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RETURN TO LIGHTER-THAN-AIR TRANS-
PORTATION FOR MILITARY AND CIVILIAN
APPLICATION

Richard M. Stepler

Defense Systems Management School
Fort Belvoir, Virginia

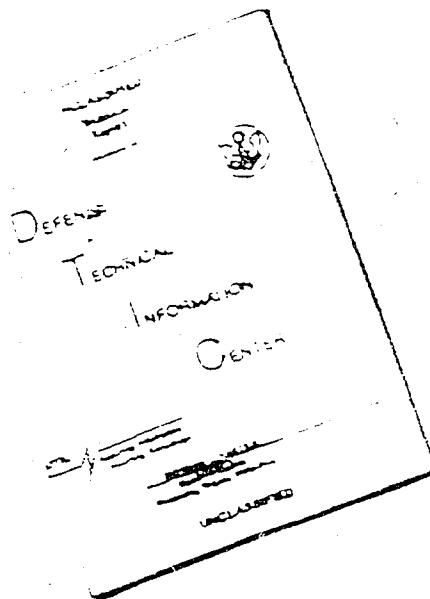
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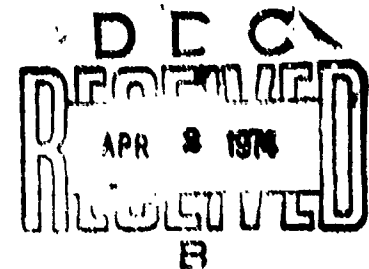
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RETURN TO LIGHTER-THAN-AIR
TRANSPORTATION FOR MILITARY AND
CIVILIAN APPLICATION
STUDY REPORT
PMC 73-2

Richard M. Stepler
CS-12 USN

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21. ABSTRACT (Continue on reverse side if necessary and identify by block number) The United States aerospace community has entered an era characterized by declining activity, due largely to the increasing complexity and cost of aerospace systems. Industry and Government are engaged in a search for air vehicles that will carry increasingly larger payloads at reduced cost and levels of pollution, and that will not require vast expanses of land from which to operate. To this end, the dirigible (rigid airship), a versatile and ecologically		

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"clean" transportation system which offers exceptional payload capability, endurance, range and flight stability, may be given renewed consideration.

RETURN TO LIGHTER-THAN-AIR
TRANSPORTATION FOR MILITARY AND
CIVILIAN APPLICATION

An Executive Summary
of a
Study Report
by

Richard M. Stepler
GS-12 USN

November 1973

Defense Systems Management School
Program Management Course
Class 73-2
Fort Belvoir, Virginia 22060

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EXECUTIVE SUMMARY

The history of human flight began with Montgolfier in 1783. For many years, the realm of discretionary flight was limited to vertical ascents and descents with only the prevailing winds to provide lateral movement. Not until the discovery of petroleum and invention of the internal combustion engine did lighter-than-air vehicles become directable (from the French Dirigible).

Early military applications saw the United States and others use blimps in anti-submarine warfare. Two-hundred blimps (15 squadrons) compiled an enviable record in World War II by escorting over 89,000 ships (over 550,000 flight hours) in convoy without a single loss to enemy submarines and in so doing set a record operational availability of 87%.

Goodyear operated commercial blimps between 1911 and 1958 and carried over 483,000 passengers on about 179,000 flights without a single injury or fatality.

Rigid airship design was principally initiated and exploited by Count F. Von Zeppelin who by 1918 had built a 2,400,000 cubic foot airship capable of speeds in excess of 80 miles per hour, 50 ton (100,000 pounds) useful lift with the capability of cruising at 20,000 feet. Zeppelin built the "Los Angeles" which was sold to the United

States in 1924. Grof Zeppelin I saw nine years' service in commercial operation without a single fatality. The Hindenburg, Shenandoah, Akron and Macon were all lost in ways that could in no way reflect on the design or safety of airship operation.

What's new in airship design? Nothing! No design work has been accomplished since 1937. The original design airship is a Ford Tri-Motor by comparison to the advanced technology airship, the SST of the airship set.

There are four major distinctions among types of airships:

1. Non-Rigid or Blimp -- so named after the English B-type limp (as opposed to rigid) airship. B-limp became blimp. It is a gas tight bag that maintains its shape due to the pressure of the gas.

2. Semi-Rigid -- the same as the blimp with a keel to support the airship in vertical shear.

3. Rigid -- this design was originated by Zeppelin and has a rigid frame, is fabric-covered and contains numerous gas cells.

4. Metal-clad -- a hybrid, both a pressure and a rigid framed vehicle. Gas tight aluminum alloy ship and a light structural frame.

Safety considerations restrict the use of hydrogen as the lifting gas. Helium is used in this study even though one can gain 40% in gross lifting capability by using hydrogen.

Airships are all displacement vehicles, i.e., they displace their weight in air. Blimps do rely on some dynamic lift (1-2%) in flight. Both temperature and density altitude effect the lifting capability of the airship. For example, air at 5,000 feet is only 86% as dense as it is at sea level and only 74% as dense at 10,000 feet. A 1% increase in gross lift can be obtained for every five degrees increase in gas temperature.

The "Macon" and "Akron" airships were constructed of 7075 ST aluminum alloy frame which is inferior to today's super alloys and composites. New materials and redesign of the basic airship could gain as much as 32% increase in useful lift for the same displacement.

Vast technological jumps have occurred in power plant designs which feature low fuel consumption, minimum fire hazard and reliable operation. Either diesel or nuclear/electrical drive is available. Power is provided to the driving propellers either by drive shafts and gears or directly by incapsulated electric motors.

Stresses induced in the frame can be detected with strain gauges which, when coupled to a computer, could direct the power plant to

change thrust and be vectored such that the resultant force would be a relieving load on the frame.

The future of airships is now! Using a fleet of six 10,000,000 cubic foot displacement airships in semi-precious cargo operation on 3,500 mile (New York to London) and 2,500 mile (San Francisco to Honolulu) flights, one can compare the anticipated cost of operation of ten cents per ton-mile against the same route serviced by the all cargo configuration 747F at 29 cents per ton-mile.

It is the intent of this study to renew interest in the aerospace community for the airship.

RETURN TO LIGHTER-THAN-AIR
TRANSPORTATION FOR MILITARY AND
CIVILIAN APPLICATION

STUDY REPORT

Presented to the Faculty

of the

Defense Systems Management School

in Partial Fulfillment of the

Program Management Course

Class 73-2

by

Richard M. Stepler
GS-12 USN

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November 1973

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RETURN TO LIGHTER-THAN-AIR
TRANSPORTATION FOR MILITARY AND
CIVILIAN APPLICATIONS

Introduction

When manned flight is the subject, one naturally thinks of the pioneer efforts at Kitty Hawk; this, however, is an oversight. Manned lighter-than-air flight technology was in a maturing state when heavier-than-air flight began. Airship history, both civil and military, offers insight into lighter-than-air capabilities and limitations.

The future of airships is in question. New technology in materials and nuclear propulsion make airship travel both feasible and economically attractive. Maybe once again airships have come of age.

By presenting some of the options and possibilities (some admittedly extreme), it is hoped to stimulate renewed interest on the part of the aerospace community, particularly the Navy, and in so doing initiate the first step toward a return of the airship.

***ABSTAINER**

This study represents the views, conclusion and recommendations of the author and does not necessarily reflect the official opinion of the Defense Systems Management School nor the Department of Defense.

CHAPTER I

Historical Background

Contrary to popular belief, the history of human flight begins in 1783, more than a century before the Wright Brothers, with the first successful passenger-carrying flight made by a lighter-than-air ship. This feat was accomplished by the Montgolfier Brothers in France, who constructed a 35-foot paper balloon with a brazier of charcoal suspended beneath it. Almost immediately thereafter, a Paris physician named Charles devised a silk balloon of 1,400 cubic foot capacity and sent it aloft inflated with hydrogen gas. Not to be outdone by their competitor, the Montgolfier Brothers subsequently fashioned a second balloon whose basket carried a rooster, a duck and a sheep. The safe landing of these "passengers" marked the birth of the airship. The following month, a young French adventurer named deRouzier earned the honor of being the first man to fly by ballooning over Paris and touching down intact. Soon thereafter, in 1785, Blanchard, a Frenchman, and Jeffries, an American, flew a balloon from the cliffs of Dover to Calais in a three-hour journey. Although the attention of the world was now focused on the phenomenon of flight, significant progress was disappointingly slow during the next hundred years. Free balloon flight is largely limited to vertical movement, with horizontal progress

dictated solely by wind movement. Many ingenious men experimented with airship development, but their success was impeded by the lack of an efficient power plant to make the balloon dirigible, or directable. Not until the discovery of petroleum in Pennsylvania and the invention of the internal combustion engine in the 1890's did the lighter-than-air ship get the boost it needed. Even before this time, however, the airship found some practical application as observation posts in warfare during the American Civil War, and the first bombing raid in history was executed by means of an unmanned balloon sent up by Austria against Venice in 1849. Free balloons were further utilized in the Franco-Prussian War (1870-71) to evacuate personnel and carry mail during the siege of Paris.¹

The first airship powered by a gasoline engine was also the first rigid lighter-than-air ship constructed; it was a 130,000 cubic foot aluminum-hulled craft built and tested in Germany in 1897 by David

¹ While discussing the military use of free balloons, it is worthwhile to note that the only successful bombing of the United States occurred in 1943-44, when the Japanese sent gas-filled balloons aloft with incendiary bombs. These weapons ascended into the jet stream, remaining there with the aid of aneroid wafers which compensated for thermal effect. Drifting east with the jet stream to the U. S., the bombs were dropped after a preset interval. Eighteen of the 2,000 sent aloft actually started fires in the Pacific Northwest but due to careful censorship of the news media, no news of these successes reached Japan and the program was cancelled.

Schwartz. Simultaneously, a native of Brazil residing in Paris, Alberto Santos-Dumont, completed the first of fourteen non-rigid ships powered by gasoline engines, and his exploits won world-wide recognition. Also of great importance to early airship history was Count Ferdinand von Zeppelin, a retired German Army officer whose first rigid airship, the LZ-1, proved the practicability of the Zeppelin design. Other Germans were of prominence in the development of early non-rigid airships; Major August von Parseval constructed approximately twenty-eight pressure airships for the German Army, and Gross and Hosenbach built five airships for the German Navy circa 1913.

Britain's contribution to non-rigid airship history was meager during the pre-war years, but following the outbreak of hostilities in 1914 England used a fleet of over 200 non-rigid ships for anti-submarine, anti-mine and coastal patrol duties. France, on the other hand, utilized non-rigid warships prior to World War I for private use and export, and continued airship production during the conflict; French Naval airships executed over 3,000 missions against German forces, and non-rigid ships were continued in use until 1937.

Italian airships were largely of the semi-rigid type, with the best known being the N-type of General Umberto Nobile. In May, 1926, the "Norge" (N-1) flew over the North Pole and landed in Alaska.

Italy's airship program ceased soon after, in 1927. Russian airship activity did not even begin in earnest until 1931, when a public fund was set up for construction and the services of the Italian, Nobile, were secured. It is believed that Russia had as many as fifteen non-rigid and semi-rigid airships in operation at the end of World War II.

The history of lighter-than-air craft in the United States began in 1903 with Captain Thomas S. Baldwin's "California Arrow", the first practical airship in this country. The first government airship was a craft purchased from Baldwin by the Army in 1908. United States Naval airship activity began in 1915, but not until 1917 was serious attention devoted to the development of non-rigid ships for anti-submarine and coast patrol. During World War I, United States Navy blimps operated from seven Atlantic coast air stations from Massachusetts to Florida. The United States Army also utilized blimps in Europe during World War I, and continued with the development of non-rigid and semi-rigid airships until 1937, when it terminated its program and turned over its non-rigid ships to the Navy.

During the period between World Wars, United States airship activity was limited almost exclusively to the operation of commercial and advertising blimps by the Goodyear Company, constructor of nearly every major United States airship since 1911. In civil employment through 1958, the Goodyear blimp fleet accrued an enviable record;

these airships had carried over 483,000 passengers on over 178,000 flights without a single passenger injury or fatality. As the United States entered World War II, the Navy took over the Goodyear fleet for combat service, and an increased airship strength was authorized.

During the conflict, the Navy operated nearly 200 blimps for anti-submarine patrol and fleet escort; fifteen airship squadrons flew a total of 55,900 flights for over 550,000 hours, and escorted 89,000 ships without the loss of a single vessel to enemy action. Of these blimps, 87% were in operational readiness at all times, thereby establishing a record availability for military aircraft not equaled to date.

The first transoceanic flight in a non-rigid airship was executed by United States Navy blimps in 1944. When World War II ended, United States Naval airship activity waned, only to be resumed upon the outbreak of the Korean conflict in 1950 and again decreased. In 1957, a squadron of non-rigid airships became part of the United States early warning system at sea, and quickly demonstrated the all-weather reliability, economy and technical efficiency of airships for such use. The last of the United States Navy blimp force was retired in 1961 due to age and the Kennedy administration's disbelief in the need for a World War II airship in view of our "new technology" land-based radars.²

²"Taps for Blimps," Time, 7 July 1961.

The history of the rigid airship begins in Germany with Count Zeppelin, who had few competitors. During World War II, the Germans standardized on the Zeppelin type; eighty-eight Zeppelins were built during this period at a production rate of one every two weeks. These rigid airships were used by the Army and the Navy for bombing raids and North Sea patrol. In an effort to increase military efficiency, the Zeppelins underwent significant modifications during this period; by 1918 they had increased to 2,400,000 cubic feet in size, 80 miles per hour in speed, 50 tons (100,000 lbs.) in useful lift, and over 20,000 foot ceiling. Zeppelin activity ceased temporarily with the capitulation of Germany in 1918. The next Zeppelin built was the "Los Angeles," delivered to the United States in 1924. The "Graf Zeppelin," completed in 1928, saw nine continuous years of successful service. The next in the Zeppelin series, the hydrogen-inflated "Hindenburg," was destroyed by fire at Lakehurst, New Jersey, in 1937 with a loss of thirty-six lives (the first recorded passenger fatalities of commercial airship operation). Although it was originally believed that this disaster was the result of static electricity, evidence now suggests that the fire resulted from a bomb planted aboard the craft in an effort to dramatize the German people's dissatisfaction with Hitler's pre-war government.³ Set to detonate six hours after the ship's arrival, the bomb went off

³A. A. Hoehling, "Who Destroyed the Hindenburg?" Newsweek, 16 April 1962. See also Waugh, "The Unforgettable Unforgotten Hindenburg" National Review, 5 September 1970.

prior to the "Hindenburg's" docking due to unforeseeable delays in its schedule. The "Hindenburg's" sister ship, again named "Graf Zeppelin," never saw commercial or military use due to the tense international situation upon its completion in 1938; this craft was designed for helium inflation, and the United States, alone possessing the technology and hardware to produce this gas in the quantities required, refused to part with it. As the outbreak of World War II approached, the German government discontinued all lighter-than-air manufacture due to materiel shortages, and the Zeppelin works were among the first targets bombed by the Allied Forces.

Great Britain's early attempts to develop rigid airships were not equal to those of the Zeppelin designers, and several airship catastrophes ended the activity of rigid airships for military use in 1921 and for commercial application in 1931. France also capitalized on German rigid airship technology when three Zeppelins were turned over to the French as reparations in 1921; in 1923 one of these ships was lost with its entire complement, thus ending rigid airship activity in France as well.

The first rigid airship built in the United States was the "Shenandoah," constructed in 1919 and patterned after the German Zeppelin design. In 1924, America acquired the "Los Angeles" from the German Zeppelin works. This dirigible was used for experimentation

on flight and mooring problems, and developed a means for hooking and releasing airplanes in flight (see photos). Also in 1924, the Goodyear Company acquired the patents and processes of the German Zeppelin Company and in 1928 began constructing two rigid airships for the Navy. The "Akron" was completed in 1931 and crashed two years later in a storm with the loss of seventy-three lives. Her sister ship, the "Macon," was launched in 1933 and was lost at sea in 1935.⁴

The End of the Airship Era

This left the Navy without an operational rigid airship and led to an extensive investigation into the safety and practicability of rigid airships. Since these studies endorsed further construction of rigid dirigibles, funds were appropriated in 1938. However, due to delays in selecting size and design, the money reverted to the treasury and the rigid airship was never revived (a lesson for the program manager).

⁴The "Macon" lost a vertical fin while participating in fleet maneuvers with a Known and uncorrected weakness in an attaching frame. The "Akron" struck the water during a storm over the Atlantic due to error in the interpretation of altimeter readings and the extreme turbulence near the storm center. Both incidents demonstrate poor tactical judgement and human error rather than inherent limitations of the airship.

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CHAPTER II

What's New in Design?

What's new in the design and construction of airships? Almost anything would be new! No innovative design work has been accomplished subsequent to 1937.⁵ Significant advances have been made in heavier-than-air airframe structural design, metallurgy, aerodynamics and propulsion systems. The Ford tri-motor is to the SST what the "Graf Zeppelin" would be to the dirigibles which could be constructed with today's technology.

For a better understanding of the chapters which follow, a brief summary of lighter-than-air aircraft is included here. Attention and study have been directed principally to the rigid airship because of the size and operational limits of the non-rigid and semi-rigid dirigibles. Lighter-than-air aircraft may be divided into four types: non-rigid, semi-rigid, rigid, and metal-clad. The class of non-rigid airships, in addition to the balloon, includes the so-called "blimp" used by the Navy so effectively in World War II. It is comprised of a gas-tight fabric envelope of streamline shape with control car and power units

⁵ McGuire, "Airship Study as Booster Carriers," Missiles and Rockets, March, 1963.

supported below and the control surfaces aft. The shape of the envelope is maintained by pressure. With synthetic fabrics, such aircraft have a probable maximum practicable usable speed of about 100 miles per hour and size of about 1,500,000 cubic foot displacement.

Semi-rigid airships are similar to the non-rigid type described above except that a structural keel member is added to aid in distributing shear and bending loads along the envelope.

Heretofore, all airships in excess of 1,250,000 cubic foot displacement have been of the rigid type, which were originated by the Zeppelin organization and further developed by the Goodyear Company. It incorporates a rigid framework fabric-covered and containing a number of gas cells free to change volume with pressure changes. Control car, passenger and cargo accommodations, power plants, and control surfaces are attached to the rigid framework.

The metal-clad airship is both a pressure airship and a rigid airship. The streamline envelope comprises an extremely thin gas-tight aluminum alloy skin, supported by light frames. As in the non-rigid, internal pressure is required to maintain the form at high speed. Cars, power plant and control surfaces are attached in a manner similar to the non-rigid. Aside from an unsuccessful attempt in Europe in 1897, only one metal-clad airship has been built, an eminently successful design of 200,000 cubic foot displacement which was capable of 175 knots cruise speed (German ZMC-2, 1927).

This study is based throughout on the use of helium as the lifting gas. Hydrogen weighs only half as much as helium and therefore provides approximately 10% greater gross lift and as much as 40% greater pay load, but it is extremely inflammable (contrasted with the inert nature of helium). Safety considerations bar hydrogen from consideration in any future airship program.

All lighter-than-air aircraft are displacement vehicles deriving their lift from their buoyancy. Hence, the weight of the airship and its contents, including the lifting gas itself, must be approximately equal to the weight of the air displaced by it. For example, in a hypothetical 10,000,000 cubic foot displacement dirigible, the weight of the air displaced at sea level would be about 765,000 pounds, and the weight of the helium used to displace the air about 111,400 pounds. The difference of about 653,600 pounds is then available for structure, power plants, equipment, and useful load, including the fuel. In actual practice, gas impurities and under-inflation to prevent loss of helium in case of temperature or altitude increase would reduce that to about 600,000 pounds.

The above figures are based on sea level standard air conditions. At 5,000 feet altitude, air is approximately 86% of its sea level density, while at 10,000 feet the density drops further to 74%. The displacement and load-carrying capacity of our dirigible is therefore reduced by

107,000 pounds at 5,000 feet and about 200,000 pounds at 10,000 feet. It is obvious then that, in contrast to long-range transport airplane trends, the dirigible is most efficient at low altitudes. Certain procedures may be used to vary and improve the buoyancy relationships. Ground equipment or favorable climatic conditions may permit heating the gas just prior to take-off, resulting in an increase in effective lift by 1% per 5° F. temperature increment of the lifting gas over the outside air (up to the point of full inflation of the ship).

Generally, small airships are operated with the weight exceeding the buoyancy. A blimp, for example, can take off "heavy" with a very short ground run. In this case, the envelope of the airship acts as an airfoil, and despite its inferior shape for the purpose, the size of the envelope causes it to affect a large mass of air so that the additional weight is sustained at a low forward speed. This practice is generally limited to smaller, non-rigid airships due to the difficulty of maneuvering larger craft close to the ground. Once aloft and underway, an airship can readily support a substantial overload by means of dynamic lift.

The term "pressure height" is used in airship terminology to designate the altitude at which the gas cell or cells are completely filled. Normally, the airship is not completely filled with gas prior

to take-off. As the ship rises, the reduction in barometric pressure permits the helium to expand until, at a certain altitude, 100% displacement is achieved; flight at higher altitudes results in a loss of gas. Below this altitude the varying density of the air is balanced by the varying volume of the gas cells and the buoyancy remains constant, assuming, of course, that the temperature and pressure of the air and gas remain equal to each other.

Materials

The "Macon" and the "Akron" utilized 7075 ST aluminum alloy ($76,000\text{#/in}^2$ ultimate tensile and $65,000\text{#/in}^2$ yield compression) in their girder design. For reasons of inferior strength to weight ratio at a given corrosion level, this material is no longer widely used in airframe design. Today's super-alloys of titanium, beryllium, and even more sophisticated composite materials of beryllium/carbon epoxies and Boron/aluminum, would significantly impact the usable load factor⁶ of existing frame designs and permit sweeping design improvements. If, for example, the "Macon" or "Akron" had been made of Boron/aluminum composite, a 32% increase in usable load could have been realized with no increase in gross weight.

⁶ Boron/aluminum composites are 50% lighter than 7075 ST in uni-axial loading and 23% lighter in multi-axial loading at the same strength level. (Materials info courtesy Materials Division, Naval Air Systems Command)

A large amount of fabric is used in a dirigible. The outside envelope for existing design dirigibles is a single-ply cotton cloth which, when doped, weighs about six ounces per square yard and has a coefficient of drag of about .0025. By using existing fabrication technology and the polyester synthetics or polymerized plastics (e.g., neoprene) and coating them with teflon, one could achieve a lighter, more durable envelope. By conservative estimates, this technique would result in a material with three times the life span (about six years) at two-thirds the weight with a 15% reduction in the coefficient of drag.

Power Plants

For the existing design of dirigible the most important requirements for the power plant are low fuel consumption at cruising power, minimum fire hazard, and reliability. If the specific fuel consumption can be reduced from .40^{lb}/hp/hr to .35 by an increase of 0.5^{lb}/hp in the engine weight, it will pay for itself in ten hours of flight. Thus, the diesel engine, despite its additional weight per horsepower, permits substantial increases in payload. In a modern design, the ultimate in fuel consumption, the nuclear reactor, could be used to optimally meet all three requirements.

The reactor would be a small industrial type, or a unit much like the one currently used to power the nuclear submarine fleet. This

propulsion system represents existing technology. The reactor would be a fission type using enriched uranium (U-235) because of its high yield-to-size ratio. One-thousand-six-hundred-sixty-five kilograms (about 3,680 pounds) of U-235 would give the system an endurance of nearly twelve years between restocking.⁷ (Figures 1 and 2). Shielding of the reactor and liquid loop heat exchanger would be by either lead or expended uranium (U-238); the latter has the advantage of being more dense and would thus deliver the same level of protection with less thickness than lead. Such shielding would protect the crew to a level of five Roentgen Equivalent Man (REM), a degree of exposure proven safe for an infinite period. The heat-producing process in the reactor (Figure 3) would be ducted away from the core by a circulating liquid sodium cycle (tube side) to a heat exchanger with water on the fin side. The sodium cycle will reduce the operating pressure to about 200 p. s. i. within the core while maintaining 1,000° F. temperature there and reducing the thickness (weight) of the pressure vessel. The water system is the actual working fluid and is super-heated in the heat exchanger and is allowed to expand through either or both of the primary turbines,

⁷Nuclear power info courtesy of Atomic Energy Commission: U-235 produces 1 megawatt/gram/day using 10% contamination as replacement criteria and a system thermal efficiency of 30%.

REACTOR INFORMATION

SODIUM LOOP -

1000° F.; 200 p. s. i.; use sodium to minimize size/weight of reactor pressure vessel.

REACTOR -

Fission type; fuel-enriched uranium-235 (U-235)

SHIELDING -

Expanded uranium-238 (U-238) - denser than lead; shielding provides protection to a gamma level of 5 REM (Roentgen Equivalent Man), i. e., safe for indefinite exposure.

WEIGHT -

Reactor, turbines-generators, shielding, environmental control system, motors and propellers, governors, and pylon and controls = 180,000 pounds.

FINAL DRIVE -

Electrical

Figure 1

SIZING REACTOR

Enriched U-235

Assume 12 year life-cycle requirement

Assume 30% thermal efficiency

Assume replacement at 10% U-235 contamination

Given U-235 provides 1 megawatt per gram per day

Power requirement for "super airship" (to be defined later):

20,000 HP drive; 10,000 HP reserve power

$$(30,000 \text{ HP}) \left(746 \frac{\text{watts}}{\text{HP}} \right) = 2.24 \times 10^7 \text{ watts}$$

$$(1.7) (2.24 \times 10^7) = 3.8 \times 10^7 \text{ watts required}$$

$$(1 \times 10^6 \text{ W/D/G}) (3.8 \times 10^7) = 38 \text{ grams/day}$$

$$(38 \text{ grams/day}) (365) (12) = 166,500 \text{ grams}$$

10% contamination factor gives 1,665 KILOGRAMS

U-235 costs \$20/gram

Cost of fuel - \$33,000,000 or \$2,750,000 per year

Figure 2

Nuclear Power Plant

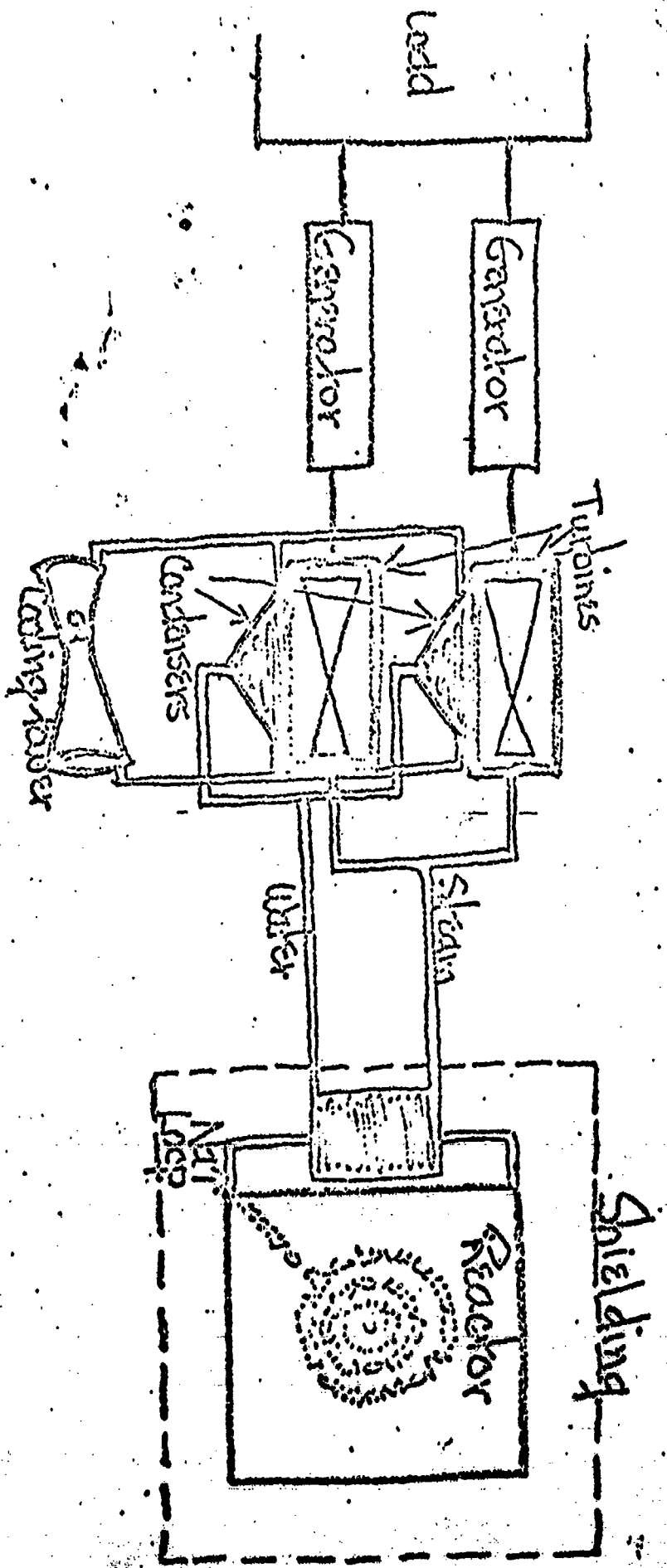


Fig 3

each driving a 15,000 kilowatt generator; this would provide electrical power for remote direct electrical drive of the airship and all other power requirements. The water system need not be shielded and, unlike the equivalent system in a ground nuclear power plant, the "waste head" (i. e., the heat from the condenser) would be vented into the airship by forced convection to heat the helium for improved lift and environmental control of living/working quarters.

Remote Drives

In the classical airship, general practice has been to mount the engines in nacelles outside the hull and to drive the propellers directly through reduction gearing. In the "Akron" and "Macon", the engines were mounted within the hull and drove the propellers by means of extension shafts and bevel gear sets. This arrangement reduced drag, increased the accessibility of the engines for adjustment and repair in flight, and facilitated incorporation of a swivel mounting for the propellers which, combined with reversible engines, permitted the thrust to be directed up or down as well as fore and aft. In a new design (the super airship, for example), one would use a variable cambre/variably ducted propeller to give optimal power at all flight speeds from each of the eight reversible electric motors. Each twenty-foot diameter propeller would be connected directly to a shrouded 3,000 horsepower motor, giving a minimum of resistance to

POWER REQUIRED FOR SUPER AIRSHIP
(cruise of 175 KIAS at sea level)

REYNOLDS NUMBER

$$R_n = (10,776) (1560) (185) (1)$$

$$R_n = 31 \times 10^8$$

COEFFICIENT OF DRAG

$$C_D = .0030 \text{ (Horner)}$$

STAGNATION LOADING

$$Q = \frac{1}{295} (185)^2 = 116 \# / A^2$$

FRONTAL AREA

$$S = \pi r^2 = \pi (185)^2 = 107,000 \text{ Ft}^2$$

DRAG

$$D = (116) (107,000) (.0030)$$

$$D = 37,000 \# \text{ of drag}$$

POWER REQUIRED

$$\frac{37,000 - 175}{325.5} = 19,980 \text{ Hp total}$$

$$\frac{19,980}{8} = 2500 \text{ Hp/motor}$$

Figure 6

flow and, with no drive shafts or gear boxes, the lightest possible reliability (see Figures 4, 5 and 6). Each of the propeller mounts can pivot 90° either side of forward (i. e., full up or full down), and by using reverse thrust/differential thrust a maximum of flexibility and maneuverability is afforded the operator. Engine pylons are retractable into the hull to make them accessible for maintenance en route to overcome an inherent weakness in airships. Strain gauges at key stress points in the frame can relate information to a computer that will, in turn, swivel one or more of the engines or adjust power or prop pitch to provide a relieving result load for the frame. This function is dependent on proper feedback loops and independently gimballed and controllable propellers, and limited by the need to follow a desired tract or heading, or hold a desired altitude or speed. This system will provide relief from the nemesis of earlier dirigibles, i. e. wind shear or gust loads.

Ground Handling

The question of ground crews is one with so many variables that no estimates can be made as to minimum requirements. German ground crews often numbered in the hundreds when all hands at the Zeppelin works turned out to help land and greet a returning ship. United States Navy mechanical methods of mast mooring required less than a hundred men, with about 25% of those being mechanical equipment handlers. It appears that modern technical development with increased

mechanization could reduce to between twenty-five and forty men, the ground crew requirement for mooring or unmooring an airship from a mast. The requirement for large ground crews is mainly caused by hangar operations where the airship must be warped into the dock in a manner somewhat similar to docking a large steamship. Mechanization in this operation also could reduce the historical manpower requirement.

The technology for a two-man ground crew presently exists by virtue of a technique called "bear trapping," a method used by helicopters landing on a pitching ship, whereby a cable is lowered from or pulled to the airship and is then winched in by single or multiple cables; single or multiple winches.

In the old airships, purification of helium was periodically required because air seeped through the gas cell fabric and eventually filled a certain volume which otherwise would contain helium. A helium purification plant was therefore required at a hangar overhaul base, and portable plants were needed at all terminals.

A new design would take advantage of the modern coated or rubberized polyesters to produce a light, non-porous, no-leak gas bag which when punctured could incorporate the feature of being self-sealing. As an added protection, a helium generator could be carried on board.

POWER REQUIREMENT FOR SUPER AIRSHIP
(cruise of 175 KIAS at 10,000 ft.)

REYNOLDS NUMBER

$$R_n = (10,776) (1) (r) \left(\frac{v_1}{v_{amb}} \right)$$

$$R_n = (10,776) (1560) (185) (.781)$$

[Note: Based on total length but due to aft section taper best estimate would be (.75) (total length)]

$$R_n = 24 \times 10^8$$

COEFFICIENT OF DRAG

$$C_D = .0025 \text{ (Horner)}$$

Note: Aerodynamic info and calculations courtesy Airframe Division, Naval Air Systems Command Headquarters

STAGNATION LOADING

$$Q = \frac{.7389}{295} (185)^2 = 86.1 \text{ #/A}^2$$

FRONTAL AREA

$$S = \pi r^2 = \pi (185)^2 = 107,000 \text{ Ft}^2$$

DRAG

$$D = (86.1) (107,000) (.0025) = 23,000 \text{ # of drag}$$

Figure 4

POWER REQUIRED

$$\frac{\text{Thrust} - \text{Velocity}}{325.5} = \text{Hp}$$

$$\frac{23,000 - 175}{325.5} = 12,400 \text{ total Hp}$$

$$\frac{12,400}{8} = 1,545 \text{ Hp/motor}$$

Figure 5

Economics

No definite answer can be given to the query - Is the airship economically feasible for commercial operations? No experience exists from which costs can be derived. The lighter-than-air craft is suited primarily for long-distance operations in excess of 2,500 miles. Its operation is limited by practical considerations to relatively low altitudes; hence, its routes should be selected with due consideration to topographical conditions. This factor, together with its very long range, makes it particularly suited to over-water operations. Because of its very large payload, the airship can operate economically only when there is a relatively large market for service. Because of its relatively low cruising speed, the airship is handicapped to a greater extent than the high-speed airplane if it encounters continuous headwinds of 30 miles per hour or more. On the other hand, because of its extremely long range, the airship appears able to operate with regularity, navigating around storms and selecting its routes to take advantage of favorable wind conditions. Inasmuch as most parts of the airship are accessible for service in flight, and the engines are operated at moderate power, all of the engines need not be operated continuously.⁸

⁸On her first voyage to South America, three of the four motors of the Hindenburg were out at the same time, yet the ship maintained its course, effected repairs and completed its trip.

CHAPTER III

The Future Is Now

In their operations the "Graf Zeppelin" and the "Hindenburg" had no airplane competition over their routes. In the future, no airship operation will presumably serve a route alone; all will be operating between points served by scheduled airlines. The longer the over-the-sea routes the greater the advantages of the airship as compared to the longer time required by the steamship and the higher costs of the airplane. In the age of the SST (their's, not our's) the premium of passenger transportation is speed, thereby eliminating the dirigible from competition for the passenger-mile. However, cargo of all types, especially semi-precious cargo, could be economically carried in bulk. According to estimates submitted by the Goodyear Aircraft Corporation for a hypothetical operation of an existing technology six-dirigible fleet, each of 10,000,000 cubic foot size, it would be possible to operate each ship for an average of 48 weeks each year, using the remaining four weeks for overhaul. For cargo operation, Goodyear estimated (using 1937 designs) that each ship would make an average of 96 round trips per year on a 2,500-mile route, and 48 round trips per year on a 3,500-mile route. It is further estimated that as an exclusively cargo operation, approximately 180,000 pounds

of payload could be carried per trip. On a yearly basis this would result in 61,290,000 ton-miles per year, at a cost of ten cents per ton-mile,⁹ at a rate of 6,120 ton-miles per hour. This is impressive when compared to a 747 F (all cargo) capable of carrying 100 tons at a cost of 29.5 cents a ton-mile,¹⁰ at a rate of 43,000 ton-miles per hour. At twelve flight hours/day, this would provide a 188,000,000 ton-mile per year load per airplane, or 1,128,000,000 ton-miles/year for a fleet of six. This represents an increase of 84% over the 1937 design airship. By the same technique, it can be shown that you would expect only a 57% increase in ton-mile/year over a fleet of new technology airships. Total transportation costs reflect a dramatic difference; for the airship, \$6,129,000, and for the 747, \$33,600,000 in total shipping costs.¹¹

The cost of constructing a 10,000,000 cubic foot rigid dirigible with current technology has been estimated at \$14,000,000/ship if at

⁹Normalized to 1969 dollars.

¹⁰Ibid.

¹¹In view of the absence of any commercial airship experience, estimates of current cost are difficult to arrive at or evaluate. The lack of such experience leaves little basis for either questioning or endorsing these estimates.

least three ships are built; helium for inflation would approximate \$780,000/ship, making a total initial investment of about \$13.7 million. This compares to \$19.8 million per copy for a 747.

Limited only by the lack of imagination, the design engineers tasked with the responsibility of an advanced technology airship would want to consider but not be limited to the following conceptual applications. Sufficient information does not currently exist to be more specific in some areas and the resolution of details of design and tactics of application are left to future engineers as a challenge.

Having shown the economic feasibility of using 10,000,000 cubic foot airships (about 160 feet in diameter and 600 feet long) and given a usable hold of 400,000 cubic feet, what is likely to be shipped by "slow air"? Any semi-precious cargo would lend itself to this application. Cars, for example, could be delivered direct to inland cities from the overseas manufacturer with only two handling intervals rather than the current four or six.¹² By eliminating the additional handling, the consumer price can be decreased, and the marketability of special order items would increase as a result of the more rapid delivery rate of airships (four to six times that of surface ships). Mail, including parcel post, is another cargo that would be easily carried continent to

¹² i. e., From factory, to rail, to dock, to ship, to dock, to rail, to truck, to dealer.

continent, city to city, being sorted in transit and picked up and delivered without stopping by use of drop lines, winches, and containerized shipping techniques.

Auto train, a recent and very successful experiment in luxury rail transportation, includes as part of the ticket price accommodation for the family car to provide mobility at the destination point; in this manner one can tour as much as desired without the inordinate cost of car rental or the trouble of driving to distant locations.¹³ By applying airship technology, one could enhance the auto train concept by adding transoceanic capability and at least twice the speed.

With the large lifting source and storage cavity, and an almost infinite loiter time aloft, the airship would lend itself to a variety of heretofore impossible material handling/transportation techniques. Equipped with existing strip mining slurry and pumping equipment, a dirigible could loiter or orbit in the vicinity of a mine or well, load large quantities of ore, coal or petroleum (from Alaska for example) for direct delivery to the smelting or refining plant, even doing some preparatory processing en route (taking advantage of the reducing temperature/pressure as it climbs to altitude). In similar fashion,

¹³ Two weeks after introducing the service, the company was booked full for three months.

logging operations in heretofore impenetrable woodland (e. g., in Siberia or Alaska) would be possible, owing to the ease of transporting men and materials into and out of the area by airship. Again, initial processing of the logs can be accomplished on site, and prior to departing the area the airship could seed and fertilize the cleared land for future harvesting.

In yet another transport application, the movement of a completely assembled Saturn V rocket (scale size shown in Figure 7 for comparison to a "super airship") could save NASA the expense of the final assembly building and the platform tractor used to transport the assembled rocket to the launch gantry. Yet another example of the airship's ability to transport large cargo intact is the DC-10 aircraft. Currently, the wings and tail are made in St. Louis and the fuselage and final assembly in Long Beach. This division of work, although seemingly illogical, actually serves a very useful purpose, i. e., efficient utilization of existing tools and technical personnel. This system requires transportation of large airframe sections, now shipped singly by rail; they could be shipped more safely and quickly in quantity by airship.

Forest fires consume an average of 100 acres of woodland every fifteen minutes in the United States. Airships could quickly deliver large quantities of dry chemical or water to the area of the fire. If a large enough supply of water was locally available, the airship could

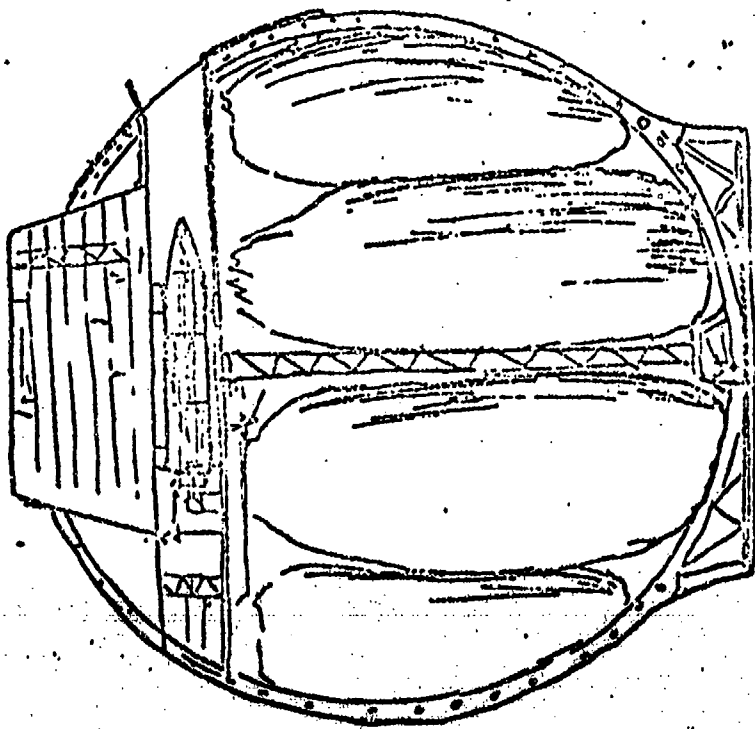
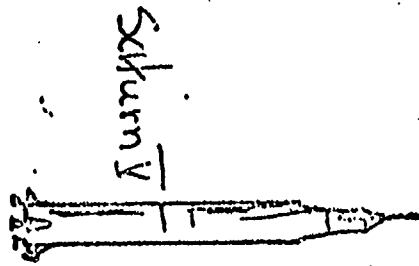


FIG. 1

orbit the area of the fire and continuously pump water through a sprinkler system fixed to the frame by tapping the nearby water source.

In addition, the Agriculture Department could provide a much-needed service by developing crop-dusting airships which, in a single day, could eliminate every boll weevil in Mississippi, or spray Florida for mosquitoes.

The housing industry could further benefit from airships with on-site delivery of factory-preassembled houses.

Every new transportation system comes under the scrutinous eye (and maybe ear) of the ecology cult. The airship would fare well. As explained earlier, the nuclear power plant doesn't produce pollutants, and even the excess or waste heat from the condenser is used to aid lift. The noise level, internal near noise and far field noise, would not exceed 81 PNdb, about the noise level in a modern office.

Current Military Applications

The super airship (100,000,000 cubic foot displacement with 5,390,000 pounds useful load) or even the 10,000,000 cubic foot airship could be a panacea for the military airlift command, whose most recent effort in the field of large cargo transport, the C5-A, has gone awry. With the low direct operating cost, usable life, flexibility and large cargo-carrying capability, the airship would have all the cargo/transport capabilities described in the commercial section and the proven opera-

tional readiness vital to national security. For example, an entire Army regiment, complete with support, could be transported from Fort Knox, Kentucky, to London, England, in 21.5 hours (once loaded).

Potential Combatant

Almost every United States missile site and airfield is known and targeted. To ease this tactically clumsy situation, hardened missile sites (a very expensive operation) were devised to withstand direct attack, and aircraft carriers and Polaris submarines were introduced to diversify assets and provide flexibility and mobility for a retaliatory strike capability. While these weapons systems are currently feasible, increasing complexity of design and inflating cost¹⁴ use up too much of our assets. In this age of tactical nuclear weapons, half or more of the carrier fleet may not survive the first strike (my own opinion). The vulnerability of the carrier was dramatized recently (1971) when a CVA was rendered inoperative for 18 months following the accidental launch of an unarmed five-inch rocket into aircraft parked on the flight deck. The Polaris subs, relying on the concealment of the ocean's depths, are also becoming increasingly vulnerable with advances in anti-submarine warfare. Assets; or rather the lack of assets, will

¹⁴Our newest aircraft carrier (CVA), the Nimitz, is presently at a cost of \$1 billion and still growing.

determine the victor of an armed conflict. The power that depletes its assets first is doomed to defeat. Therefore an inexpensive, effective, flexible and expendable weapons system is needed. The "super airship" could meet these requirements (see Figure 7 for artist's representation and Figure 8 for comparative data).

All aircraft are susceptible to attack; the airship, even with self-sealing bags, would be vulnerable to cruise missiles with larger Fuel Air Explosive (FAE) warhead. For this reason, a target as large and relatively slow as an airship must be escorted or armed. An armed "super airship" could truly achieve the status of the mythological Hydra. With the addition of an epoxy-coated Neoprene envelope and self-sealing¹⁵ helium gas bags to the super alloy frame and atomic power plant, an inflight tour to exceed six years could be achieved. This term inflight would lend uncertainty as to exact location and eliminate long overhaul periods. With the relatively low construction costs, one creates a no rework aircraft, i. e., after the six-year service tour, the "reusable" items are scrapped/sold and the bulk of the airframe is melted down or destroyed.

¹⁵ A self-sealing bag is constructed by laminating a layer of polyurethane into the bag wall and permeating the deflating bag with a fixer so as to "swell" the hole shut (the same concept used in self-sealing fuel cells).

Comparative Data	"Los Angeles"	"Graf Zeppelin"	"Akron"	Modern Airship**	Super Airship***
Nominal gas vol. (cu ft)	2,470,000	3,700,000	6,500,000	10,000,000	100,000,000
Length (ft)	658	776	785	845	1,560
Maximum diameter (ft)	91	100	133	156	370
Usable vol. (cu ft)	1,810,000	2,400,000	4,400,000	6,900,000	66,700,000
Height (overall) (ft)	104	113	146	174	420
Surface area (ft ²)	188,000	244,000	328,000	414,000	1,310,000
Gross lift (lbs)	153,000	258,000	403,000	770,000	7,700,000
Useful lift (lbs)	60,000	117,000	182,000	540,000	5,390,000
No. of engines	5	5	8	6	8
Type engines	diesel	diesel	diesel	nuclear	nuclear
Total horsepower (BHP)	2,000	2,800	4,500	5,860	17,340
Max speed (MPH)	112	120	125	175	185
Normal cruise speed (MPH)	74.9	80	83.8	115	178
Max range w/o refueling (miles)	4,300	6,125	10,580	11,100,000	11,400,000

* Historical data courtesy of the Navy Historical Society.

** Extrapolation of data based on existing airship design with current materials and technology.

*** Projection of airship design to include advanced aircraft technology -- the C-5A of the airship world.

All resupply would be by Blimp Onboard Delivery (BOD) techniques similar to present Carrier Onboard Delivery (COD) technology, which by once underway all personnel and supplies are flown to and from the operationally-ready airship. This technique would permit fullest use of the 1% increase in usable lift created by the dynamic lift of the airship in flight (an increase of 539,000 pounds in this case).

With the 175-knot cruise from sea level to 10,000 feet, the airship has an area of uncertainty of 120,000 square miles (at a given altitude) per hour. For purposes of visual acquisition (identification would be no problem) and observation, if the tracking aircraft loses sight of the airship for six minutes, the search area for reacquisition will be 12,000 square miles. Visual acuity limits sighting of even so large an object to 26 miles in clear day conditions with black/white contrasts, and 97 miles from the side or top.¹⁶ Satellite visual observation platforms are limited by cloud cover, and infrared (near field) could not discern the airship from storm clouds.

Navigation could be principally by stellar sighting coupled to Loran and Omega when available with continuous Doppler update to an inertial navigation platform. Location could be so determined to within

¹⁶ Search uncertainty courtesy of the Naval Air Test Center, Patuxent River, Maryland.

120 feet of a datum and speed could be accurately determined to within 0.5 knots. This accuracy is essential for updating the weapons control computer and for rendezvous with aircraft. The airship, though equipped with multi-band radar, will operate passively, forcing the searcher to be an active pulse generator to detect the position of the ship. The airship could serve as a mobile platform on which a variety of offensive weapons could be "hidden," much like the Polaris submarine. Each airship could be equipped with four rotating cylinders, each of which could carry 16 Poseidon (MIRV, nuclear warhead) missiles to be ejected from the airship; they would ignite after a safe distance of free fall (stabilized by frangible fins), pitch up and go ballistic to target. By using two cylinders linked together, the airship could carry 16 Minutemen III missiles to be launched in the same manner.

To adequately evaluate the defense needs of the airship, a threat must be clearly defined. No threat would be posed by 20mm or 30mm gun fire, as the helium bags are self-sealing and the source would be in range of the same or larger guns on the airship. The threat of aircraft would be covered by the fighter squadrons stationed aboard the airship. The fighters would be complemented by one squadron of early warning aircraft to fly perimeter patrol and one squadron of attack aircraft to neutralize ground sights. Operations could be carried on from a flight deck built atop the airship. Arrestment of the aircraft

would be by cable and suspended weights, and launch by taxiing the aircraft to the front ramp and rolling off. Approaches could be controlled by laser designation systems with automatic landing by a gimballled laser seeker tracking a narrow beam source in the flight deck. Rendezvous with the airship after a mission could be achieved by prearranging rendezvous locations and alternates; this eliminates the need for active transmission by the airship and could be programmed into an inertial platform/computer in the aircraft with stellar backup.

Attacking aircraft would also face a variety of defensive missiles such as the Phoenix Missile. For surface sites, an optically guided weapon such as the Condor or cruise missile could be used, and for subsurface, i. e., submarines, the airship could carry Subroc.

The only potentially significant threat to the super airship would be from a cruise-type missile launched from beyond the horizon and skimming the surface until nearly under the airship, then popping up -- giving minimal time for detection and destruction prior to impact. Some protection could be accomplished by M-61 type Vulcan cannons of 20mm of firing rates of 6,000 rounds/minute, with each round radar corrected to the closing target (Vulcan Falanx). With multiple guns, a "shower of lead" might destroy the oncoming missile.

CONCLUSIONS

Manned flight has progressed considerably since the Montgolfier Brothers. In this age of reducing abundance, an efficient and reasonably fast means of most transportation is desperately needed. The airship could fulfill this need. Today's technology of materials and nuclear propulsion make airship travel both feasible and economically attractive. It is hoped that the potentials of the airship will soon be exploited. Further, it is the desire of the author to be a participant in the return of the airship. To that end, this study is dedicated.

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STUDY TITLE: RETURN TO LIGHTER-THAN-AIR TRANSPORTATION

FOR MILITARY AND CIVILIAN APPLICATION

STUDY PROBLEM/QUESTION: An endeavor to find alternate economical and ecological acceptable means of transportation of air cargo for civilian and military applications.

STUDY REPORT ABSTRACT:

The United States aerospace community has entered an era characterized by declining activity, due largely to the increasing complexity and cost of aerospace systems. Industry and Government are engaged in a search for air vehicles that will carry increasingly larger payloads at reduced cost and levels of pollution, and that will not require vast expanses of land from which to operate.

To this end, the dirigible (rigid airship), a versatile and ecologically "clean" transportation system which offers exceptional payload capability, endurance, range and flight stability may be given renewed consideration.

Student, Rank Service

Class

Date

Richard M. Stepler, GS-12, USN

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November 1973