**Chapter** 6

# LIGHTER-THAN-AIR VEHICLES

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# LIGHTER-THAN-AIR VEHICLES[1]

Lighter-than-air vehicles (LTAs), or airships, were very active from the first years of this century until about 1960. During World War I, each side operated about 100 airships. They ranged from the smaller (100,000 $ft^3$) non-rigids to larger (2.5 million $ft^3$) rigids. In 1933, the Good year Zeppelin Corp. completed two rigid airships, Akron and Macon, for the U.S. Navy; these were the largest airships built to that date, and two of the largest airships ever built.[2] Four of the largest non-rigid airships ever built (ZPG-3W) were completed in 1960 also by Goodyear.

Rigid airships are built of a lightweight rigid structure with an outer fabric of treated cloth. The lifting gas is contained in several indepen dent gas-tight cells. In contrast, the non-rigid airship consists merely of an envelope (hull) typically of a coated fabric filled with a lifting gas and pressured slightly above that of the outside atmosphere. Several air compartments within the hull are used to maintain a constant pressure and provide ballast by ducting air in and out as needed.[3]

[1]We wish to thank D. E. Williams of Goodyear Aerospace Corp. for his assistance in the preparation of this chapter.

[2]Goodyear Aerospace Corp., Feasibility *Study of Modern Airships, Vol III Historically Overview (Task 1),* prepared by Gerald Faurote, NASA report No. CR-137692 (Moffett Field, Calif.: Ames Research Center, National Aeronautics and Space Administration, August 1975), pp. 2-3,

[3]Ibid,, pp. 4-8.

## LONG RANGE AIRSHIPS[4]

Both rigid and non-rigid airships have been used extensively as long endurance/long-range platforms to carry payloads which are essentially fixed (constant weight). Due to the difficulty in managing excess buoyancy, applications with widely varying payload weights, such as cargo transport, were not pursued; passenger service was considered more suitable. In addition, limited ability to exercise control at low speed complicated ground handling and made terminal operations cumbersome.

The rigid airship declined in popularity after the Hindenburg disaster in 1937. No doubt the disaster itself had an effect, but there were more fundamental causes at work. In the 1930's, the airplane surpassed the airship in speed, productivity, operating cost, and even safety. In 1937, the most advanced passenger airplane, the DC-3, had double the cruising speed of the most advanced airship, the Hindenburg; the DC-3 also had total operating costs per seat-mile between one-half and one-third those of the Hindenburg. Thus, although the Hindenburg disaster and the approach of World War II hastened the end of even the commercial passenger carrying airship operations, it is clear that the fundamental cause was the growing inability of the airship to compete economically with the airplane.

The economic nonviability of the long-haul airship can be better understood by noting the standard computation of a vehicle's productivity: payload by speed. The airplane came to far surpass the airship's speed; the present-day ratio is roughly four to one for a wide-bodied jet versus an airship. This means that a jet with the same payload as an airship can transport several times as much freight in the same time as the airship (although less than fourfold because of the terminal time at each end).

The productivity difference is reflected in direct operating costs. Direct operating costs per available ton-knot of an airship based on the

[4]This discussion is based on Mark D. Ardema, "Economics of Modern Long-Haul Cargo Airships," paper presented at Lighter-Than-Air Systems Conference, Aug. 11-12, 1977, AIAA paper No. 77-1192

latest technology are calculated to be from 50 to 150 percent higher than those of an equivalent size modern fanjet transport airplane. One study concluded that 747 costs were 21.6 cents per revenue ton-mile and airship lower bound costs were 35.7 cents per revenue ton-mile, assuming a 55 percent load factor and a 25 percent profit before taxes.[5] Other studies project airship costs to be four times those of airplanes. These studies assume the existence of adequate numbers and locations of airports.

There are other advantages to higher speed besides increased productivity. One is that a fast vehicle is less susceptible to weather delay than a slower one because head winds have less effect on ground speed, and adverse weather can be more easily circumvented. Airplanes also have the very important customer appeal of shorter trip times, which is a vital factor in passenger service and is also important for most air cargo service.

Higher fuel prices raise airplane operating costs more than those of the more fuel-efficient airship. However, surface transportation—trucks, rail, and some ships—is more fuel efficient than airships. Thus higher fuel costs alone are not likely to appreciably enhance the airship's competitiveness.

Airships, as they are presently conceived, are not competitive with airplanes for the long-range transportation of cargo. There are, however, other roles for which a modern airship or a hybrid airship is well suited. Airships have definite advantages over airplanes in short distance hauling of very heavy or bulky cargo, and for jobs that require long endurance in the air, such as certain types of patrol. Airships can also be configured to perform vertical lift operations more economically than helicopters and can do so with much heavier and larger payloads. If airships do make the comeback some predict, it probably will be because they solve new transportation problems and not because they compete directly with existing types of long-range aircraft.

[5] 1bid., p. 93.

## POTENTIAL PROPERTIES OF MODERN AIRSHIPS

Under a recent National Aeronautics and Space Administration (NASA) -funded study, the Goodyear Aerospace Corp. estimated that a 26 percent reduction in empty weight as compared to the 1933 Macon could be achieved using modern plastic and metallic materials. The empty-weight-to-gross-weight ratio can be reduced from 0.59 to about 0.40. The amount of payload would depend on the amount of fuel taken on, which depends on the requirements of the mission.[6] Such technological advances can substantially improve the payload of modern airships of the ZPG-3W and Macon designs.

In addition, studies conducted by Goodyear for NASA, the U.S. Coast Guard, the Alberta Ministry of Transportation, and the U.S. Air Force show that operational versatility as well as operating economies can be substantially improved by marrying modern propulsion technologies to rigid or non-rigid conventional airships. The propulsion system might be conventional fan/prop units, which would improve cruise performance and terminal operations, or multiple rotor units to provide precision hover capability for lifts ranging from 20 to 150 tons. Such an airship could operate into and out of remote and unprepared areas at substantially lower costs than current alternatives with payloads substantially larger or heavier than existing air lift methods.

[6] Goodyear, op. cit., pp. 118-126.


Photo credit Goodyear Aerospace Corp

## MODERNIZED CONVENTIONAL AIRSHIPS (MCA)

One of the inherent characteristics of conventional airships has been their ability to fly at slow speed with little expenditure of fuel. This could make them appropriate for surveillance missions of relatively long duration, provided ground-handling and basing could be simplified, Modernization of these ships with efficient vectorable propulsion could address this problem. In addition, it would provide the airship with the ability for vertical takeoff and landing (VTOL) and coarse hovering, which would enable it to accomplish tasks not possible for fixed wing aircraft.

An MCA of this design would have takeoff and landing characteristics that approach those of a helicopter, together with range and payload capabilities well beyond that of the helicopter.

The ability of such an airship to carry moderate payloads (20,000 to 80,000 lb) relatively long distances and to service unprepared sites would enable it to provide transportation for people or cargo in many locations for which it is impractical to use conventional transportation.

## SURVEILLANCE ACTIVITIES

In 1957, a U.S. Navy airship set an endurance record of 11 days aloft and 9,000 miles traveled without refueling.[7] This is well beyond what is possible with fixed or rotary wing aircraft. The LTA also has low vibration level, low noise level, and low pilot workload, all of which reduce crew fatigue. Some suggested applications have been:

1. *Mineral detection.* Armed with the necessary instruments, airships used in large mineral surveys could outperform airplanes in both accuracy and costs. Computers and a large amount of equipment could be put on board. The steady flight and low vibration would contribute to accuracy.[8]
2. *Pollution watch.* A small airship, controlled by a radio signal and carrying several hundred pounds of detection instruments and television cameras, could patrol the space above a city. The air pollution level of any chosen point could be monitored accurately, and signals from pollution sources could be transmitted to the control center on the ground.[9]
3. *Border lookout.* Airships equipped with electronic surveillance instruments could serve as lookout posts and communication links between patrol units and command posts in key border areas.
4. *Radar platform.* The U.S. Defense Department recently installed special target-detecting radar on stationary ballons to spot even very slow movements of troops. The U.S. DOD estimates that the cost of using stationary ballons for day/night low altitude observation is only one-tenth the cost of using airplanes. The mobility of an airship combined with its tolerance for a broader range of atmospheric and environmental conditions would greatly expand this capability.
5. *Police patrol.* Both manned and unmanned LTA's have been tried for police patrol. Goodyear and the city of Tempe, Ariz. independently experimented with manned dirigibles. One experiment included the development of remotely controlled miniblimps of up to 10,000 $ft^3$, with downward pointed TV cameras. This application is expected to have several economic and operational advantages over other patrol and surveillance systems. Introduction of such a system has been considered in Southern California.

An MCA of about 875,000 fts has been assessed by the U.S. Coast Guard to be economically and operationally effective in satisfying an array of missions, including monitoring of buoy placement, surveillance activities, port traffic control, and monitoring ice conditions on the Great Lakes.

‘Letter dated Mar. 27, 1980, from K. E. Williams, U.S. Coast Guard.

[8]Hsu Te Pao, “Prospects of Airship Applications” (originally published in Hang K'ung Chih Shih, Peking, No. 8, 1976, pp. 30-32), translation prepared by Foreign Technology Division, FTD-ID(RS)T-2043-77 (Dayton, Ohio: Wright-Patterson AFB, Foreign Technology Division, December 1977), p. 607.

‘Ibid., p. 8.

[10]Ibid., p. 11.

“ G. R. Semann, “Unmanned Blimp Patrol, ” paper No. 79-164, 1979 AIAA Lighter-Than-Air Systems Technology Conference.

# HEAVY LIFT AIRSHIPS (H LA)

The Heavy Lift Airship (HLA), a concept first proposed by Piasecki Aircraft Corp., consists of a helium-filled airship hull with propulsive lift derived from conventional helicopter rotors. The buoyant lift essentially offsets the empty weight of the vehicle; thus all the rotor thrust is available for lifting the useful load, maneuvering, and controlling the vehicle.[12] The purpose of the HLA is to vertically lift and haul heavy outsized cargo. The Piasecki version of this concept is shown in figure 9. Piasecki is now under contract to the Navy to build and demonstrate in flight a prototype of this aircraft.

Goodyear has also designed a 75-ton HLA (figure 10). It is estimated to have a range of 300 nautical miles, and can be ferried without payload, with rotors folded, for over 3,000 miles. Without the buoyance, the collective payload capability of four equivalent helicopters at their rated 100 mile range would be less than half that of the HLA.[13]

The HLA fuel consumption for a design speed of 80 knots with design payload of 150,000 lb is estimated to be 0.22 gal/ton-mile. Without the benefits of buoyancy, fuel requirements would be on the order of 0.52 gal/ton-mile.[14]

Table 4 indicates the estimated numbers and required payloads of HLAs in several potential markets.

The two primary markets for the HLA appear to be logging and unloading cargo at congested ports. The environmental benefits of this use of the HLA when used in remote locations has been described as follows:

> In a study of the potential application of advanced aircraft in developing countries sponsored by NASA, it was found that the ecology of the tropics can be seriously altered if normal methods (i. e., timber roads) are employed to gain access to certain natural resources—such as forests. Air lifting can mitigate these effects provialed the aircraft is capable of handling the loads. A heavy lift-type airship showed significant benefit for such applications. Similar ecological constraints also exist in Northern regions subject to heavy winter freezes and surface thaw conditions. These were discussed in studies by the Canadian Province of Alberta which also pointed out that undeveloped areas do not contain the surface transportation systems required to bring equipment into such regions or remove the resources. Furthermore, the costs of building adequate rail or road systems for short term use did not justify such construction.[15]

**Figure 9.—Heavy Lift Airship Concept**

SOURCE: Piasecki Aircraft Corporation,

Interest in LTA continues to be active. In July 1981, the fourth international conference on

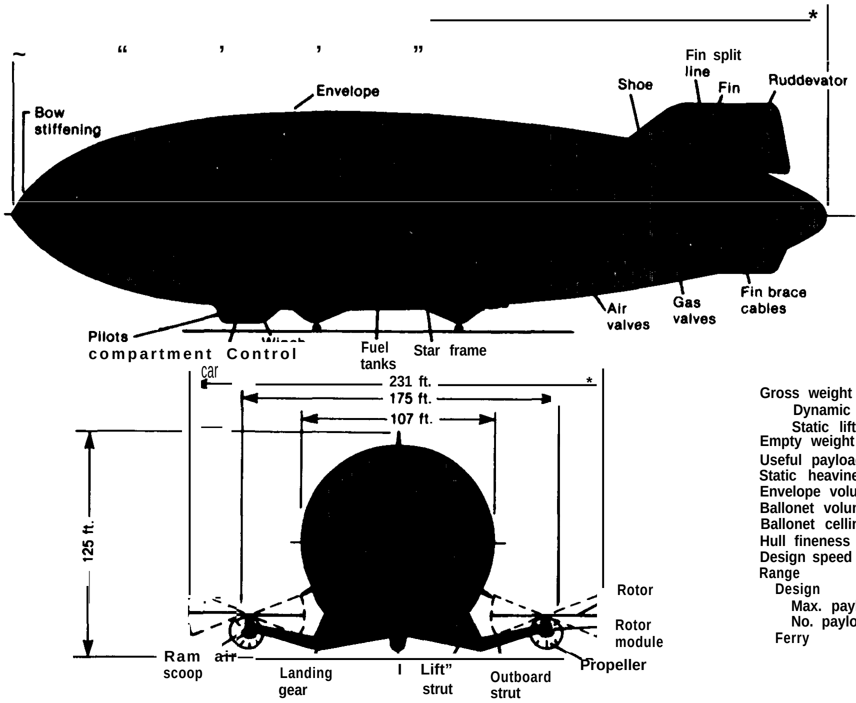
[12] Goodyear Aerospace Corp., *Feasibility Study of Modern Airships, Phase 11– Executive Summary*, NASA report No. 2922 (Moffett Field, Calif.: Ames Research Center, National Aeronautics and Space Administration, November, 1977), pp. 7-8.

[13] Ibid., p. 12.

[14] Ibid., p. 9.

[15] Goodyear Aerospace Corp., Modern Airships Program, communication, March 1980.

**Figure 10.—Heavy Lift Airship—General Arrangement and Selected Performance Characteristics 75 Ton Payload[a]**




| | |
|---|---|
| Gross weight | 290,807 lbs. |
| Dynamic lift | 150,000 lbs. |
| Static lift | 140,807 lbs. |
| Empty weight (including EREW, residual fuel) | 140,564 lbs, |
| Useful payload | 150,000 lbs |
| Static heaviness | |
| Envelope volume | 2,600,000 ft³ (unstretched) |
| Ballonet volume | 650,000 ft³ |
| Ballonet ceiling | 9,500 ft |
| Hull fineness ratio | 418 |
| Design speed (TAS) | 80 knots |
| Range | |
| Design | |
| Max. payload | 300 nm |
| No. payload | 1,137 nm |
| Ferry | 3,180 nm |

[a]5,000 ft altitude, standard day, one engine out

SOURCE: Goodyear Aerospace Corp., Modern Airships Program, Akron, Ohio.

LTA systems technology was held in this country. The three-day conference, sponsored by the American Institute of Aeronautics and Astronautics (AIAA), received over 30 papers describing work presently being funded by the National Forest Service, NASA, the Navy, and the Coast Guard as well as work underway in Canada, England, France, and Germany. Projects currently in progress range from theoretical analysis, through subsystem and component development to construction of a proof-of-concept HLA.