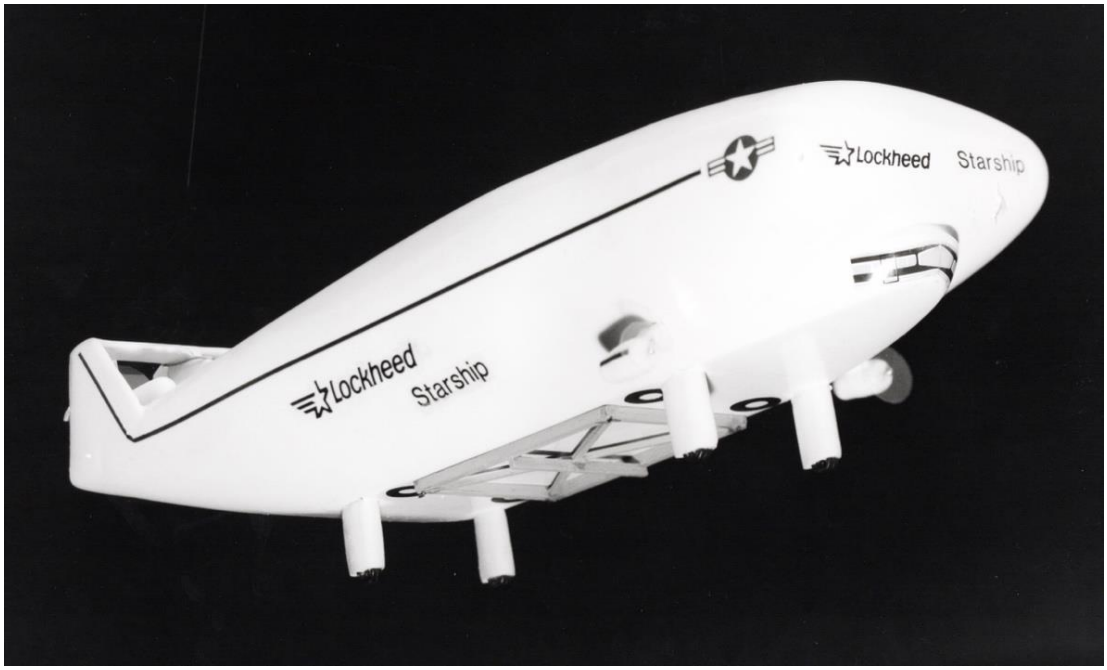
Lockheed Corp. – Starship hybrid thermal small rigid airship (SRA)

Peter Lobner, 27 October 2023

1. Introduction

Beginning in the mid-1970s, the Lockheed-Georgia Company (a division of Lockheed Corporation) was engaged in developing several advanced airship concepts. One that emerged in the early 1980s was a small rigid airship (SRA) that was similar in size, but was a radical departure from the designs of contemporary non-rigid blimps. Novel features incorporated in the SRA's design included a rigid hull, a flattened ellipsoidal lifting body hull shape, and the use of two lifting gases: helium and hot air.

This work, led by Lockheed engineer Roy P. Gibbens, at the Lockheed facility in Meridian, Mississippi, was first disclosed to the public in a July 1983 paper. By then, the SRA had become known as the Lockheed Starship.



Lockheed Starship SRA model. Source: Roy P. Gibbens (1983)

In his 1983 SRA paper, Roy P. Gibbens identified the following attributes of his SRA design concept:

> **Structurally stronger than blimps:** "With modern materials and technology we can now build small, lightweight, pressure rigid airships, which will be structurally stronger than a non-rigid (blimp) type vehicle. Up to now the material to fabricate a 'practical' Small Rigid Airship (SRA) has not been available. The small rigid airship will open new ground for Lighter-Than-Air (LTA) airships because of their rigidity and size, down to approximately 100,000 ft^3 (2,832 m^3 envelope volume)."
>
> **Improved aerodynamic & functional shapes:** "Engineers are no longer restricted to use the classical 'cigar' shapes of the past, which were dictated by the use of fabric construction and gas distribution. Because we can form these new materials to more desirable aerodynamic and functional shapes, we can now develop the small rigid airship to be a practical vehicle……Through the use of rigid structures we can design vehicles with improved dynamic lift, which will give us larger payload capabilities over equal displacement hulled blimps. These new SRA'S will look more like 'lifting body' vehicles than blimps"
>
> **Improved controllability:** "New freedom of movement will be developed by SRA's as helium and hot air lifting gases will be used in conjunction with each other. This combination of gases will result in positive ground handling methods; airship trim can also be maintained through the management of the hot air portion."
>
> **Greater speed:** "Because of its rigid outer shell, the SRA's can be designed to fly at higher altitudes and at greater speeds, 120-150 knots, thus giving a wide margin of block-to-block time over the bag-type blimps"
>
> **Simpler manufacturing & servicing:** "Mass manufacturing would be enhanced by the rigid structure of these airships and will allow for easier maintenance and greater flexibility of servicing facilities."

Gibbens noted that only one SRA-class airship had previously been built and flown, that being the 200,000 ft^3 (5,663 m^3) rigid, metal-clad ZMC-2 built by Detroit Aircraft Corp. in the late 1920s. Among its demonstrated attributes:

- It was operated successfully by the U.S. Navy for 12 years.
- Its aluminum alloy gas envelope showed no major corrosion or structural problems.
- Its envelope weighed less per cubic meter of volume than the fabric envelopes on Goodyear's "state-of-the art" blimps *America* and *Columbia II* (circa 1969).
- Its designer, Vladimir Pavlecka, thought the metal envelope could have been made even thinner with today's metals, allowing greater payload.

In spite of these impressive attributes, no other SRA-class airship was built in the years following the ZMC-2's retirement in 1941. If built with modern composite materials instead of metal, Gibbens speculated that the ZMC-2 might have been 25 – 40% lighter.

Lockheed never built the Starship SRA.

2. Design concept for the Lockheed Starship SRA (circa 1983)

In his 1983 paper, Roy P. Gibbens noted that there are a variety of designs that could be considered as small rigid airships. He chose to focus on just one design for the Lockheed Starship SRA: 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.

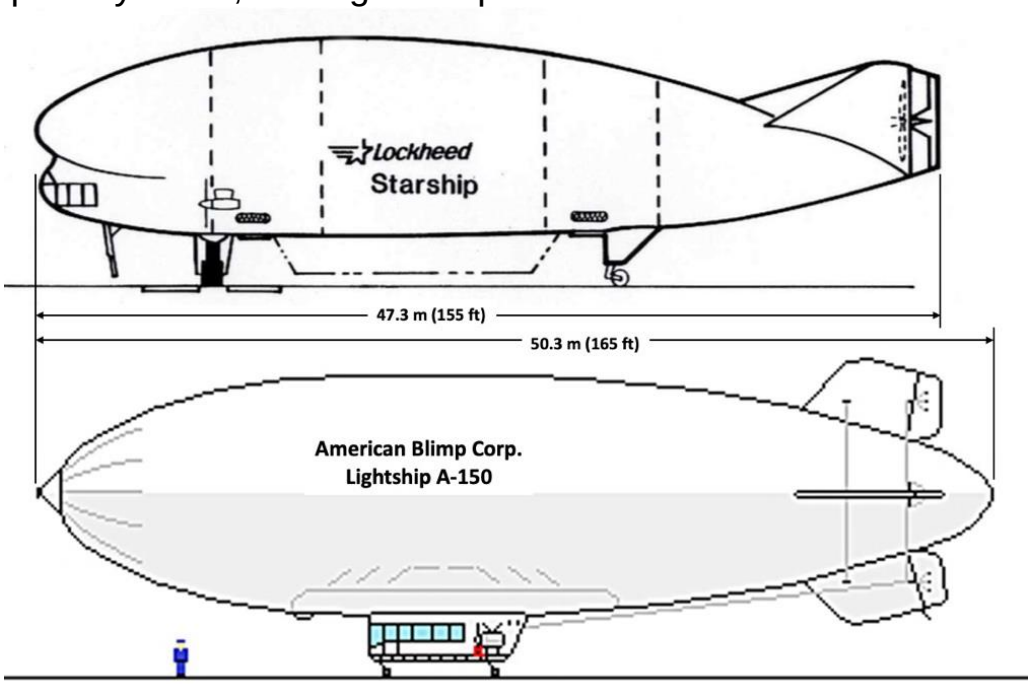
This buoyancy control concept was developed and applied in the 1700s in hybrid balloons designed by Jean-François Pilâtre de Rozière. Such "Rozière" balloons have separate chambers for a non-heated lift gas (hydrogen or helium) and a heated lift gas (air).

General design characteristics of the Lockheed Starship SRA

Parameter	Starship small rigid airship (SRA)
Type	Rigid, hybrid thermal
Length	47.2 m (155 feet)
Width (max)	15.2 m (50 feet)
Height (overall)	13.7 m (45 feet)
Hull	Three layers: • Lightweight carbon fiber, filament-wound load-bearing shell, self-supporting at atmospheric pressure • Middle insulating layer • Outer Kevlar fabric (or similar) layer
Lifting gas	Fixed mass of helium & variable mass of hot air
Propulsion & maneuvering	• 2 x tail-mounted, shrouded main pusher propellers • 2 x forward pylon-mounted tractor maneuvering propellers
Speed, max	120 – 150 knots (222 to 278 kph)

Rigid hull

The Starship SRA hull had an unconventional, broad, lifting body shape that became commonplace in the following decades on hybrid airships. At the time (early 1980s), it was a significant departure from the simple ellipsoid-of-revolution (prolate spheroid) shape of comparably-sized, non-rigid blimps.



Starship SRA & conventional blimp profile view comparison.
Sources: Adapted from Roy P. Gibbens & American Blimp Corp.

The rigid hull would be fabricated from three layers of material. The inner load-bearing shell is a carbon fiber, filament wound vessel manufactured using technologies similar to those employed on large solid rocket casings. The second layer is insulating foam, which helps improve thermal control of the lifting gases. The outer layer is a tough protective skin of Kevlar fabric or similar material.

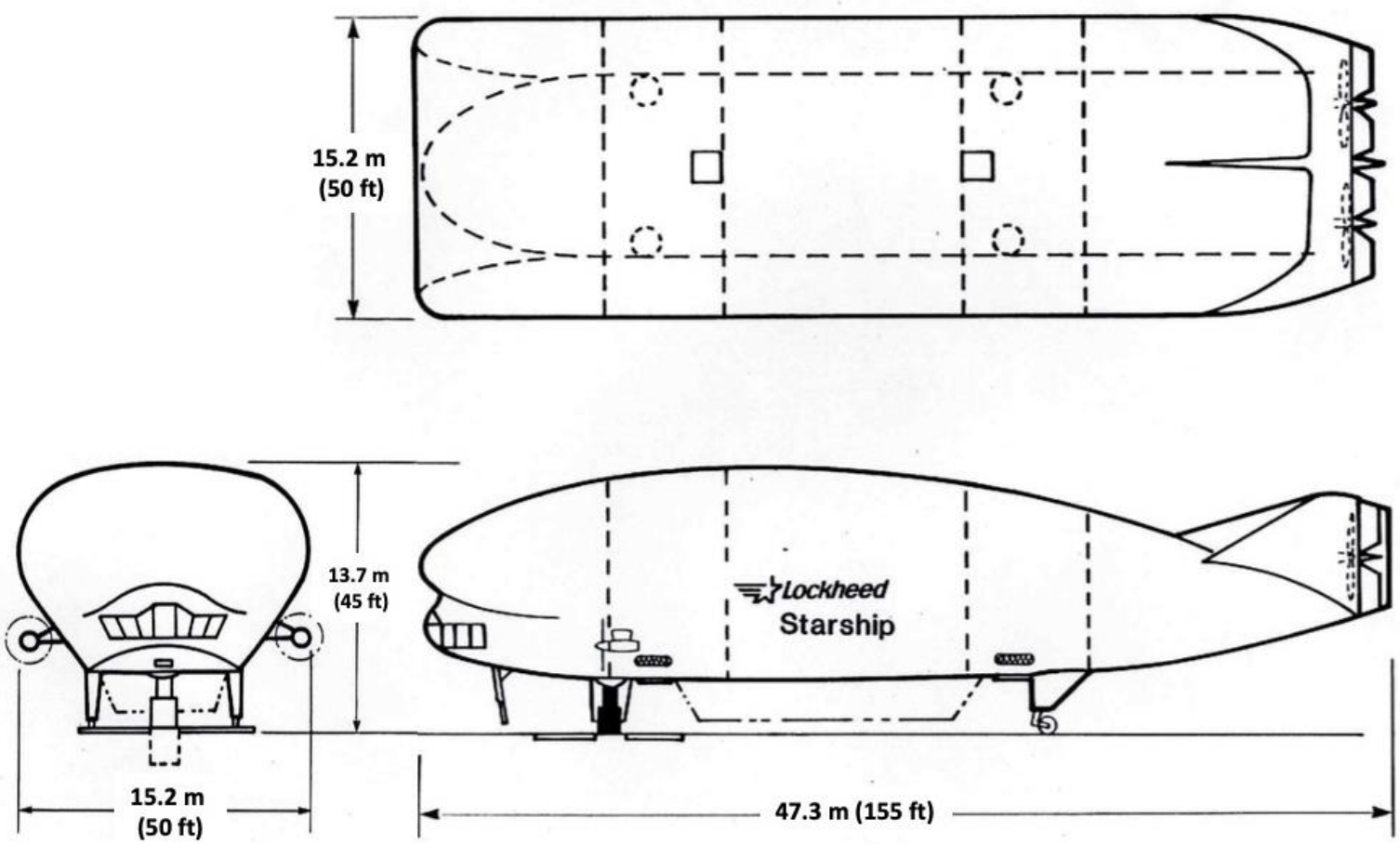
Variable buoyancy control with hot air

Within the broad, rigid hull there were five gas compartments, laid out one behind the other. The three atmospheric pressure helium compartments were located in the bow, middle and stern compartments. Each helium compartment contained a fixed mass of helium in a low-permeability gas bag, with no ballonet. The two self-supporting, atmospheric pressure hot air compartments were located between the helium compartments. Each hot air compartment was equipped with propane burners that serve as the heat source, two ambient air intakes in the lower flanks of the compartment, and a controllable hot air vent at the top of the compartment to release hot air to the atmosphere on command.

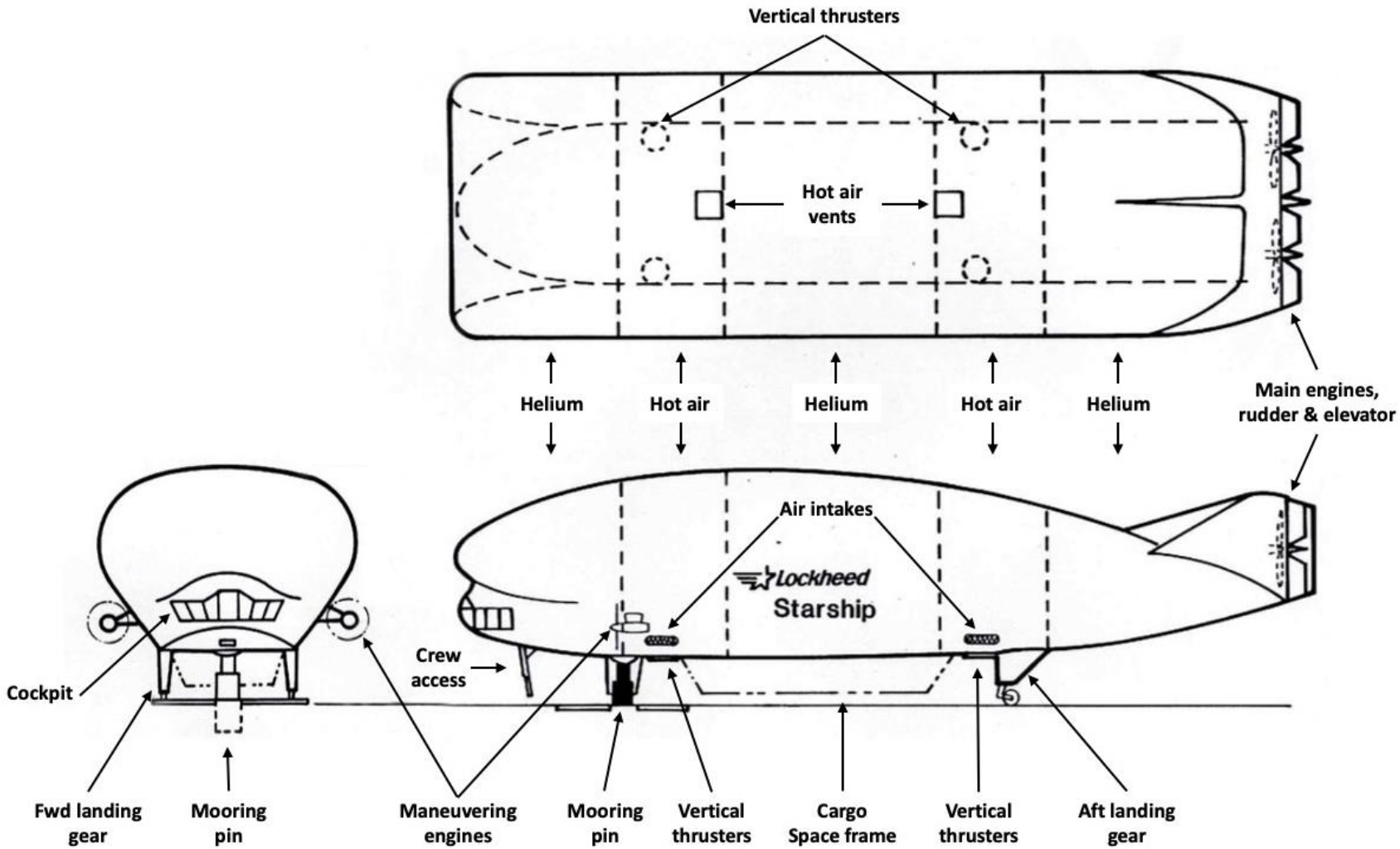
With helium alone, the Starship SRA was semi-buoyant (heavier-than-air). Airship structural integrity was maintained even when the heaters were OFF and all hot air had been vented.

Overall buoyancy was managed by controlling the heating and venting of air in the two hot air compartments. The variable aerostatic lift from hot air enabled the Starship SRA to execute vertical takeoffs and landings (VTOL), hover and compensate for the increasing aerodynamic lift from the hull as the airship accelerated to cruise speed. In addition, it was easy to compensate for cargo load exchanges, in-flight fuel burn and changes in exterior temperature without the need for disposable ballasting materials (i.e., sand or water) or helium venting.

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.



Lockheed Starship SRA design concept. Source: Adapted from Roy P. Gibbens (1983)



Lockheed Starship SRA design concept. Source: Adapted from Roy P. Gibbens (1983)

Options for increasing lifting capability

Gibbens identified several design features that could be implemented in a production Starship SRA to give it the ability to “carry loads equal to those of (LTA) vehicles with much larger volumes.”

For example, aerostatic lift could be increased with the following design features that could be employed individually or together:

- "Super heating" the helium to maximum displacement in the fixed-volume, atmospheric pressure helium compartments.
- Introduce steam in the hot air compartments. This would double the lift provided by the dry hot air.

Adding vertical thrusters would provide a dynamic (propulsive) lift capability to augment aerostatic lift, primarily during VTOL and while hovering.

Trim control

The two hot air compartments are located forward and aft of the airship’s center of gravity. Airship trim can be controlled automatically by adjusting the relative temperatures (and hence the aerostatic lift) of the fore and aft hot air compartments.

Propulsion and low-speed maneuvering

The Starship SRA main propulsion system consisted of two tail-mounted pusher propellers installed in a shrouded tailplane structure that includes the rudder and elevator in the propeller slipstreams.

Gibbens noted, “In order for any LTA vehicle to be viable today, whether large or small, it must be manageable and controllable on and near the ground at zero speed.” Low- and zero-speed maneuvering was accomplished with the aid of two pylon-mounted maneuvering propellers installed forward, on the flanks of the hull. Gibbens did not mention if these maneuvering propellers had a thrust vectoring capability until a 2009 paper describing a later design, which used cycloidal propellers in place of the “vectored thrusters.”

Load handling

All cargo is carried externally under a rectangular space frame structure that is attached to the airship at its four corners with cables. The space frame is designed to be lowered for loading and cargo delivery, and raised and secured during flight. Gibbens noted, “By carrying all external loads under a ‘Space Frame’, the airship structure will always be stressed in the same direction and can be lighter.

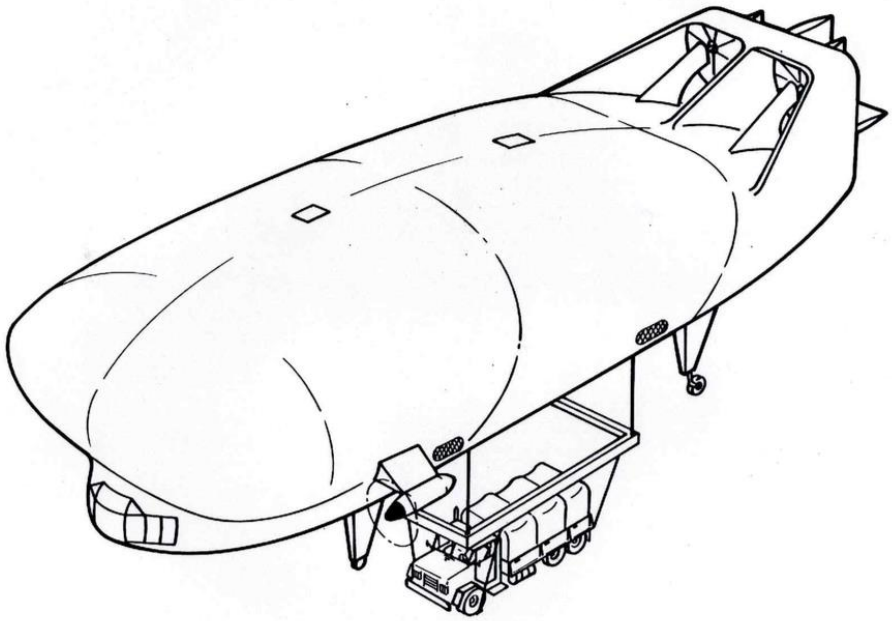
With its tall, fixed landing gear legs, the Starship SRA could load and deliver cargo on the ground. Alternatively, the space frame could be lowered and raised from a hovering airship during an airborne load exchange (cargo pickup or delivery without landing). During the airborne load exchange, the buoyancy control system would manage the heating and venting of hot air as needed to maintain airship control throughout the transaction.

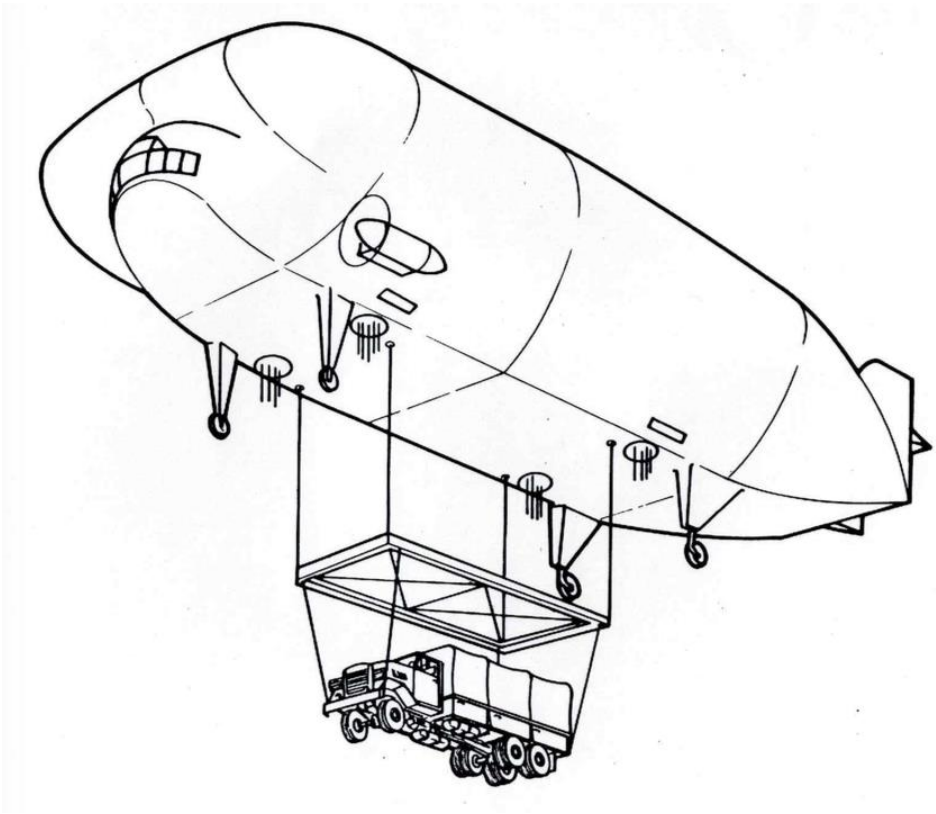
Landing and ground handling

Upon landing, the pilot can vent both hot air chambers, making the Starship SRA a heavier-than-air vehicle that can taxi on its 3- or 4-point landing gear to a designated mooring site (a fixed dock or a rotating mooring table) or to a tie-down area if no mooring facility is available.

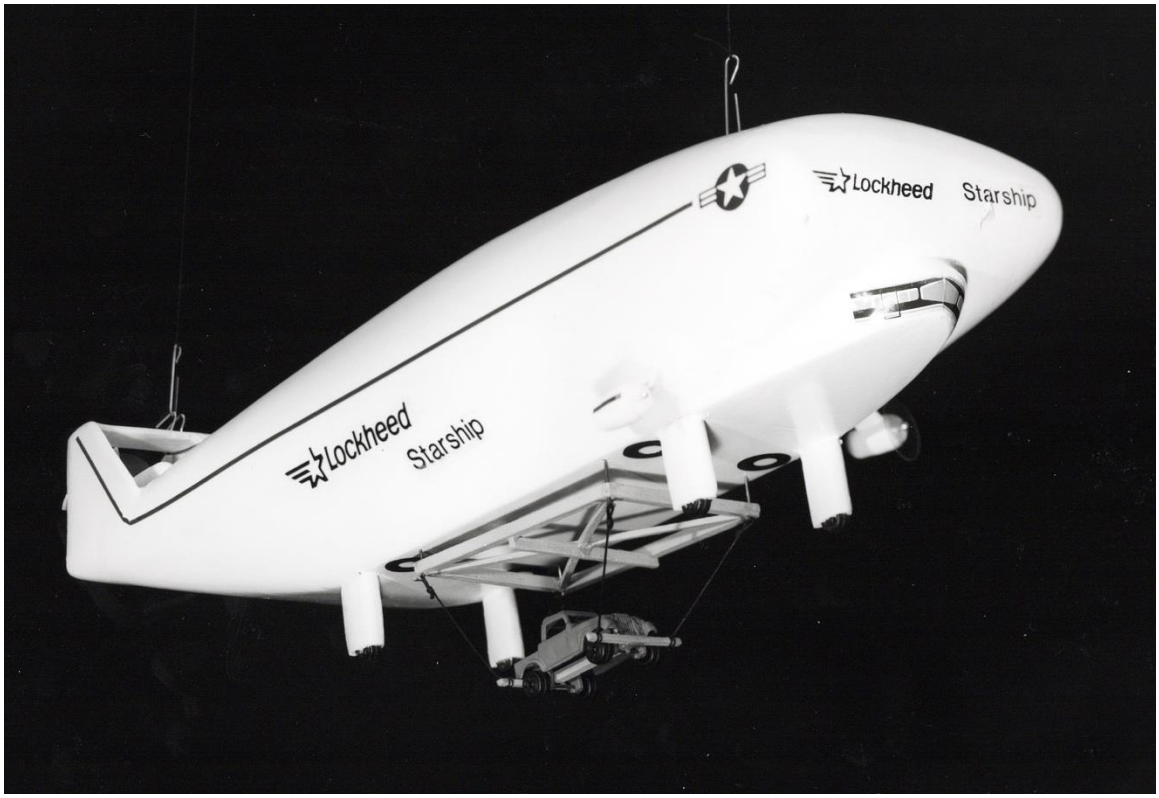
The mooring attachment point on the bottom of the airship, between the front landing gear, is designed to engage a mooring pin on the ground. Gibbens noted, “It is proposed that a system be designed so that the pilot can operate the launch and recovering devices from inside the cabin with no external help.”

Once secured to the mooring pin, the airship is free to “weather vane” and point into the wind. A mooring table provides a work space and servicing area that moves with the airship as it weather vanes.

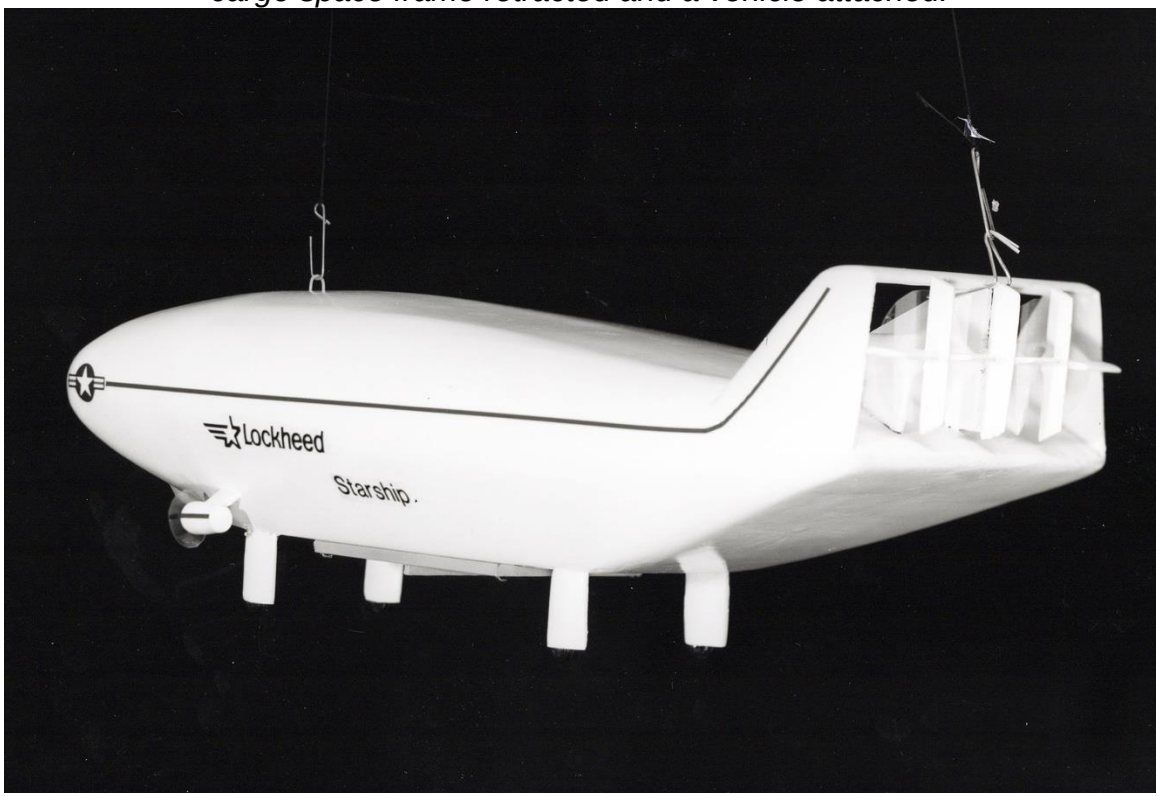




Two views of a Starship SRA in flight, carrying a large truck under its extended cargo space frame. Note the four vertical thrusters are shown in operation in the lower graphic. Source, both graphics: Roy P. Gibbens (1983)



Bow quarter view of Starship SRA model with the cargo space frame retracted and a vehicle attached.



Stern quarter view of Starship SRA model.
Source, both photos: Roy P. Gibbens (1983)

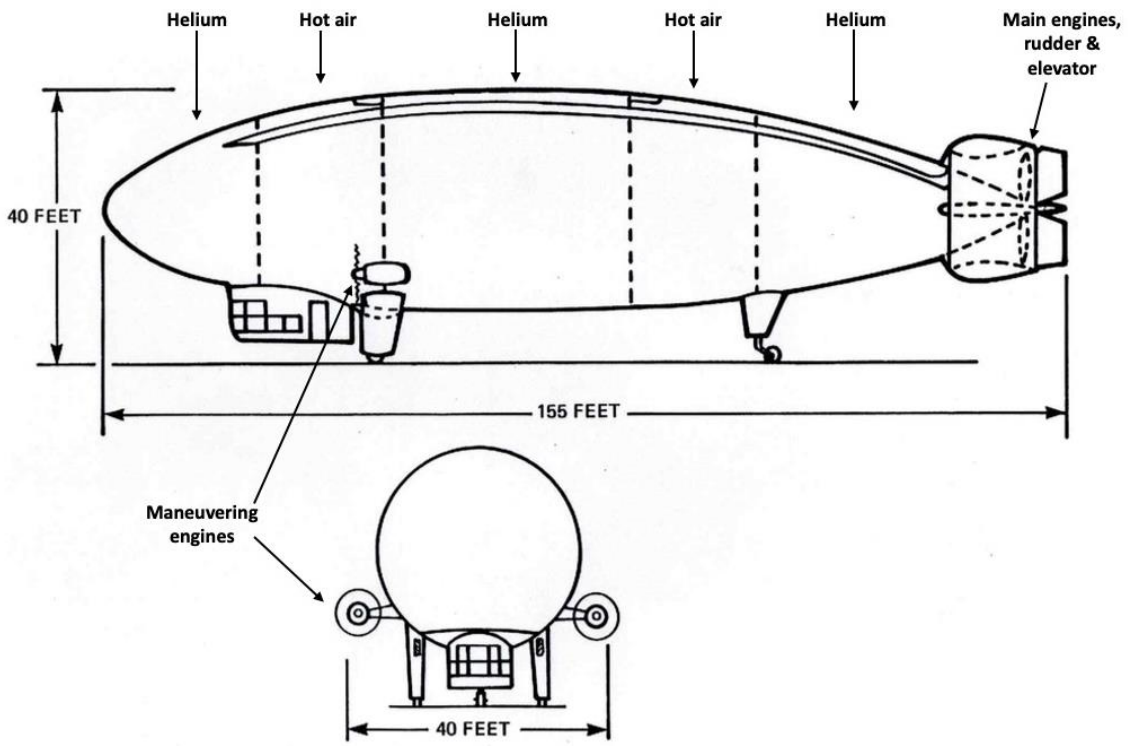
Bow view of Starship SRA model.
Source: Roy P. Gibbens (1983)

3. Design concept for an SRA prototype (circa 1983)

To demonstrate the operation of the hybrid thermal airship system at relatively low cost, Gibbens proposed a prototype “based on the classical blimp shape because of the ease of construction.” The prototype was the same length and had the same five gas compartments within the hull as the Starship SRA.

For the prototype, Gibbens noted that the propane burners could be similar to the type used in hot air sport balloons.

The prototype would not have the additional vertical thrusters proposed for the Starship SRA.

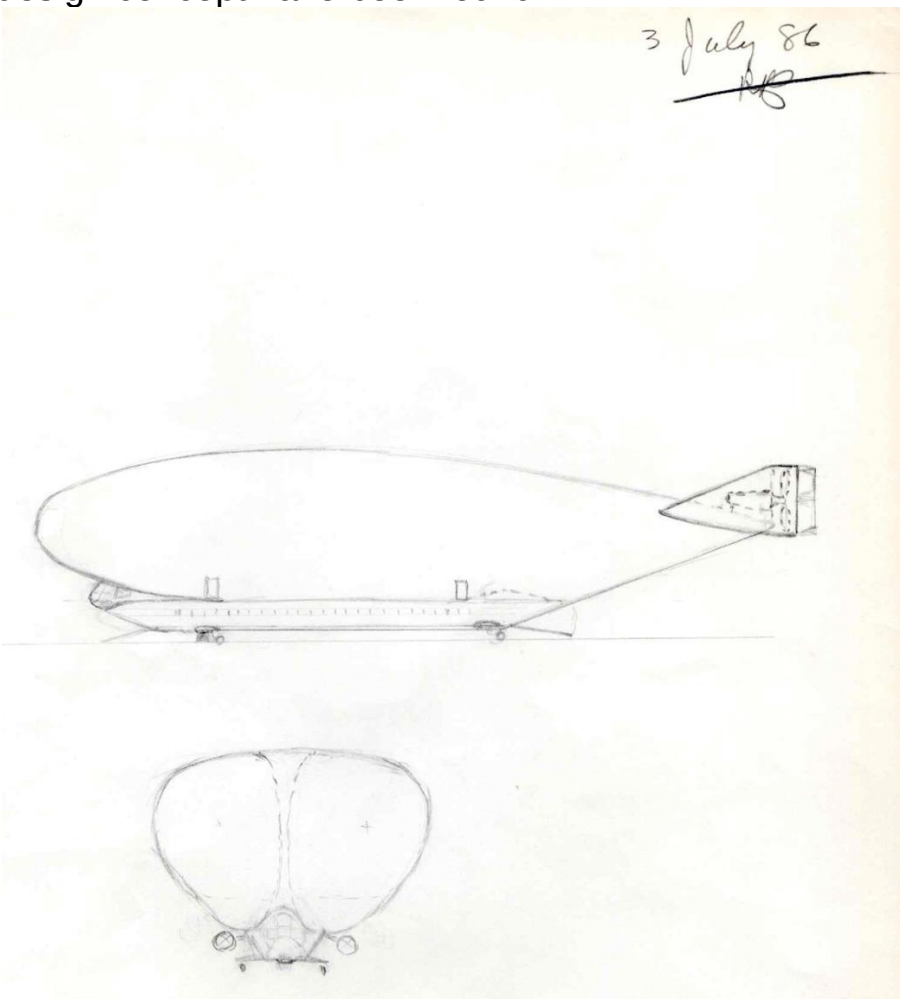


Lockheed SRA prototype design concept.
Source: Adapted from Roy P. Gibbens (1983)

4. Design concept for a cargo / passenger carrying SRA (circa 1986)

One of Gibbens' later SRA designs is shown in the following pencil sketch dated 3 July 1986. While generally resembling the Starship SRA, this design concept has short landing gear and a long internal cargo bay with bow and stern loading ramps to facilitate a rapid load exchange on the ground. The profile view appears to show windows along the whole length of the bay, suggesting that it may be convertible for use as a passenger transport.

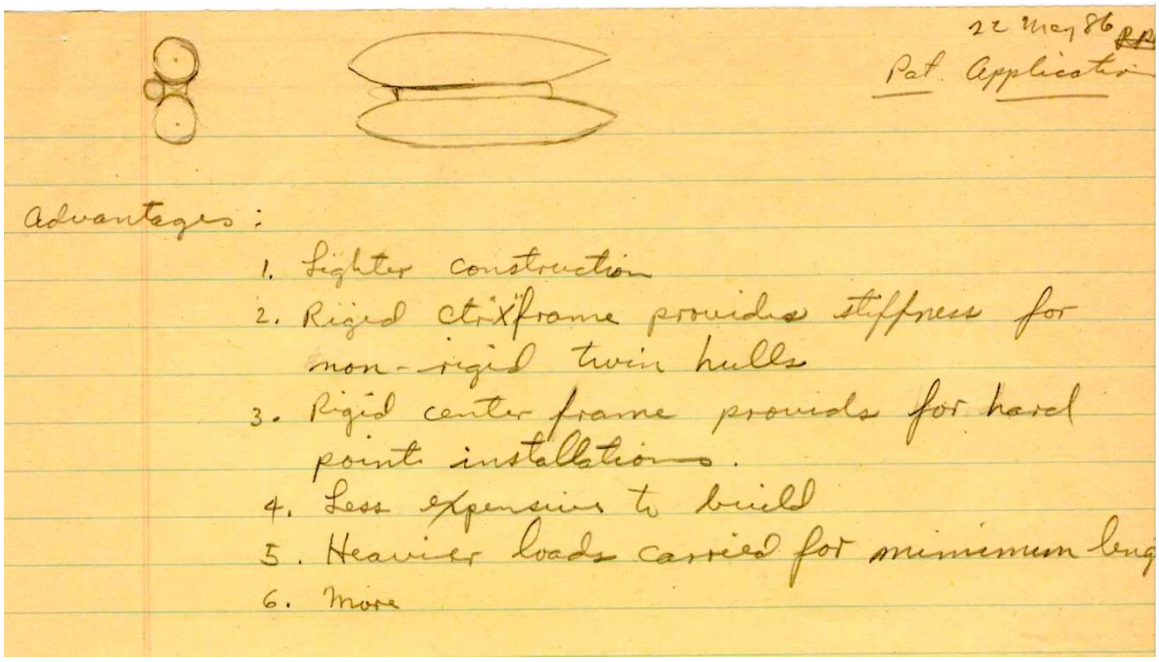
The main propulsion installation at the tail is very similar to Starship SRA design. It appears that there are two shrouded propellers installed fore and aft, along each flank of the airship. No other details on this design concept have been found.



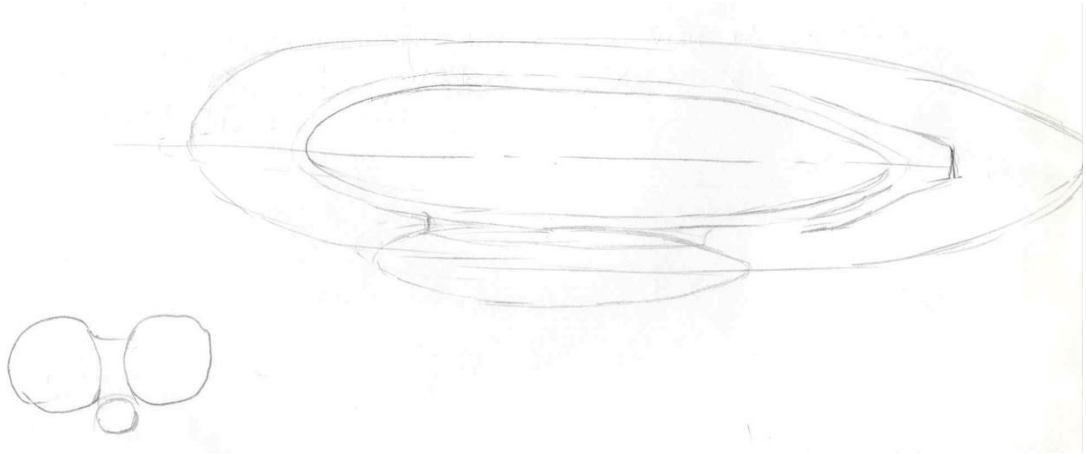
Roy P. Gibbens pencil sketch of a cargo / passenger airship based on the Starship SRA. Source: Roy P. Gibbens (signed 3 July 1986)

5. Design concept for a twin-hull airship (circa 1986)

A very different design concept examined by Gibbens in 1986 was a twin-hull, semi-rigid cargo airship with a rigid central frame joining two non-rigid hulls. This design allowed a shorter airship to carry heavier loads than a single-hull counterpart. Cargo was carried from hard points on the central frame. Gibbens expected that this design could have lighter construction and would be less expensive to build than comparable conventional cargo airships.



Gibbens' notes on the advantages of twin-hull airship.
Source: Roy P. Gibbens (22 May 1986)



Pencil sketches of a twin-hull airship concept. Source: Roy P. Gibbins (1986)

6. Design concepts for improved airship ground support

Before developing the Starship SRA design concept, which incorporated several novel mooring and ground support features, Roy P. Gibbens developed new concepts for ground support systems for large fixed-wing aircraft in the 1960s at Martin Company. In the 1970s, he developed simplified ground handling concepts for large and small airships, which are addressed in this section.

In a 1975 paper, Gibbens noted that ground support systems can be a significant fraction of the total project cost for any aerospace system. Total project cost can be better controlled by proactively addressing the interfaces between the air vehicle and its ground support systems early in the design process. This enables necessary hard points and other air vehicle and support equipment interface features to be designed and implemented in concert with one another, thereby minimizing the need for costly retrofits later in the project.

Large airship ground support

Gibbens defined airship support equipment as including: (a) mooring systems, (b) docking systems, (c) ground carts, (d) refueling and waste disposal equipment, (e) an electronic monitoring system that can be plugged into the airship's computer systems, and (f) special ground checkout points.

His goals for ground support system were to enable the following airship operational capabilities:

- Takeoff and land in the same weather conditions expected of aircraft (perhaps even worse).
- Be moored in high winds
- Be loaded and unloaded in a minimum time, with minimum effort.

He said, "I consider mooring and docking the same as an airplane landing and going to a terminal. Mooring is landing and being tethered so as to be free to weathervane rather than staying in a fixed

position. Docking, on the other hand, is to be secured in one spot regardless of wind direction."

The following series of diagrams illustrate a docking process advocated by Gibbens. In Figure 4A, the airship lowers a set of lines, each connected to a hardened mooring point on the hull. Each line is connected to a winch on a dock, which can be fixed or movable (Figure 4B), and then the airship is winched down to the ground and secured to the dock (Figure 4C).

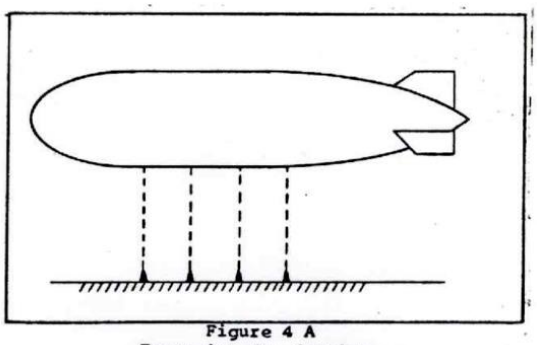


Figure 4 A
Preparing for docking.

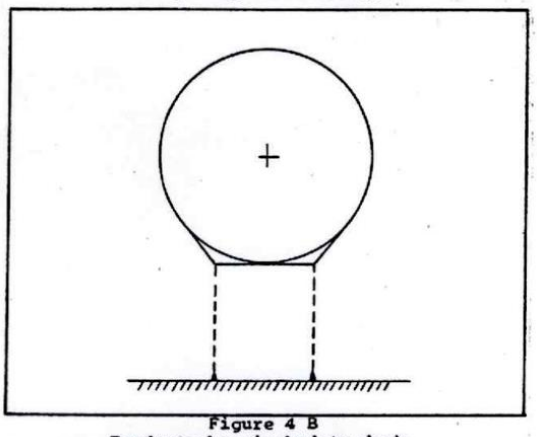


Figure 4 B
Ready to be winched to dock.

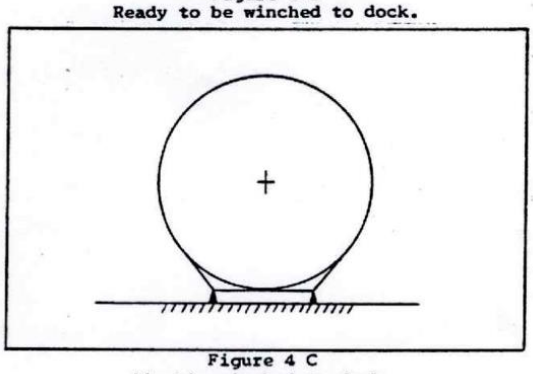


Figure 4 C
Airship winched to dock.

Source, three figures: Gibbens (1975)

To help stabilize the airship once it is docked, Gibbens proposed, "to make the ship heavy, not by loading it with ballast, but by transferring controlled amounts of lifting gas to storage tanks in conjunction with ballast transfer." In a single lifting gas (helium) airship, his approach involved transferring some helium off the airship to a ground support system for helium storage and cleanup. The appropriate amount of clean helium would be transferred back to the airship prior to takeoff.

In his 1983 Starship SRA "Rozière" design concept with two lifting gases, this matter was easily handled without a ground support system by simply venting the hot air lifting gas to the atmosphere once the airship was on the ground, at which point the airship could engage an anchored mooring pin or taxi like a conventional aircraft.

Once a helium airship has docked on a transportable carriage, it can be moved to other facilities on an airport where routine inspections, maintenance and repairs would be performed. Gibbens considered the utility of lower cost wind fences and open top buildings for performing such work.

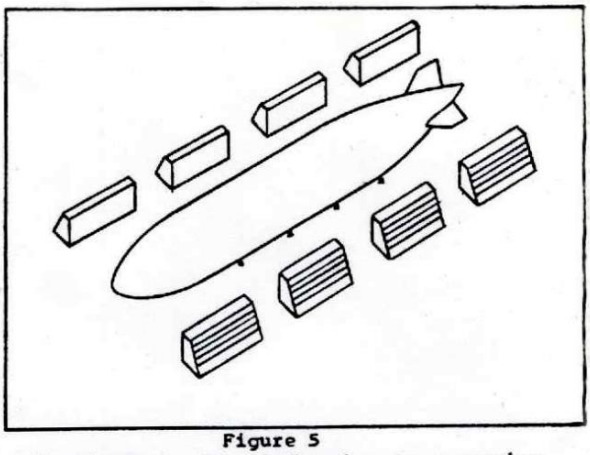


Figure 5
Airship dock with windbreaker type service buildings.

"Wind fences (similar to jet blast fences) can be permanently installed alongside the docking site to help break up ground winds. Because of the size of these wind breakers they could actually be made part of ground level service buildings (Figure 5). These buildings would have maintenance shops and warehousing in some, others would have offices and terminal facilities." ……."With fixed docking, ground space would be better utilized, which means less real estate would have to be purchased per facility. Side-by-side docking could become common place and 'mooring out' almost a thing of the past."

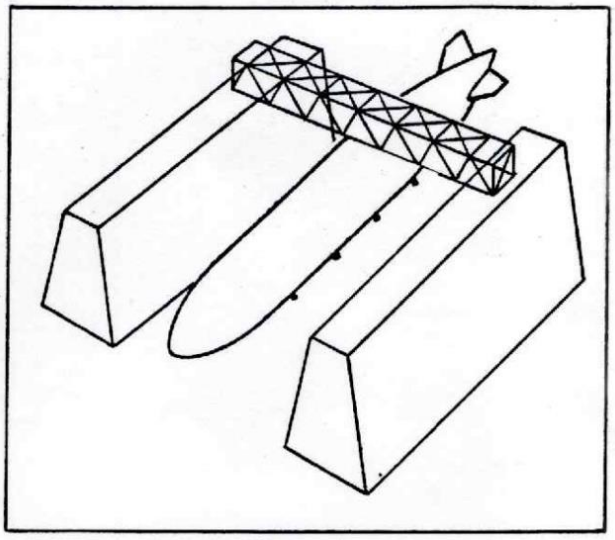


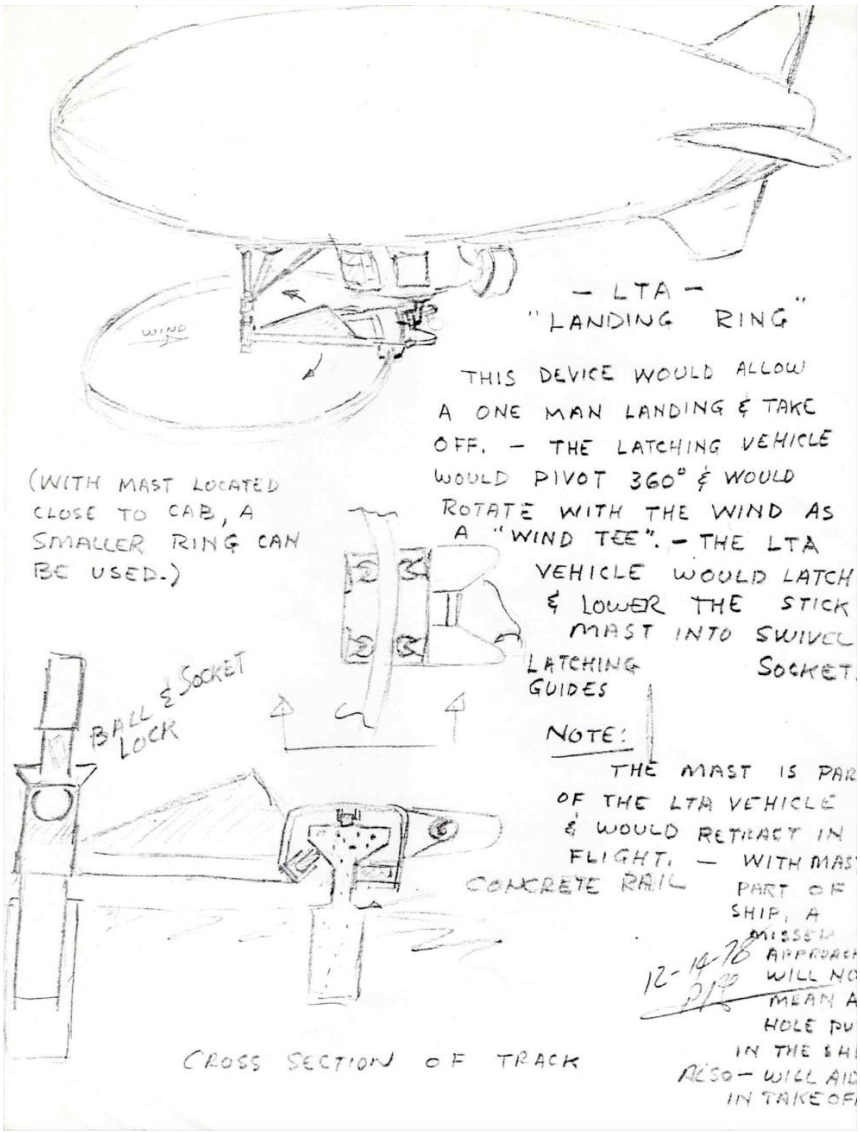
Figure 6
Airship maintenance buildings with overhead crane.

"Less-expensive open-top maintenance buildings (Figure 6) could be built with large overhead cranes stretching between their rooftops. Weather could be a problem at times, but most maintenance work would be on the inside of the ship and unaffected."

Source, both figures: Gibbens (1975)

Small airship LTA mooring ring (circa 1978)

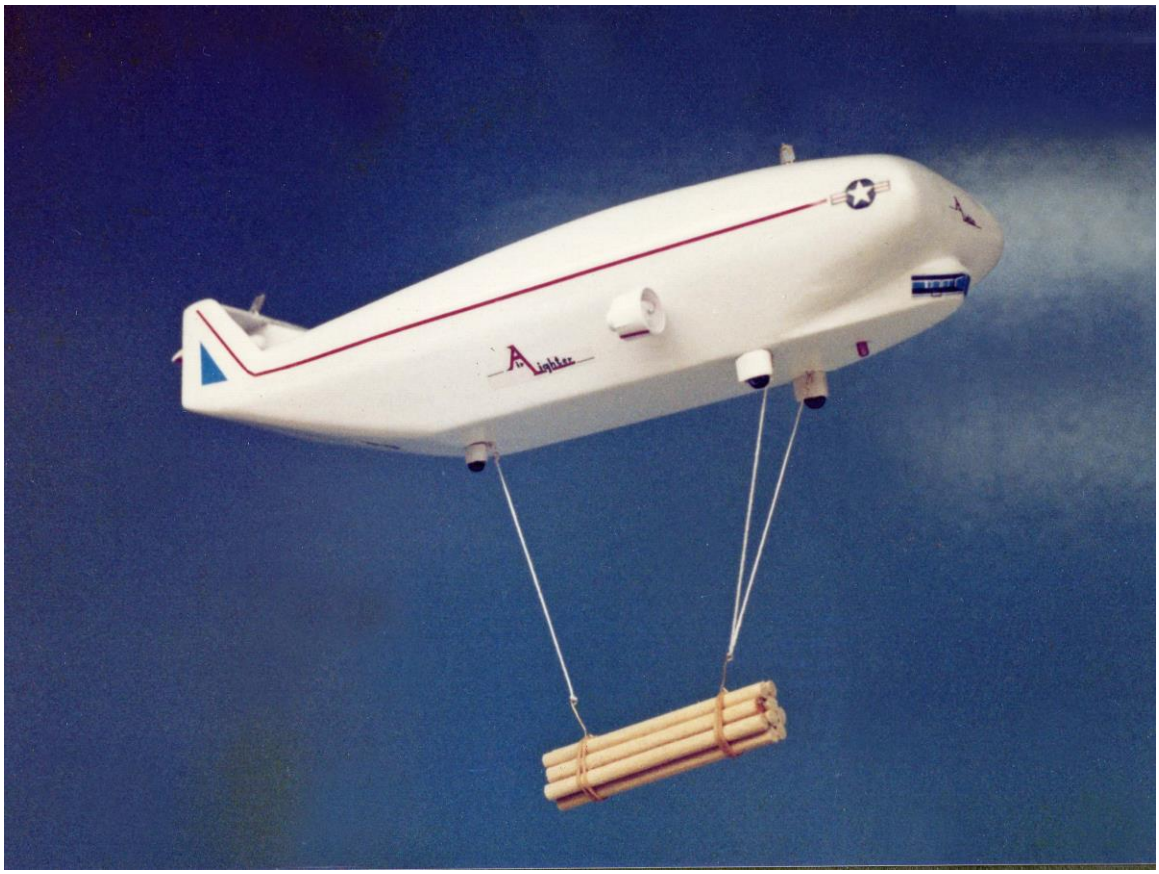
Prior to developing the Starship SRA design concept, Gibbens was engaged in designing ground support systems for LTA vehicles. One concept he developed in 1978 was the “LTA landing ring” shown in the following pencil sketch. This device is designed to enable an airship pilot to dock and undock with minimal assistance from a ground crew. A retractable mast is part of the LTA vehicle. It is extended after landing and latches to a fixed 360° pivoting fitting anchored at the docking site. Gibbens included a different unassisted docking concept in his 1983 design of the Starship SRA.



Pencil sketch of LTA landing ring.
Source: Roy P. Gibbens, 14 December 1978

7. After the Starship SRA

After his retirement from Lockheed in 1990, Roy P. Gibbens formed a new firm, Gibbens & Associates, in Meridian, Mississippi. He continued developing the Starship SRA design concept and rebranded it as the “AirLighter.” He also became an advocate for the use of cycloidal propellers on airships and conducted test flights that demonstrated their benefits, especially at low speed and in hover. This is the subject of a separate article.



Roy P. Gibbens’ Airlighter cargo airship is a direct descendent of the Starship SRA. Source: Roy P. Gibbens.

Roy Powell Gibbens passed away in Meridian, Mississippi on 20 February 2013. The author is grateful to his daughter, Sue Henderson, for generously providing access to his files.

8. For more information

- Roy P. Gibbens, “Airship Support Systems,” 1975: https://lynceans.org/wp-content/uploads/2023/10/Airship-Support-Systems_RPG_1975_AIAA.pdf
- Roy P. Gibbens, “Small Rigid Airships as an Alternative to Non-Rigid “Blimp” Type Airships,” Lockheed-Georgia Company, Presented at the AIAA Lighter-Than-Air Systems Conference, Anaheim, CA, July 1983: https://lynceans.org/wp-content/uploads/2023/08/1983_Small-Rigid-Airships.Alternative-to-Non-Rigid-22Blimp22_RPG_1983.pdf
- “Small rigid airship concept has potential, says Gibbens,” Southern Star, 1 September 1983: https://lynceans.org/wp-content/uploads/2023/08/1983_Roy-Gibbens_Small-Rigid-Airship-article_Southern-Star_crop.png

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    - Boeing - hybrid thermal airship
    - LocomoSky - hybrid thermal airships
    - Roy P. Gibbens – AirLighter and cycloidal propellers
    - Thermoplan - hybrid thermal airships
    - Thermo-Skyships Ltd. (TSL) - hybrid thermal airships
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