Navy ANVCE program airships (1976 – 1979)

Peter Lobner, updated 12 February 2022

1. Introduction

In 1976, the US 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.

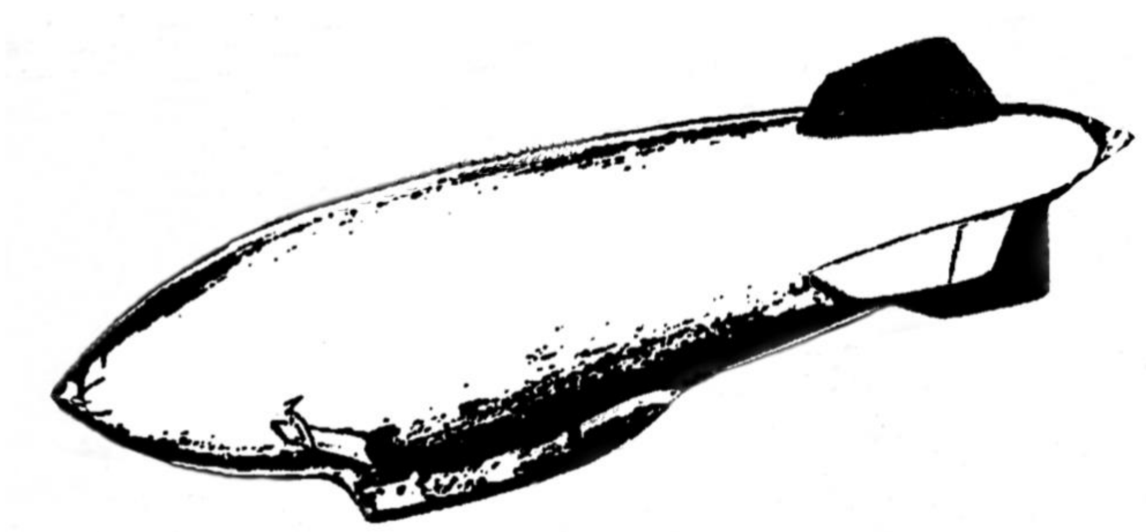
This article takes a look at three airship design concepts from the ANVCE program: The fully-air buoyant non-rigid Goodyear ZPG-X and the rigid Martin Marietta Model 836, and the semi-air buoyant Goodyear SABV.

2. Goodyear ZPG-X

The ZPG-X is a derivative of Goodyear's ZPG-3W blimp, which was retired from active service in 1961, but remains the largest non-rigid airship ever flown. The ZPG-3W required a short takeoff and landing (STOL). 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.

General characteristics of the Goodyear ZPG-X

Parameter	Goodyear ZPG-X
Mission	Naval task force & ship convoy protection
Length	403 ft (123 m)
Diameter	85 ft (25.9 m)
Envelope volume	1,465,000 ft^3 (41,484 m^3)
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	• 2 x AVCO Lycoming T53 turboprop engines @ 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 @ 420 shp (313 kW) each mounted on the X-tail, driving a single 3-bladed, constant speed, 20 ft (6.1 m) diameter vectoring propeller for propulsion and 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 rotates up.
Source: UNIDO (1983)

The ZPG-X has a buoyancy / gross weight ratio (Beta) of > 0.85. That means it was heavier-than-air when it was sitting 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 are cross-shafted using the configuration flown successfully on the Canadair CL-84 tilt-wing V/STOL research aircraft for a decade between the mid-1960s and the mid-1970s. The CL-84 also used AVCO Lycoming T53 turboprops. On the ZPG-X, the wings could be tilted vertically from 0º (horizontal) to +90º (vertical).

The Goodyear ZPG-X design concept used the same tilt-wing and engine configuration as the Canadair CL-84 “Dynavert” V/STOL aircraft. Source: San Diego Air & Space Museum Archives

The ZPG-X tail engines are geared to a common drive shaft for a single pusher propeller that normally is aligned on the longitudinal axis (at 0º) and can be vectored horizontally from 90º port to 90º starboard.

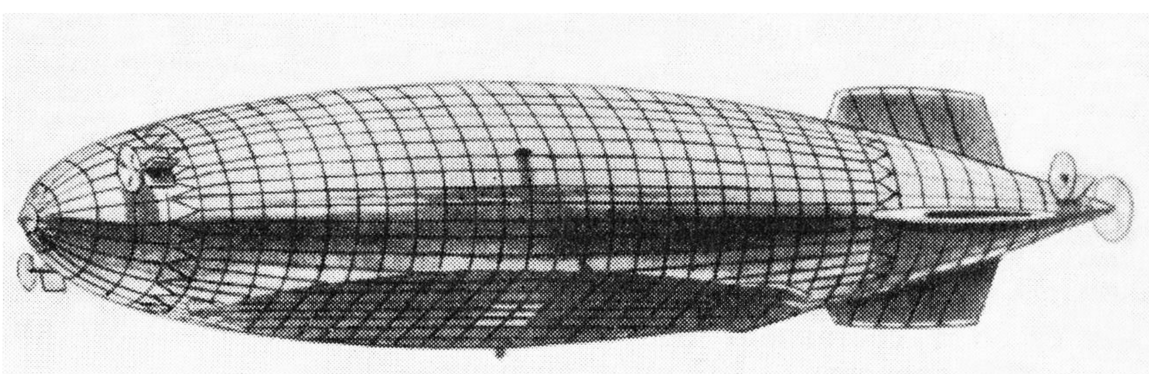
Goodyear claimed the ZPG-X could be operational by 1985 using currently available technology.

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	9,319,541 ft^3 (263,900 m^3)
Ballonet volume	28%, 11 ballonets
Operating weight empty	116.6 tons (106 metric tons)
Gross operating weight	206.8 tons (188 metric tons)
Payload	37.4 tons (34 metric tons)
Propulsion	• 4 x turboshaft engines @ 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 @ 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 are 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.

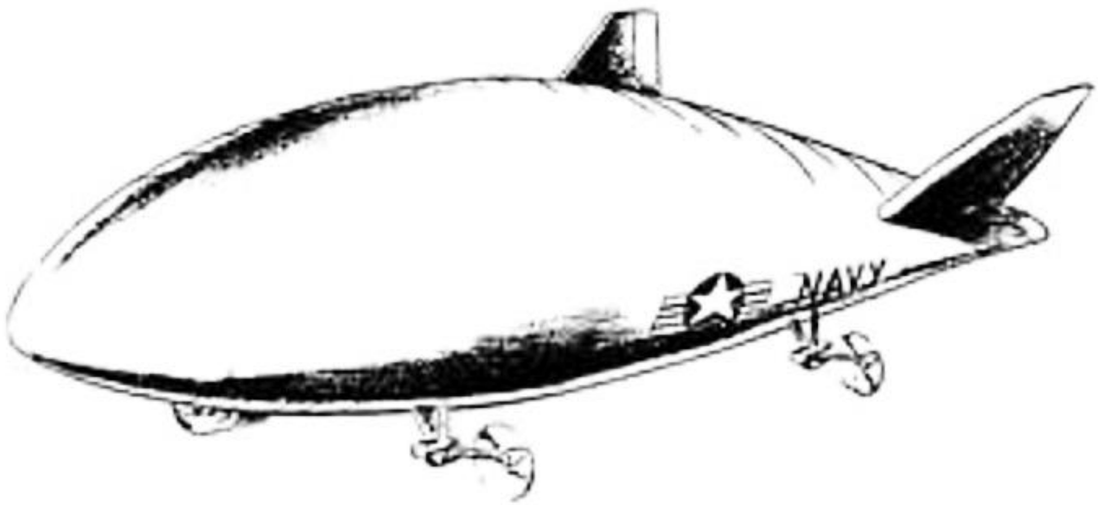
4. Goodyear SABV

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

- VTOL with the ability to hover
- 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 SABV design concept. Goodyear Aerospace Corp.

A similar 1976 study of a 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.”

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

The Navy's ZPG-3W non-rigid airship, which was retired in 1961, was the largest blimp ever flown. Here's how the Goodyear SABV compared to the ZPG-3W.

Parameter	**Goodyear SABV**	**Goodyear ZPG-3W**
Envelope volume	3,216,000 ft^3 (91,067 m^3)	1,465,000 ft^3 (41,484 m^3)
Gross lift	155,980 lb (70,751 kg)	About 71,000 lb (32,205 lb)
Surface area	149,500 ft^2 (13,889 m^2)	About 84,000 ft^2 (7,803 m^2)
Structure weight	66,385 lb (30,112 kg)	About 25,000 lb (11,340 kg)
Propulsion	4 x turboprops	2 x Wright Cyclone 9 piston engines
Design max speed	150 knots	82 knots
Crew	13	21

The SABV had a nominal aerostatic lift-to-gross weight ratio of 0.64 at a vertical takeoff gross weight of 222,708 pounds (191,019 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. Propulsive lift from the four vectored-thrust engines carries the remaining 36% of the gross weight (80,175 lb / 36,367 kg). In flight, the aerodynamic lift of the lifting-body hull provides the balance of lift required and the engines are vectored to provide longitudinal thrust for cruise flight.

In lightly loaded conditions, the SABV may approach neutral buoyancy and have improved low speed operating characteristics at low engine power settings.

Goodyear's SABV was not built. It is notable that the "semi-air buoyant" hybrid SABV design was developed only a few years after Aereon's semi-buoyant Dynairship, which had a somewhat similar delta wing lifting body planform.

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.

The ANVCE project made no recommendation for continued work on the SABV.

6. For more information

- Jon Lancaster, "Semi-Buoyant Lifting Body Hybrid Characteristics for Advanced Naval Missions," Goodyear Aerospace Corp, conference paper for the 2nd Lighter Than Air Systems Technology Conference, Melbourne, FL, 11 – 12 August 1977: https://arc.aiaa.org/doi/10.2514/6.1977-1194
- M. Harper, "A hybrid airship concept for Naval missions," NASA Ames Research Center, AIAA Paper 76-923, 1 September 1976: https://ntrs.nasa.gov/citations/19760062434
- Lancaster, J.W., "ZPG-X design and performance characteristics for advanced Naval operations," AIAA conference paper, 2nd Lighter Than Air Systems Technology Conference, August 1977: https://arc.aiaa.org/doi/abs/10.2514/6.1977-1197
- Lancaster, J.W., "Feasibility Design Study for Scale Model of ZPG-X Airship," Report NADC-77265-30, Goodyear Aerospace Corp., June 1978: https://apps.dtic.mil/sti/pdfs/ADA058624.pdf
- Advanced Navy Vehicle Concepts Evaluation (ANVCE) Project, Summary – Volume I," US Navy, December 1979: https://www.foils.org/wp-content/uploads/2017/12/Advanced-Naval-Vehicles-Concepts-Evaluation-ANVCE-Project-Volume-71240.pdf
- Anthony J. Dolman, "Current and Possible Future Developments in Lighter-Than-Air (LTA) System Technology," United Nations Industrial Development Organization (UNIDO), Section 4.1, pp. 48 - 52, 1983: https://open.unido.org/api/documents/4793600/download/CUR

RENT%20AND%20POSSIBLE%20FUTURE%20DEVELOPMENTS%20IN%20LIGHTER-THAN-AIR%20

- M. Ya. Arie, “Dirigibles” (in Russian), Publishing House "Naukova Dumka", Kiev, Ukraine, 1986

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/