Navy ANVCE program airships (1976 – 1979)

Peter Lobner, updated 17 January 2025

1. Introduction

In 1976, the U.S. Navy initiated the Advanced Navy Vehicle Concepts Evaluation (ANVCE), which was aimed at developing and evaluating design concepts for Navy advanced air and sea vehicles for the medium term (1990s) and long term (2000s). As part of this evaluation, the Navy committed $4 million to lighter-than-air (LTA) vehicle investigations that were conducted in collaboration with the National Aeronautics and Space Administration (NASA). Two classes of LTA vehicles were of interest:

- Fully-air buoyant (FAB) vehicles
- Semi-air buoyant (SAB) vehicles

This program was undertaken to evaluate designs in the areas of aerodynamics, materials, structures, survivability, vulnerability, and life-cycle cost. Goodyear Aerospace Corp. (GAC) and Martin Marietta were contracted to perform parametric studies of naval rigid and non-rigid airship design concepts. The firm Turbomachines was contracted to perform a hull study for a rigid, metal-clad airship.

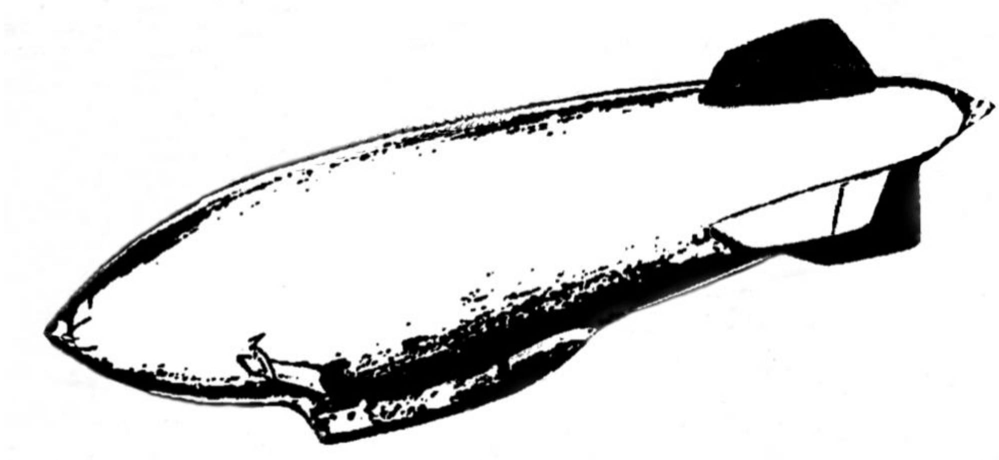
This article takes a look at three airship design concepts from the ANVCE program: The fully-air buoyant, non-rigid Goodyear ZPG-X and the rigid Martin Marietta Model 836, and the semi-air buoyant Goodyear SABV.

2. Goodyear ZPG-X

The ZPG-X is a derivative of GAC's ZPG-3W blimp, which was retired from active service in 1961, but remains the largest non-rigid airship ever flown. The ZPG-3W had typical blimp short takeoff and landing (STOL) capability. The primary adaptations for ZPG-X were to provide thrust vectoring propulsion and controls to deliver vertical takeoff and landing (VTOL) and hovering capabilities, and optimize mission equipment for naval task force and ship convoy protection. GAC claimed the ZPG-X could be operational by 1985 using currently available technology.

General characteristics of the Goodyear Aerospace ZPG-X

Parameter	Goodyear Aerospace ZPG-X
Mission	Naval task force & ship convoy protection
Length	403 ft (123 m) (same as ZPG-3W)
Diameter	85 ft (25.9 m) (same as ZPG-3W)
Envelope volume	1,490,000 ft^3 (42,192 m^3) (almost same as ZPG-3W)
Structure weight	25,200 lb / 12.6 tons (11,431 kg / 11.4 metric tons)
Operating weight empty	51,100 lb / 25.5 tons (23,179 kg / 23.2 metric tons))
Useful lift	45,000 lb / 22.5 tons (20,412 kg / 20.4 metric tons)
Military payload	20,300 lb / 10.1 tons (9,208 kg / 9.2 metric tons)
Propulsion and maneuvering	• 2 x AVCO Lycoming T53 turboprop engines rated @ 1,500 shp (1,119 kW) each, driving 3-bladed, 15.5 ft (4.6 m) propellers mounted on tilting stub wings for thrust vector control of lift. • 2 x Allison 250-C20B turboshaft engine rated @ 420 shp (313 kW) each, mounted on the X-tail, driving a single 3-bladed, constant speed, variable pitch, 20 ft (6.1 m) diameter propeller integrated with a vectoring ruddervator for propulsion, vertical lift, and pitch / yaw control.
Speed	90 knots, max
Altitude	5,000 ft (1,524 m), cruise
Crew	18
Range	4,000 nautical mile (7,408 km), ferry
Endurance	2 days on station



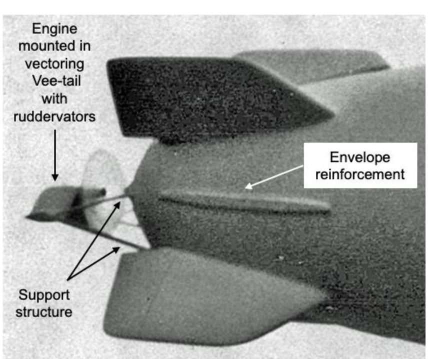
ZPG-X. Note the tilt wing rotated up.
Source: A.J. Dolman, UNIDO (1983)

The ZPG-X had a buoyancy / gross weight ratio (Beta) of > 0.85. That means it was heavier-than-air when it sat on the ground with its engines off. Dynamic lift from its tilt-wing engines gave the ZPG-X its VTOL and hovering capabilities.

The main engines were cross-shafted using a configuration similar to the Canadair CL-84 tilt-wing V/STOL research aircraft, which flew successfully for a decade between the mid-1960s and the mid-1970s. The CL-84 also used AVCO Lycoming T53 turboprops. On ZPG-X, the tilt-wings could rotate from 0º (horizontal) to +90º (vertical).

Canadair CL-84 “Dynavert” V/STOL aircraft.
Source: San Diego Air & Space Museum Archives

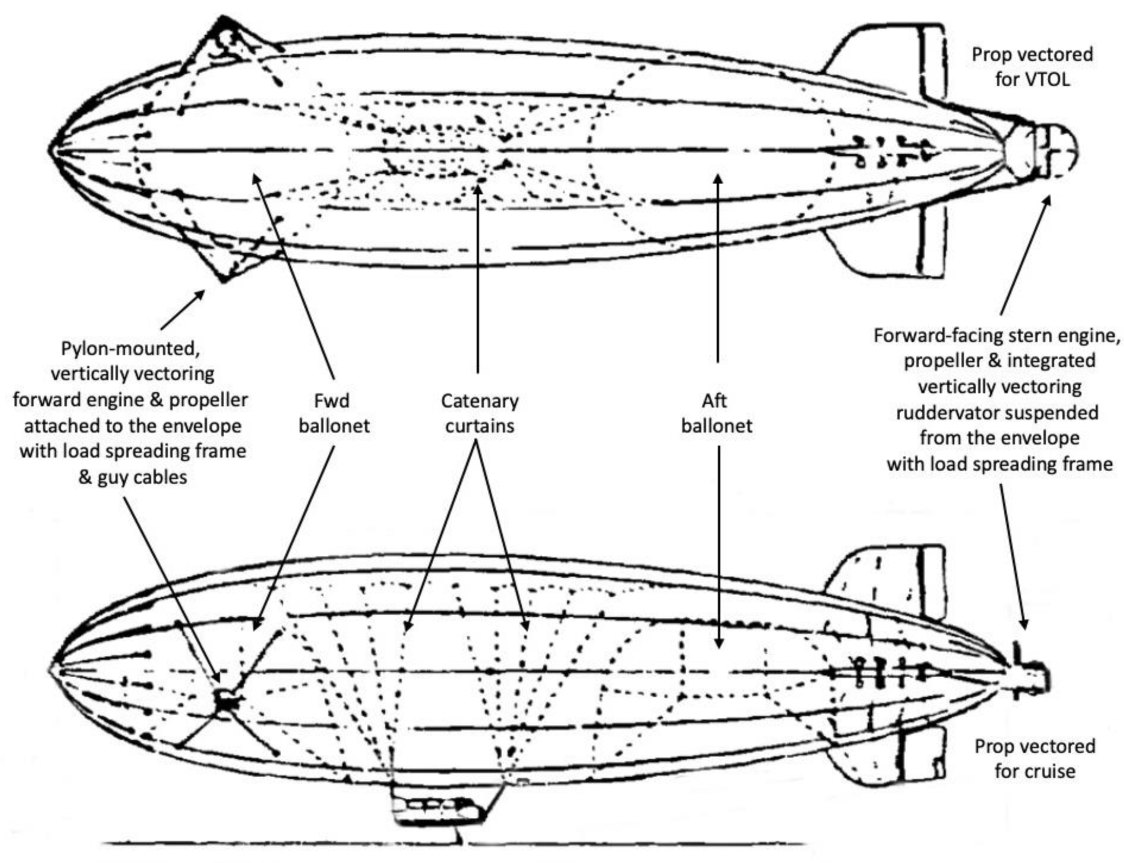
The two tail engines were geared to a common drive shaft for a single tractor propeller integrated in a thrust-vectoring ruddervator housing. Further details on the proposed ZPG-X stern propulsor installation are sparce. It appears that it was an early version of the thrust-vectoring tail propulsor GAC offered on their ZP3G airship in the 1980 Maritime Patrol Airship study for the Navy and Coast Guard. In cruise (at 0º), the stern propeller thrust was aligned with the longitudinal axis and ruddervator control surfaces in the propeller slipstream provided pitch and yaw control. For VTOL flight and hovering, the propeller / ruddervator assembly rotated 90º to generate dynamic vertical lift, while the ruddervator control surfaces in the propeller slipstream provided fine control for yaw and longitudinal position.



ZP3G tail propulsor. Source: Adapted from NASA Tech Memo 81158, Fig. 1 (1979)

Proposed sub-scale ZPG-X demonstrators

Goodyear Aerospace proposed a one-half scale flying model ZPG-X derived from their manned GZ-20 civilian blimp for use in a test program to collect operational data for defining the VTOL flight dynamics of a ZPG-X type vehicle and refining its control laws. With its original propulsion system removed, the GX-20 host blimp would have been modified with the addition of forward, flank-mounted, thrust-vectoring propulsors supported from the non-rigid gas envelope and a tail-mounted thrust-vectoring propulsor / ruddervator also supported from the gas envelope.



Half-scale ZPG-X side & top views.
Source: Adapted from NADC-77265-30 (1978)

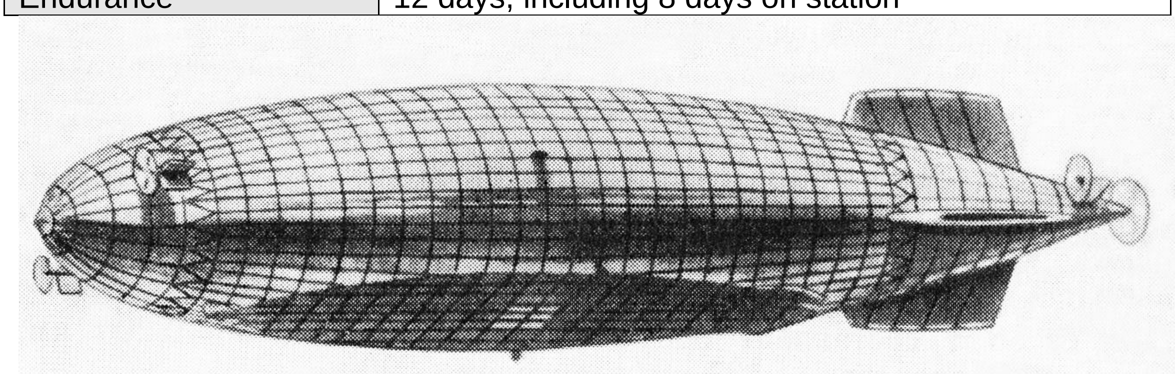
GAC also proposed developing a one-twelfth scale model for a less-ambitious, but more affordable test program. Neither sub-scale model was built.

3. Martin Marietta Model 836

The Model 836 was a concept for a rigid airship designed as an ocean surveillance and patrol vessel, with the ability to carry a large payload of surveillance, attack and defense equipment, operate in an area 3,000 km (1,864 miles) from base, and patrol on station for 8 days at an altitude of 3,000 m (9,843 ft).

General characteristics of the Martin Marietta Model 836

Parameter	Martin Marietta Model 836
Mission	Ocean surveillance and patrol
Length	784 ft (239 m)
Diameter	164 ft (50 m)
Envelope volume	9,320,000 ft^3 (263,913 m^3)
Ballonet volume	28%, 11 ballonets
Structure weight	109,200 lb / 54.6 tons
Operating weight empty	233,200 lb / 116.6 tons (106 metric tons)
Gross operating weight	413,600 lb / 206.8 tons (188 metric tons)
Payload	74,800 lb / 37.4 tons (34 metric tons)
Propulsion and maneuvering	• 4 x turboshaft engines rated @ 4,280 shp (3,192 kW) each driving large diameter, reversible propellers. The engines are mounted outboard on rotating pylons for vertical thrust vector control • 1 x diesel engine rated @ 932 shp (695 kW) driving a large vectoring stern propeller for yaw control
Speed	• 148 kph (92 mph), with all engines • 54 kph (33.5 mph), loitering on the stern engine
Altitude	• 9,843 ft (3,000 m) operating • 10,302 ft (3,140 m) max
Endurance	12 days, including 8 days on station



General arrangement of the Martin Marietta Model 836.
Source: Arie, "Dirigibles" (1986)

The conventional rigid hull was constructed of wire-braced transverse frames, longitudinal girders, and diagonal shear wires. The airship had a fabric outer skin with low gas permeability. Unlike contemporary rigid airships, the Model 836 did not have lifting gas cells within the hull. Instead, the hull was divided into 12 helium-containing compartments that were separated by 11 vertical lenticular air ballonets that were used to control the overall buoyancy and trim of the airship. The Model 836 hull volume was more than six times the volume of the Navy's ZPG-3W blimp and 30% larger than the volume of the LZ-129 Hindenburg rigid airship.

The Model 836 was propelled by one diesel-powered, horizontally vectoring, pusher propeller at the tail and four turboprops installed outboard on rotating pylons, two on each side of the nose and two on each side of the tail. During high-speed cruise flight, all five engines would be in operation. To conserve fuel, the turboprop engines were secured and feathered during low speed (loitering) flight.

Aerodynamic control was provided by a combination of control surfaces.

- Three tails fins (inverted Y-configuration) functioning as a rudder and ruddervators
- Front turboprop pylons had horizontal and vertical control surfaces
- Rear turboprop pylons had only horizontal control surfaces.

These aerodynamic control surfaces collectively provided three independent pitch and two independent yaw controls.

During VTOL operations and hovering, the four turboprop engines vectored vertically (up or down) by 60° from their horizontal (cruise) position to provide dynamic lift. Differential engine controls provided pitch and roll control. During slow speed, VTOL and hovering flight, the stern-mounted propeller can be vectored horizontally (left or right) by 60° to provide additional yaw control when needed.

A fully automated, fly-by-wire flight control system coordinated the operation of the thrust vectoring engines and the aerodynamic control surfaces during all flight modes.

The hull had a large flat lower surface that was intended to improve operations near and on the ground. The airship was equipped with a four-point landing gear for better rolling and pitching resistance on the ground, particularly in gusty conditions.

Martin Marietta claimed that a low altitude, cargo carrying Model 836 could carry a payload of 44 metric tons (48.4 tons) around the world in 45 days.

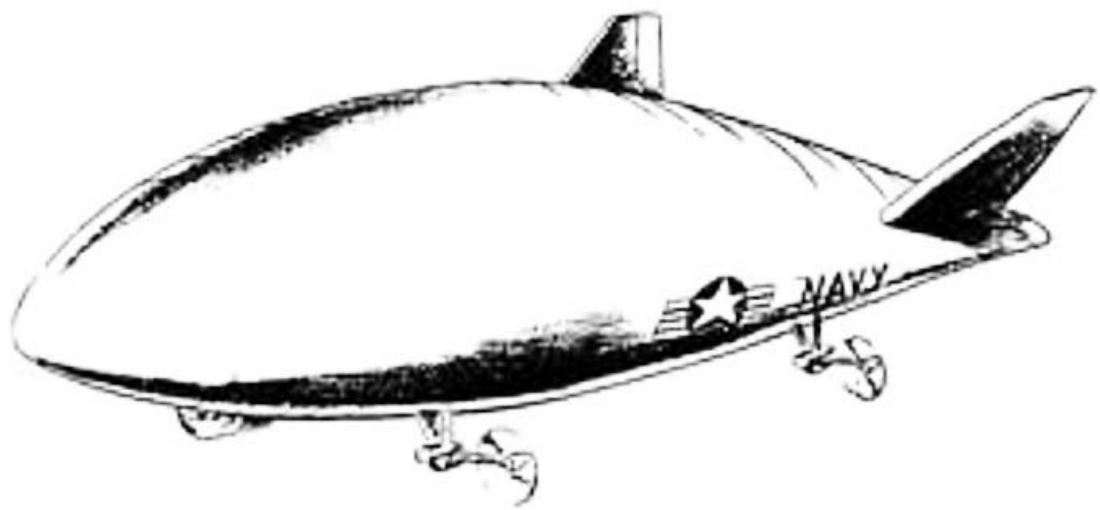
4. Goodyear Aerospace SABV

The GAC semi-air buoyant vehicle (SABV) was a hybrid aircraft with a delta-planform, rigid lifting body hull. The Advanced Navy Vehicle program office specified the following basic operating parameters of the SABV:

- VTOL with the ability to hover at maximum gross weight with thrust vectoring engines
- Fully-buoyant at VTOL takeoff maximum gross weight minus 98% of fuel and 100% of variable payload (i.e., at the end of a mission, with all weapons and sonobuoys expended).
- Cruise speed: 150 knots
- Ferry range: 8,000 nautical miles (14,816 km)
- Endurance: 12 hours to 7 days, depending on speed, mission profile and payload
- Combat suite: comparable to an advanced fixed-wing Navy patrol (VP) aircraft, which includes:
    - 11,000 lb (4,990 kg) of fixed mission systems
    - 12,800 lb (5,807 kg) of expendable payload

The SABV was intended to operate with the Navy's surface assets to provide anti-submarine warfare (ASW) and airborne early warning (AEW) screening protection. An initial operating capability (IOC) of 1990 was planned based on an assessment of low technical risk. A special-purpose module was developed to enable at sea replenishment. Time on station was expected to be one to three days on these fleet screening missions. The SABV also could conduct independent shore-based operations. The SABV would have nine crew stations and carry a crew of 13 to enable crew rotation and rest during long missions.

During their study, GAC evaluated options in three key technology areas: structures, propulsion and aerodynamics. No technology gaps were identified that would preclude developing the SABV in time for a 1990 IOC. GAC assessed that, "The growth and far-term potential (i.e., for vehicles of this class in the 2000 IOC time frame) appear good."



Goodyear Aerospace SABV design concept. Goodyear Aerospace Corp.

A 1976 parametric analysis of a similar hybrid, semi-buoyant, delta-planform lifting body airship by NASA Ames Research Center concluded: "The results suggest that long-range mission vehicles require a near buoyant or fully buoyant design and that there is no special advantage to the use of a lifting-body hull shape. For shorter-range missions, hybrid vehicles may have merit, and optimum vehicle buoyancy varies depending on whether a minimum weight or minimum fuel consumption design is desired. As compared with conventionally shaped airships, the benefits, if any, from a lifting-body configuration will be limited to missions requiring relatively higher fight speeds." The GAC SABV offered a significantly higher maximum speed than the GAC ZPG-X and Martin Marietta 836.

GAC identified the following additional missions for the SABV: ocean area operations, submarine launched ballistic missile (SLBM) defense, and mid-ocean ASW barrier operations.

General characteristics of the Goodyear Aerospace SABV

Parameter	Goodyear Aerospace SABV *
Type	Hybrid, rigid
Length	455.6 ft (138.9 m)
Width, max	236.0 ft (72.0 m)
Height, max	133.0 ft (40.5 m)
Envelope volume	3,210,000 ft^3 (90,907 m^3)
Outer shell material	Kevlar-based fabric
Lifting gas	Helium, 96.2% purity
Lifting gas volume	3,033,450 ft^3 (85,905 m^3) in 11 film laminate cells
Aerostatic lift	142,533 lb (64,651 kg)
Gross lift	222,708 lb (101,019 kg)
Buoyancy ratio	0.6 to 0.7 (nominal 0.64)
Deadweight weight, empty vehicle	125,365 lb (56,865 kg)
Useful lift	97,343 lb (44,154 kg)
Buoyancy control	Up to 34,200 lb (4,000 gallons / 15,513 kg) of water ballast
Fuel	67,943 lb (30,818 kg)
Payload	23,800 lb (10,795 kg)
Crew	16 total, 9 duty stations
Propulsion and maneuvering	• 4 x flank-mounted, thrust-vectoring, 29-ft (8.8-m) diameter, 3-bladed prop-rotors, each driven by a pair of turboshaft engines individually rated @ 1,822 shp (1,359 kW). • Total installed power: 14,576 shp (10,869 kW)
Speed	• For best range: 60 kts • Max. cruise: 150 kts
Range	• 2,150 naut. mi (3,982 km) @ 150 kts • Ferry: > 8,000 naut mi.
Altitude	• 8,000 ft (2,438 m) operational altitude • 10,000 ft (3,048 m) pressure altitude
Endurance	• Up to 10 days, with periodic refueling from a ship at sea • 14.3 hrs @ 150 kts

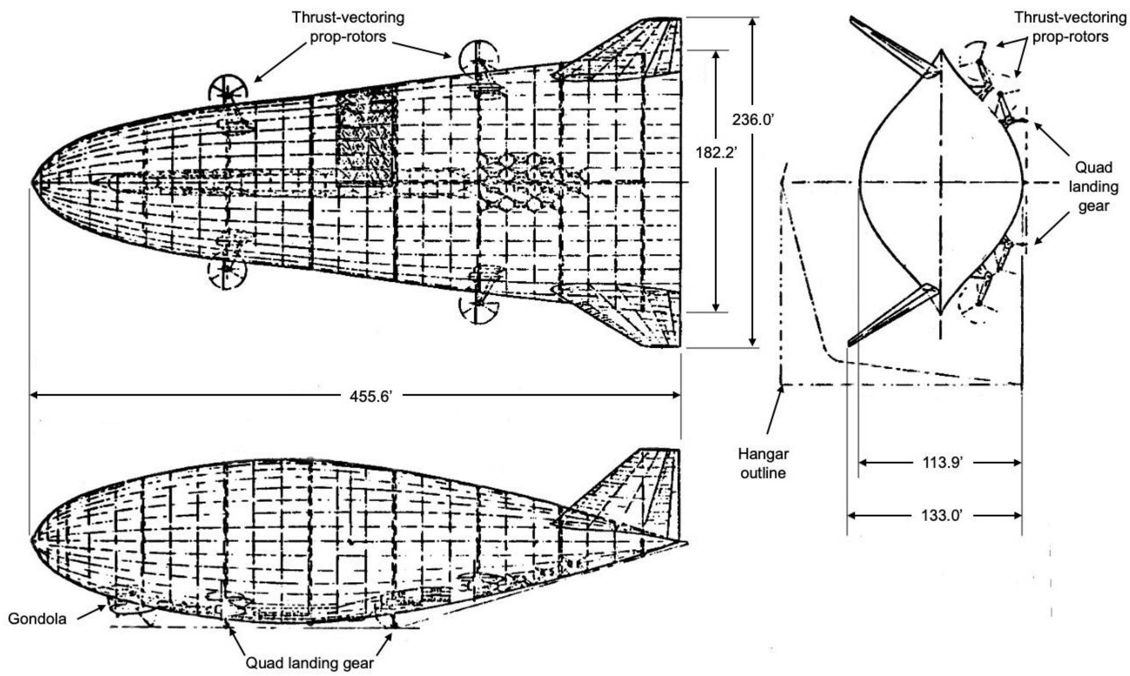
** Source, SABV data: GER-16457 / NADC 76014-30, June 1977*

The SABV rigid envelope had more than twice the volume of the Navy's ZPG-3W non-rigid airship.

Following is an overview of selected SABV features and systems.

Rigid lifting body hull

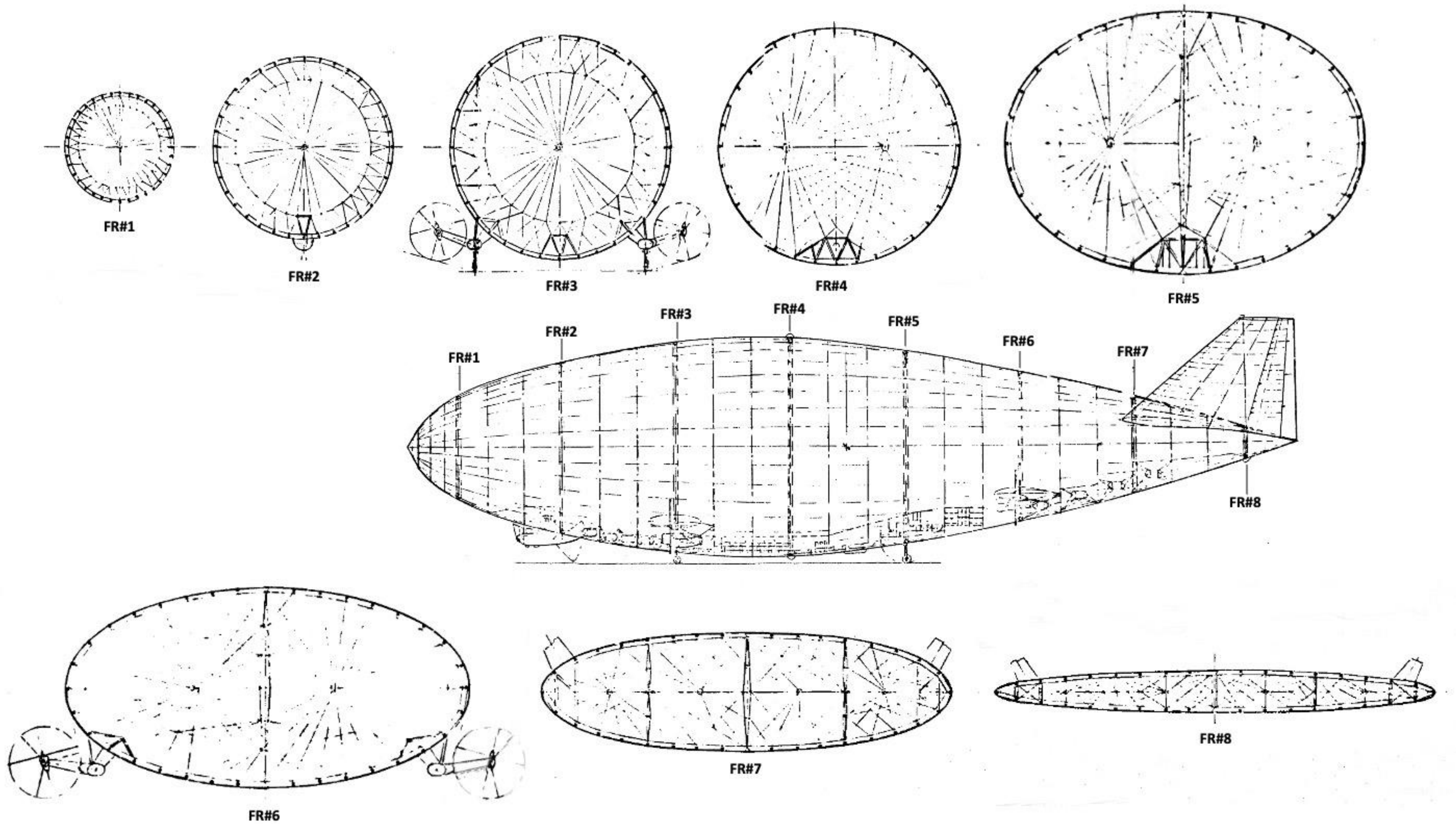
GAC selected a rigid hull instead of a pressure-stabilized non-rigid hull to deal with VTOL thrust loads and the complex lifting body shape. The hull would be a classical, wire-braced, 7075 T6 aluminum frame structure with beryllium braces.



SABV 3-view diagram highlighting the complex delta planform & lifting body shape. Source: Adapted from GAC report GER-16456, Fig. 10

The SABV had a nominal aerostatic lift-to-gross weight ratio of 0.64 at a vertical takeoff gross weight of 222,708 pounds (101,019 kg). During VTOL and hovering, 64% of the SABV's gross weight (142,533 lb / 64,652 kg) is carried by the aerostatic lift of the helium lift gas. The remaining 36% of the gross weight (80,175 lb / 36,367 kg) is carried by propulsive lift from the four vectored-thrust propellers. In flight, the aerodynamic lift of the lifting-body hull provides the balance of lift required and the propellers are vectored horizontally to provide thrust for cruise flight.

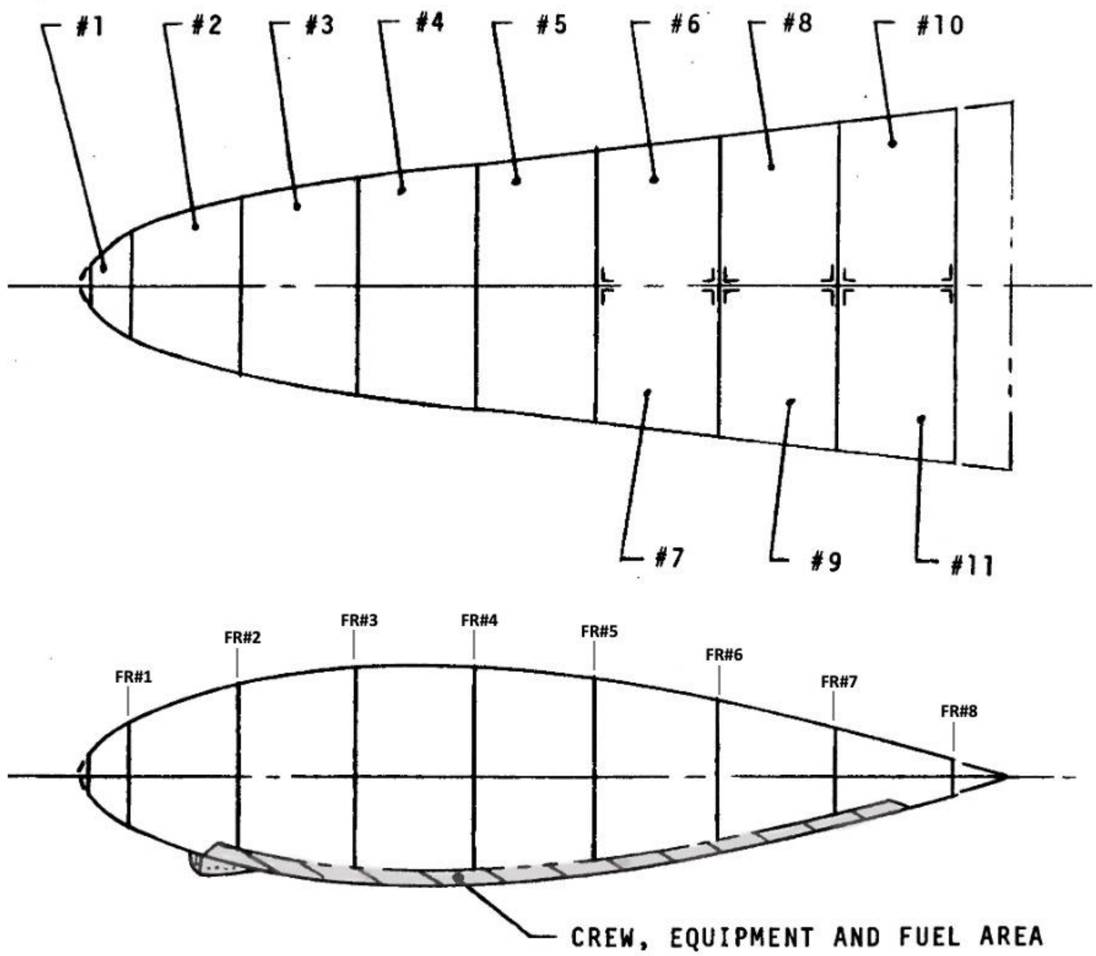
The control car (cockpit) under the nose of the airship and a long, rectangular keel created a habitable volume to house the crew and equipment. The interior volume of habitable areas totaled 30,630 ft^3 (867 m^3).



SABV rigid hull design details, showing the transition from circular transverse cross-sections forward, to highly-elliptical cross-sections aft. Source: Adapted from GAC report GER-16456, Fig. 10

Lift gas cells

The SABV had 11 lift gas cells installed inside the rigid hull, laid out internally as shown in the following diagram. The lift gas cells are installed over the habitable area along the keel.

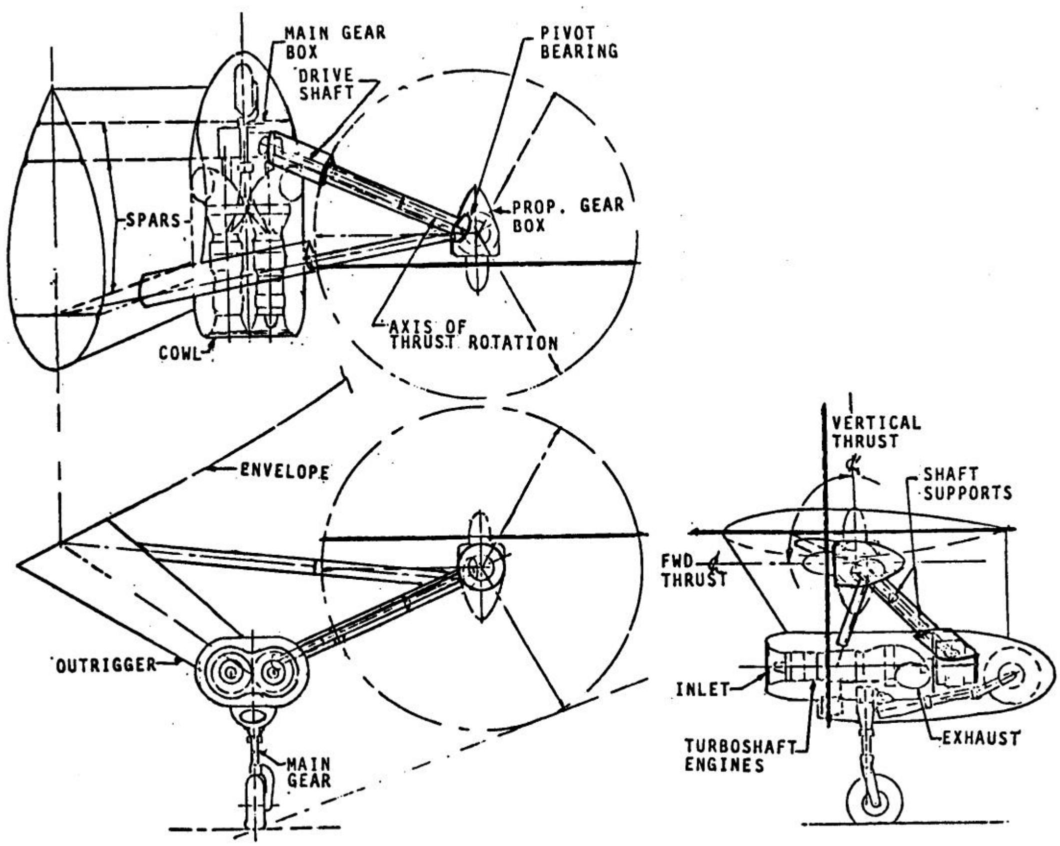


SABV lift gas cell arrangement within the rigid hull and around the keel structure housing the habitable zone for crew & equipment. Source: Adapted from GAC report GER-16456, Fig. 51

The gas cells are made of light-weight, scrim-reinforced film laminate material (i.e., reinforced by embedding a woven fabric mesh). The gas cells are free to expand or contract with changes in temperature and altitude. A network of gas cell wires and netting is used to keep the cells in place while minimizing stresses on the gas cell material.

Propulsion and maneuvering system

The SABV is powered by four flank-mounted, thrust-vectoring, 29-ft (8.8-m) diameter, 3-bladed prop-rotors, each driven by a pair of turboshaft engines individually rated @ 1,822 shp (1,359 kW). The two pod-mounted turboshaft engines and the prop-rotor are supported from the rigid hull by outriggers, as shown in the following diagram. The twin-engine pod also houses one of the four main landing gear. The two turboshaft engines are connected via a common main gear box and angled drive shaft to a propeller gear box and vectoring unit at the end of the outrigger structure. From its horizontal cruise position (0º), the propeller can be rotated vertically 105º to deliver vertical thrust (90º) for VTOL operations, with a range of ±15º for precision maneuvering.



Typical SABV flank-mounted engine, prop-rotor and main landing gear installation. Source: GAC report GER-16456, Fig. 55

Electric power system

Each turboshaft engine pair also drives an electrical generator to supply airship and mission systems. Total generating capacity was 100 KVA. Mission systems require 76 KVA. Any one generator can supply all the power required by airship flight systems.

Buoyancy control system

A water ballast system with a capacity of 34,200 lb (4,000 gallons / 15,513 kg) is provided. If needed, water can collected from the sea with a “bag” water pick-up system similar to the approach used by Navy non-rigid airships. On most missions, adding ballast while underway would be unnecessary, since the SABV was designed to be neutrally buoyant at the end of a mission with all variable payload and almost all fuel expended.

Armament

The SABV armament compartment was designed to carry torpedos, Harpoon anti-ship / surface strike missiles and self-defense missiles. In addition, it could deploy sonobuoys and markers for use an anti-submarine warfare. Harpoon missiles would be loaded vertically in pallets (i.e., 4 or 5 missiles per pallets) and dropped or ejected individually at launch.

Ground handling

An SABV ground handling systems would be very similar to systems used for a fully-buoyant vehicle. In good conditions, with a VTOL landing, an SABV may require as few as 3 people (tractor / mule driver, mobile mast operator and lanyard handler), with more people being required in windier conditions.

The SABV could fit in the airship hangers at Akron and Lakehurst, and with a small modification to the tail fins, at Moffett Field as well.

5. ANVCE recommendations

The Navy's 1979 ANVCE summary report (Section 2.1.7) provides the following conclusions regarding naval applications of LTA vehicles:

> "The ANVCE Project explored two main avenues in the LTA concept: the FAB (fully air-buoyant) configuration and the SAB (semi air-buoyant) configuration. In order to carry multi-mission payloads of about 50 tonnes (metric tons), the FAB vehicle becomes extremely large and therefore impractical in terms of ground handling and storage facility requirements. Even with vectored thrust, the sheer size of the craft induces large, fluctuating forces in gusting wind conditions that do not appear to be sufficiently controllable to permit precision landing."
>
> "Despite these problems, the large FAB LTA vehicle, because it is relatively low in cost, has promise in the maritime patrol aircraft role. Therefore, R&D is recommended in the use of improved materials and shapes for the FAB concept applied to vehicles of 1 million to 3 million ft^3 of internal volume for use in ASW (anti-submarine warfare) surveillance missions."
>
> "The technology of aerodynamic lift as applied to LTA vehicles was not sufficiently well developed during the ANVCE Project to generate reliable designs. It was felt that the SAB point design was larger than it needed to be although the SAB LTA vehicle design had a dash speed of 150 kt (as opposed to the 80-kt dash speed of the FAB design). Some quick analyses were done within the ANVCE Project to ascertain the technical feasibility of a smaller SAB LTA vehicle (about 1 million ft^3) with a payload approaching that of the S/L(V) (sea-loiter vehicle, an aircraft). Based on these analyses, the Project recommends that investigation of the technical feasibility of a small, ship-supporting SAB LTA should be pursued."

In a letter dated 17 March 1980, the Chief of Naval Operations distributed the ANVCE reports and the programmatic recommendations of the ANVCE project, which included the following recommendation for the Navy's LTA program:

"Establish a balanced R&D program in materials for Fully Air Buoyant (FAB) vehicles and develop designs for 1 to 3 mil ft^3 FAB."

This recommendation may have led to the Navy's Maritime Patrol Airship Program, which was initiated in 1980.

6. For more information

ANVCE program

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Goodyear Aerospace – SABV

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Other *Modern Airships* articles

- *Modern Airships - Part 1*: https://lynceans.org/all-posts/modern-airships-part-1/
    - Goodyear - N-Class blimps
    - US Navy - Maritime Patrol Airship (MPA) study airships (1980)
    - US Navy - YEZ-2A (Sentinel 1000 & 5000)
- *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/