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THE AIRSHIP AS A MULTIPURPOSE PLATFORM--
INCLUDING IMPACT ON MILITARY LOGISTICS

Thesis No. 65

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INDUSTRIAL COLLEGE OF THE ARMED FORCES
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INTRODUCTION

Today the United States faces the greatest challenge to its position as the strongest nation on earth. The President, leaders in Congress, the Department of Defense, and military leaders recognize the seriousness of this challenge. In order that our way of life may prevail, it is up to each of us to earnestly, sincerely, and energetically contribute our combined talents in the best interests of our country to retain the world leadership we enjoy.

To do this we must all know where we are going and how we are going to get there.

Mr. Thomas J. Watson, Jr., president of International Business Machines Corporation, put it this way:

"I believe that the winning of any contest begins with ideas. The creative thinker is the priceless ingredient of progress. We have been famous for nearly 200 years for fostering an atmosphere which has produced the original thinking we have needed to build our Nation. The atmosphere is not as conducive as formerly to the breeding of new ideas.

"It is all too easy to criticize new and creative approaches. . . . This tendency to reject the new and creative act is all too prevalent today."(23:pt. 1:94)1/

Many of today's achievements are old ideas recast in the light of today's technology. The principle of rocketry was known by the Chinese centuries ago. Magnetic tape recording was patented in 1860, rediscovered in 1942 using steel wire the size of human hair, and later refined to the point where today it is used extensively in missiles, telemetry, video tape, for programing computers, and a host of other uses.

This thesis reexamines the large structural airship in the light of current technology in the hope that it may create the spark of imagination leading to serious consideration of its great potential.

1/ Numbers in parentheses represent items in the bibliography and page numbers.

"Three great Army generals--General Maxwell Taylor, General Matthew Ridgway, and General James Gavin--have all resigned their command before mandatory retirement age because they found they could not carry the responsibilities with which they were charged as Army Chief of Staff due to a lack of air transport for men, materials, and supplies. Yet each of these military men agrees that 80% of our exposure is to 'limited wars' in which air movement and supply is the prime requisite.

"Berlin is an immediate threat in point. Asia and Africa present grave dangers in the immediate offing. Only the airborne movement of troops from the United States to any point in the world will give us the force in place that can help prevent the limited wars before they start.

"We are also faced with a heavy outflow of dollars that in turn presents a potential drain on our shrinking gold reserves. Each dollar spent abroad for additional military forces may become an IOU against our \$17 billion of gold reserves. The outflow of these dollars can be lessened by supplementing our overseas military strike forces with an ever-alert United States-based airborne force that could move anywhere, anytime that danger threatened. Air supply could lessen the number of bookkeepers, auditors, warehousemen, and the chairbound troops that exist in such great numbers on our bases abroad. Instead of so many thousands of housekeeping troops abroad, leaving so many U.S. dollars abroad, they would be American-based and American-supported, ready to move in any direction where danger threatens.

"At the same time that we are gearing ourselves to protect United States interests by airlift against 80% of the exposure to war, we could, if we but had the wisdom to do so, create a new air cargo industry geared to the present-day need for fast, modern transportation. In doing so we create a ready reserve airlift fleet, supported in peacetime by its own revenues, but ready on six hours' notice with trained crews to supply our military forces in any part of the world where danger threatens. We can today help to stop the little wars before they start by using airpower for world security."(14:7)

These were the words of Senator Mike Monroney, U. S. Senator from Oklahoma.

The author of this paper has addressed himself to this subject because of a deep sense of conviction based on seven years of association with and study of the great unexplored potential of airships.

Admiral Arleigh Burke, USN, in an address before the Industrial College of the Armed Forces on 15 February 1961, cited the demise of lighter-than-air activity in the Navy as an example of a field of endeavor where no one has risen from among the ranks of enthusiasts with the strength of his own convictions and the guts to speak out in a convincing manner. And so he said it must go. Anyone who listened couldn't help but feel that the Admiral believed that lighter-than-air activity was fading from the scene without having had a fair trial.

Airships (large structural airships) have never been given a just trial, and it is for this reason that I have chosen this subject for my thesis. I have been a naval aviator for 22 years but am not a qualified lighter-than-air pilot. As commanding officer of a research organization operating three airships (blimp type) from 1954-57, I did gain an excellent insight regarding the potential of airships. The compartmented airship offers tremendous potential where great load-carrying capacity is required and speed in flight is not of paramount importance. It is also the only air vehicle which can use nuclear propulsion with the present state of the art in that field and provide a practical and useful vehicle.

From the time man first tried to fly, he has been trying to devise new ways to get off the ground. The first successful flights took place more than 200 years ago in large "hot air" balloons. In fact, "Air Force Times" (7 February 1961) carried an article captioned "Navy Takes 200-Year Leap Backwards in Flight." The article concerned recent experiments with the old technique of "hot air" balloons. These experiments, carried on under contract with the Office of Naval Research, can have considerable impact upon the design of a modern structural airship in pointing the way to eliminate ballast problems.

Today we are trying "the hard way" to get ourselves off the ground using VTOL (vertical takeoff and landing) and STOL (short takeoff and landing) aircraft, helicopters, and pressure craft. In fact, the tires of one large aircraft are inflated with helium to lighten the load.

Why don't we use helium (which only the United States possesses) to lift the whole aircraft off the ground? Then we need our power only for propulsion.

The potential of large airships will be presented in this paper in the hope that it may encourage interest for further investigation of this genuine workhorse of the air.

Very little that has been written on the subject of airships has appeared in print or been published in the last 10 years. For this reason the bibliography for this paper is somewhat limited.

I. THE STRUCTURAL AIRSHIP--DESCRIPTION AND CHARACTERISTICS.

A. Airship Structure.

To embark upon a serious airship development program requires critical and objective analysis as to its military potential. Considering the rapid scientific and technological progress which has taken place since 1935, when the last large airship (USS Macon) was constructed, it is apparent that the improvements which could be made in engineering and construction are too numerous to be mentioned within the scope of this paper.

Today's better materials, structural techniques, and engineering knowledge concerning fatigue, creep, and rupture of airframe structures--about which little was known 25 to 30 years ago--places today's engineer at a tremendous advantage. Older types of airframe construction would be replaced by new light-weight, strong sandwich construction. The covering for most of the airship might consist of tough modern plastics. Applying the aircraft industry's latest materials and structural analysis and fabrication techniques to large structural airships offers intriguing possibilities which can serve to reduce its cost and weight. Today computers make possible detailed design computations which were impossible 30 years ago. This will shorten materially the time required to determine by analysis the optimum design.

B. Classes of Lighter-Than-Air Aircraft.

A brief description of the structural (rigid) airship being considered in this paper is desirable from the point of view of clarity. In general, the term lighter-than-air embraces all types of aircraft that depend upon buoyancy produced by gases. The buoyant forces oppose the weight of the airship so that it becomes effectively weightless. There are basically three types of airships, i. e., nonrigid, semirigid, and rigid airships:

a. Nonrigid airship (blimp). --The nonrigid airship has no internal support and its aerodynamic shape is maintained by the pressure of the lifting gas inside the envelope.

b. Semirigid airship. --This class has a keel extending the length of the airship and to which the control surfaces and car are

attached. This structure maintains the lengthwise shape of the envelope while the round shape is maintained by the pressure of the lifting gas. (10:1)

c. Rigid airship. --The rigid or structural airship uses structure to give strength and shape to the airship. The lifting gas is contained in cells accomplishing for the airship what compartmentation does for a surface ship. The control surfaces are integral parts of the structure. Since the gas cells are normally not taut, the difference between internal and external pressure is zero. For this reason it is sometimes referred to as a "pressureless airship." It is this type of airship that this study will consider.

C. Helium.

Helium is the lifting gas used in the United States. This country has a world monopoly on this valuable resource. Helium will not burn or explode. It has 92 percent the lifting capability of explosive hydrogen. Helium will lift 62 to 65 pounds for each 1,000 cubic feet when used as a lifting gas. Helium is being wasted to the atmosphere at a rate estimated to be 4 billion cubic feet per year. Known resources of helium are estimated at 154 billion cubic feet. (20:41) A helium conservation program was initiated this year whereby private industry will produce crude helium by extracting it from helium-bearing natural gas in the areas where it is now being wasted. It will then be purchased by the Government and stored underground for future use.

D. Airship Characteristics.

The airship characteristics presented here are those of a 10-million-cubic-foot airship which incorporates boundary layer control, thereby extending its speed and range for a given payload, they are:

- a. Speed--zero to 140 knots.
- b. Range--10,000 nautical miles plus.
- c. Military payload--200,000 pounds (with inflight refueling this can be increased 10 to 15 percent).
- d. Deck space available--80,000 cubic feet.

e. Altitude--surface to 10,000 feet.

Note: Dependent upon configuration and displacement, an airship can be designed to go to 60 or 70 thousand feet (the Germans bombed London in World War I from 25,000 feet in this type of airship). It should be noted that the complexity of any aircraft is greatly increased if designed for high altitude operation, i.e., the need for pressurization, oxygen, etc., needed any time a vehicle is designed to operate above an 8,000-foot altitude for prolonged periods of time.

f. Endurance.--In maintaining station over a fixed geographic location, this airship could remain aloft for one to two weeks, depending upon configuration and distance of the station from the point of departure.

g. Vibration-free, quiet, and comfortable.--These three characteristics are extremely important in certain military applications and cannot be equaled in fixed-wing aircraft. The noise level measured aboard the German airship Hindenburg was nine decibels below that of the lounge aboard the Queen Mary. All of the first research done by the M.I.T. Lincoln Laboratories in developing new airborne radars for use in aircraft was done in airships. (12:50)

h. Flexibility.--The airship in various configurations provides an excellent vehicle for Airborne Early Warning, Anti-submarine Warfare, Logistics, Electronic Countermeasures, Command and Communications, Air-Sea Rescue, Airlift of Troops, Search and Reconnaissance, Convoy Escort, to mention a few of its military applications.

Its commercial possibilities for passenger and cargo service are equally attractive.

i. Mobility.--In naval fleet operations involving any of the above-mentioned missions, the airship, because of its tremendous endurance and load-carrying capacity, would greatly increase the fleet's mobility by providing a vehicle which does not have to be landed aboard ship or refueled for extended periods of time, even with conventional power. Using nuclear propulsion the airship can remain with the fleet at all times.

j. Vulnerability.--In these days of nuclear warheads, vulnerability is universal:

(1) Like all aircraft, surface ships, and mobile vehicles, the airship too is vulnerable. It is not as vulnerable to surface and subsurface attack as the surface ships currently employed in the same military tasks set forth in the "Military Applications" subsection B, page 14. Vulnerability is a relative term and therefore the airship is considered to be satisfactory from the point of view of vulnerability in that all vehicles (surface, subsurface, and air) must be employed in missions which afford an acceptable calculated risk. The airship can be employed in any area where we have reasonable control of the air. If the helicopter had been ruled out because of its vulnerability, it never could have performed the combat missions it became famous for in Korea.

(2) It is axiomatic when considering the vulnerability of any air vehicle, regardless of its aerodynamic shape or speed, that the vehicle which can lift the largest payload (assuming an air-to-air missile capability) can lift and provide the power to operate the most effective defensive weapon system.

k. Safety. --Record of safety is as follows:

(1) Up to 1936 the Graf Zeppelin and Hindenburg made 173 trans-Atlantic crossings from Frankfurt, Germany, to Lakehurst, New Jersey. Only 13 commercial, paying passengers lost their lives in all of lighter-than-air history, and these were all on the Hindenburg. Most airship accidents were of a military or experimental nature where participation in a fleet maneuver was of major importance. The modern airship would be no more affected by bad weather than any other present-day aircraft. Structural airships are tough. It took 70-mile-per-hour gusts with vertical velocities of 1,000-feet-per-minute speeds to break up the USS Shenandoah.

(2) The USS Akron crashed into the sea not as a result of structural failure but was flown into the sea in a dense fog as a direct result of navigational errors and a defective altimeter.

(3) Only 2 people were lost out of 83 aboard the USS Macon, which suffered a structural failure while flying through a squall. In this case the airship was flown with a known defect which would be a safety-of-flight discrepancy today. Even so, while the structural failure precipitated the events which followed, it was the panic of the crew which ultimately lost this airship.

The Germans have stated that during the period of German airship operation, the safety record of no other type of transportation could compare with that of the airship. (13:31)

E. Other Considerations.

The large structural airship is capable of vast improvement. Most of what has taken place in aviation progress has application. The areas set forth below should be seriously considered in visualizing a truly modern airship.

Systems Analysis and the Prediction of Airship Fleet Requirements

A systems analysis is a vital first step in the design of a modern structural airship of the type envisioned in the study. It considers both the need for transportation services and the capabilities of all alternative means in providing such services. The designer thus lets the functional capabilities dictate the physical characteristics; he need no longer follow the traditional practice which essentially reverses this practice. Such an approach has never been taken in the case of large airships.

Airship Design

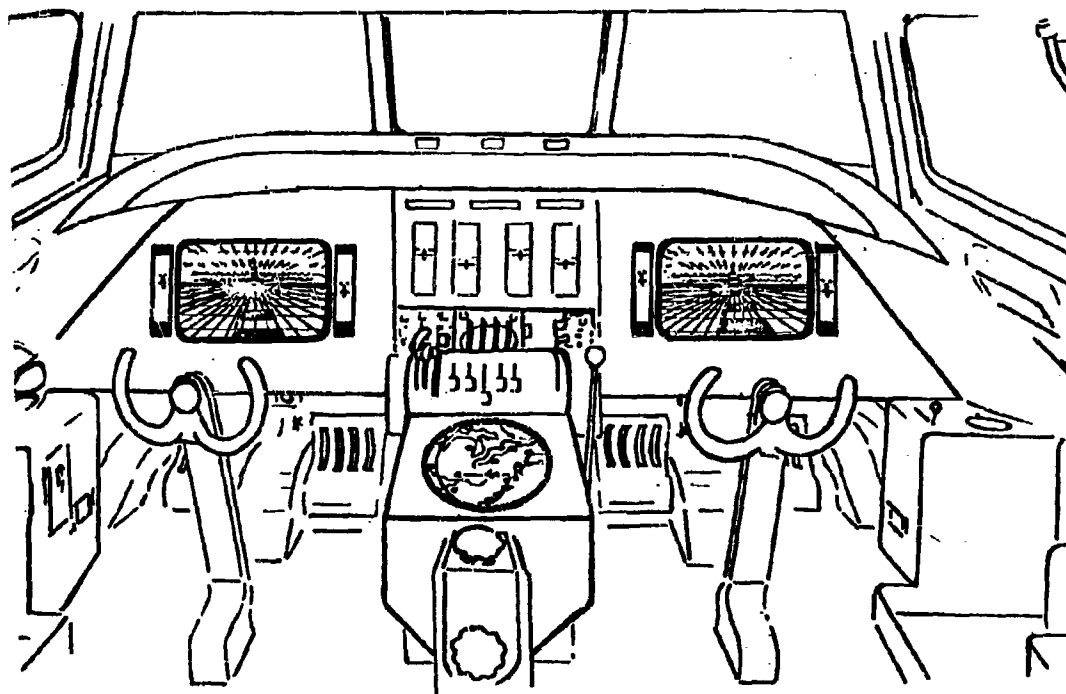
Technological progress in the design of large airships can best be accomplished through the exploitation of currently available technologies--including developments in allied fields--and through careful emphasis on economics in design. Careful planning can do much to reduce the cost of the first unit of production and ultimately total fleet cost.

Improved Operations

Improved airship operations through the electronic management control systems approach can make important contributions toward optimizing the effectiveness of an airship fleet for military and commercial applications. Such developments can increase the economy in military operations, commercial competitiveness, the safety, reliability and convenience of U. S. air transport. Such a system would coordinate most of the operational functions of the airship's subsystems through the use of one central digital computer. Such a system would provide the airship commander with complete up-to-date information in the form of an automatic and continuous display. The Army-Navy Instrumentation Program (ANIP) has made this new concept possible.

This system is currently going into the Navy's A2F Grumman attack bomber. Now satisfactorily solved is the basic problem of combining complicated flight data into an integrated display that is instantly and completely informative. Such an integrated system will:(13:16)

- a. Virtually eliminate pilot computation.
- b. Provide constant orientation in all-weather conditions.
- c. Provide instantaneous position fixes (automatic navigation control and display).
- d. Provide automatic programming of flight procedures.
- e. Provide automatic fuel management for all conditions of range and endurance.



Depicted above is a pilot's display utilizing a development of the Army-Navy Instrumentation Program. Television tubes present

a continuous display reproducing a synthetic picture of what the pilot would see in clear daylight. Also indicated are speed, altitude, and a prescribed course to be flown appearing as a "pathway in the sky." The central tube displays a horizontal navigation map showing position, fuel range, ground track, and the relation of the airship to its proper course. Obstacles and other air traffic may be shown by use of proper sensing devices. New electronic techniques of high reliability are employed throughout.

Improved Propulsion Systems

An airship's power requirements are about 20 percent that of fixed-winged aircraft and possesses certain unmistakable advantages: (1) because of its low power and shielding requirements, it is considered peculiarly suited for nuclear propulsion, (2) with conventional power in an "on station" role it is capable of two weeks' unrefueled endurance, and (3) with nuclear power its endurance would be limited only by the endurance of the crew.

The cost per ton-mile of a conventionally powered fleet of our airships reveals the economy which accrues to airship operation as compared to a fleet of 20 stratocruisers (see table 5, page 27) having the same initial capital investment. (27)

The hypothetical 10-million-cubic-foot airship presented uses four 1100 horsepower diesel engines. The equivalent nuclear power is (746 watts/hp) (4400 hp) = 3.28 MW, and at 20 percent thermal efficiency requires 16 MW.

The gap between the airship and the stratocruiser cost per ton-mile will remain the same when the chemical propulsion system is replaced by the nuclear power configuration.

A \$500,000 nuclear powerplant with the standard 15-percent amortization per year for the 7-year life of the reactor costs (\$500,000) (.15) per year/7 year = \$10,700 per year or \$206 per week. The U235 fuel burnup cost is (1.334) (Power MW) (days of operation) = 21 gm/day and at \$15 per gm is \$315 per day or \$2,205 per week per zeppelin. Utilizing an aqueous, homogeneous solution reactor or slurry type of reactor will keep the inflight reprocessing costs down to \$100 per day or \$700 per week. On the other hand the chemical fuel burnup cost is (.375 lbs/hp hr) (10¢ gal) (1/6 gal/lb) (4400 hp) (24 hrs/day) (7 day/week) = \$4,620 per week per zeppelin.

The difference in propulsion system costs is \$308,400, total operating cost per week for 4 zeppelins $+ 4 (\$206 + \$2,205 + \$700) - 4 (\$4,620) = \$300,000$ per week / 2,592,000 ton-miles per week = 11.5¢ per ton-mile for the 2,500-mile range and 11.5¢ per ton-mile for the 4,000-mile range. Thus, the cost per ton-mile remains unchanged in converting to nuclear power but the vast store of chemical fuel is eliminated leading to a larger payload and a substantial reduction in cost per ton-mile.

Comparing with other modes of transportation makes one immediately aware of the tremendous impetus of the nuclear-powered zeppelin concept--see table 1.

Table 1. Cost--cents per ton-mile

	2,500-mile range		4,000-mile range	
	Small cargo	Volume cargo	Small cargo	Volume cargo
Stratocruiser	18.2	18.2	34.9	34.9
Truck	9.1	7.3	17.5	14.0
Rail	6.0	6.0	11.6	11.6
Ship	6.0	6.0	11.6	11.6
Nuclear airship (10 million ft. ³)	11.5	11.5	11.5	11.5

The trend toward longer ranges places the nuclear zeppelin in an even more favorable competitive position along with the reduction in reactor costs with volume sales and the lower costs accompanying research in reactor technology. With a very reasonable cost picture firmly in mind, one is enthralled by the fact that the zeppelin can move four times as fast as seagoing vessels and at least twice as fast as truck and rail.

Because of the size of the airship, shielding problems are minimized and reduced to practical dimensions to permit human continuous tolerances.(27) Mr. Jack E. Van Orden, aeronautical engineer and nuclear technologist, Northrop Aircraft, Inc., Hawthorne, California, considers the nuclear-powered airship practical with today's technology.

He is not alone in his thinking, for Gordon Dean, former Chairman of the Atomic Energy Commission, says, "One place where the atomic engine can come into its own is in the all-but-forgotten dirigible."

The chances of a nuclear-powered heavier-than-air aircraft being turned into hardware cannot even be remotely predicted at this time, yet it is feasible and practicable in an airship now. (25:907)

Cargo Handling

It has been estimated that a typical shipment of freight spends 80 percent of its total transit time on the ground. No superhuman powers are required to discern that here is a promising area for streamlining and cost-cutting. Today when mechanization is the order of the day in so many fields of human activity, air freight packages are still being loaded and stowed manually, piece by piece in many cases. The ideal to be aimed at is to be able to load an aircraft's full payload within the time required for normal ground servicing--no small job when an airship is capable of taking a payload of 100 tons! Research should be directed toward preloaded modular containers which are interchangeable with airships, fixed-wing, rotary-wing aircraft, ships and trucks. This is further discussed in "Loading, Unloading, and Terminal Facilities," page 29.

Cost considerations

All airlift studies in costing out systems include only the air terminal to air terminal costs. The costs of trucking or shipping the cargo from point of origin to the air terminal and from the destination air terminal to the point of ultimate delivery are not considered.

In considering the airship in its logistic role, its unique characteristics for both military and commercial applications should be carefully considered. In commercial application the cost comparison is even more in the airship's favor when one considers that the airship can transport bulky cargoes or troops nonstop to any location in the world--i. e., from the port of embarkation to the deployment site or from the factory to the consumer. Expensive new terminal facilities in the form of runways, taxiways, aprons, etc., are not required.

Other cost comparisons of importance which should be kept in mind--the airframe weight of a 10-million-cubic-foot airship will be about 180,000 pounds. This airframe will carry a 200,000-pound payload where an average large air transport can carry only 40 percent of its airframe weight. Assuming the same dollar cost per pound of airframe, we find that here too the airship has a heavy advantage.

II. THE MULTIPURPOSE CAPABILITY OF STRUCTURAL AIRSHIPS.

A. General.

The structural airship of approximately 10-million-cubic-foot displacement is believed to have characteristics which, if exploited, could provide an ideal platform for many military uses.

B. Military Applications.

In setting forth the military applications, no attempt has been made to list them in an order of priority.

Airlift of Troops in "Vertical Envelopment" Tactics

The airship is an ideal vehicle to support Marine troops in "vertical envelopment" tactics. The large airship, at one-third to one-half the cost in operation of heavier-than-air vehicles, is capable of transporting 200 to 300 combat loaded troops or 100 tons of supporting material nonstop from the continental United States to any location on earth. Terrain is no obstacle since the hovering airship can descend vertically into an extremely small landing area or just hover while lowering the cargo by winch.

Because of its ability to hover, delays in the time of assault can be readily accommodated. (The German Hindenburg on more than one occasion after an East-West crossing cruised along the east coast for two days waiting for fog to clear. Additionally, it usually had 60 percent of its fuel remaining after such a flight.)

The airship does not require airfields. Support equipment can be dropped using paradrop techniques or offloaded in containers.

Vulnerability (a relative term) does not present a problem here where control of the air is a requirement before any amphibious assault can commence. In other words, the airship is not as vulnerable as assault ships committed and in the process of transporting troops by helicopter, employed in current vertical envelopment tactics. Being an air vehicle, it is not as vulnerable to submarine and air attack as are the assault ships currently employed to transport troops to the attack area.

Logistic Support

The airship as an addition to our peacetime "logistic" support forces offers a vehicle with approximately 80,000 cubic feet of deck space capable of accommodating up to 100 tons of military payload.

Here, as in its supporting role for vertical envelopment, it has the advantage of delivering its loads from continental United States to the scene of action.

There is a need to expand the numbers of peacetime logistic support aircraft to meet higher wartime consumption rates. It is believed that the airship can be developed to fulfill this requirement in sufficient time to match the time scale currently programed for fixed-wing aircraft.

Antisubmarine Warfare

A modern airship capable of carrying four to six helicopters and latest detection equipment and capable of launching any air-launched antisub weapon could be the very "breakthrough" needed to combat the nuclear-powered submarine.

Neither the blimp nor the helicopter as presently employed has this capability alone, but teamed up in the structural airship (nuclear-powered), capable of speeds up to 140 knots and practically unlimited endurance, we have the ideal platform which could excel all present airborne systems for accomplishing this task.

The blimp can not do the job because to dunk a sonar and hover it must be statically light, which means its fuel load has to be left home, giving it very short endurance and range. The helicopter has the same endurance and range limitation, but an airship capable of carrying the helicopter equipped with dunking sonar to the scene can have tremendous range, endurance, and excellent crew accommodations to effectively perform this task.

Having spent 11 days in the air in an airship (ZPG-2 airship flight March 1957, setting the world's endurance and distance record), I can attest to the fact that we were all more rested and alert at the end of the period than we were on takeoff. In fact one becomes most efficient after being out about three days, when every crew member is well established in the watch routine.

Employing the airship in this application has distinct advantages over the operation of helicopters from an ASW carrier in that it is not subject to detection by submerged submarines; and because it can detect a surfaced submarine at greater distances than it can be detected by the submarine, it will not be vulnerable in this situation.

Airborne Early Warning and Electronic Countermeasures

The airship in this application provides the best platform possible and will excel any other airborne vehicle for AEW and ECM.

The airship's characteristics of range, endurance, stability, and freedom from vibration, plus near-perfect conditions for crew comfort, make the airship the best vehicle for this purpose. The all-weather capability has been successfully demonstrated in a 3-year project for the Office of Naval Research, the final report of which was submitted in September 1957. This work was done at the Naval Air Development Unit, NAS, South Weymouth, Mass. (12:50)

Because the airship is the most ideal airborne radar platform, it was used by the Lincoln Laboratories for all initial testing of the Navy's new APS-70 radar system. In this application the airship could remain on station for periods of time comparable to surface picket ships.

In radar work increased detection ranges are a function of transmitted power and antenna size. Using the latest electronic scanning techniques the whole envelope could be used for an antenna, and the airship's great lifting capacity would permit more power to be available for the operation of electronic equipment than could be possible in conventional aircraft. ECM equipment (passive and active) capable of working against a wide frequency spectrum could be easily accommodated, thus providing the ultimate in an AEW/ECM vehicle. In barrier applications the airships would be based in continental United States and save tremendous expense now necessary to support an advanced base situation.

In air defense in fleet operations the airship equipped with the Navy's Air Tactical Data System (ATDS) with its detection and tracking capability could also be capable of launching air-to-air missiles in defense of the force and for its own protection.

One might question the vulnerability of the large airship when used as an airborne early warning device. A surprise unprovoked

attack on an airship standing watch would immediately place this country on alert to an impending attack. The act in itself is sufficient warning.

Command and Communications Ship

There is need in the fleet for a communications ship capable of handling force communications during periods of electromagnetic silence without at the same time disclosing the position of the force. Here again the characteristics of the airship offer tremendous potential in that it is capable of remaining on station for extended periods of time.

In this application it is conceivable that the task force commander would desire to direct the force operations in this ship in an area where for dispersal and other reasons the individual combatants are so widely separated.

In this configuration the airship could provide command and control to the Strategic Air Command, the Minuteman's missile system, and the Polaris submarine fleet by providing reconnaissance and acting as a communications ship to transmit command instructions. This airship if equipped with an inertial navigation system (backed by stellar supervision and doppler radar) could assist the Polaris submarine in establishing its precise position. In this instance I am assuming that the submarine will surface the equipment necessary to establish its position sometime prior to launching its missiles as a final check on its own inertial navigation system.

Convoy Escort

The airship historically has demonstrated its capability in this application as the best means of protection. Navy blimps escorted 90,000 ships during World War II without a single escorted vessel lost through enemy action. (10:59)

Once a fleet of airships of the type proposed here is in being, the reduced costs of production would make this the ideal vehicle for this purpose. Because of its range and endurance, fewer would be required than was the case in World War II where blimps were employed.

Missile Transport

For the transport of large missile boosters, the airship can provide the most practical means of transportation.

Missiles now being designed will be so large that it will be impossible to move them by railroad, haul them on a highway, or even transport them by conventional cargo vessels. This now is the problem with the Saturn booster which measures 21 feet in diameter and 80 feet in length.

The airship is the ideal vehicle for transporting these large rockets from factory to launching pad.

III. THE AIRSHIP IN SUPPORT OF LIMITED WAR.

A. Historical Background.

Despite the fact that the Germans aggressively and profitably operated large structural airships for both military and commercial purposes during the first 40 years of this century, no nation since 1939 has built or operated such ships.

The Germans demonstrated the practicability of transoceanic cargo and passenger flights. The 7-million-cubic-foot Hindenburg, costing \$2.6 million, could fly nonstop from Germany to Rio de Janeiro, Brazil. In the 14 months it was used in trans-Atlantic service, it made 36 crossings. On the average westbound flight from Germany to Lakehurst, New Jersey, there would be 60 percent of the fuel supply remaining at the end of the flight and 75 percent remaining on an eastbound crossing. Not a single departure was ever canceled due to weather. The Hindenburg carried 1,002 passengers on 10 of its scheduled round trips between Germany and the United States. Unfortunately, Germany had to rely on explosive hydrogen for the lifting gas. After a year of successful trans-Atlantic operation, in May 1937 the Hindenburg burst into flames at Lakehurst. Had nonexplosive helium been used instead of hydrogen, we probably would have large structural (rigid) airships in operation today. In all the history of commercial airship operations, only 13 passengers have lost their lives--and they were lost aboard the Hindenburg. (10:15)

The United States actively operated four structural (rigid) airships after World War I on into the 1930's. These were the Shenandoah, Los Angeles, Akron, and Macon. The Shenandoah, Akron, and Macon were all lost in "avoidable" accidents and under circumstances that would not occur today. The Los Angeles was dismantled after more than 15 years of service primarily because planners could no longer visualize its value for military uses.

~~The Akron and Macon were 6.5 million cubic foot airships,~~
each with a diameter of 133 feet and were 725 feet long. They carried five aircraft in a hangar aboard the airship and could land and launch them in flight. These ships had 4480 horsepower available for propulsion and were capable of a top speed of 85 miles per hour. It should be remembered that the transport aircraft of contemporary design had cruising speeds of a mere 80 miles per hour. (1)

B. Present Situation.

At the present time there is no program for the construction of airships of any type. In fact, some have seriously advocated discontinuing the small military airship program still in being. The current program is the minimum considered necessary to foster and maintain the state of the art in the lighter-than-air field.

The present decline in lighter-than-air activity should be a matter of vital concern to the Government, industry, and especially to the military services in view of the growing emphasis on strategic mobility for Army ready forces and for a number of other missions for which it excels. (28)

The reasons for this decline are many. There is currently no person in Government, the Department of Defense, or in the military services who is knowledgeable, experienced, and aware of the real potential of airships of all types, of structural airships in particular, and who at the same time is in a position of authority. In other words, there is no champion for the airship in a position to promote an objective study to determine its value in military and commercial applications.

Consideration of the airship's great capabilities is of especial interest at this time. Our Nation is presently engaged in a political-economic struggle which Soviet leadership, at least, regards as a struggle for survival.

Airlift is so vital a part of today's weapon systems and warfare techniques that we as a nation must examine carefully and objectively every vehicle which has potential. This has never been done in the case of large, structural airships as differentiated from blimps. In fact, not one dollar has been spent on Government-sponsored research concerned with such airships since the USS Los Angeles was disassembled in 1937--23 years ago.

Now in 1981 there are many military missions which require an air vehicle capable of lifting heavy loads, remaining aloft for prolonged periods of time under varying circumstances, and for being able to deploy forces globally on short notice. (25:10)

Certainly the structural airship deserves studied consideration to determine its rightful role in the military scheme of things.

C. Probability of Small or Limited Wars.

Possession of weapons of mass destruction has not served to deter limited or small wars since many of these crises are not sufficiently grave to warrant the use of such weapons. Today it is quite generally agreed that while it is hoped that limited wars will be less frequent due to the indirect deterrent effects of the existence of atomic weapons, that small wars will have a high probability of occurrence. The United States can not afford to be unconcerned about any war situation, however small it may be or wherever it may occur. In some cases of incipient military aggression, the situation may require only a show of force, as in Lebanon in 1958. In other cases, the United States may have to use force to oppose aggressive acts already in progress. In any event the United States forces must be tailored to meet the military needs in limited war and crises situations.

D. Limited War Needs.

What are some of these needs?

In responding to limited war situation, speed is most important. The United States must be ready to fight with men and weapons in jungles, on beachheads, in the Arctic, here, there, and everywhere, and in a matter of hours after the go signal is given. Our ability to wage a small war successfully is critically dependent upon our ability to transport at least a small force, together with its supporting material, rapidly to the scene of conflict wherever that may be. If the limited war is to be kept limited, it can be crucially important for us to be able to act very rapidly, even though the force involved may be small. Just as in the case of fire, one man's early efforts with a fire extinguisher can often do more to save the house than the delayed action of all the fire departments in town. (16:6)

This all points up the importance of providing and maintaining adequate and modern airlift and surface transportation to support Army limited war forces.

Other Considerations

The problem of providing transportation systems capable of transporting and maintaining United States limited war forces to any potential trouble spot in the world is currently commanding more attention. This problem must be resolved in the light of the various considerations which can affect the problem, many of which cannot be determined with any degree of certainty. These include when, how, and where they will break out, varying levels of Soviet participation, and possible United States responses, speed of military deployment, force tonnages, air and sea lift, and vulnerability of lines of communications. (16:1)

E. Scope of the Problem.

If general war or the threat of nuclear attack on the continental United States is considered unlikely, then the most likely threats will come from cold war crises and limited or small wars. In the latter, the response has to be considered in terms of our ability to move troops rapidly overseas to meet the military exigencies of the situation.

The best operational plan in the world is no better than its logistic support; and in turn, logistic support, that is, the entire system of planning for and providing goods and services, is correspondingly dependent on the supply lines. The question of how best to assure that our forces are supplied in future limited wars is therefore vital. Should it be by ship or aircraft, just how much, and what kind of long-range air transport capability must we have? This requires an overall transportation Systems Analysis. The preferred system may be the one which (1) requires the smallest number of military personnel, (2) provides the greatest safety for operating crews, and (3) entails the expenditure of the least amount of money for its procurement and operation. The criterion of cost is not only intended to reveal which system requires the smallest expenditure in dollars; it is also assumed to give some measure of the relative amount of economic resources required for the system. Thus the system which can achieve the desired military effectiveness at the lowest cost is assumed to be the most economic alternative. Such a system would provide the United States with a transportation system which would be the most effective mix of surface and air transport required to support any future limited war situation. (10:5)

The next section will present an assumed limited war situation where urgency or the speed of reaction is the overriding consideration governing the choice of transport. This consideration rules out the use

of surface or sea transportation for the situation under consideration, and therefore eliminates the need for examining the comparative costs of surface and air transport. It is hoped that this hypothetical situation will serve to stimulate some serious thoughts concerning the consideration of large airships as an important alternative worthy of serious consideration.

IV. HYPOTHETICAL MOVEMENT PROBLEM.

A. Operational Concept.

As the cold war is intensified, the likelihood of limited war situations can be expected to increase rather than decrease. In responding to limited war situations, including potential limited wars such as the recent crisis in Lebanon, speed is essential. It is possible to be confronted with situations where zero military response time can be too late, which implies the possible necessity of placing even greater importance on political-diplomatic activities in preventing or providing earlier warning of an impending crisis. (10:6)

Because this paper is concerned with developing the strategic lift potential of large airships as an alternative means in the deployment of Army forces, we will consider a hypothetical situation where an Army airborne division must be deployed within three to four days over a distance of 7,200 miles from the continental United States. This distance is chosen because it realistically simulates the distances to likely troubled spots, such as the Congo or Middle East.

This paper is not concerned with determining the best mix of currently available air transport for such a fleet but rather a comparison which contemplates the use of the airship as an alternative to aircraft presently being considered. The focus of interest is on speed of deployment. To deliver this airborne division within the time limit imposed requires an instantaneous capability to do so. In other words, the cargo airlifted will be that simultaneously transportable.

B. Force Tonnages.

The kind and sizes of limited war forces can vary widely. For purposes of comparison we will consider the new Army airborne division with 11,500 men, which is designed for air transport and weighs 14,500 tons with its supporting equipment. Once in place the division would require 9,500 tons of supplies over a 30-day period. (16:8) It is assumed that a fleet of transport aircraft which can simultaneously lift

the airborne division within the time set for completion of this deployment can easily provide the 20-day support requirement, since the support tonnage is considerably less than the total airborne division's weight. (16:9)

C. Sortie Requirements.

Air Transport Types

Modern transport aircraft are usually space limited when loaded with Army equipment. Therefore, dividing the allowable payload of the aircraft into the total weight of the force to be deployed can grossly underestimate the number of sorties required. In response to an Army request, the Operations Research Office of Johns Hopkins University devised a method of estimating aircraft fleet requirements in strategic deployments. The method devised takes into account the weight, cube, and density of Army forces of varying composition, which provides a more accurate estimate than those derived from calculations based on the weight of such forces.

In the past, both requirements and capabilities have been expressed in ton-miles. For example, a unit weighing 100 tons to be lifted 1,000 nautical miles was said to require 200,000 ton-miles (taking into account the 2,000 nautical miles round trip). An aircraft with a payload of 20 tons at 1,000-nautical-miles range could fulfill this requirement in 5 sorties or 5 round trips. This is true only if the unit can be loaded in the aircraft at an average rate of 20 tons per sortie. If the load is composed of vehicles and these fill the space in such a way that the average load weighs only 10 tons, obviously 10 sorties rather than 5 are required. (7:9)

The sortie requirements used in this paper are calculated from information derived from the ORO-staff paper (ORO-Sp-150) described above. (7:10)

For airlifting an airborne division of the size contemplated here (see Force Tonnages, p. 22), three types of aircraft will be compared. The three types are the C-133, C-124A, and the airship.

Taking the loading factors described above into consideration, i.e., all organic equipment, personnel, basic load of supply plus density, weight, and cube of the load, a table of sortie weights was developed (column A, table 2). Basic loads of ammunition in FM 101-10 were used. Five days of supply were assumed to be a basic load, which

was computed on the basis of 50 pounds per man per day. It was assumed that in most cases other organic equipment and basic load of supply can be loaded in the vehicles organic to the division. A survey of the payload of vehicles shows that in airborne units the payload equals roughly 40 percent of the empty weight of the vehicles. The weight of personnel was based on the usual factor of 240 pounds per man. (7:18)

The range with the payload calculated is shown in column B, table 2, and the numbers of aircraft required are obtained by dividing the total weight of the division (14,500 tons) by the figure in column A in table 2 for each type aircraft. Column C is the total number of aircraft required on the assumption that the time to deploy does not permit more than one trip per aircraft as in this case.

Table 2. Sortie weights

	Tons per sortie (A)	Range (B)	Number of air- craft required (C)
C-133	33	3,200 <u>a/</u>	439 <u>b/</u>
C-124C	23	3,000	631
Airships	100	10,000 <u>+</u>	145

a/ Fitzpatrick, George R. and Mary J. O'Brien, Method of Estimating Aircraft Fleet Requirements in Strategic Deployments, July 1960, p. 17. (ORO-SP-150)

b/ Number of aircraft equals total weight of airborne division divided by column A.

Time Required for Deployment

The round-trip time used in these calculations is an average based on the performance of a fleet of aircraft, taking account of the estimated time required for maintenance, operational delays, loading and unloading, and en route stops. The method used in calculating the round-trip time is set forth in detail in ORO-T-374 "Strategic Lift for a Future Army--Case A," pp. 102-110. The results are shown in table 3.

Table 3. En route time in days

One-way distance	Round-trip days			One-way trip days		
	C-133	C-124C	Airship	C-133	C-124C	Airship
7,200 N.M.	3.6 <u>a/</u>	5.5	5.6 <u>b/</u>	1.8	2.8	2.5 <u>b/</u>

a/ Fitzpatrick, George R. and Mary J. O'Brien, Method of Estimating Aircraft Fleet Requirements in Strategic Deployments, July 1960, p. 23. (ORO-SP-150)

b/ Calculated on 120 knot cruising speed.

It can be seen that while the cruising speeds of the C-133 and C-124C (280 and 185 knots respectively) are considerably above the airship (120 knots), the range of the airship (10,000 nautical miles), plus the capability to perform engine maintenance and air-frame inspection en route, makes the airship attractive as an alternative air transport vehicle worthy of careful examination. If en route facilities were unavailable, the airship is the only air transport vehicle capable of performing this airlift.

Different assumptions as regards any of the parameters used in this hypothetical problem would cause a change in the total time necessary to deploy a force of this size. Since the same factors were applied in the case of each type aircraft compared, the results proved a valid comparison for judging the relative merits of each of these vehicles.

D. Fleet Costs.

A comparison such as this must be considered in the light of real costs in arriving at the most effective system per dollar of cost.

For purposes of this paper, we are considering a 10-million-cubic-foot airship. In 1946 the Goodyear Aircraft Corporation submitted estimates to the Air Coordinating Committee studying the feasibility of rigid airships, (10:55) indicating that six (10-million-cubic-foot) airships capable of lifting 100 tons of cargo could be built for \$8 million each. In terms of 1958 dollars, this could be done for \$13.5 million today. These estimates were considered sound in that the 6.5-million-cubic-foot USS Akron cost \$5.8 million to build and the second airship (the USS Macon) cost \$2.6 million. Assuming that the first airship of such a fleet cost \$20 million (instead of the \$13.5 million mentioned above which stated the 1946 estimates in 1958 dollars), then applying

the 80-percent learning curve in arriving at the cost of the airship fleet (145 airships), we find that cost per airship would average \$4.5 million. The total fleet cost or investment would be \$652.5 million (145 x \$4.5 million).

Table 4 is a comparison of the airship fleet to a C-133 air transport fleet in lifting the airborne division of 11,500 men, plus supporting equipment--total weight 14,500 tons.

Table 4. Capital investment for aircraft fleets

(Cost in millions of dollars)			
Type aircraft	Fleet size	Unit cost	Fleet cost
Airship (10 million cubic feet)	145	4.5 <u>a/</u>	652.5
C-133	439	3.0 <u>b/</u>	1,317.0

a/ Based on 80-percent learning curve.(4:157-181).

b/ Cost figures, with 80-percent learning curve applied.
(21:356-357).

It can be seen from table 4 that the initial capital investment for a fleet of C-133's capable of lifting an airborne division would be more than twice the cost of an airship fleet.

To gain a better idea of the comparative costs, table 5 is presented. These were the comparative costs prepared in 1953 for operating a fleet of four 10-million-cubic-foot airships costing \$35 million as against a fleet of 20 Boeing stratocruisers costing the same amount. (10:54)

Table 5. Comparative costs

	2,500-mile flight		4,000-mile flight	
	Airship	Strato-cruiser	Airship	Strato-cruiser
Investment & equipment	\$35,000,000	\$35,000,000	\$35,000,000	\$35,000,000
Units employed	4	20	4	20
Fleet miles per week	28,800	160,000	28,800	160,000
Average cargo capacity per unit	90 tons	18.5 tons	70 tons	9.5 tons
Ton-miles per week	2,592,000	2,960,000	2,016,000	1,520,000
Total operating cost per week	\$ 306,400	\$ 530,000	\$ 306,400	\$ 530,000
Total cost per ton-mile	11.9¢	18.2¢	15.2¢	34.9¢

In no case is the stratocruiser as economical as the airship on a per ton-mile cost basis. This is partially explained by the fact that a 10-million-cubic-foot airship needs only 20 horsepower per each ton of gross load, while a large airplane requires a minimum of 100 horsepower per ton of gross weight. The difference in fuel consumption is even more marked than the installed horsepower indicates. The late Dr. August Raspet, former head of the Aerophysics Department, Mississippi State College, an acknowledged expert in the field of boundary layer control, has estimated that using this new technique a modern large airship could cruise at a speed 1.7 times its former speed, or cruise 5 times its former range using the same power. His calculations indicated that there were many applications where a fast, efficient airship could outperform airplanes and helicopters on a ton-mile basis. This means a modern airship can cruise at speeds of from 127 to 135 knots.

E. Airship Airframe Production.

Determining the feasibility or practicability of building an airship fleet of the size indicated calls for a determination of the U. S. airframe industry's production capacity. Historically, the Goodyear Aircraft Corporation's facility at Akron, Ohio, is the only place where a building dock (hangar) exists at a manufacturer's plant capable of assembling a 10-million-cubic-foot airship. Existing airframe manufacturing facilities conceivably could be made available to handle the fabrication of such airships provided additional airship docks were erected on the site of such facilities. To produce the 145 airships required to provide a fleet of the size contemplated would require 14 additional assembly airship docks. The delays inherent in such a building program led to investigation into the Army experience in building relatively inexpensive air-supported buildings. Results of this investigation indicate that such a solution offers encouraging promise and should be seriously considered. It is considered that an air-supported assembly dock could be built at a fraction of the cost of permanent installation. Such buildings have been designed to withstand winds of 60 miles per hour, with gusts to 75 miles per hour.

F. Route Selection.

Because of the great range of the airship (10,000 nautical miles plus), the route selection is not as critical as it is for fixed-wing transports which must make some en route stops for the distance involved (7,200 nautical miles to a hypothetical area). In each case the

airship can fly the great circle course to destination with no intermediate stops and at the same time take advantage of the wind circulation pattern prevailing over the Atlantic. One refueling would be required per round trip. Fuel would have to be available at destination or within 3,000 miles of destination to permit one refueling stop on the return trip. With no land bases available, it is practical to refuel from a naval aviation fuel tanker stationed at sea, a possibility not open to fixed-wing transport aircraft. This has been done many times in the past.

Loading, Unloading, and Terminal Facilities

The basic requirements for any transportation system are terminal facilities and fuel supplies. In the likely trouble spots in the world (the Congo, Middle East, south and southeast Asia), the number of fields that have the kind of facilities required by large aircraft such as the C-133 is limited. In fact during the Lebanon crisis lack of terminal facilities adequate to receive, unload, and service large numbers of aircraft was the greatest problem.

With present-day transport aircraft having gross takeoff and landing weights in excess of 300,000 pounds, and with future aircraft weights expected to exceed 500,000 pounds, the length and strength of runways, taxiways, and loading aprons become extremely important.

The airship contemplated in this paper would need little or nothing in the way of terminal facilities at destination. Because of the airship's ability to hover, it can land, release its containerized cargo, and depart. This permits loads to be delivered to the tactical location required in the field. This would relieve the congestion at terminal facilities. Runways and hardened unloading aprons are not required.

In the case of heavier-than-air vehicles, the terminal facilities are often the determining factor in whether the particular aircraft can be used. Information on terminal facilities, runway lengths, strengths, fuels available, and other information must be gathered from many sources, complicating the job of the military logistic planner. The airship, because of its tremendous range, can use other terminal facilities for refueling on its return leg if such facilities are available within 3,000 nautical miles of the objective area.

No additional terminal facilities over those now in existence would be required to support approximately 40 airships of the type described in this paper. There would, however, be a requirement for mooring masts and ground-handling tractors. This equipment would

cost less than \$20 million (145 masts, 168 ground-handling tractors). Every military air facility is a prospective base. No attempt has been made to determine the additional facilities or ground-handling equipment required to support the other aircraft used for comparison.

The primary purpose of this thesis has been to highlight the potential of large airships as an alternative system in performing military missions, as worthy of further serious consideration.

The author has shown the multipurpose uses for which large structural airships appear attractive. The scope of this paper has not permitted exploration of all possibilities. Many uses were surveyed in their broader aspects and one of its most promising--that of airlifting an airborne Army division--was given detailed treatment.

CONCLUSIONS

It is concluded that:

There is a clear need for a detailed study of the unique advantages inherent in the operation of large airships for military and commercial uses.

Airlift today can be an extremely important factor in every world crisis. However, airlift requirements are being radically changed by changing conditions. Failure to modernize our airlift capability with an objective analysis of all alternatives will leave it inadequate to the needs and strategy which will exist 5 to 10 years from now.

A modern structural airship exploiting current technologies, including developments in allied fields, would provide a vastly superior vehicle compared to the airships of the 1930's, greatly extending its effectiveness for military and commercial applications.

The large airship can accommodate a nuclear propulsion system and is practical with today's technology. Operating costs remain the same as with a chemical propulsion system.

The large airship can provide the most economical and efficient form of air transportation where speed for speed's sake is not the controlling factor.

RECOMMENDATIONS

This paper has revealed the promising potential inherent in large structural airships as a multipurpose system. From the standpoint of cost and the fact that its great range will permit the transport of Army or Marine forces and their rapid deployment to strategic or tactical locations anywhere in the world, the airship appears extremely attractive. As for vulnerability, it is asserted that the large airship is no more vulnerable than any other transportation system being considered for the deployment of troops.

It is recommended that the Secretary of Defense take the following actions:

Direct a detailed technical feasibility and design study to substantiate the practicability of designing large structural airships meeting the design characteristics presented in this paper.

Upon completion of the feasibility and design study, proceed with the construction of a prototype airship which can be assigned to the Army and the amphibious forces for an operational evaluation of its capability for the rapid deployment and support of military forces.

Upon completion of the design and feasibility study and concurrent with the preceding recommendation, proceed with an operational analysis of the airship's potential as an air transportation system for lifting and supporting Army and Marine Corps limited war forces.

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