Boeing Vertol – Helipsoid VTOL hybrid lifting body airship

Peter Lobner, updated 17 January 2025

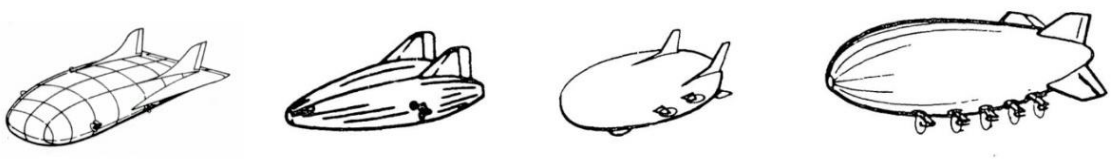
1. Introduction

In 1975, NASA sponsored a study named *Feasibility of Modern Airships – Phase I* with Goodyear Aerospace Corp. and Boeing Vertol Company as contractors performing studies of civilian roles for lighter-than-air (LTA) craft. The following six categories of airships were considered in the NASA study:

- Fully buoyant, conventional
  - Rigid airships
  - Non-rigid airships
- Partially buoyant, vertical takeoff and landing (VTOL), hybrid
  - Lifting body concepts
  - Combined / integrated concepts
- Partially buoyant, short takeoff and landing (STOL), hybrid
  - Lifting body concepts
  - Auxiliary wing concepts

Airship designs selected to represent each of the six categories were evaluated on three different mission profiles, short-range, transcontinental and intercontinental, with the airship sized for two different payloads, 50 and 100 tons (45.4 and 90.7 metric tons).

The candidates in the partially-buoyant VTOL category of hybrid lifting body airships were the Boeing Vertol Deltoid and Helipsoid, the NASA / Douglas Deltoid, and the Goodyear Aerospace Dynastat.



Boeing Deltoid | NASA/Douglas Deltoid | Boeing Helipsoid | Goodyear Dynastat

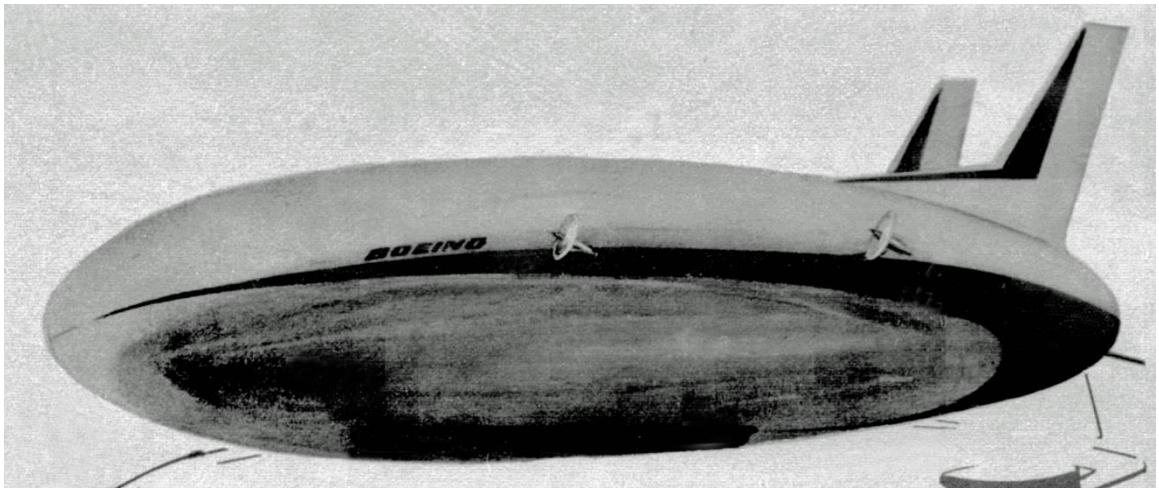
Source: Adapted from NASA CR-137691, Vol. I (1975)

The particular mission parameters for the NASA study are summarized in the following table.

PARAMETER \ MISSION	SHORT RANGE	TRANSCONTINENTAL	INTERCONTINENTAL
RANGE (STILL AIR)	300 NM (556 km)	2,000 NM (3,704 km)	5,000 NM (9,260 km)
CRUISE ALTITUDE	2,000 ft ISA (610 m ISA)	13,000 ft ISA (3,962 m ISA)	2,000 ft ISA (610 m ISA)
CRUISE SPEED*	50, 100, 200 kt (25.7, 51.4, 102.9 m/s)	50, 100, 200 kt (25.7, 51.4, 102.9 m/s)	50, 100, 200 kt 25.7, 51.4, 102.9 m/s
RESERVES	50 NM (93 km) DIVERSION & 10% INITIAL FUEL	250 NM (463 km) DIVERSION & 10% INITIAL FUEL	250 NM (463 km) DIVERSION & 10% INITIAL FUEL
DESIRED PAYLOAD	50–100 TONS	50-100 TONS	100 TONS
DESIGN ALTITUDE (FOR HULLS, PROP/ ROTORS AND ENGINE SIZING)	5,000 ft ISA (1,524 m ISA)	15,000 ft ISA 4,572 m ISA	5,000 ft ISA (1,524 m ISA)
*CRUISE SPEED AT CRUISE ALTITUDE			

Source: NASA CR-137691, Vol. I (1975)

The Phase I initial screening led to the selection of the Boeing Vertol Helipsoid to represent the category of partially-buoyant VTOL hybrid lifting body airships in the parametric analysis.

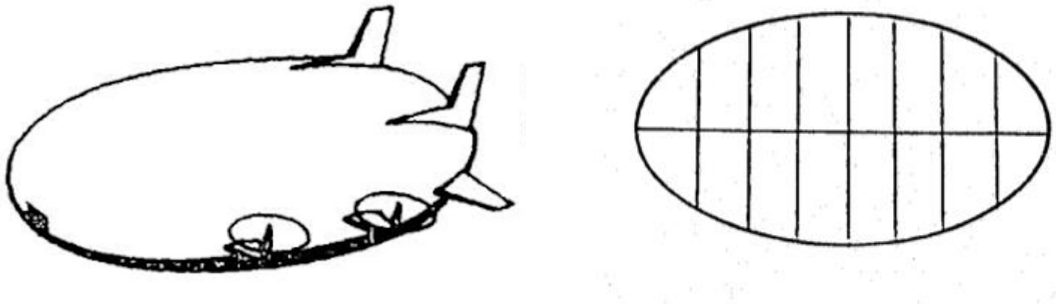


Helipsoid general arrangement with prop / rotors vectored partially up, in transition flight. Source: Adapted from NASA CR-137691, Vol. I (1975)

2. The NASA-sponsored analysis of the Helipsoid concept

2.1 Helipsoid airship design and operation

The Helipsoid is a large, rigid, hybrid airship with a broad elliptical, lifting body hull, partitioned internally with longitudinal and transverse structures. The Boeing Vertol study assumed the following configuration of lifting gas cells within the hull.



Helipsoid general arrangement with prop / rotors vectored up for VTOL flight (L), and internal lifting gas cell arrangement (R)
Source: NASA CR-137691, Vol. I (1975)

The airship is propelled by four powerful, vectoring prop / rotors extending horizontally on stub wings from the midplane of the envelope. The vectoring prop / rotors function as large diameter propellers in the horizontal (cruise) position and, when rotated to the vertical position, function as helicopter-type rotors with collective and differential collective control of dynamic lift in slow speed and vertical flight. The lifting body hull generates aerodynamic lift in forward flight and aerodynamic flight controls are provided by twin rudders and horizontal tail planes.

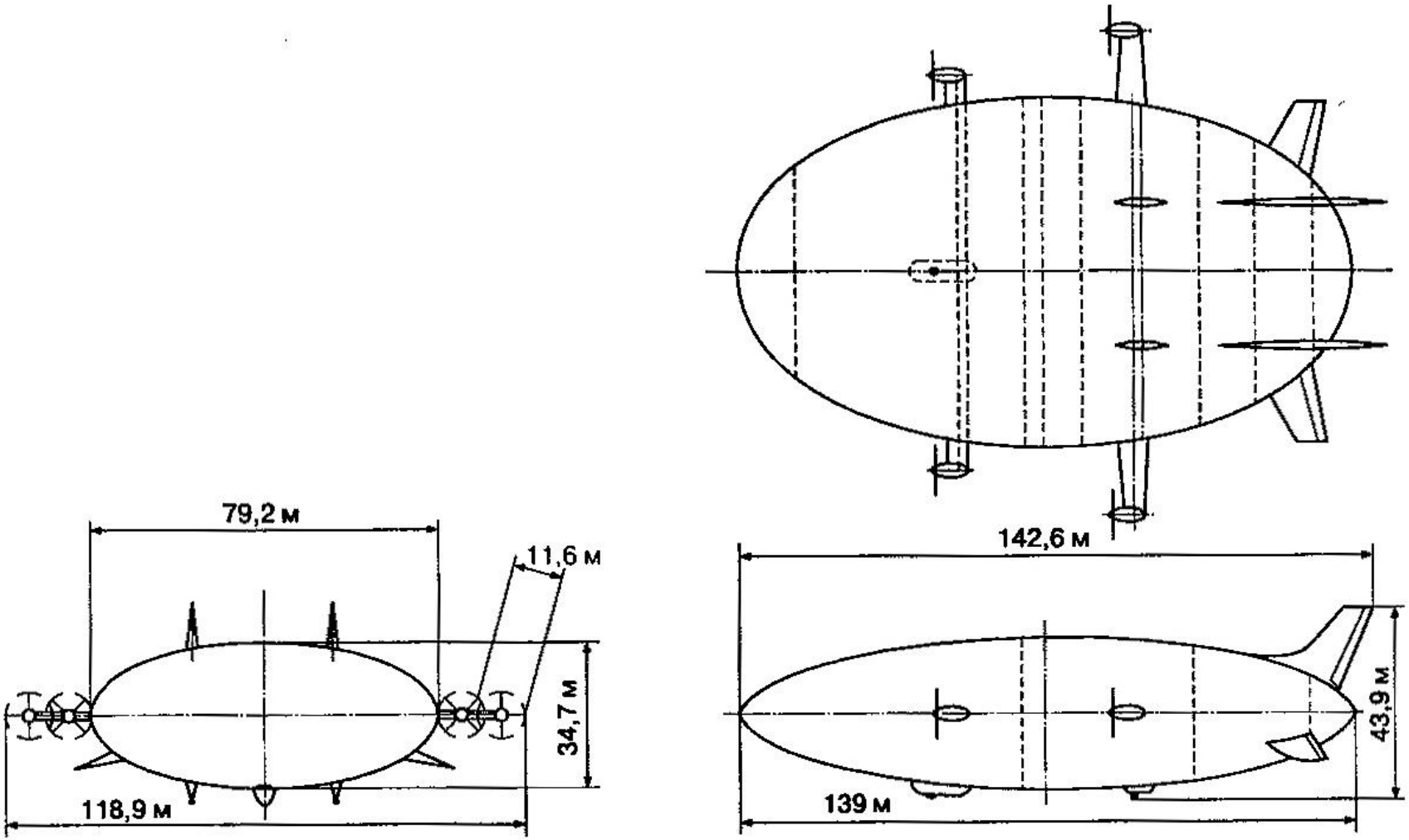
Boeing described their Helipsoid concept as follows:

> "The partially buoyant Helipsoid V/STOL airship …. is an attempt to achieve the best compromise shape for a moderately high speed airship considering optimum structural, aerodynamic, and control requirements along with a compact lifting body."

> “The selected composite geodetic rigid structure approach will include load spreader panels and Kevlar rope catenaries to achieve the optimum shape. The turboshaft engines and tilting prop-rotors are disposed about the center of buoyancy to provide, through collective and differential collective control systems, both lift and control as well as propulsion.”
>
> “For this concept, the aerodynamic lift may be reduced progressively to trim and maintain altitude. However, if the buoyant lift is more than the OWE (Operational Weight Empty), a load/unload sequencing system, a ballast/load transfer system, or heavy ground support equipment (like ‘mules’) will be required for terminal loading / unloading operations and parking / hangaring equipment will be necessary.”
>
> “However, in a VTOL variant, negative thrust on the prop-rotors during landing operations may be used to eliminate ballast requirements. Restraints after power shutdown might, of course, be required.”
>
> “The concept endeavors to reduce length and height to facilitate manufacture and hangaring as well as better matching the dimensions of a typical (helicopter) landing pad.”

The semi-buoyant Helipsoid can operate over at a range of buoyancy ratios (static buoyancy / max. gross weight), for example, from 30% to 75% (low to moderate buoyancy). Like the semi-buoyant Aereon Dynairship and the Ohio Airships Dynalifter, an STOL Helipsoid takes off and lands almost like an STOL fixed-wing aircraft. On the ground, the Helipsoid is heavier than air and, hence, should be relatively unaffected by light-to-moderate wind and gust effects, and can taxi unassisted to a parking spot and be quite stable on the ground without an immediate need for a ground crew.

With its powerful prop / rotors, the Helipsoid can, within certain gross weight limits, hover and make vertical takeoffs and landings (VTOL) with precise dynamic lift control.



Boeing Vertol Helipsoid airship general arrangement and scale for an envelope volume of 200,000 m^3 (7,063,000 ft^3). Source: Boyko (2001)

2.2 The Phase I parametric analysis

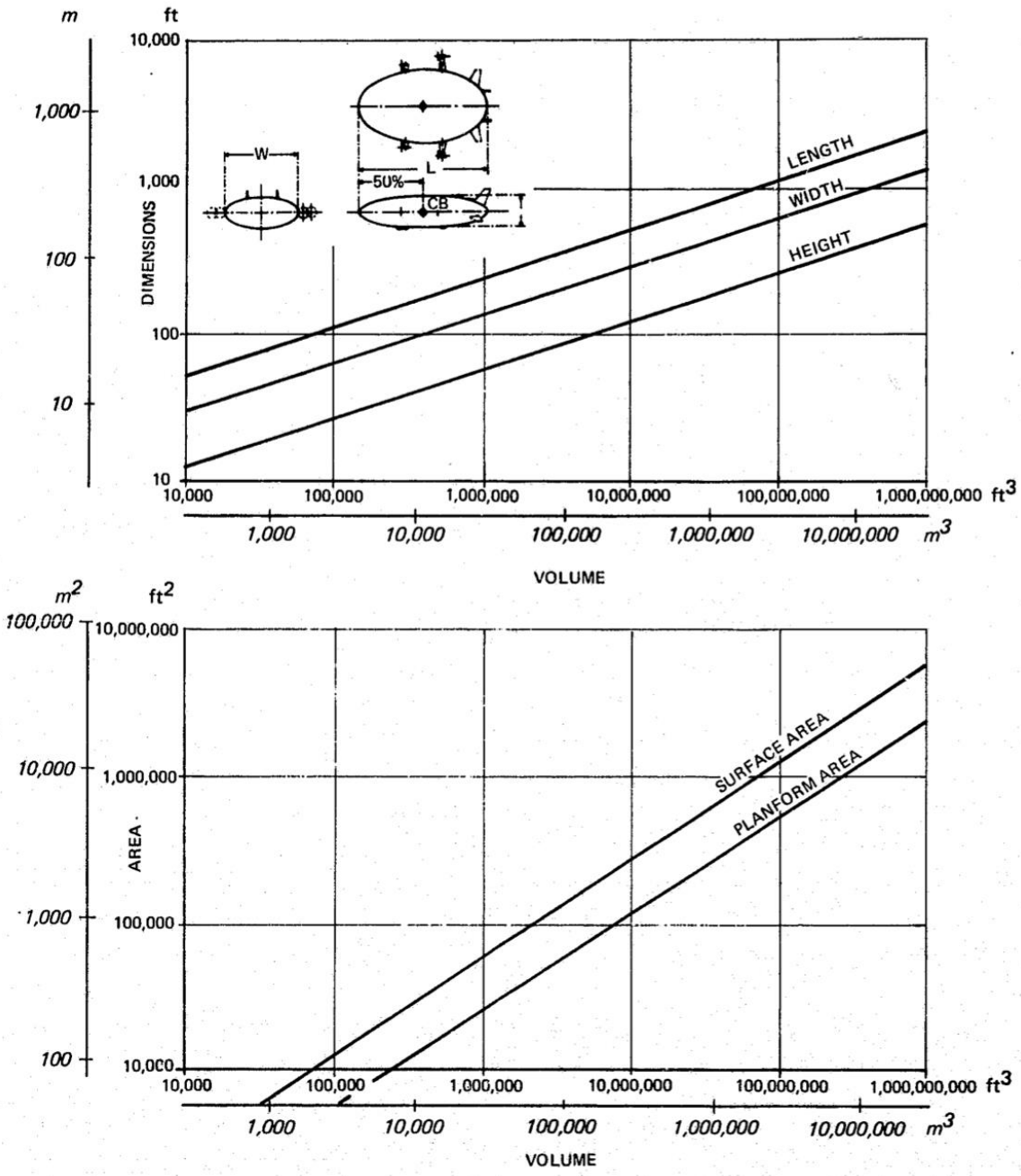
A computer code named CASCOMP (Comprehensive Airship Sizing and Performance Computer Program) was used to perform the parametric analyses of the six airship design concepts operating on the three civil transportation mission profiles and two different cargo loads. For each airship design concept / mission / cargo combination, this analysis developed basic airship scaling parameters and a figure of merit called the Maximum Specific Productivity (PV/E) that was used to establish a relative ranking of the six design concepts. Results for the Helipsoid are summarized in the following table and scaling charts.

Optimal results from Helipsoid parametric analysis *

Parameter	Short range mission		Transcontinental mission		Inter-continental mission
	50 ton payload	100 ton payload	50 ton payload	100 ton payload	100 ton payload
Max PV/E ** (Figure-of-merit)	200 knots (102.9 m/s)	240 knots (123.5 m/s)	137 knots (70.5 m/s)	135 knots (69.4 m/s)	37 knots (19 m/s)
Speed for above	150 knots (77.2 m/s)	180 knots (92.6 m/s)	150 knots (77.2 m/s)	145 knots (74.6 m/s)	110 knots (56.6 m/s)
Buoyancy ratio	0.35	0.35	0.35	0.35	0.75
Volume	1,200,000 ft^3 (33,984 m^3)	2,700,000 ft^3 (76,464 m^3)	2,300,000 ft^3 (65,136 m^3)	5,100,000 ft^3 (144,432 m^3)	20,000,000 ft^3 (556,4000 m^3)
Gross lift	190,000 lb (86,184 kg)	385,000 lb (174,636 kg)	260,000 lb (117,936 kg)	560,000 lb (254,016 kg)	1,400,000 lb (635.040 kg)
Length, OA	260 ft (79.2 m)	335 ft (102.1 m)	320 ft (97.7 m)	420 ft (128.0 m)	655 ft (199.6 m)
Width, OA	145 ft (44.2 m)	189 ft (57.6 m)	180 ft (54.9 m)	235 ft (71.6 m)	365 ft (111.3 m)

* Data from “Feasibility Study of Modern Airships – Final Report – Phase I – Volume I”, CR-137691, Section 6.

**This index is known as Maximum Specific Productivity (PV/E) = (P, payload weight) x (V, speed) / (E, empty weight)



Boeing Vertol Helipsoid scaling study results.
Source: NASA CR-137691, Vol. I, Fig. 5-44 (1975)

Based on the computed Maximum Specific Productivity (PV/E) figure-of-merit, the Helipsoid outperformed all other candidates by a wide margin on the short range and transcontinental mission profiles, with the deltoid Aereon Dynairship coming in second. The Helipsoid also came in second on the intercontinental mission profile. The NASA

In Section 6.3 of the Phase 1 report, the Boeing Vertol study team concluded:

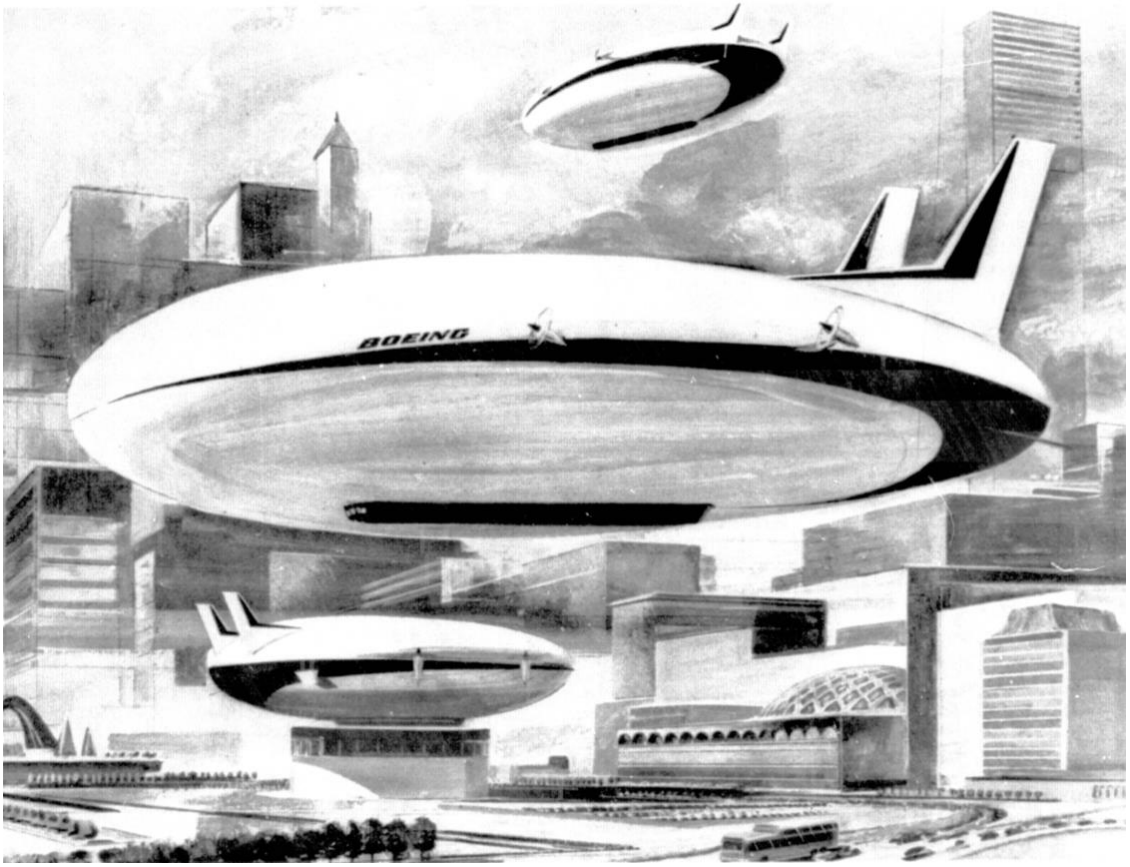
> "A partially buoyant Helipsoid of the optimum buoyancy ratio has the potential to solve the critical problems facing a future airship development program. Although the optimum buoyancy ratio is mission dependent (as a function of speed, range, etc.), generally the Helipsoid airship with its longitudinally / laterally disposed tilting low disc loading prop / rotors will have a buoyancy ratio near 50%. On this basis, a Helipsoid configuration can be optimized to accomplish the following:
>
> - **Eliminate ballast and ballast recovery systems:** Since weight losses due to fuel burnoff can be counteracted by aerodynamic trimming in cruise flight and prop/rotor collective pitch in low speed flight, no water recovery apparatus will be required. In addition (depending on the mission optimization), transfer of payload may also be accomplished without ballast - replacement systems.
>
> - **Full low-speed controllability:** Depending on the mission requirements, a full VTOL capability may be provided with the attendant implications of full low- speed controllability provided by proper utilization of the tilting prop/rotors. Provision of this capability in addition to the low buoyant lift can remove the airship's susceptibility to wind, eliminate requirements for ground handling crews and equipment, and generally improve the airship's operating aspects. Since strong control power is available, as well as the availability of dynamic lift trimming, weather and icing constraints should be eliminated."

2.3 Supplementary analysis

The versatility of the Helipsoid airship was explored further by examining its use on a commuter passenger service mission and a representative U.S. Coast Guard (USCG) mission.

Analysis of Helipsoid commuter airship passenger service

The commuter airship passenger service concept evaluated by Boeing Vertol in the NASA-sponsored Phase I study assumed a 200 passenger, semi-buoyant, short-range Helipsoid commuter airship with a buoyancy ratio of 67%. Approximate airship volume was 2,000,000 ft^3 (57,000 m^3) and the dynamic lift from the vectoring turboprop engines enabled vertical takeoff and landing (VTOL).



VTOL Helipsoid airships in commuter airline service.
Source: NASA CR-137691, Volume I, Section 4.6, Fig. 4-11 (1975)

With relatively frequent stops, the flight altitude was only 330 ft (100 m). The pilot-optional vehicle followed a fixed route lane guided by ground-located electronic beams sending signals to the autopilot in the airship. Each passenger station consisted of a platform at an elevation of 66 ft (20 m) above the ground, with a staging area to enable rapid passenger debarkation and loading.

A fleet of 66 commuter airships with a maximum cruise speed of 100 mph (161 kph) would be required to deliver a traffic volume of 10,000 passengers per hour.

Potential Navy and Coast Guard missions

Several Navy missions were considered, with the most promising being anti-submarine warfare (ASW) and airborne early warning (AEW) missions, much like those performed by the N-class blimps (ZPG-1, -2, -2W and -3W) from the mid-1950s until the Navy's LTA program was terminated in 1961. The ZPG-3W, with an envelope volume of 1,465,000 ft^3 (41,484 m^3) remains the largest non-rigid airship that has ever flown.

The primary USCG mission of interest was coastal surveillance with endurance up to 10 – 14 days, with operational trade-offs between payload and range, and the potential to conduct special missions with remotely-piloted vehicles.

Example Helipsoid design parameters

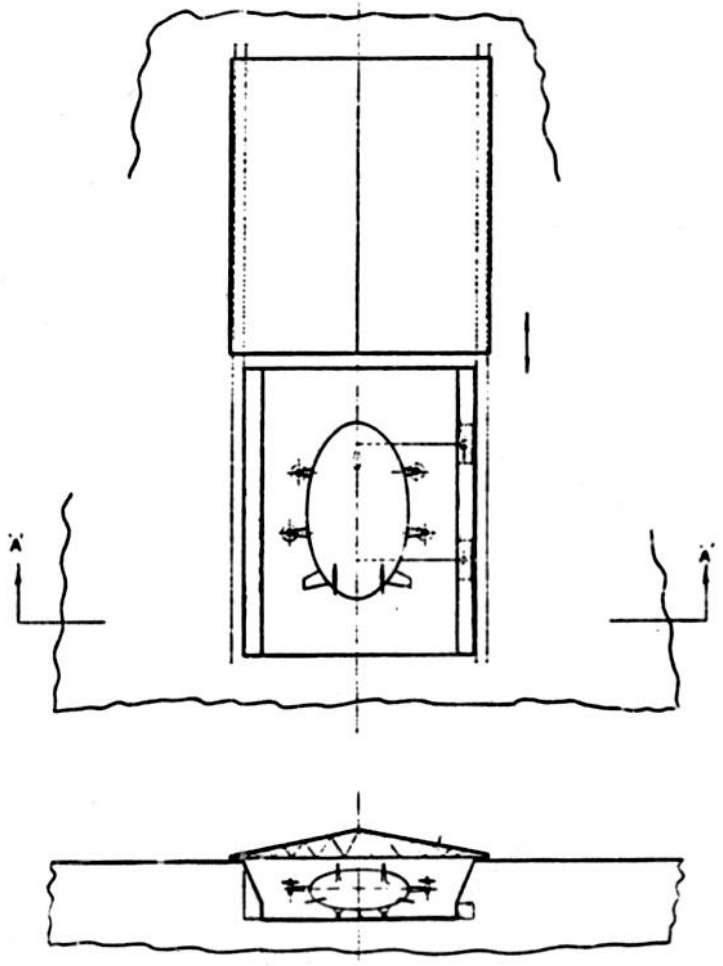
The CASCOMP parametric analysis produced the following results that are examples of Helipsoid characteristics tailored for specific civil passenger and Coast Guard missions.

Parameter	**Commuter passenger mission**		**US Coast Guard short mission**	
Payload	100,000 lb (45,359 kg)		50,000 lb (22,680 kg)	
Buoyancy ratio	0.5	0.7	0.5	0.7
Volume	2,450,000 ft3 69,384 m3	2,560,000 ft3 72,499 m3	1.100,000 ft3 31,152 m3	1,050,000 ft3 29,736 m3
Gross lift	274,068 lb (124,317 kg)	287,068 lb (130,214 kg)	123,190 lb (55,879 kg)	119,190 lb (54.065 kg)
Empty weight	128,000 lb (58,061 kg)	145,000 lb (65,772 kg)	50,000 lb (22,680 kg)	51,000 lb (23,134 kg)
Mission fuel	42,000 lb (19,051 kg)	38,000 lb (17,237 kg)	18,000 lb (8,165 kg)	13,000 lb (5,897 kg)
Installed power	14,100 hp (10,514 kW)	11,500 hp (8,576 kW)	8,700 hp (6,488 kW)	7,000 hp (5,220 kW)
Length	322 ft (98.1 m)	369 ft (112.5 m)	254 ft (77.4 m)	289 ft (88.1 m)
Width	184 ft (56.1 m)	209 ft (63.7 m)	147 ft (44.8 m)	164 ft (50.0 m)

Source: NASA CR-137691, Volume I (1975)

2.4 Novel airship hangar design concept

The Boeing Vertol team developed a concept for a below-grade hangar with a sliding roof structure. With some limitations on its maximum weight, the Helipsoid could operate as a VTOL craft and land into and takeoff directly from the hangar. The relatively low profile of the ellipsoid hull (relative to a conventional cylindrical hull) reduces the below-grade depth of the hangar.



Below grade airship hangar with sliding roof, designed for vertical takeoff and landing. Source: NASA CR-137691, Volume I, Fig. 3-35 (1975)

2.5 Conclusion of the Phase I study

The Boeing Vertol team recommended that further study of the Helipsoid be included in Phase II of the NASA study. It was not, and Boeing Vertol did not continue work on the Helipsoid on its own.

3. For more information

- "Feasibility Study of Modern Airships – Phase I, Volume I – Summary and Mission Analysis," NASA CR-137691, Section 5.3.1.5, "Helipsoid Concept," Section 5.4.3.5, "Helipsoid Parametric Results," and Section 6, "Selection of Vehicle / Mission Candidates," Boeing Vertol Company, May 1975: https://ntrs.nasa.gov/api/citations/19750024930/downloads/19750024930.pdf
- "Description of CASCOMP – Comprehensive Airship Sizing and Performance Computer Program," NASA CR-137691, Volume II, Boeing Vertol Company, May 1975: https://core.ac.uk/download/pdf/42887077.pdf
- Y.S. Boyko, "Aeronautics: Tethered, Free, Managed," p. 352 (in Russian), ISBN 5.8122-0233-8, Publishing house MGUP, Moscow, Russia, 2001

Other *Modern Airships* articles

- *Modern Airships - Part 1*: https://lynceans.org/all-posts/modern-airships-part-1/
    - Boeing Vertol Deltoid hybrid airship
    - NASA / Douglas Deltoid hybrid airship
    - Goodyear Dynalifter hybrid airship
- *Modern Airships - Part 2*: https://lynceans.org/all-posts/modern-airships-part-2/
- *Modern Airships - Part 3*: https://lynceans.org/all-posts/modern-airships-part-3/