Thermo-Skyships Ltd. (TSL) - hybrid thermal airships

Peter Lobner, updated 11 February 2022

1. Introduction

The "Skyship" was a design concept originated in the early 1970s by John West and his firm John West Design Associates, Epsom, Surrey, for a rigid, lenticular (lens-shaped), variable buoyancy, hybrid thermal airship. This novel airship generated aerostatic lift from the combined buoyancy of helium lift gas, hot air and, in some early designs, steam. With helium alone the airship was semi-buoyant (heavier-than-air). Buoyancy was managed by using the heat produced from gas turbine engines (turboprops) to provide additional aerostatic lift from hot air. The engines also generated propulsive thrust and/or dynamic lift from fixed or vectoring propulsors. The lenticular aerobody hull generated aerodynamic lift during forward flight.

The UK firm Mercantile Airship Transportation Limited (MAST) began work on the Skyship (later known as the Thermo-Skyship) in 1972. This article addresses the Thermo-Skyship airship during the period from 1972 to about 1982, when the concept was abandoned.

2. From MAST to Airship Industries Ltd.

Before looking at the airship design, we'll take a look at the changing corporate landscape and a few milestones in the development of the Thermo-Skyship.

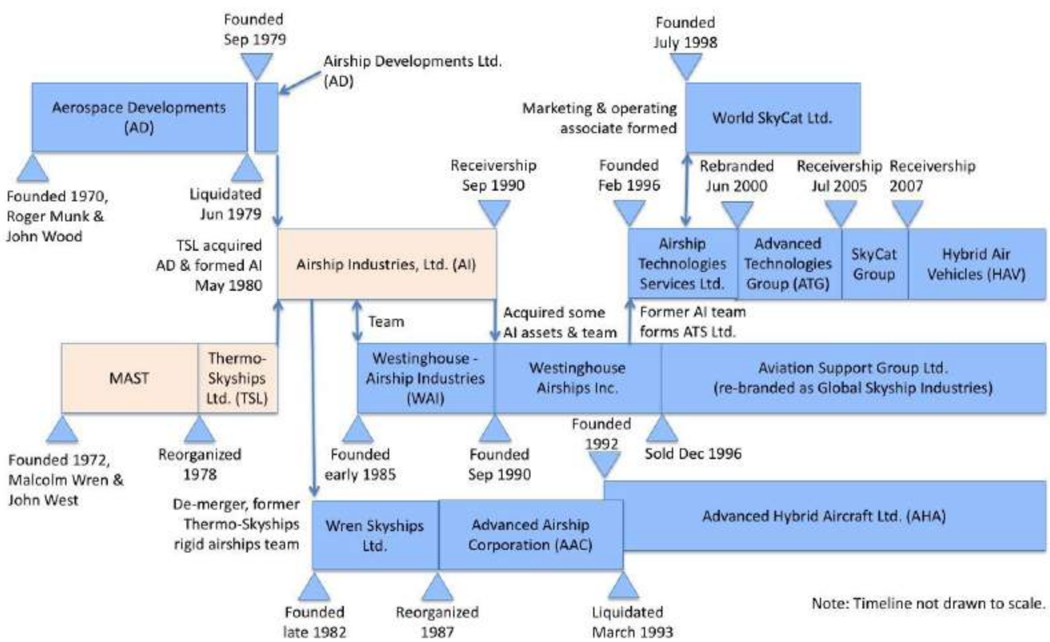
- **1972:** The firm Mercantile Airship Transportation Limited (MAST) was formed for the development of large rigid airships to fill a transportation gap between fast jet air transportation and slower sea transportation. Major M.W. Wren was the Managing Director. As a Public Limited Company, MAST raised £2.4 million on the London Stock Exchange towards the development of an "unconventional rigid airship." One of MAST's early design concepts was the lenticular, hybrid thermal airship that became known as the Thermo-Skyship. This was the Skyship design originally conceived by John West.

- **May 1974:** A commercial airship project named “Skyship” was publicly announced by John West Design Associates.
- **17 April 1975:** A 9.1-meter (30-foot) diameter proof-of-concept “Skyship” demonstrator was unveiled at a press conference in the former R101 airship hangar at Cardington Airfield in Bedfordshire and indoor test flights were conducted.

Skyship team, with designer John West and a desktop model of a Skyship in the center, at the unveiling and test flight of the Skyship demonstrator. Source: Screenshot, 17 Apr 1975 Reuters video

- **April 1977:** The UK Parliament debated lighter-than-air (LTA) business development, including possible funding to support the MAST Thermo-Skyship.
- **1978:** The firm Thermo-Skyships Limited (TSL) was formed in the Isle of Man with headquarters in Ramsey and a London Liaison Office.
- **Early 1979:** TSL acquired MAST as a wholly owned subsidiary. Major M.W. Wren became the Chairman and Chief Executive.
- **September 1979:** Roger Munk founded the firm Airship Developments, Ltd., (AD) after the liquidation of his former firm, Aerospace Developments. Munk’s firms developed the non-rigid AD-500 blimp and had been involved with MAST and TSL since about 1976.

- **May 1980:** TSL acquired AD for £1 million. A goal of the AD acquisition was to form a firm large enough to produce a large rigid airship and a smaller non-rigid airship.
- **July 1980:** TSL changed the name of the newly merged firm to Airship Industries Limited (AI).
- **1980 – 1982:** During the next two years, AI focused on the developing the Skyship 500 non-rigid airship. The AI rigid airship team, under Malcolm Wren, also proposed several designs for conventional rigid airships, including the large, metal-clad RS150, but no contracts were awarded. Development of the Thermo-Skyship ended during this period.
- **Late 1982:** In late 1982, a "de-merger" was agreed, and the former TSL rigid airship technical and management team left AI and formed Wren Skyships, Ltd. on the Isle of Man with Malcolm Wren serving as Managing Director. Their focus was on developing the R.30 and the RS.1 rigid, metal-clad airships. Roger Munk remained with AI and focused on developing the Skyship line of non-rigid airships.



Roadmap to airship firms managed or strongly influenced by M.W. Wren and Roger Munk, highlighting MAST, TSL and Airship Industries, Ltd.

3. 1972 MAST evaluation of airship designs

When MAST was formed in 1972, the firm undertook an evaluation of operating problems with conventional (cigar-shaped) airships and identified five key problem areas that adversely affected the use of airships in commercial service. MAST then developed ways to resolve each of those problem areas. This effort produced the specification for the airship that became known as the MAST Thermo-Skyship. Following is a comparison of conventional airship and Thermo-Skyship design features, paraphrased from a March 1979 Thermo-Skyship proposal.

Mooring

A conventional airship has a relatively small cross-section when viewed from the nose and a very broad and variable cross-section when viewed from the sides. It has to be flown into the wind and docked to a mooring mast that allows the airship to weathercock 360° and maintain its nose pointed into the wind. The airship is neutrally buoyant and remains "flying" while moored. A large land area around the mooring mast is required, particularly for larger airships that can exceed 700 ft (518 m) in length.

Thermo-Skyships have a generally circular planform that presents a similar cross-section to the wind from any direction. This greatly reduces the effects of changing wind direction, eliminates weather cocking, and permits the use of simple tethers symmetrically deployed around the hull to secure the airship to the ground.

On the ground, the Thermo-Skyship's high temperature air (HTA) system is shut down, reducing aerostatic lift, making the airship heavier-than-air, and thereby improving stability on the ground. Any lift produced by a horizontal wind blowing across a Thermo-Skyship's hull on the ground is counterbalanced by the net weight of the airship and the array of tethers.

Control and maneuvering close to the ground

Control surfaces on conventional airships become ineffective as airspeed is reduced and are virtually useless on final approach to a destination. The airships must depend on “limited vectored thrust from the power system. This does not permit the highly accurate controlled vertical takeoff or landing (VTOL) required for commercial operation.”

Thermo-Skyships also have conventional control surfaces that are used during cruise flight. A true VTOL capability is provided by the combination of thrust from the main engines at the stern and flank-mounted control jet nozzles for precise maneuvering.

Buoyancy management

In flight, buoyancy is constantly changing for a variety of operational and environmental reasons. Conventional airships can manage buoyancy by discharging ballast (usually water) to gain lift, or vent some lift gas to reduce lift. It is expensive to replace helium vented during flight. There may be complex systems to minimize loss of mass (i.e., an engine exhaust gas condensation system).

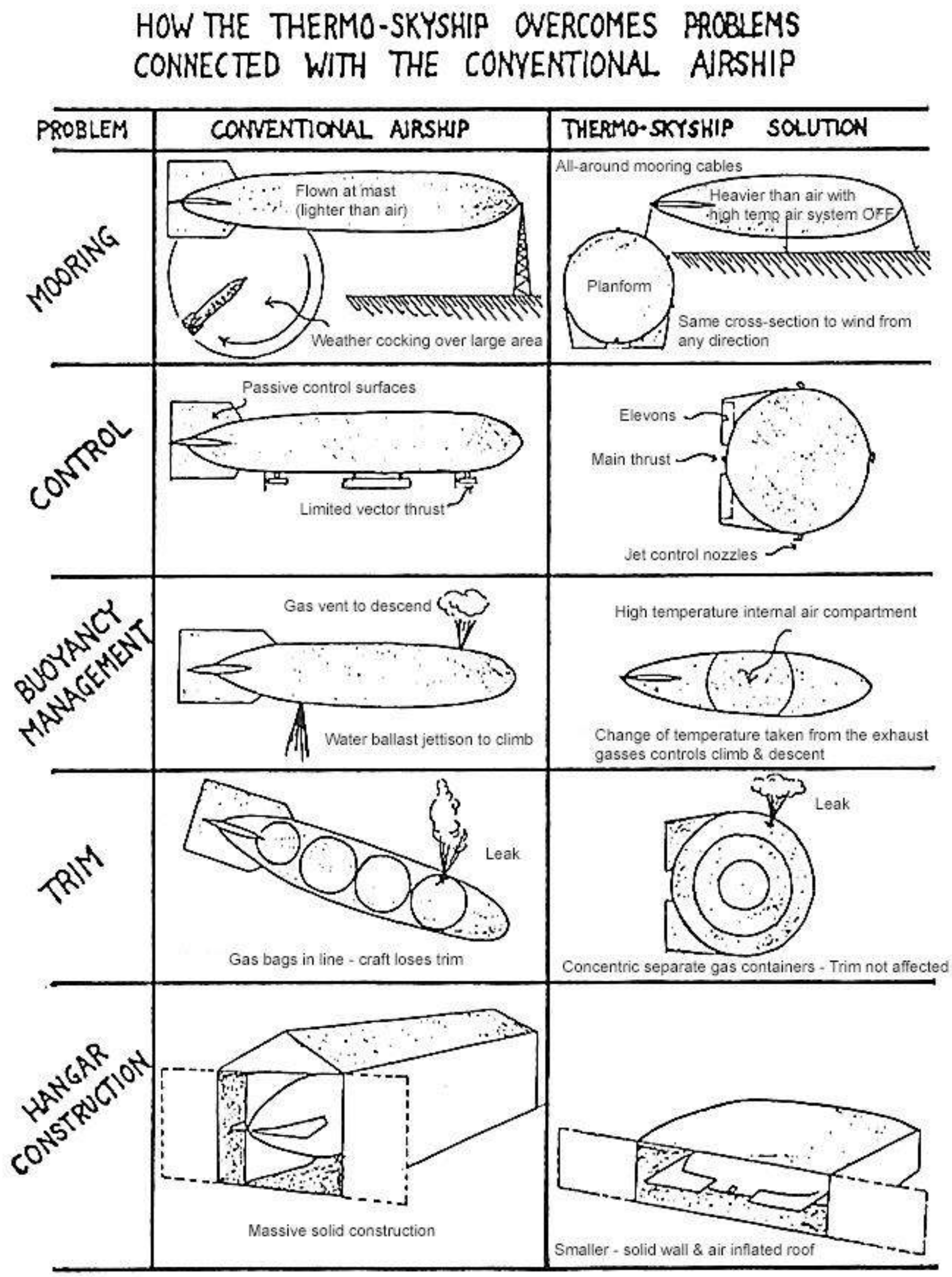
The Thermo-Skyship is a variable buoyancy, fixed volume airship. Aerostatic buoyancy is the sum of the buoyancy from a fixed amount of helium lift gas and a variable amount of buoyancy from hot air in the central high temperature air (HTA) chamber. Buoyancy is managed by controlling the air temperature in that chamber. When the HTA system is shut down, the Thermo-Skyship is heavier-than-air with the aerostatic lift from helium alone.

Trim management

In conventional airships, the lift gas cells are positioned one after the other in a long cylindrical hull. Trim is affected by the loss of lift gas from any cell. Thermo-Skyships have concentric gas cells, with the helium in the outer ring and the HTA system in the center. Loads are concentrated under the center of lift. A leak from any one of 19 helium cells or the hot air cell does not significantly affect lift or trim.

Hangar construction & use

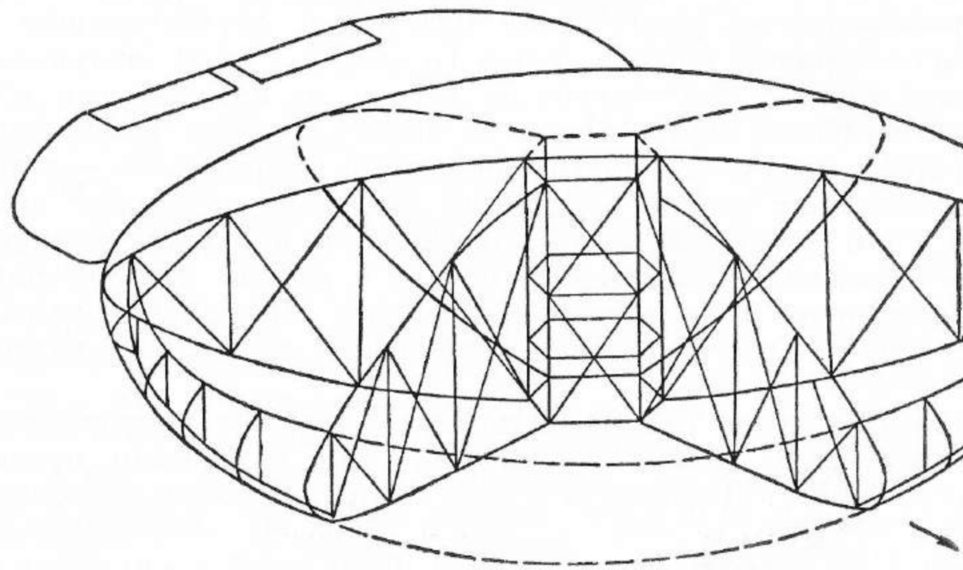
Conventional airships require very large hangars at their construction sites and operating bases for protection from the wind during construction and maintenance, when the airships can't be "flown" and pointed into the wind. Thermo-Skyships do not need hangars at their operating bases and do not need such a large hangar during construction. Once the main structure is manufactured and the outer skin attached, the balance of construction can be completed in a simpler unconventional structure.



Source: Thermo-Skyship Ltd. 1979 proposal

4. Basic structural design

The lenticular hull structure of the Thermo-Skyship is a circular spaceframe in six sections, built around a vertical hexagonal core structure. The six radial truss partitions in the circular section are connected by a peripheral ring truss that establishes the outer edge of the hull. The light alloy or composite tubular spaceframe is reinforced with cable braces to increase rigidity. At the aft end of the hull, the horizontal stabilizer ("beavertail") with control surfaces is an extension of the hull structure. The exterior surface of the Thermo-Skyship is a multi-layer fabric skin installed over the spaceframe.



Structural elements of a Thermo-Skyship.
Source: M. Arie (1986)

The cargo compartment is located at the bottom of the hexagonal core. This core is surrounded by a large toroidal volume containing heated air. The helium lift gas is contained in 19 cells; three cells in each sector are radially outside the heated air volume and one cell is at the top of the hexagonal core, above the cargo compartment. The maximum volume of an individual lift gas cell does not exceed 10% of the total lift gas volume. As a result, loss of helium from one cell will result in only a small and manageable loss of aerostatic lift and a minor change in trim. Containers with gaseous fuel are located inside helium lift gas cells to reduce fire risk.

5. Evolution of the Thermo-Skyship

Comparing lenticular airships to conventional airships, Edwin Mowforth noted that lenticular airships have a higher structural weight-to-volume ratio and higher aerodynamic drag due to its wake vortex. In addition, he stated: "the bare saucer is inherently unstable, to the verge of paranoia, in the pitch mode, tending to flip into a steep climb or descent at a relatively low critical speed……A degree of pendulum stability can be arranged by lowering the center of gravity, but it is structurally difficult to drop it far enough to ensure stability at viable flight speeds. Alternatively, the pitch problem can, in theory, be solved by stabilizing tail surfaces, as in a conventional airship, but the tail of the saucer has a much smaller moment arm and either is buried ineffectively in the wake or must be displaced clear of the airflow on some kind of structure, all adding weight."

Over a period of a decade, the design of the Thermo-Skyship evolved significantly, with notable changes in external appearance of the hull, an extended "beaver tail" for flight stability, and engine / propulsor type and placement. The subscale Skyship demonstrator that first flew in April 1975 had a symmetrical lenticular hull. Most of the other design concepts for production Thermo-Skyships had asymmetrical hulls, until about 1980, when the Thermo-Skyship seems to have evolved back to a symmetrical lenticular hull shape.

Initial desktop model (1974)

Skyship initial design, model by John Gibbs, circa 1974. Source: Bill Rose, "Flying Saucer Technology" (2011)

Author Charles Luffman described this design as follows:

> “The design was based on a lenticular (saucer) shaped craft with a centrally mounted ducted fan. The lenticular form was intended to generate a significant amount of aerodynamic lift in forward flight, allowing it to transport substantially higher loads than for pure buoyant flight. For takeoff when heavy, a central lifting fan was planned and, where possible, a short takeoff run into wind also was intended. The aft end featured a flat tail, meant to provide pitch and roll control when the airship was in forward flight. Looking at the desktop model of the proposed design, it may be considered that this was an early hybrid airship type, but needing a way to control yaw (not apparent).”

The subscale “Skyship” demonstrator (April 1975)

Three years after MAST was formed, a remotely controlled, 30 foot (9.1 meter) diameter, 9.5 foot (2.9 meter) tall, proof-of-concept, symmetrical, lenticular Skyship demonstrator had been built and was ready for indoor flight testing in April 1975.

The rigid frame of the airship used rim-and-spoke construction, with a circular aluminum ring beam forming the rim and curved plywood ribs forming the spokes, which were connected to a central hub. Sail canvas was stretched over the ribs to form the outer “shell” of the demonstrator. The lift gas cells were made of a lightweight material, possibly Mylar.

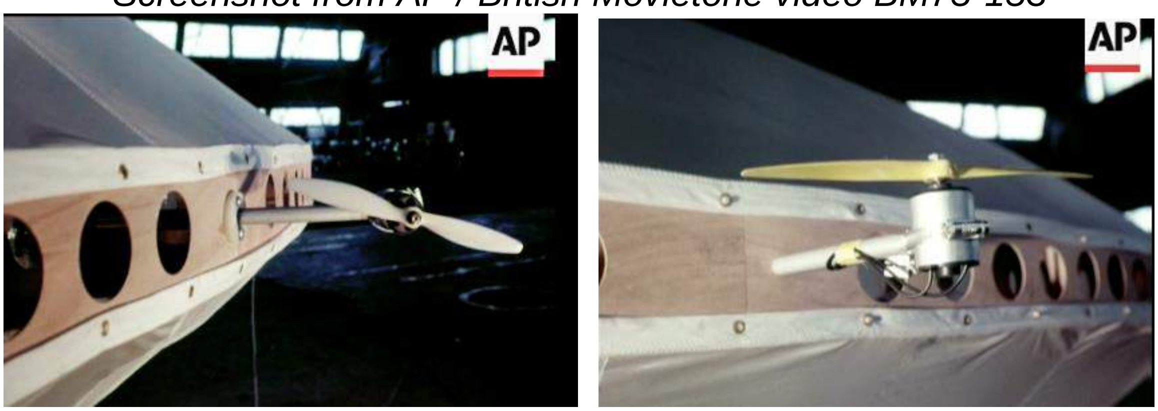
M.W. Wren reported that the model had eight drive units attached to the rim with a total of just under one horsepower, but could lift over 132 lb (60 kg), travel at up to 10 mph (16 kph) and stop in flight and reverse direction.

The indoor flight tests were conducted in April 1975 in the former R101 airship hangar at Cardington Airfield. For these tests, which were intended to evaluate the Skyship’s basic flying characteristics, the demonstrator was trimmed for neutral buoyancy.

Subscale Skyship model aloft in a Cardington hangar, 1975.
Sources: Pinterest

Subscale Skyship model aloft in a Cardington hangar, 1975.
Sources: LTA Solutions

Overhead view of the Skyship model in a Cardington hangar. Source: Screenshot from AP / British Movietone video BM75-153



Skyship prototype, two of eight electric motor installations. Source: Screenshot from AP / British Movietone video BM75-153

Charles Luffman described the first flight test as follows:

> “The model could not be controlled as well as had been hoped. Too late it was realized that the fluorescent lighting in the Cardington shed was probably interfering with the R/C (remote control), at one time causing the airship to rise far too high. The ‘Telegraph’ published unflattering remarks about control of the craft, especially as their own reporter had caused the model to nose-dive by treading on a restraint line! It clearly needed more development before passing judgment.”

In their press release on the April 1975 test flight, Reuters reported on future development plans announced by the Skyship team:

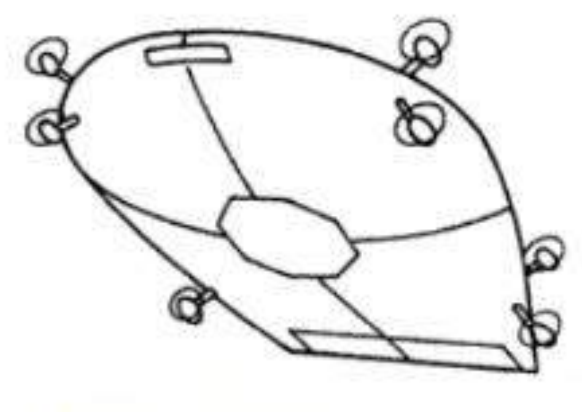
> "'Skyship' has been designed mainly as a bulk cargo carrier requiring no major ground terminal installations on the scale of modern airports or harbors. It is designed to accept a wide variety of cargoes such as containers, vehicles or conventionally packed freight, and eventually passengers."
>
> "For military purposes 'Skyship' could transport in a single lift two infantry battalions consisting of 1,600 men, 70 small vehicles, 14 large vehicles, 60 trailers and 100 tons of stores. All this could be disembarked at the exact place required. An equivalent operation using existing air transport, would involve 105 individual aircraft sorties."
>
> "When the thirty-foot model has completed its flight tests successfully, the next step will be to build a prototype 'Skyship' with a diameter of about two hundred feet (about 61 meters), and a payload of between six and ten (metric) tons. The eventual target is to produce a four hundred (metric) ton cargo-carrying Skyship within a few years."

<u>Desktop model at the flight demonstration (April 1975)</u>

A previous photo showed John West and the Skyship team at the unveiling of the Skyship demonstrator in April 1975. On the table in front of them was the following model of a production Skyship concept. In comparison to the 1974 desktop model, note the more pronounced beaver tail, the eight propulsors (Rolls-Royce Tyne turboprops) arrayed top and bottom on stalks, and the long landing legs.

Author Edwin Mowforth described the control of this airship: "…live thrust control for pitch and yaw would be obtained by varying, but apparently not vectoring, the thrust of these units. Later models evolved a beaver tail with elevators, which could not have been very effective in the main body wake…"

Source: Bill Rose, "Flying Saucer Technology" (2011)

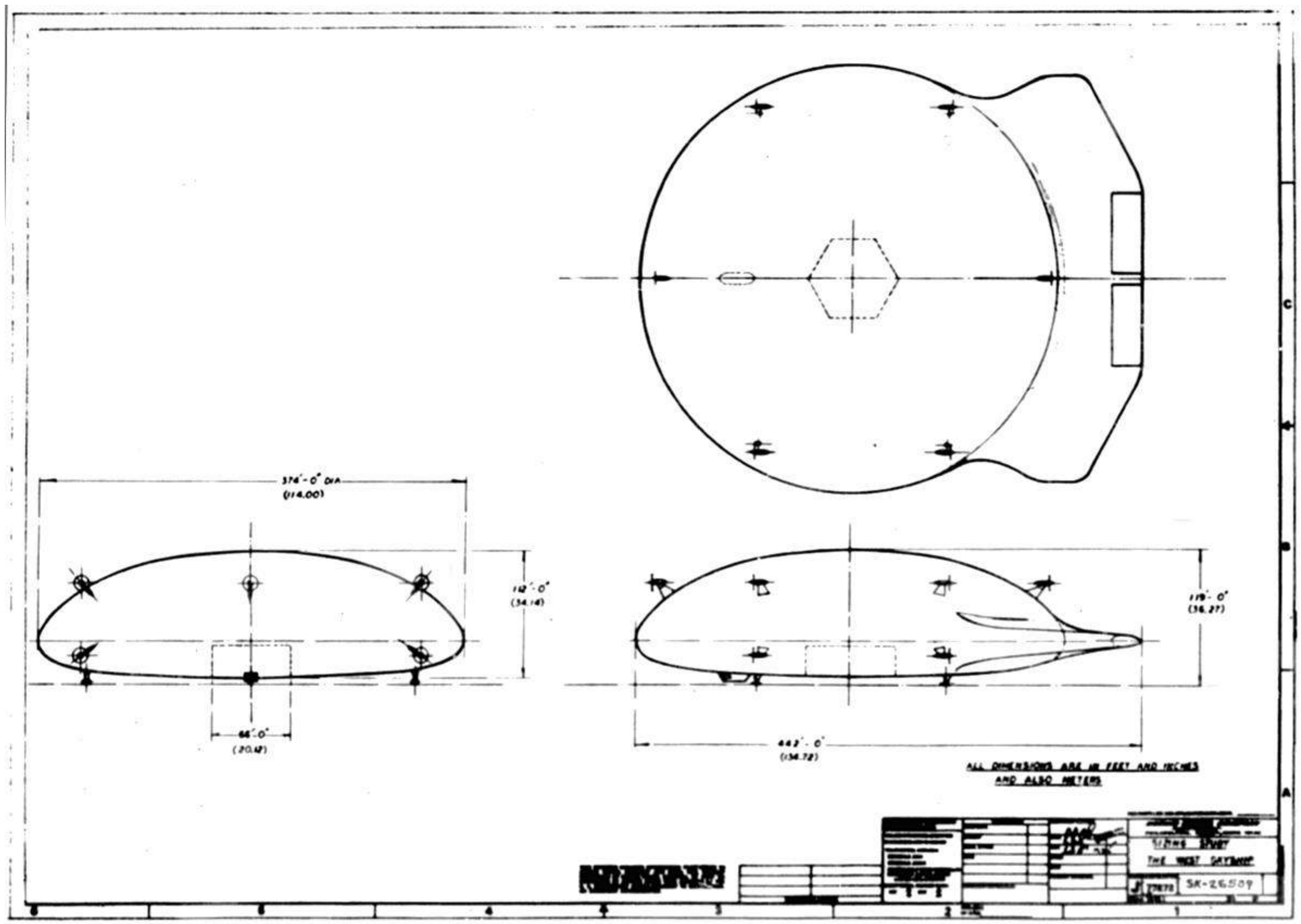


A similar design with eight engines, retracted landing gear and elevators on the beaver tail is shown in the adjacent diagram. The hexagonal shape on the bottom of the airship is an interchangeable cargo module.

Source: Airship Technology, G.A. Khoury (2002)

1975 NASA Feasibility of Modern Airships Phase I Study

This NASA study was one of the first large-scale US studies of modern airship technology, particularly for heavy lift cargo and passenger applications. The Thermo-Skyship was one of the airship concepts examined, but not selected for detailed analysis. The Phase I Study report contains the following diagram of a 10-engine Thermo-Skyship concept with an overall length of 442 ft (134.7 m), a width of 376 ft (114.6 m) and an overall height of 119 ft (36.3 m). Aerodynamic control surfaces are on the pronounced beaver tail.



"The West Skyship," John West Design Associates. Source: NASA CR-137691, Volume I (1975)

Thermo-Skyship designs capable of carrying up to 500 metric tons (550 tons) of cargo in the interchangeable cargo module were developed. Such an airship would have had a diameter of about 700 feet (215 meters).

1977 Lighter-than-air industry discussion in the UK Parliament

On 28 April 1977, a discussion on the UK's lighter-than-air (LTA) transportation industry was held in Parliament. During these discussions, the Earl of Kimberley promoted "a tiny company" (MAST) and identified the following general characteristics of their Thermo-Skyship:

- Simple construction methods are intended to keep costs down.
- Vertical take off and landing (VTOL) can be made from small city center sites.
- Operation is sufficiently quiet to comply with noise regulations for city centers.
- The airship is controlled at low speeds by vectored thrust.
- Helium provides aerostatic lift, like any conventional airship.
- Lift is increased or decreased (buoyancy is controlled) by varying the air temperature inside the hull, like a hot air balloon.
- External ballast is not used to control buoyancy.
- Altitude performance can be improved by using steam for lift, which is generated by an onboard boiler.
- The airship is able to take off and land in any weather, short of a hurricane.
- The airship is not susceptible to wind direction changes during takeoff and landing because of its symmetrical lenticular shape.
- When on the ground, the airship is heavier than air and is stable in the wind without using a mooring mast, as required by conventional airships.
- The airship has excellent fuel economy.
- A central, interchangeable module provides easy access for cargo loading and unloading, enabling rapid turn-around times in any conditions.

During the Parliamentary discussion, the following roles for Thermo-Skyships were identified: military transport, fishery protection and servicing and protection of oil rigs.

The Earl of Kimberly noted that an experimental prototype could be available in a year and could appear at the 1978 Farnborough Air Show if funds were made available to MAST. This prototype, possibly designated the TS26, would be designed to carry 5,000 lb (2,268 kg) of payload with fuel for a range of 1,250 miles (2,000 km). It could operate at about 50% of the cost of a helicopter and its cost to build would be slightly more than 50% of the cost to build a helicopter. He also noted that, while the airship complements the airplane and does not replace it, the airship has worldwide applications and enormous export potential for the UK.

March 1979 Thermo-Skyship proposal

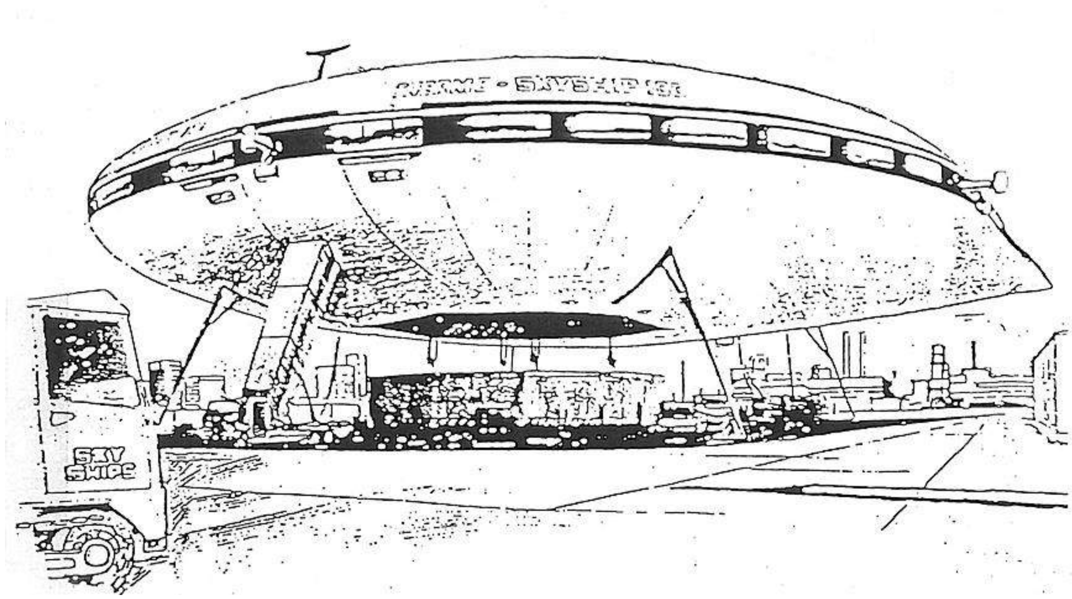
Thermo-Skyship Ltd. issued a proposal in March 1979 to "build and market a Thermo-Skyship with a nominal payload of 6 tonnes, which gives an excellent return on capital invested." Proposed design and operating characteristics were similar to the Earl of Kimberly's April 1977 presentation in Parliament, except there was no mention of using steam to control buoyancy.

Additional information on operating characteristics included:

- Sized for at least 60 passengers
- Capable of carrying standard ISO containers
- Maximum speed: 90 knots
- Maximum range: 900 miles (1,448 km)
- Capable of hovering for 12 hours
- Capable of operating on fuels other than oil based liquids (i.e., natural gas)

By 1978, Thermo-Skyship Ltd. had defined a development program requiring investments of about £6 million to reach the point where the first airship was sold.

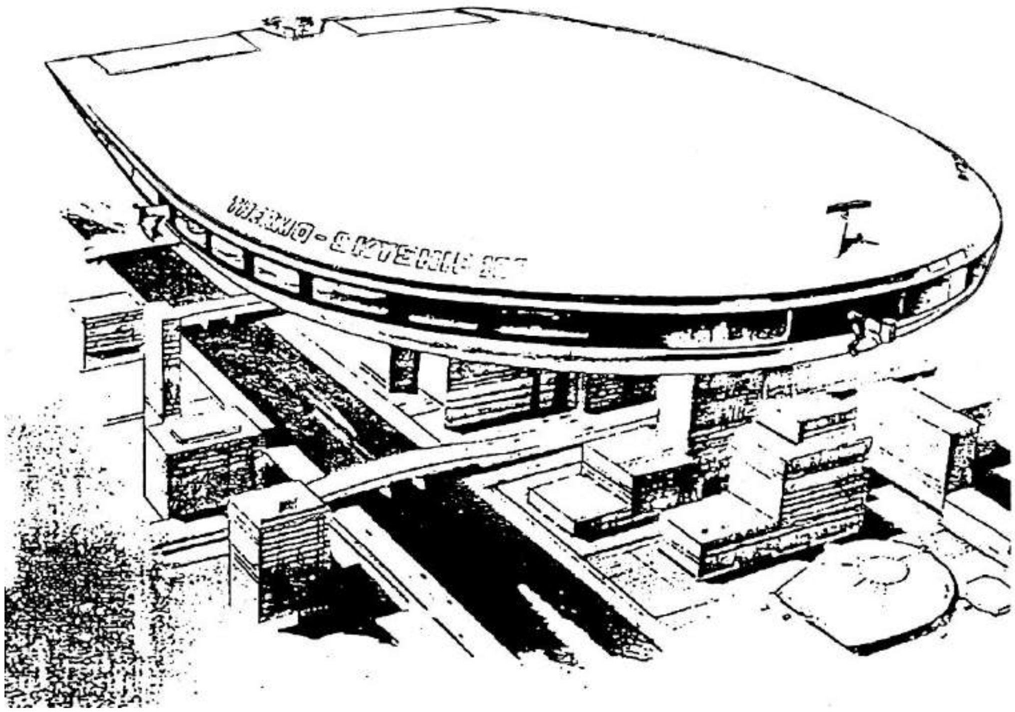
A Thermo-Skyship sits on long retractable landing legs with the payload module lowered to the ground. Note the steep passenger boarding ramp in the graphic below. Source: LTA Solutions (above), Thermo-Skyship Ltd. 1979 proposal (below)



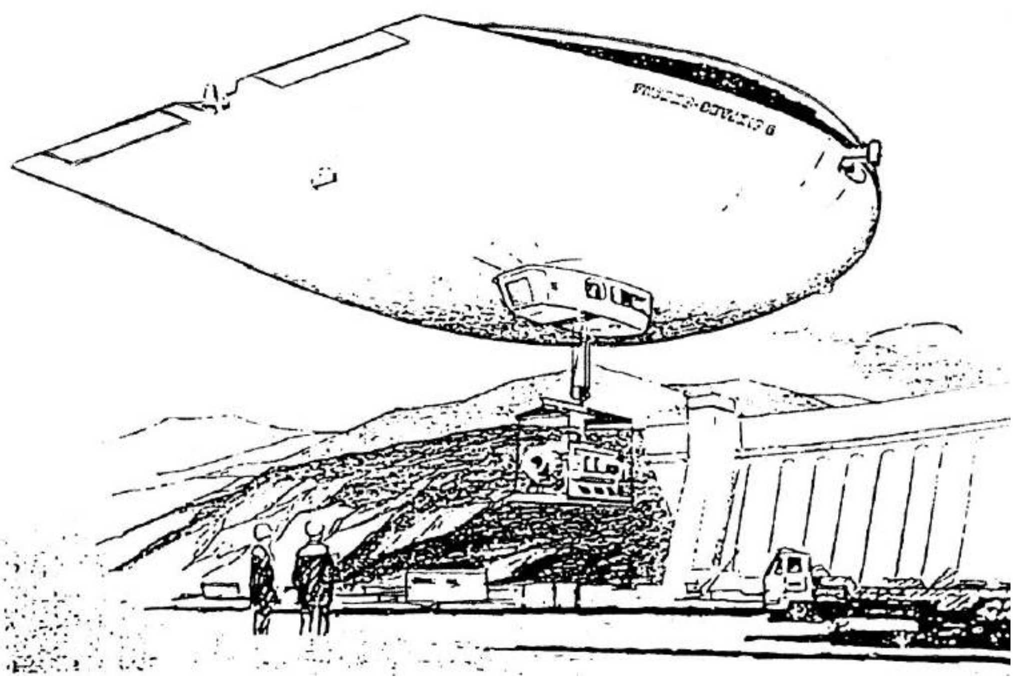
Here's the proposed development time frame:

Complete project financing	1 May 1979
Design optimization studies	Until March 1980
Preparation of TSL Jurby site, Isle of Man	May 79 – Jan 80
Detailed design of prototype	Jul 79 – Aug 81
Construction of prototype	Mar 80 – Oct 81
Test flying prototype	Nov 81 onward
Construction of customers craft #1	Nov 81 – Jul 82

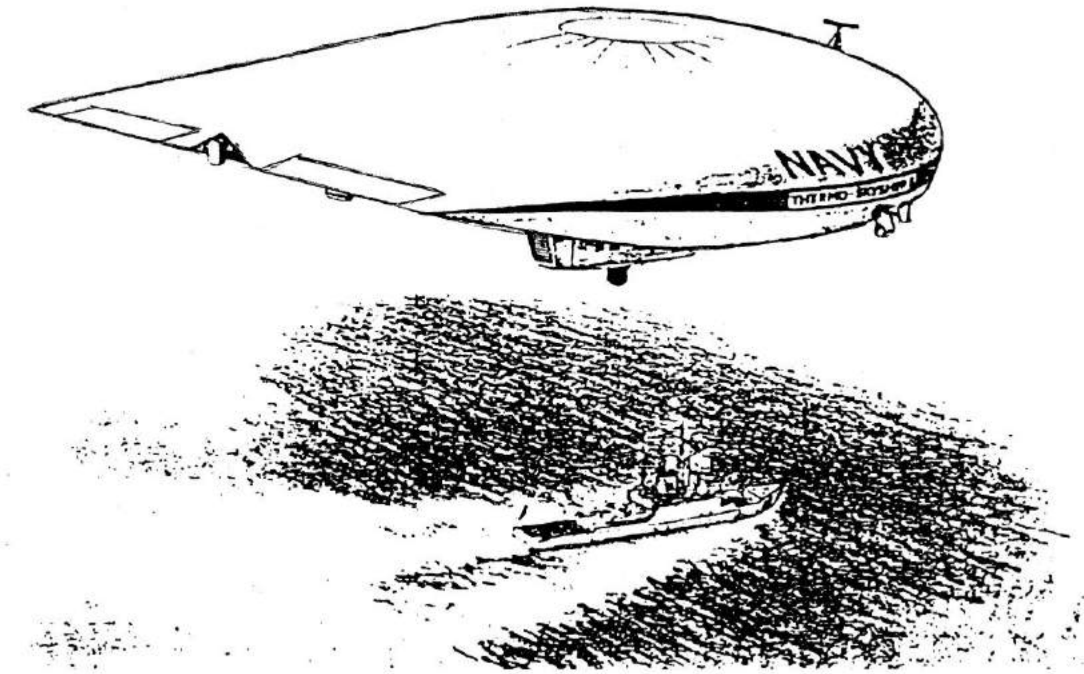
Thermo-Skyship Ltd. claimed that further development to intercontinental ranges and payloads up to 400 tonnes (440 tons) could be done within 10 years.



Thermo-Skyship configured as in inter-city passenger transport.



Thermo-Skyship carrying a large external load.
Source, both graphics: Thermo-Skyship Ltd. 1979 proposal



Thermo-Skyship serving as a Navy maritime patrol airship.
Source: Thermo-Skyship Ltd. 1979 proposal

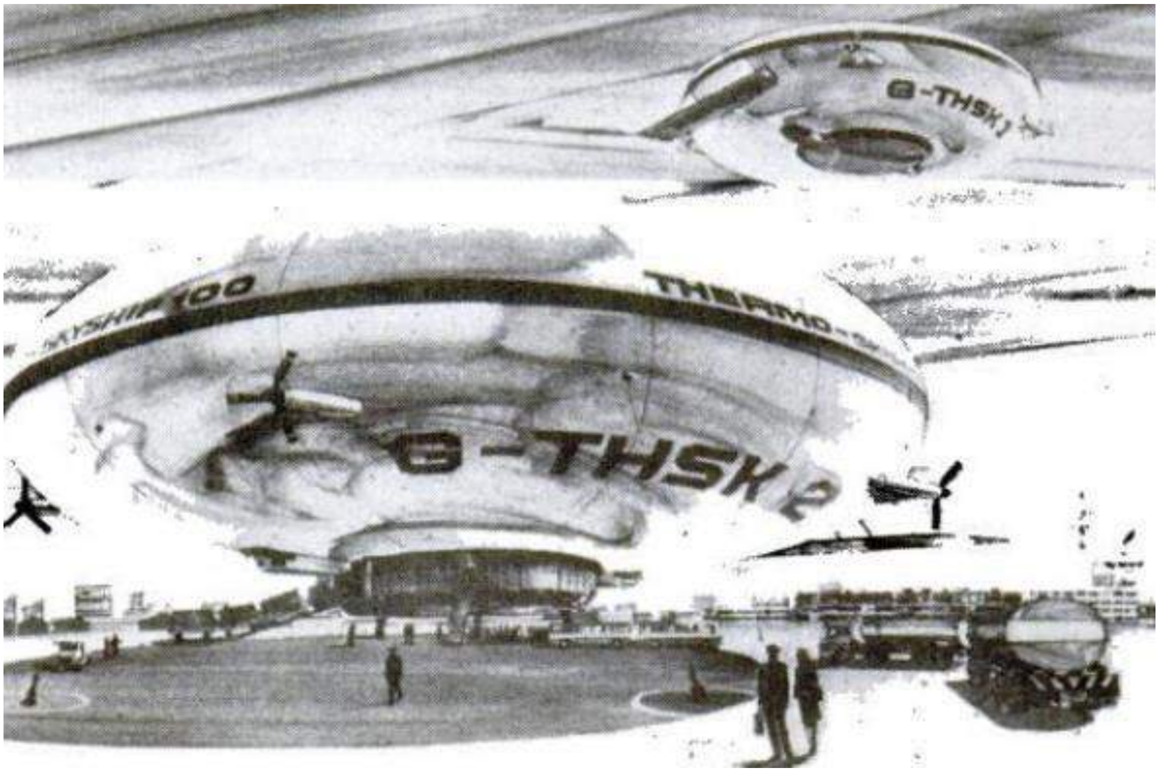
You can read the complete March 1979 Thermo-Skyships Ltd. proposal here: https://lynceans.org/wp-content/uploads/2021/02/The-Thermo-Skyship-Project_26Mar1979.pdf

1980 Thermo-Skyship proposal

In 1980, British Information Services (BIS) announced that the go-ahead had been given to build a pre-production model of the 230-foot (70-meter) diameter Thermo-Skyship design shown in the following graphic. Powered by four turboprop engines, this model was designed to carry 10 metric tons (11 tons) in VTOL operation or 19 metric tons (20.9 tons) in short takeoff and landing (STOL) operations, at a maximum speed of 90 knots.

This design appears to have abandoned the beaver tail planform in favor of a symmetrical lenticular design. In addition, the propulsion and control scheme on the beavertail designs has been replaced by four turboprop engines in a tandem “tractor-pusher” arrangement.

A pre-production model was never built.



The Thermo-Skyship design announced by BIS, 1980.
Source: Popular Science, July 1980

European Ferries and the end of the Thermo-Skyship

European Ferries, a company that operated services across the English Channel, made a 15% equity purchase in Airship Industries (note: AI was formed from TSL in July 1980) and made loans for the further development of the Thermo-Skyship as a passenger and cargo ferry. European Ferries had expressed an interest in operating six Thermo-Skyships for a passenger service between city center sites in London and Amsterdam, operating at speeds of up to 170 kph (91.7 knots), and offering fares similar to those paid for hovercraft services across the English Channel. Originally, this model of the Thermo-Skyship was intended to carry 60 passengers and a 6 metric ton (6.6 ton) payload. However, the design was progressively scaled up during the course of its development and it was sized to carry 200 passengers and a 20 metric ton (22 ton) payload when design work was stopped.

6. The end of the Thermo-Skyship

The decision to stop development of the Thermo-Skyship was motivated by its very high research & development costs, estimated by Airship Industries to be on the order of £100 million, and by the relatively poor performance of the design in wind tunnel tests. It appears that development of Thermo-Skyship airships ended in the 1981 - 1982 time frame.

Except for the 9.1-meter (30-foot) diameter symmetrical lenticular flying model that flew indoors in 1975 at Cardington Airfield, Thermo-Skyship designs remained as design concepts only.

There are several boxes of uninventoried Thermo-Skyship records in the manuscript archive at the Manx Museum, Douglas, Isle of Man. Their one inventoried item on Thermo-Skyships (item MS14556), *The Thermo-Skyship Project,* dated 26 March 1979, was a very useful resource for this article. I understand that local researchers are available for hire to undertake research for private clients. The museum's website is here: http://www.manxnationalheritage.im/

7. For more information

- "Feasibility Study of Modern Airships – Phase I, Volume I – Summary and Mission Analysis," NASA CR-137691, Volume I, Boeing Vertol Company, May 1975: NASA Technical Reports Server (NTRS) 19750024930: Feasibility study of modern airships, phase 1, volume 1. [structural design criteria/technology assessment
- UK Parliament, "Lighter Than Air Transport, Volume 382: debated on Thursday 28 April 1977 in the House of Lords: https://hansard.parliament.uk/lords/1977-04-28/debates/96cbb107-27c6-4f87-8ad2-9ccb6c76475e/LighterThanAirTransport
- "The Thermo-Skyship Project," a proposal from Thermo-Skyships Ltd., 26 March 1979: https://lynceans.org/wp-content/uploads/2021/02/The-Thermo-Skyship-Project_26Mar1979.pdf

- “Liftoff for Skyship,” Popular Science, July 1980, p. 30: https://books.google.com/books?id=bfLnBTJ2nkYC&printsec=frontcover&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false
- Anthony J. Dolman, “Current and Possible Future Developments in Lighter-Than-Air (LTA) System Technology,” United Nations Industrial Development Organization (UNIDO), pp. 75 – 77, 1983: https://open.unido.org/api/documents/4793600/download/CURRENT%20AND%20POSSIBLE%20FUTURE%20DEVELOPMENTS%20IN%20LIGHTER-THAN-AIR%20
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- G.A. Khoury & J.D. Gillett, “Airship Technology,” Cambridge Aerospace Series, Cambridge University Press, ISBN 13: 9780521430746, 2002
- Edwin Mowforth, “An Introduction to the Airship,” 3rd edition, p. 115, ISBN 0-9528578-6-2, The Airship Association, 2007
- 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
- Bill Rose, “Flying Saucer Technology,” Ian Allen Publishing, UK, ISBN 978-1-857803-31-0, pp. 150 – 152, 2011

Videos of the sub-scale prototype test flights

- “U.K.: Model of "Flying Saucer" Skyship Demonstrates ITS Potential in Old R101 Airship Hangar,” Reuters, with embedded video, 18 April 1975: https://reuters.screenocean.com/record/434045
- “Flying Saucer – Color” (1:39 minutes), AP Archive / British Movietone, Story No.: BM75-153, 27 April 1975: http://www.aparchive.com/metadata/youtube/e30ffd6dc1e8409983c1f6b8a46feb63

Other *Modern Airships* articles

- *Modern Airships - Part 1*: https://lynceans.org/all-posts/modern-airships-part-1/
    - Airship Industries Ltd. airships
    - Wren Skyships & AAC
- *Modern Airships - Part 2*: https://lynceans.org/all-posts/modern-airships-part-2/
    - Aerosmena hybrid thermal airships
    - Boeing hybrid thermal airship
    - LocomoSky hybrid thermal airships
    - Thermoplan hybrid thermal airships
- *Modern Airships - Part 3*: https://lynceans.org/all-posts/modern-airships-part-3/