, etc., on such an airship, is greater than that of the Kirsten- Boeing propellers. Moreover, an airship equipped with Kirsten-Boeing propellers would require less ballast and a smaller crew, since it would not be necessary to have men stationed at the engines to receive orders."

5. Design concepts for simplified ground support for airships using cycloidal propellers

Gibbens felt that the improved airship maneuverability derived from cycloidal propellers would give airships new options for simplified ground handling with a small or no ground crew.

In 1990, Gibbens wrote:

> "Since the airship is now capable of controlled hovering, the use of the 'Roundhouse' type turntable for (large airship) ground operations becomes more feasible, (Fig. 9). With this equipment, the airship hovers over a railed transporter vehicle on the turntable and lowers a series of cables attached to hard points on its sides. The cables are then attached to the transport vehicle's winches and the ship lowers to docking pads (Fig. 10) and is secured. A separate railed mooring mast on an outer circle is then attached and the ship is taken into the dock. Passengers and cargo are exchanged and maintenance and servicing are provided for a quick turn-around of the ship.
>
> The …. system allows for side-by-side docking of large airships, minimizing the amount of land required for major airship ports. Servicing buildings are also shared as they can be built between the airship docks. Even so, an area one half mile by one mile long will still be required to handle several ships at a time."

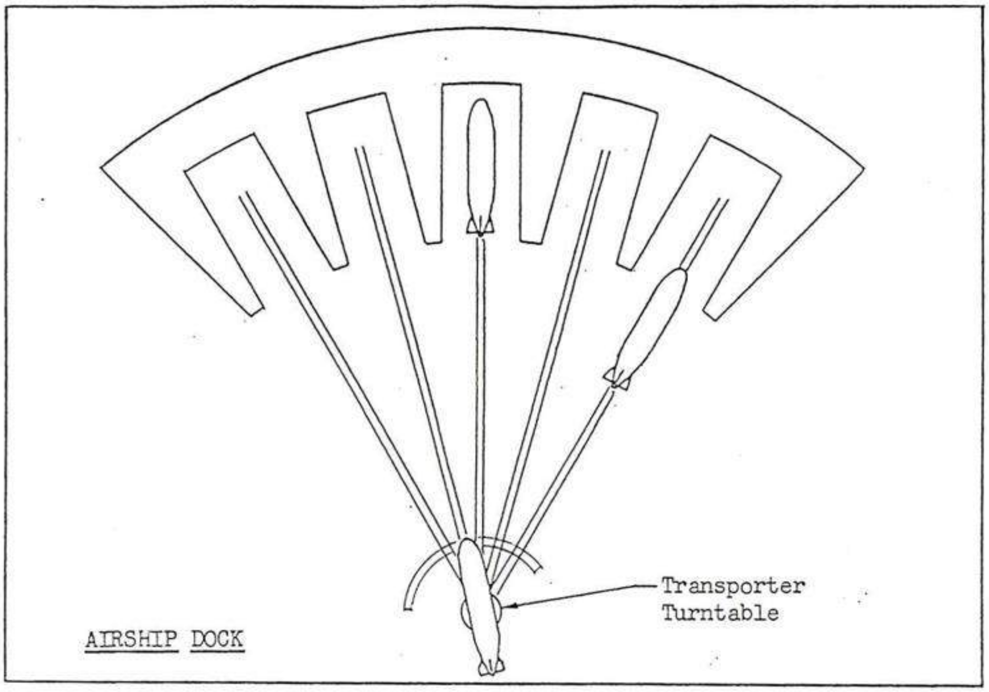


Fig. 9

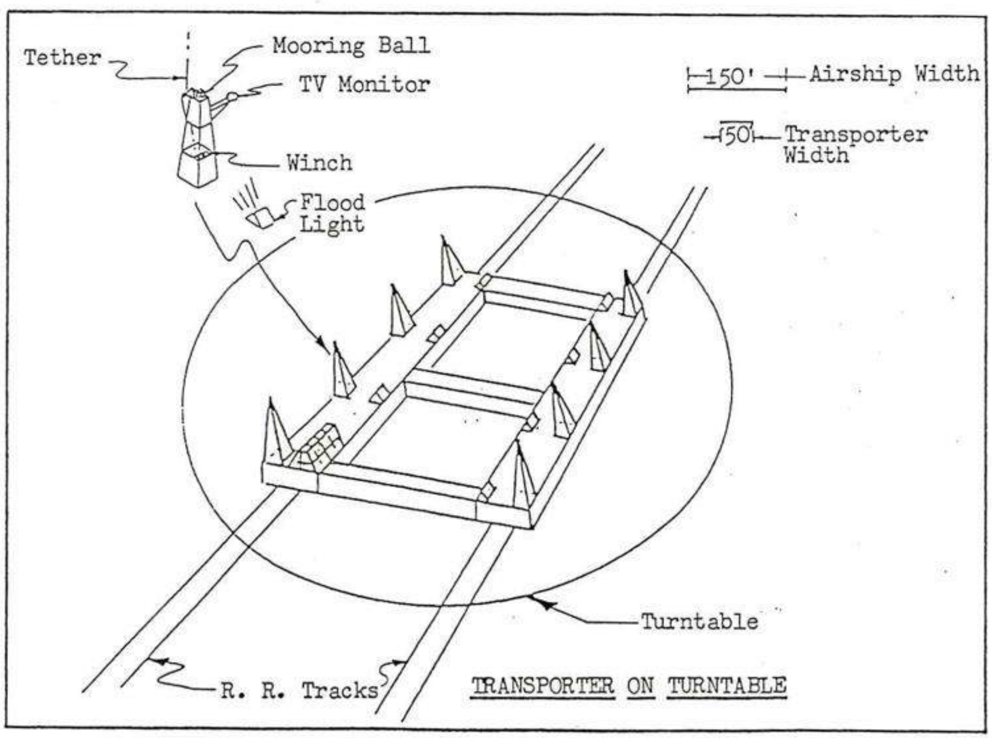


Fig. 10

Source: Gibbens (Nov 1990)

For smaller airships with cycloidal propellers, Gibbens proposed an updated version of a “mooring ring” concept he developed a decade earlier.

In 1990, he wrote: “This simple device is a ring with a wind tee pivoted in its center with a mooring bar mounted on its aft end. Mounted on top of the tee is a ‘docking cup’ designed to accept the ‘docking probe’ mounted on the airship (Fig. 11). The pilot has a manual release/engage device operated from the cabin for the mooring latch.

To dock, the pilot maneuvers the ship until the probe, mounted in front of the control car, fits into the docking cup (Fig. 12). Rails on the sides of the mooring bar guide the ship’s docking latch onto the mooring bar where it locks and then the ship is free to rotate. The ship is prevented from vertical movement by the mooring bar and therefore does not need additional ballast nor to be continuously monitored.

To takeoff from the dock, reverse thrust is applied, the pilot pulls the manual docking latch release…..and the ship backs out a safe distance for a normal takeoff. Units of this design can be mounted on various types of vehicles, in open fields and on buildings.”

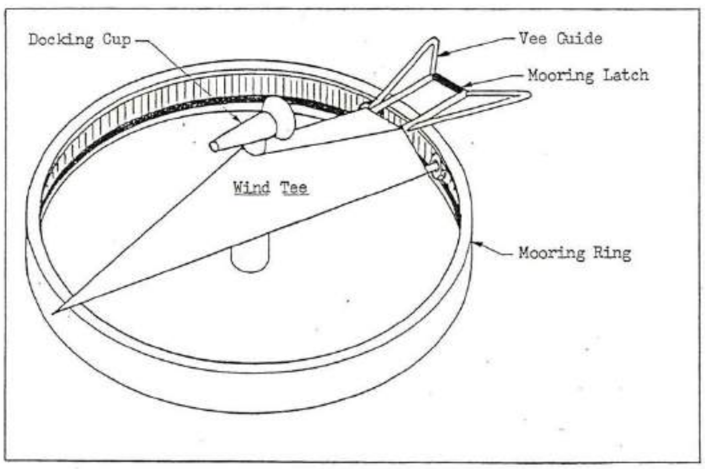


Fig. 11

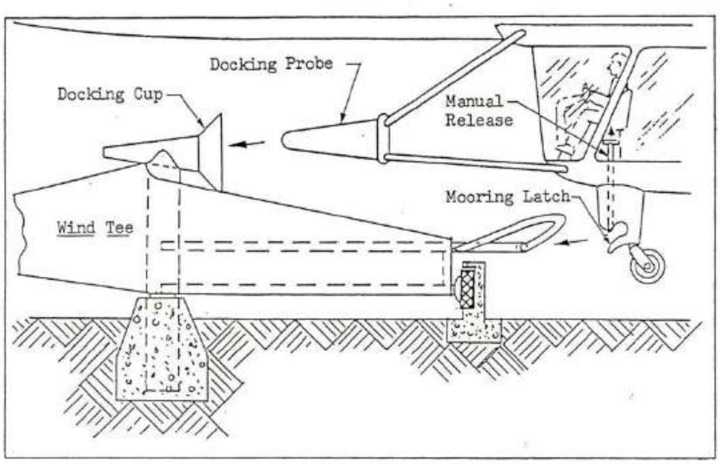


Fig. 12

Source: Gibbens (Nov 1990)

6. For more information

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Other *Modern Airships* articles

- *Modern Airships - Part 1*: https://lynceans.org/all-posts/modern-airships-part-1/
    - ISL – Bosch Aerospace – prototype cycloidal propeller
- *Modern Airships - Part 2*: https://lynceans.org/all-posts/modern-airships-part-2/
    - Aerosmena - hybrid thermal airships
    - Airspeed Airships – cycloidal propeller test platform (AS-300)
    - Boeing - hybrid thermal airship

    - Lockheed Corp. – Starship hybrid thermal small rigid airship (SRA)
    - LocomoSky - hybrid thermal airships
    - Skylifter – conventional airship with cycloidal propellers
    - Thermoplan - hybrid thermal airships
    - Thermo-Skyships Ltd. (TSL) - hybrid thermal airships
    - University of Virginia (UVA) Charlottesville - Solar Airship Program
- *Modern Airships - Part 3*: https://lynceans.org/all-posts/modern-airships-part-3/