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The Navy Rigid Airship

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Applied Mechanics Branch
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Abstract

Lighter-than-air (LTA) craft were used with great success by the Navy for some fifty years. Consideration of the unique capabilities of these craft, particularly rigid airships, suggests that they would be well suited to some present-day Navy missions. This memorandum presents a resume of past experience with rigid airships and outlines their performance characteristics. The most prominent of these include the ability to remain airborne for great lengths of time carrying large payloads, the ability to land and take off vertically and hover, and their apparent compatibility with nuclear propulsion. In view of the considerable technical potential, a mission-oriented systems analysis of updated rigid airship designs is recommended.

Problem Status

This is the final report on this phase of the problem.

Manuscript completed; May 1971

THE NAVY RIGID AIRSHIP

1. Conclusions and Recommendations.

1.1 Conclusions.

This memorandum presents a review of the past performance and applications of lighter-than-air (LTA) craft, particularly rigid airships, and extrapolates from this background to estimates of the performance of modernized designs.

LTA craft possess a unique combination of operational characteristics which is reflected in a unique combination of mission capabilities. Historically, the most significant of these capabilities were long flight endurance and high load capacity: Navy applications have ranged from the use of large, aircraft-carrying rigid airships as Fleet scouts to the use of the non-rigid blimps as pickets and convoy escorts. Capabilities such as these remain attractive today.

During the 1920's and 30's the Navy gained a great deal of experience with rigid airships of all sizes. The operational and logistic problems associated with these craft are well known, and the proper remedies are worked out and documented. Further, some of the most substantial problem areas of the past may be essentially eliminated by present-day technology.

For example, the (over-emphasized) hazard of flight in rough weather would be reduced by the employment of up-to-date aeronautical instrumentation, control systems, and radar. Also, the structure of the rigid airship would be improved (in strength, lightness and skin smoothness) by using new materials, fabrication techniques, and procedures for structural design and analysis.

Still another area where great strides have been made over the last few decades is that of power sources. Not only are aviation engines far lighter, more powerful and more efficient than before, but a large rigid airship would appear to be the ideal vehicle for nuclear propulsion. The combination of nuclear propulsion and a thoroughly modernized airship airframe would form a vehicle whose performance eclipses that of any hitherto known. It is reasonable to project payload capacities of 700,000 lb and virtually unlimited flight endurance.

For these reasons, the role of the rigid airship in the modern Navy should be considered anew.

1.2 Recommendations

It is recommended that a systems analysis be performed to estimate the mission capabilities and costs of modern rigid airships in the context of current and projected military requirements. The analysis should consider the performance profiles of the existing small (3×10^6 ft^3) and large

(10^7 ft^3) designs, and the potential performance of very large (2×10^7 ft^3) airships of advanced design. The possible employment of nuclear propulsion by the two larger designs should also be considered.

It is estimated that such an analysis would require 1.5 man-years and cost $60 K. Should its findings substantiate the apparent military potential of rigid airships, an engineering study concerned with structural design, materials, fabrication, facilities, etc., would be indicated, followed by a pilot production program at an estimated annual cost of $11 M.

2. Review of Airship Characteristics

Man's earliest successful attempts to fly were made with balloons, at first tethered and free flight, later powered flight. The airship has had a history of successful operation both military and civilian for many years. In 1961 the U.S. Navy closed out its LTA Program. Since then ten years have passed. Over thirty years have passed since the last rigid airship was constructed. The "Hindenburg" disaster seems to have effectively curtailed design, construction and use of these vehicles, even though in that instance flammable hydrogen was used rather than inert helium, and even though the suspicion of sabotage has remained strong.

There are many areas of military need which entail the requirement of a vehicle capable of carrying large loads for long distances or for great lengths of time, or capable of providing a steady platform on station for extended periods. These areas of need are encountered in connection with functions such as surface and underwater surveillance, ASW, ship escort, fast response transport of men and materiel, etc.

In many respects the rigid airship presents an ideal vehicle for such needs. It has high load-carrying capacity, long flight endurance, 100 m/h speed, it can hover at low to moderate altitudes, and its sheer inertia makes it stable.

2.1 Classification of Airships

Airships may be taken to comprise the class of self-powered dirigibles. The term dirigible in itself properly applies to any steerable aerostat, powered or not. Airships of the past have been of three basic designs: rigid, semi-rigid and non-rigid. The first features a mechanically strong hull of the desired form, while the other two rely on (slight) internal overpressure to maintain the proper hull form. The semi-rigid type is distinguished from the non-rigid by having a keel, a strong member which carries the operational forces, while the non-rigid distribute the forces throughout the fabric of the airship itself.

2.2 Design and Construction of Airships

All airships have had hull forms approximating an ellipsoid of revolution. During World War I, rigid airships (Zeppelins) were built as cylinders with elliptical ends since this was quicker and cheaper. The peacetime practice was to taper the central section somewhat from fore to aft. The non-rigid and semi-rigid types have largely had hull forms more nearly ellipsoidal (save for some very early specimens).

The 'fineness ratio' (length/diameter) strongly affects the dynamic stability of the airship. However, values of 4 to 8 give satisfactory results and the practice has been to build rigid airships with ratios of 6 and non-rigid with about 4.5 to 5. The slenderness of the rigid airships was a matter of manufacturing convenience more than a reasoned choice.

The structure of the rigid airship was a frame of ring girders and stringers (of wood or metal) covered with doped fabric. The interior of the hull was occupied by gas cells and passenger/cargo space. Gas cells were constructed of gold-beater's skin, and bulkheads between them usually were a group of taut wires. The semi-rigid and non-rigid types had envelopes of rubberized fabric and the envelope was filled by the gas cells, save for small communication passages. One non-rigid airship, the U.S. Navy AMC-2, had an envelope of very thin aluminum.

The rigid type has the advantages that its hull is not deformed appreciably by external pressure, so is capable of higher speeds than the other types, and that space is available within the hull.

2.3 Flight Performance Characteristics of Airships

Airships of all types have the characteristic that the bigger they are, the better: their virtues are proportional to volume, while their faults are proportional to surface area.

2.3.1 Aerostatic Performance

Under standard conditions (temperature 32F, pressure 29.92 in Hg) dry air has a density of 80.72 lb/1000 cubic feet, hydrogen 5.61 lb/1000 cubic feet and helium 11.14 lb/1000 cubic feet. It is usual to take the operational lifting capability of hydrogen as 68-70 lb/kf3 and that of helium as 62-65 lb/kf3. Hydrogen is slightly cheaper than helium, but highly flammable. It is used little (if at all) in manned aerostats because of this, although the perils entailed are somewhat exaggerated. There are numerous instances of airships being struck by lightning, etc., without harm.

The flight ceiling of an airship for a given load is determined by the volumetric percentage fullness to which the gas cells are inflated at take-off. If the cells are completely filled initially, it is necessary to valve off some of the lifting gas as altitude increases. In the interests of gas conservation cells may be filled to about 90% of capacity and a ceiling of some 3500 ft reached without valving. The resulting loss in take-off lift may be made up by superheating.

It was usually the practice to valve hydrogen to compensate for the loss of weight from consuming fuel. The introduction of helium (much more expensive at that time) led to the development of exhaust condensers for ballast recovery. These devices condensed the water contained in the propulsion engine exhaust, and could recover up to 1.4 lb of water for each pound of fuel burned. The normal small variations in total lift resulting from air temperature fluctuations, uneven insolation, etc., were compensated by changing the trim of the airship, as the dynamic lift is strongly dependent on the angle of attack.

2.3.2 Dynamic Lift

The airship derives some lift from its fins, and an approximately equal amount from its hull. This dynamic lift may be substantial, and it was early recognized that payload could be increased by a running take-off. This technique was used by the blimps.

2.3.3 Flight Performance

Airships can be optimized for practically any flight characteristic except high speed. The high altitude versions of the World War I Zeppelin were capable of flight ceilings of 20,000 ft, speeds of 80 m/h and payloads of 100,000 lb. Long range (7,000 m) models were under development when the World War I ended. Postwar effort was pointed primarily to developing the capacity for carrying large loads for long distances or long periods of time. Continuation of this effort even after the abandonment of rigid airships culminated the large (1.5 m ft^3) U.S. Navy blimps of the ZPG-3W class, which could carry a useful load of 23,000 lb and remain airborne for about two weeks. Shortly after demonstrating their unrivalled performance as pickets, the Navy airships were abandoned in June 1961.

2.3.4 Problems of Rigid Airships

The majority of airship problem areas were of the sort which are part of developing any new device, and gradually vanished as experience was gained. Some were solved by the introduction of new materials and techniques throughout industry generally. Yet others are intrinsic in the nature of the airship and to these some accommodation must be made; it is to these areas that attention will be directed.

The area which has always presented airships with their greatest peril is that of ground-handling. Being large and lighter than air, airships are blown around easily by the wind and can be difficult for a group of men on the end of a line to control. Many of the early airships (e.g., until the end of World War I) were damaged by being blown into buildings, etc., while being held or moved by the ground crews. Wind per se is no threat to an airship. Since it normally flies at 100 m/h or more, it is obviously capable of tolerating winds of such speeds. However, it is the nature of an airship to head into the wind, and if it is tethered in such a way that the nose does so while the tail is prevented from moving, the resulting bending moment can do damage. This situation can be avoided by tethering by the nose only, using a short mooring mast to keep vertical motions small. This method was used successfully with fairly large vessels. When the very large ships 'Akron,' 'Macon,' 'Graf Zeppelin' and 'Hindenburg' appeared, the stern beam was added. This was a heavy carriage running on circular railroad tracks. The tail of the airship was tied to this, the nose to a mooring post in the center of the circle and the ship oriented to point into the prevailing wind. The stern beam also restrained the buoyancy when the ships were unloaded. At their home bases these large ships were kept in hangars, and the mooring post and stern beam ran on tracks so that the moored ship could be moved directly from the mooring circle into its hangar. With the development of this procedure ground-handling of even such large vessels ceased to be a problem, but it should be remembered that there is an intrinsic propensity to trouble in this regard ready to develop if proper procedures are not followed.

Although it was not identified as such, the next most troublesome problem area was that of structural analysis. This was not an intrinsic problem, of course, but the inability to calculate airship structural responses made it impossible to predict its behavior accurately, let alone optimize its design.

2.3.5 Modern Improvements

The rigid airship presents a structure in which gigantic improvements could be made today. First, with today's large, fast computers and modern knowledge of structural dynamics it is possible to analyse the airship's structure. The basic procedure was to lay out a moment diagram and determine requisite member strengths by simple beam theory. In time, the development of relaxation techniques allowed fairly accurate analysis of some of the structural components (e.g., ring girders), but the structure as a whole retained elements of mystery. Proven design details were changed with reluctance and to as small an extent as possible. The evolution of rigid airship structures was accordingly slow. Most post World War I airships were basically of Zeppelin-type due to the fact that Zeppelin Company had built far more than anyone else. It was a proven, dependable design, and while it was recognized as inefficient, it was not possible to improve on it at that time by any method other than trial and error. The present ability to analyse an airship structure as a complete frame can be relied on to produce more efficient designs.

Modern materials would also have great impact. The early airships used wood, duralumin, and steel wire for strength members, rubberized cotton cloth and cow's intestines for fabrics. Materials available today include plastics and metals with much better strength/density ratios, and plastic films are far superior in every respect to the fabrics. Use of 'Mylar' film for gas cells, for example, should increase gas retention times from a few months to several thousand years. Even present-day plywoods and duralumins are greatly superior to those of forty years ago. In addition, the modern technology of composite materials would permit the properties of the individual structural elements to be tailored to the requirements established by structural analysis.

Improvements in power plants have been substantial also. Today high-powered Diesel engines are available which have less than half the specific weight of earlier gasoline engines, and comparable specific fuel consumptions. If high-power Wankel engines become available they would offer even more improvement. The possibilities of nuclear propulsion should also be investigated. It would appear that the rigid airship, particularly when large, would be an ideal vehicle for this. The size and weight of even a relatively large reactor can easily be carried by an airship.

The power requirements for airships, particularly large ones, are fairly substantial. It would be possible to utilize helicopter-type propulsion rather than aircraft propellors. A large (50 ft dia.) helicopter rotor can support around 14 lb/hp, compared to the 4 lb/hp of an aircraft propellor. The potential trade-off of speed for increased load capacity for a fixed horse power is an area for consideration.

The application of automatic control to airship flight should be investigated. The old wired control system would certainly be replaced by modern electro-hydraulic actuators and servos. The addition of a minicomputer to this system and placing a number of additional strain, force, and acceleration transducers at appropriate points of the airship would allow the control system to be programmed so that the vessel could never be operated unsafely. The computer could also take care of navigation, ship status reports, etc.

2.3.6 Operational Parameters of Rigid Airships

Some operational characteristics of rigid airships are functions of their size, while others are generic. Among the latter are:

1. Vertical take-off and landing
2. Ability to hover
3. Altitude can be controlled without power
4. Speed is low, probably about 100 knots as a practical limit
5. Altitude is relatively low. For purposes of this study, the service ceiling may be taken as 7500 ft, and lift coefficients given below will be adjusted to reflect the gas configuration required to allow this ceiling. It should be borne in mind that this ceiling is not a rigid barrier: for a given mission, the service ceiling may be set at up to 20,000 ft or more by adjusting the payload and fuel allowance, and if during a mission it becomes necessary to exceed the service ceiling it can be done at the expense of dropping ballast (water) and valving gas.

6. Angular and altitude stability in flight are very good

7. Noise and vibration levels in flight are low

8. The greatest risk of damage lies in collision with ground-based objects

9. The volume available for crew space is large

10. The volume available as cargo space for a given payload is large

11. Loss of gas by leakage is negligible. Gas valved intentionally for maneuvering may amount to about 1% per mission.

Some major parameters which depend on size are:

12. Propulsion system. A rigid airship of about 10^7 cu ft gas volume should be an ideal vehicle for nuclear propulsion

13. Payload capacity increases non-linearly with size. For conventional propulsion, a net lift capacity of 28 to 35 lb/1000 cu ft of gas may be assumed (volume range 3×10^6 to 2×10^7 cu ft), and this is to be shared between fuel and payload

14. For a given speed, the power required varies as the 2/3 power of the volume by the formula

$$P = .00357\ V^{2/3}\ U^3$$

where P is the power required in horsepower. V is the air volume in millions of cubic feet, and U is the speed in miles per hour. Cruising speeds may be taken as 80% of maximum, and fuel consumption to be proportional to the power expended at a rate of 0.37 lb/hp/hour

15. With nuclear propulsion the net lift would become from 24 to 27 lb/1000 cu ft (volume range 10^7 - 2×10^7), all available for payload

16. Flight endurance of an airship with nuclear propulsion is virtually unlimited. With conventional power it is subject to the trade-off of payload and fuel requirements

17. Ground facility requirements. For small rigids (up to about 3×10^6 cu ft), ground facilities need be no more than a cleared circular area about 1500 ft across with a mooring post in the center. For short term use, the same arrangement (with a larger cleared area) will also suffice for larger airships (e.g., 'Hindenberg' at Lakehurst), but as a permanent base it is desirable to have a mooring circle with stern

boom, a hangar, and some helium storage capability. Satisfactory ground facility requirements and operating procedures required for rigids of up to 10^7 cu ft volume are well known and can be provided, while those required for larger vehicles are known only from sizable (but straightforward extrapolation.

2.4 Performance of Post-World War I Airships

The safety record of commercial airship operations is remarkable. Excluding Soviet operations, for which statistics seem not readily available, commercial airship operations carried 354,265 passengers for 4,412,672 miles in flight time of 91,452 hours. The total passenger fatalities were 13, all on 'Hindenburg,' and crew fatalities of 29, 22 of them on 'Hindenburg.'

In all military and experimental operations (including World War I) 762 were killed. The automobile can match this production, in the U.S. alone, with one good three-day weekend. Of the 158 rigid airships which have existed, only 12 were built after World War I, and two of these were basically of wartime design. The following table reviews the careers of the twelve.

Name	Where Built	When Built	Last Flight	
Nordstern (LZ120)	Germany	1918	1927	dismantled.
Bodensee (LZ121)	Germany	1918	1920	dismantled.
R38 (ZR2)	UK	1921	1921	structural failure in flight.
Shenandoah (ZR1)	U.S.	1923	1925	structural failure in flight.
Los Angeles (ZR3)	Germany	1924	1932	decommissioned - dismantled in 1939.
Graf Zeppelin (LZ127)	Germany	1928	1937	laid up for conversion to Helium. Dismantled - 1940.
R100	UK	1929	1931	dismantled.
R101	UK	1929	1930	structural failure in flight.
Akron (ZRS4)	U.S.	1931	1933	crashed in storm.
Macon (ZRS5)	U.S.	1933	1935	structural failure in flight.
Hindenburg (LZ129)	Germany	1936	1937	burned.
Graf Zeppelin II (LZ130)	Germany	1938	1940	dismantled.

It may be noted that of these craft, six were peacefully dismantled after useful careers averaging six years.

It is instructive to review the losses of the remaining six in some detail.

(1) R38 (ZR2)

The 'R38' was built in the UK for the U.S. Navy. Its design was a virtually exact copy of the German L-33, a high-altitude type featuring a much lighter structure than the normal construction. During the acceptance trials, 'R38' crashed and burned while maneuvering sharply at low altitude. The Court of Inquiry found that weather conditions did not contribute to the crash, and that the airship's structure was not faulty in fabrication. The most likely explanation seemed to be that the light structure, designed for the modest flight loads at high-altitude, was overstressed by the flight loads associated with low-altitude aerobatics.

(2) Shenandoah (ZR1)

The 'Shenandoah' was ordered by the U.S. Navy at about the same time as 'R38,' but was designed and built in the U.S. Like 'R38,' its design was substantially copied from a captured Zeppelin, in this case L-49. 'Shenandoah' was successful--among her accomplishments were a 9,000 mile circumnavigation of the continental U.S. in 1924. The Board of Inquiry into the crash of 'Shenandoah' determined that she had been struck by a violent updraft in clear air and carried above pressure height, valving off gas in an attempt to control the rise. This was followed by an equally violent downdraft, during which 'Shenandoah' dropped ballast, and by another even more violent updraft.* At this transition from violently falling to violently rising air current, 'Shenandoah' apparently buckled one or more longitudinals, tearing several gas cells whose complete deflation led to yet more structural damage. The control car fell away from the hull and 'Shenandoah' broke into two parts--the forward part was landed safely as a free balloon, while the after part crashed. The Board findings were that the design, fabrication and maintenance of the craft's structure were in no way responsible for the crash, and while critical of the fact that some of the gas cell automatic relief valves had been sealed, the Board found that they had been reactivated without delay when the need arose. Damage from gas pressure, therefore, was regarded as unlikely to have contributed to the crash, which was attributed to weather conditions of rare violence.

(3) R101

The 'R101' was constructed contemporaneously with the successful 'R100,' and used much the same type of construction. This departed from

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* It was estimated that the updraft velocity was around 80 ft/sec, while 25 ft/sec is considered extremely violent (and rare) by aerologists.

the established Zeppelin type by using a few strong frames rather than many weaker ones. In the case of 'R101,' it seems that no design analysis was performed, and the characteristics of the finished product came as something of a surprise. In order to attain adequate lift it was necessary to cut the craft in two and insert an additional section. The maiden voyage was to be a flight to India. While passing over France, the craft was seen to be flying nose down and pitching, and she finally flew into a hill and burned. The Court of Inquiry established that there was no control of forward ballast available from the control car, so that when the nose became too heavy for the elevators to overcome there was too little time for a man to go forward and dump ballast. The loss of nose buoyancy was tentatively ascribed to loss of gas from the forward cells in some manner undetermined. The theory has since been advanced that the nose-heavy condition may have developed through taking on rain through the forward air-vents. The flight had been through steady rain and the curtailment of the trial flight program could have prevented inadequate hull drainage from becoming apparent earlier.

(4) Akron (ZRS4)

The 'Akron' was a large aircraft-carrying airship of extremely strong design and construction whose loss was not attributed to any structural fault. While on a routine flight, 'Akron' encountered severe storm activity. It is likely that the full magnitude of the associated barometric low was not realized, and that (since cloud cover prevented independent checks on the barometric altimeter) 'Akron' was actually flying considerably lower than the intended altitude. The craft was eventually caught in a down draft of some force, her descent being arrested by dropping forward ballast and followed by an apparent rapid rise to cruise altitude. The altitude was probably substantially less than this because of altimeter error, perhaps compounded by a local low pressure region. Then came an abrupt entrance into very rough air, and another powerful downdraft. Additional ballast was dropped, and the nose pulled up in an attempt to pull out on dynamic lift. In this altitude 'Akron's' tail assembly struck the water, and this tremendous drag brought the craft crashing into the sea.

(5) Macon (ZRS5)

The 'Macon' was sister-ship to the 'Akron' hence virtually identical in structure. Unlike 'Akron,' however, 'Macon' was lost because of structural failure. An incipient failure had been detected while 'Macon' was flying cross-country, and temporary repairs had been effected in flight. After the ship had participated in fleet maneuvers in the Caribbean and returned to California, considerable time and study were devoted to determining the seriousness of this weakness and its implications. It was decided that the weak element, a stern frame, should be reinforced with additional channels, but not enough time was available to perform this work before the start of fleet maneuvers in which 'Macon' was scheduled to participate. The repairs were deferred until after the completion of the fleet exercises. One day while returning to base after the day's exercise, 'Macon' altered course to avoid a line squall, and was apparently struck by an exceedingly sharp, violent gust while turning. The upper fin was torn loose at the weak frame, taking part of the frame with it. Three gas cells were torn open, and the tail-heavy condition pulled the ship into so sharp an inclination that dynamic lift was lost. Dropping ballast and valving gas in an attempt to recover control proved ineffective, and 'Macon' settled gently into the sea.

(6) Hindenburg (LZ129)

The 'Hindenburg' was the largest airship ever built, being slightly larger than 'Akron' and 'Macon,' and was used in trans-Atlantic commercial service. After more than a year of successful operation, 'Hindenburg' caught fire while landing at Lakehurst shortly after a thunderstorm had passed through the area. Since the ship was hydrogen-filled, destruction was complete. No satisfactory explanation has ever been suggested. All that can be determined is that somehow hydrogen escaped, and that somehow it was ignited. The possible cause offered as the most likely involved 'Hindenburg' being struck by lightning in some lingering after effect of the earlier thunderstorm, although there are several recorded instances of hydrogen-filled rigids being struck by lightning, and in these only minor damage was incurred. The suspicion of sabotage was very strong, and remains so today.

2.5 Reliability

To sum up the demises of the dozen rigid airships of 'modern' construction, six ('Nordstern,' 'Bodensee,' 'Los Angeles,' 'Graf Zeppelin,' 'R100,' and 'Graf Zeppelin II') were retired and dismantled, one (R38) was the victim of peculiar flying, one (R101) was improperly designed and inadequately tested, one ('Akron') lost to unreliable instruments, one ('Macon') to improper maintenance, and one ('Hindenburg') to mysterious circumstances. Only one, ('Shenandoah') can be considered to have been simply overpowered by the forces of the air, and this was an early design under extremely severe conditions.* It is probable that the later ships would have survived, and that better weather information (or radar) would have caused the area to be avoided.

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*With the exception of 'Hindenburg,' all of these losses have been considered by some observers to have been assisted by poor airmanship. Most of them are also considered by a significant body of opinion to illustrate the results of subordinating the requirements of sound technical operation to the demands of public relations.

It is evident that th[illegible]ter airships were strong enough structurally to withstand winds, storms and what-have-you, or certainly very close to it. There is no doubt that with modern materials and techniques they could be made stronger, and lighter as well. There is a question as to how far this should be taken. There is probably no such thing as fool-proof or completely indestructible structure, nor is there need for one. The experience of surface ships over a couple of thousand years or so is that it is not economical, if possible, to build a ship which can operate to a set schedule of time and place no matter what the sea may do. Instead, it is accepted that ships adapted for profitable commercial operations will be faced with storms which must be avoided or ridden out, harbors which can be entered only at certain times, and so on. The policy is to build ships to cope with practically any situation they are likely to meet and equip them as well as can be to avoid any situation with which they cannot cope. No attempt is made to build them to withstand any combination of circumstances which can conceivably arise. The airship in its later development had reached a similar state. Airships such as 'Akron,' 'Macon' and 'Hindenburg' were, if anything, more nearly capable of handling anything their native element could throw at them than are most surface ships.* The fact that some airships were lost, including one which was well-found and well-handled, is no more a legitimate cause for condemnation of such vessels than the fact that surface ships are occasionally lost would justify that abandonment of the sea.

3. Rigid Airship Designs for Naval Applications

3.1.1 Present Status

The variable of rigid airship design which yields the greatest payoff for military function is size. The ideal multi-purpose naval craft would be very large, having some three times the gas volume of the largest yet built. Such a vessel is fundamentally well within the reach of modern technology, but the facilities which designed, built and operated rigid airships largely ceased to function 35 years ago. Even the non-rigid blimps have not operated for ten years, save at football games. What physical plants

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*The only commercial employment of rigid airships to any considerable extent was made by the German firms 'Delag' and 'DZR' with the 'Graf Zeppelin' and 'Hindenburg.' The former was used for seven years on the South Atlantic trade route to Rio de Janeiro, where severe weather is constant and unavoidable, and the latter for a year and a half on the North Atlantic route to Lakehurst. During this use these ships achieved point-to-point speeds averaging over 90% of their nominal cruising speeds.

exist (primarily hangars) have been diverted to other uses, and in any case are too small to be useful for the construction of very large vessels. It is thus necessary to develop the capability to design, construct and operate large rigid airships virtually from scratch. This being the case, it would be wise not to attempt the ultimate at the outset, but rather to institute a more gradual program utilizing such technical facilities, designs, information and people as yet survive.

3.1.2 Development Program

It is supposed that a three-phase design and construction program would be pursued concurrent with development of operating and handling capability. The design and construction program would commence with existing designs: Phase I, the ZRN,* authorized by Congress in 1938, Phase II, the ZRCV designed in 1937. Phase III would be devoted to a completely new design, the ZRCCN. It is not proposed that the ZRN and ZRCV be constructed precisely as originally designed by BUAER. Although these are undoubtedly viable designs produced by one of the leading design groups at a time when airship technology was at its height there have been great advances in materials and structural design technology over the intervening years. However, it is important that these designs exist, since they provide as a starting point workable vessels which could be constructed in existing hangars, such as those at Moffett Field or Lakehurst. The program for developing operating and handling capability would be largely one of training personnel in 'airmanship.' Some facility construction would be necessary, mostly in connection with the ZRCCN. A start need consist of no more than reinstituting the Lighter-Than-Air training program for blimp service.

3.2 ZRN

3.2.1 Description

The ZRN as originally designed and authorized was a training vessel for airship crews and for pilots of the scout aircraft carried by 'Akron' and 'Macon.'

As designed, it represents the traditional Goodyear-Zeppelin style. Its length was 650 ft, diameter 108 ft (fineness ratio 6.0), gas volume 3,000,000 ft^3, gross lift 192,000 lb and weight 115,000 lb.

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*This nomenclature is that established by the Navy. The initial 'Z' indicates a lighter-than-air vessel, and 'R' signifies 'Rigid.' The designations 'ZRN' and 'ZRCV' are those assigned to these designs in the later 30's.

3.2.2 Static Performance

The gas volume of ZRN is 3,000,000 ft^3 with a gross lift of 192,000 lb. If the structural weight is cut to 75,000 lb, and the usual 3% of gross lift is devoted to emergency ballast, then some 111,000 lb is free for fuel, crew, stores and payload. To aid in gas retention, the service ceiling might be set at 5,000 ft, and the gas cells filled to 85% at sea level. For take-off, applying a superheat of about 30C would fill the cells to capacity and provide full lift. Once airborne, dynamic lift can be relied upon if necessary, but it would probably be preferred (particularly in a training craft) to limit the useful load to 100,000 lb and remain slightly light.

3.2.3 Propulsion

The existing ZRN design incorporates four externally mounted 750 hp engines driving 3-bladed propellors. This arrangement could be retained, using the much lighter modern engines. An alternative to be considered would be to install a single 3000 hp engine internally and couple it to the propellors electrically. This would simplify the installation of exhaust condensors, save weight, complicate the cooling system, and enable the propellors to be tiltable, like those of 'Akron' and 'Macon.' The ability to vector propulsive thrust was found to be of great value on those large ships, particularly in mooring and takeoff. While not essential in a small ship such as the ZRN, it would certainly be a feature of the larger ships to follow, and ZRN would be a training vessel for these. The available thrust from 3,000 hp would be around 12,000 lb. which could be a significant addition to the total lift if required.

3.2.4 Flight Performance

As described, the modified ZRN would have a structural weight of perhaps 75,000 lb, carry emergency ballast of 6,000 lb and an equal weight of expendable ballast for maneuvering. The gross lift would be 192,000 lb, leaving 105,000 lb for crew, fuel, payload, etc. With the assumed 3,000 hp the maximum speed would be, conservatively, 75 m/h, cruising speed 60 m/h. If Diesel engines were used the fuel consumption would be about 1100 lb/hr. If all available lifting capacity were devoted to fuel, the endurance would be some 100 hours, a range of 7500 miles. The ship might be expected to carry about 40 men, and an allowance of 10,000 lb for crew and provisions would be generous. In view of the performance of the Zeppelin of Delag and DZR in regular commercial service, a fuel reserve of 10% should be adequate. The flight performance which could be expected is outlined in Table I.

TABLE I

Length	650 ft
Diameter	108 ft
Max Width	130 ft
Max Height	120 ft
Gas Volume (nominal)	3,000,000 ft^3
Service Altitude	5,000 ft
Empty Weight	75,000 lb
Gross Lift	192,000 lb
Horse Power	3,000 hp
Speed	75 m/h (max)
Ballast	12,000 lb (includes 6,000 lb maneuvering ballast)
Useful Load	95,000 lb
Range Unloaded	5600 miles (10% reserve)
Payload for 4000 mile range	27,500 lb (10% reserve)

3.2.5 Applications

The primary purposes of the ZRN would be as a research vessel and proving ground for new construction techniques, and as a training vessel for airship personnel. Its size and performance are comparable with Navy vessels which have existed in the past. Facilities exist in which the ZRN can be built and housed. Handling and mooring procedures are thoroughly worked out and documented. It would also be well to institute a study of water-based operations, on which some work was done (by Germany and the U.S. Navy) in the 20's and 30's. The potential advantages of such techniques with the very large airships considered later are enormous.

In addition to fulfilling these purposes, the ZRN could well be applied to other Naval uses. The most obvious would be that of a radar and ASW picket. The ZRN has twice the gas capacity of the ZPG-3W (the last of the Navy's great blimp family) and would carry a greater load, even to mid-Atlantic and back. It has additional capability of hovering. Its available range is also adequate for a convoy escort. In short, the ZRN is capable of doing anything done by blimps, and doing it better.

Like the blimps, the ZRN as described would not have enough endurance for long-term fleet support activities. The ZRN was intended as a training vessel to replace the 'Los Angeles,' would be about the same size as 'Los Angeles' and would have similar but improved performance. It was 'Los Angeles' limited endurance which was largely responsible for the construction of the large ZRS4 and ZRS5, 'Akron' and 'Macon,' as scouting vessels to accompany the Fleet. The usefulness of ZRN, particularly as a submarine killer, would be greatly enhanced by the addition of aircraft, which the original ZRN design is arranged to handle. Unfortunately the type of aircraft for which it was designed were small, weighing about 2500 lb, and such military aircraft no longer exist. It would no doubt be practicable to adapt spotter and trainer aircraft to ASW applications.

3.2.6 Training

Training of aircrew and groundcrew would be an extension of the Navy's previous training program for LTA personnel. Free balloons and small blimps still operate, and the large ZPG-2W and ZPG-3W models could be re-inflated. The value of blimp training would be due to the size (the ZPG-3W has half the gas volume of the ZRN) and rough similarity in handling characteristics. There are great differences due to the blimp's negative buoyancy and pressurized hull, and the true development of the necessary skills can be expected to derive only from experience with the ZRN. The production of flight simulators should be no great problem, and extremely valuable.

3.3 ZRCV

The existing design for the ZRCV is that of a large ship carrying 9 dive bombers. At 9,550,000 ft^3, it would be the largest airship ever built The aircraft were to be stowed in line beneath the hull, where they could be deployed within a few seconds. This arrangement dictated a strong keel, and a design more nearly along the conventional Zeppelin lines than that of 'Akron' and 'Macon.' Revisions to this design would incorporate the advances proved out on the ZRN. Although larger, it is still close enough in size to previous ships to warrant confidence that earlier handling procedures can be adapted successfully, and ground facilities which exist can accommodate a ship of this size.

3.3.1 Structure and Materials

In many respects the structural problems associated with the ZRCV should be less challenging than those of the ZRN. Not only would the common questions of gas cell and outer covering fabrication have been answered, but when an airship reaches this size the scale of structural components makes more materials usable. High-strength steels become attractive for many girder applications, expanded metal becomes a lighter material for hull-forming panels than perforated plastics. Widespread use of steel components rather than, say, duralumin would lead to more economical construction, for not only is the medium cheap but the assembly is simpler and faster. The general hull form could be retained: length 897 ft, diameter 148 ft (fineness ratio 6.1), gas volume 9,550,000 ft^3, gross lift 592,000 lb, weight 295,000 lb. Utilizing design and construction advances validated on ZRN might reduce the weight of this ship to 200,000 lb or less.

3.3.2 Static Performance

The gas volume of ZRCV is 9,550,000 ft^3, gross lift 592,000 lb, weight 200,000 lb, ballast (emergency and maneuvering) 36,000 lb, crew and provisions (60 men) 15,000 lb, leaving 341,000 lb for fuel, payload, etc.

3.3.3 Propulsion

The present ZRCV design calls for eight 750-hp engines in four cars, each pair driving a single four-bladed propellor. As with ZRN, it would be preferable to arrange inboard installation and pivoting propellors, and if possible a central engine room with electrical power transmission. Fuel consumption would be about 2200 lb/hr. A reactor of 5000 kw capacity would weigh about 100,000 lb and have a volume of 5000 ft^3. Its weight, then, is about the same as that of the fuel which would be consumed in 45 hours of flight, its volume is tolerable, and nuclear power looks quite attractive for missions of long duration. The problems which frustrated attempts to apply nuclear power to heavier-than-air craft appear less challenging to an airship. Reactor size and weight are no barrier, protecting the aircrew from radiation is simpler, ground crew protection and handling problems no worse than with airplane installation. Further, airship crashes have generally been relatively leisurely affairs, so that there should be less danger to the public.

3.3.4 Flight Performance

TABLE II

Length	897 ft
Diameter	148 ft
Max Width	170 ft
Gas Volume (nominal)	9,550,000 ft^3
Service Altitude	5,000 ft
Empty Weight	200,000 lb
Gross Lift	592,000 lb
Horse-Power	6,000 hp
Speed	75 m/h (max)
Ballast	36,000 lb (includes 18,000 maneuvering balla
Useful Load	341,000 lb
Range Unloaded	10,000 mi (10% reserve)
Payload for 6500 mile range	132,000 lb (10% reserve)

Additional lift from upward-directed propellors would be 4 lb/hp x 6000 hp = 24,000 lb. If nuclear power were utilized, the last three items in Table II would become

Useful load	253,000 lb
Range with any load up to 253,000 lb	Unlimited
Payload for any range	253,000 lb

In actuality, it would be necessary to carry additional supplies and perhaps a store of liquid helium to make up losses, both of which would compromise the payload capacity. There is no doubt that the flight endurance would extend far beyond the point at which the crew would consider mutiny.

3.3.5 Applications

The primary purpose of ZRCV would be as a cargo/personnel carrier. Like the ZRN its research utility would be as a testing ground for experimental construction and materials and to gain experience in handling and operating large airships. Unlike the ZRN, its military utility as a general carrier is great and immediate. Conventionally powered, the ZRCV can carry heavier payloads for 6500 miles than any existing airborne means, although more slowly. As a personnel carrier, it could carry 500 men for this distance. With nuclear power, it could carry 1,000 men or an equivalent weight of cargo anywhere in the world. The only limit which might be set would derive from the radiation level in the passenger area.

3.3.6 Special Problems

There have been many airships about the size of ZRN in the past, some suitable facilities still exist, and procedures for operation and handling were well established. There should be no problems attached to these areas except those of teaching young dogs old tricks. The ZRCV is beginning to break new ground. Its size is on the upper limit of applicability of past methods. Hangars still exist of adequate size, but they would be well filled by the ZRCV. The 'stern beam' method for ground handling is basically still suitable, but it may be necessary to consider larger beams and perhaps even partial deflation of the ship. An area which deserves particular consideration is that of loading and unloading cargo.

Unlike the ZRN, the ZRCV was designed for long-range fleet support missions. In its original form the ZRCV was expected to have an endurance of 175 hours at 50 knots while carrying 9 loaded dive-bombers each weighing 6,000 lb. This sort of performance would have many fleet applications today. Combined with this ultimate range of 8750 nautical miles is the ability to hover and provide an outstandingly steady platform. With the improvements suggested, such as low permeability gas cells, computer-controlled maintenance of flight program and stability, and (most of all) nuclear power, the ZRCV would appear to be the ideal vehicle for long-term picket duty, ASW, fleet support and escort missions. Vulnerability should not be a problem. With (say) 25 gas cells, the complete rupture of one would mean a loss of only 4% in gross lift. It would be possible to make up the loss of two cells on dynamic lift alone, and drop ballast for another one or two. The catastrophic loss of many cells is very unlikely. For example, the usual result of a hit on a World War I Zeppelin by an anti-aircraft shell was that the shell passed completely through, leaving a slow leak in one of the cells. Catastrophic loss of up to three cells has been known to happen, however ('Shendndoah' and 'Macon'). The fast, computer-controlled flight system would be capable of the immediate response to prevent loss of the ship as a result. Detectability (radar, etc.) remains to be determined, but the use of low density non-metallic materials wherever possible should offset the large cross-section. There are no dive-bombers around today which weigh 6,000 lb, but there are several airplanes and helicopters in this range able to carry small charges and fly slowly enough to hook on to the ZRCV. The effects of the changing pattern of loads, buoyancies and hold-down forces resulting from addition and removal of cargo (probably complicated by wind forces) must be carefully explored.

3.4 ZRCCN

The ZRCCN would represent a major step into completely new territory. It would be a vessel of 22,000,000 ft^3 capacity, more than twice that of ZRCV. No facilities capable of housing such a vessel exist or have ever existed. Indeed, most of the old airship authorities felt that the optimum size was probably about 10,000,000 ft^3. The outlay for facilities would be substantial, but the performance gained would also be substantial. By the time experience with ZRN and ZRCV has been assimilated the challenges may seem less formidable.

3.4.1 Hull Form and Construction

The hull would be a moderate speed (100 m/h) type with a fineness ratio of 5, and a length of 1000 ft. It may be possible to construct a non-pressurized all-metal hull no heavier, or perhaps lighter, than one of traditional architecture. If this should not be the case, a hull of composite construction may be adequate, for example using all metal stressed-skin construction in the high-pressure region around the nose and changing to more conventional structure in the less demanding areas.

3.4.2 Static Performance

The gas volume of ZRCCN would be 22,000,000 ft^3, giving a gross lift of 1,360,000 lb, the empty weight about 400,000 lb, and total ballast 85,000 lb evenly divided between emergency and maneuvering tanks. Allowance of 20,000 lb for a crew of 80 and provisions leaves a useful lift of 855,000 lb.

3.4.3 Propulsion

Propulsive power could be furnished by light-weight Diesel engines contained in the hull driving swivel-mounted propellors. Engine power of about 20,000 hp would be required, with a total fuel consumption rate of about 7400 lb/hr. A reactor of about 18,000 kw capacity would be preferred; a conventional power-type design of this size would have a volume around 8000 ft^3 and weigh in the neighborhood of 200,000 lb with minimum shielding. This is the weight of fuel which would be burned in 27 hours of flight, or 2430 miles with reserve. The remaining 655,000 lb lift capacity would be available for cargo on flights of any duration.

3.4.4 Flight Performance

TABLE III

Length	1000 ft
Diameter	200 ft
Max Width	250 ft
Max Height	220 ft
Gas Volume (nominal)	22,000,000 ft^3
Service Altitude	5,000 ft
Empty Weight	400,000 lb
Gross Lift	1,360,000 lb
Horse-Power	20,000 hp
Speed	100 m/h (max)
Ballast	85,000 lb (includes 42,500 maneuvering ballast)
Useful Load	855,000 lb
Range Unloaded	10,500 mi (10% reserve)
Payload for 6500 mile range	326,000 lb (10% reserve)

With nuclear propulsion, the last three entries read

Useful Load	655,000
Range with any load	Unlimited
Payload for any range	655,000 lb

The additional lift from upward-directed propellors would be a substantial 80,000 lb, or 280,000 lb in the alternative helicopter version.

3.4.5 Applications and Special Problems

Military applications of the ZRCCN would probably lie exclusively in its role as carrier of very large loads or troops in regimental strength. The payoff of nuclear propulsion is so great as to render it virtually mandatory. The resulting unlimited flight endurance combined with load capacity will suggest additional military uses, such as carrying long range air-to-surface missiles or aircraft.

Ground-handling problems may be great enough to demand fairly elaborate terminal facilities. Some capacity for partial deflation and gas storage would seem essential. If wind direction can be relied upon to remain reasonably constant during the turn-around time, brute-force hold-down arrangement may still be adequate.

Stop-gap measures to provide an adequate housing, at least during construction, might include providing an existing large drydock with a light roofing structure.

The following table compares the probable performance of the ZRCCN with that of the C-5A. In some regions, such as payload and range, the performance listed for the ZRCCN is that for equivalent conditions, as the C-5A is subject to some limitations which do not exist for the ZRCCN. In both cases loads and ranges are stated for 10% fuel reserve.

Parameter	C-5A	ZRCCN
Max Length	247' 10"	1,000'
Max Width	222' 8 1/2"	250'
Max Height	65' 1/2"	220'
Empty Weight	325, 244 lb	400,000 lb
Max Payload	265,000 lb	855,000 lb
Max Take Off Gross Weight	764,000 lb	1,360,000 lb
Max Landing Gross Weight	635,850 lb	1,360,000 lb
Cruising Speed	541 m/h	80 m/h
Cruising Altitude	30,000 ft	5,000 ft
Stalling Speed	124 m/h	0 m/h
Take Off Run (Max Load)	7,300 ft	0 ft
Take Off Run to 50 ft Altitude	8,300 ft	0 ft
Landing Run (Max Load)	2,350 ft	0 ft
Landing Run from 50 ft Altitude	3,500 ft	0 ft
Range with 80,000 lb Load	6,500 mi	9,500 mi
Payload for 6,500 mi Range	80,000 lb	326,000 lb
Range with 265,000 lb Load	2,950 mi (Max Load)	7,250 mi
Payload for 2,950 mi Range	265,000 lb	615,000 lb

For the ZRCCN with nuclear propulsion, the last four entries read:

Range with 80,000 lb Load	6,500 mi	Unlimited
Payload for 6,500 mi Range	80,000 lb	655,000 lb
Range with 265,000 lb Load	2,950 mi	Unlimited
Payload for 2,950 mi Range	265,000 lb	655,000 lb

3.5 ZRCVN

The ultimate development in the line of rigid airships might take the form of a large, nuclear-powered carrier of strategic bombers. The form would be that of a pair of ZRCCN's connected by a wing section, powered by large helicopter-type rotors. Cargo space is available within the wing section in addition to that within the airship hulls, and dynamic lift is greatly enhanced. The two hulls would be spaced 800 ft apart (center line separation) for an overall width of 1000 ft. The intermediate airfoil would have a span of 600 ft and a chord of 500 ft for an aspect ratio of 1.2. A maximum thickness of 90 ft would be appropriate.

3.5.1 Static Performance

The buoyant lift would be much less than that of 2 ZRCCN's because of the weight of the wing, which for the sake of argument may be taken as 900,000 lb. This round number gives a total structural weight of 1.7×10^6 lb. The drag of the wing at 100 m/h would require some 45,000 hp in addition to that of the hulls, say roughly 85,000 hp total. Applying this power to lifting rotors for takeoff would add 1.2×10^6 lb of lift for a total take-off lift of 3.9×10^6 lb. It is also possible, of course, to devote some of the wing volume to lifting gas.

3.5.2 Propulsion

An airframe of this magnitude presents a glorious opportunity for nuclear propulsion. The flight power requirement of 85,000 hp translates to 63,000 kw, which would require a sizeable but not unreasonable reactor. A conventional water reactor of this size might occupy about 30,000 ft^3 and weigh around 500,000 lb with minimal shielding.

The rotors, 50 ft in diameter, would be driven electrically. Most of them could be installed atop the wing.

3.5.3 Flight Performance

TABLE IV

Length	1000 ft
Diameter	NA
Max Width	1120 ft
Max Height	220 ft
Gas Volume (nominal)	44,000,000 ft^3
Service Altitude	5,000 ft
Gross Lift	(2,720,000 lb (static)) (3,910,000 lb (rotor thrust included))
Horse-power	85,000 hp
Speed	100 m/h (max)
Ballast	170,000 lb (includes 85,000 lb maneuvering ballast)
Useful Load	2,800,000 lb (2,500,000 fly-on)
Range	Unlimited

The very large fly-on derives from the dynamic lift of the aerofoil section. The static lift is not impressive, less than that of a single ZRCCV, because of the weight of the aerofoil. It is true that a running take-off could derive some lift from the aerofoil, but the problems would be substantial.

3.5.4 Applications

While the cargo capacity of the ZRCVN is enormous, most of it must be flown on and off. The obvious ideal cargo would consist of aircraft. The RCVN could carry 75 - 100 aircraft loaded with nuclear weapons, and stay in the air as long as desired. The ZRCVN would thus constitute a very fast aircraft carrier, immune to submarine attack, whose complement consists entirely of bombers deployed for response within seconds.

3.5.5 Special Problems

The construction of a vessel such as the ZRCVN would be formidable task, alleviated to an extent by the modular approach of using ZRCCN's as components. Ground-handling problems would be substantial due to the vessel's tremendous size. Fully-loaded flight would be like that of no other airship because of the reliance on dynamic lift; loss of propulsion power would require that most of the aircraft carried be deployed immediately. If power could not be restored; these aircraft would be faced with the necessity to return to friendly territory on their own, and the ZRCVN would take its chances as a free balloon. If power were even partially restored, the aircraft dropped could take turns hooking on to refuel until the entire assembly had reached safety.

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5. APPENDIX - Applications of Lighter-Than-Air Craft

Listed below are some of the past employments of LTA craft, and some possible future ones. Each category is divided into areas of research applications and general operations.

5.1 Past Applications

A. Research:

1. Development of radio-location and navigation equipment and procedures.

2. Search radar development:

   a) side-looking radar
   b) moving-target indicator
   c) 360° airborne radar.

3. Radar flight instrumentation development:

   a) radar altimeter
   b) Doppler navigator.

4. ASW System Development:

   a) dunking sonar
   b) towed sonar
   c) airborne MAD gear
   d) Project CLINKER
   e) Project JEZEBEL sensor implantation.

5. Aerodynamics:

   a) boundary layer studies
   b) flying wind tunnel
   c) VTOL and STOL model studies
   d) ice formation and icing control studies.

B. General Operations:

1. Scheduled passenger service.

2. Transport of mail and priority cargo.

3. Fleet support

   a) long range reconnaissance
   b) mine sweeping (towing acoustic mine detonators).

4. ASW:
    a) picket
    b) hunter-killer
    c) convoy escort.

5. Radar picket.

6. Electronic surveillance.

5.2 Projected Additional Applications

A. Research:

1. Development of nuclear propulsion.

2. Development of portable underwater sound surveillance systems.

3. Airborne stable sensor platform for:
    a) oceanography
    b) meteorology
    c) visual and IR mapping
    d) in-flight spectrography of re-entry vehicles.

B. General Operations:

1. Electronic surveillance.

2. Emitter location.

3. Airborne EW radar picket.

4. Airborne command post.

5. Carrier for ASW helicopter teams.

6. Secure transport of large, priority items.

7. Quick response transport vehicle for:
    a) military cargo and/or personnel
    b) military rescue equipment (DSRV).
    c) civil rescue and disaster relief.

8. Airborne hospital.

9. Recovery vehicle for space-craft and personnel.

10. Disarmament inspection vehicle.

5.3 Rigid Airship as a Military Carrier

Figures 6 and 7 outline the potential capabilities of the airship designs discussed in this memorandum as carriers of troops and supplies, the suffix (N) indicating the nuclear-powered versions. The performance of the C5A, the largest extant military airborne carrier, is shown for comparison. The single-trip payload capacities are shown in Fig. 6. The C5A has different curves for troops and cargo, as the troop capacity is limited by the volume and configuration of the carrying space rather than by weight considerations. These constraints do not apply to the airships, hence the same curves apply to both troops and general cargo. The right hand ordinate (Number of Troops) reflects an allowance of 232 lb per man.

The total quantity of material which can be moved in a given time also depends on the vehicle speed, as indicated in Fig. 7. In this Figure it has been assumed that the vehicles' operation will reflect that of U.S. commercial airfreight companies, namely an equivalent full-load flight time of 1,073 hrs/annum/aircraft.

These Figures reiterate the advantages of large rigid airships in regard to payload and range.

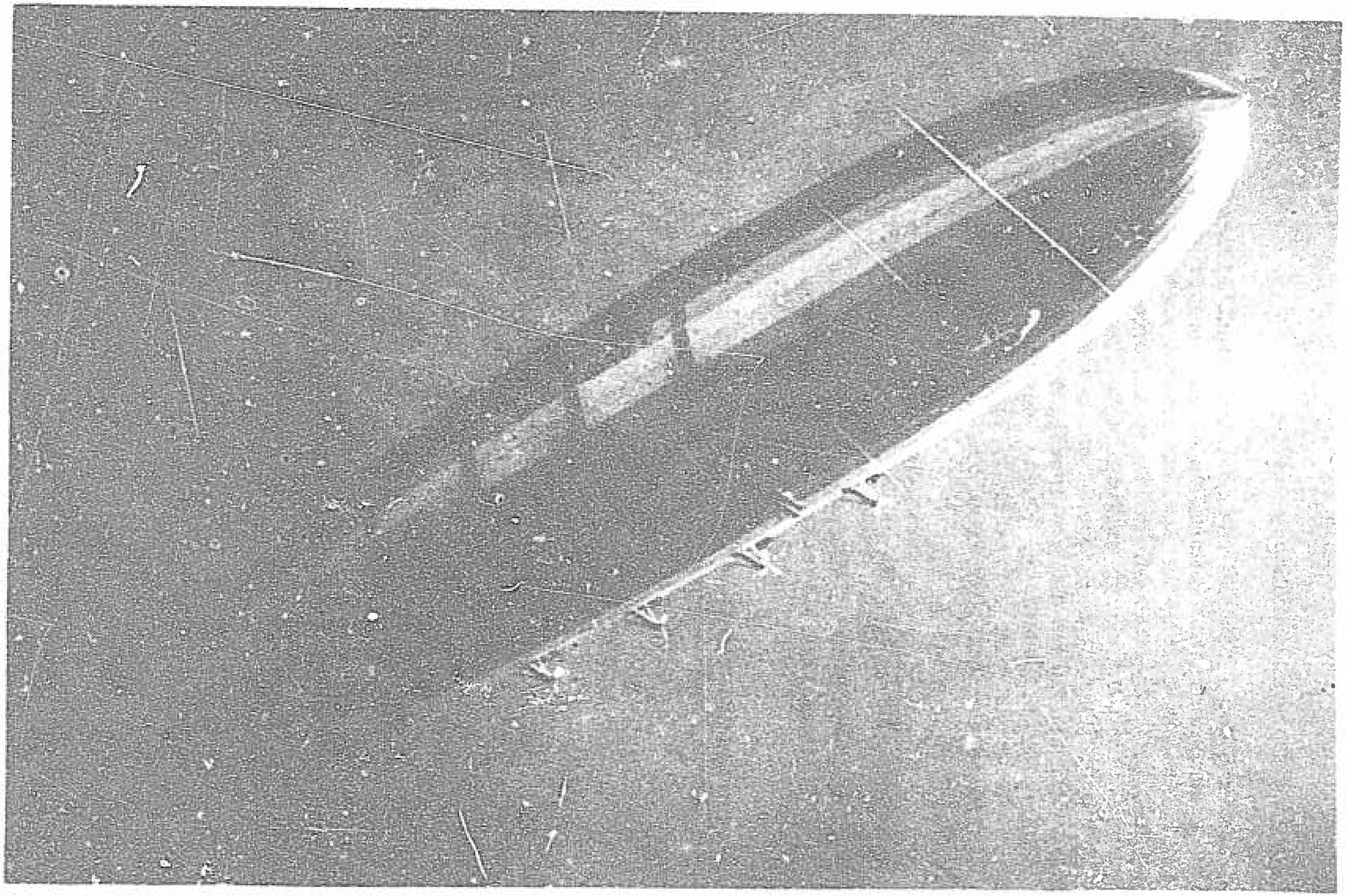

Fig. 1 - ZRS5 "Macon" in flight. Note the scout airplane about to hook up on the trapeze. The hangar door is still closed at this stage.

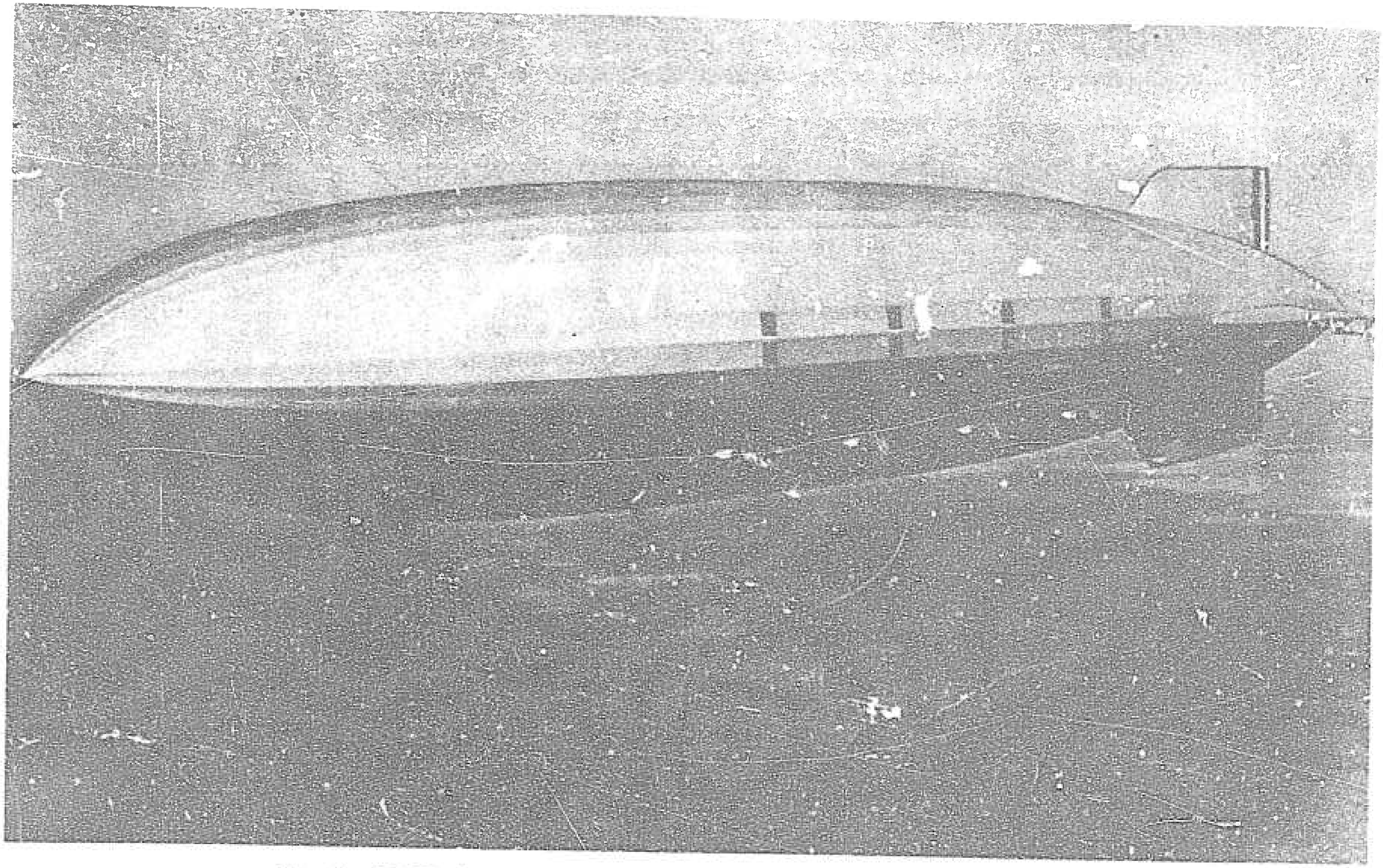

Fig. 2 - ZRS5 "macon" in flight. The trapeze is clearly seen in this view, with two scout airplanes approaching for recovery.

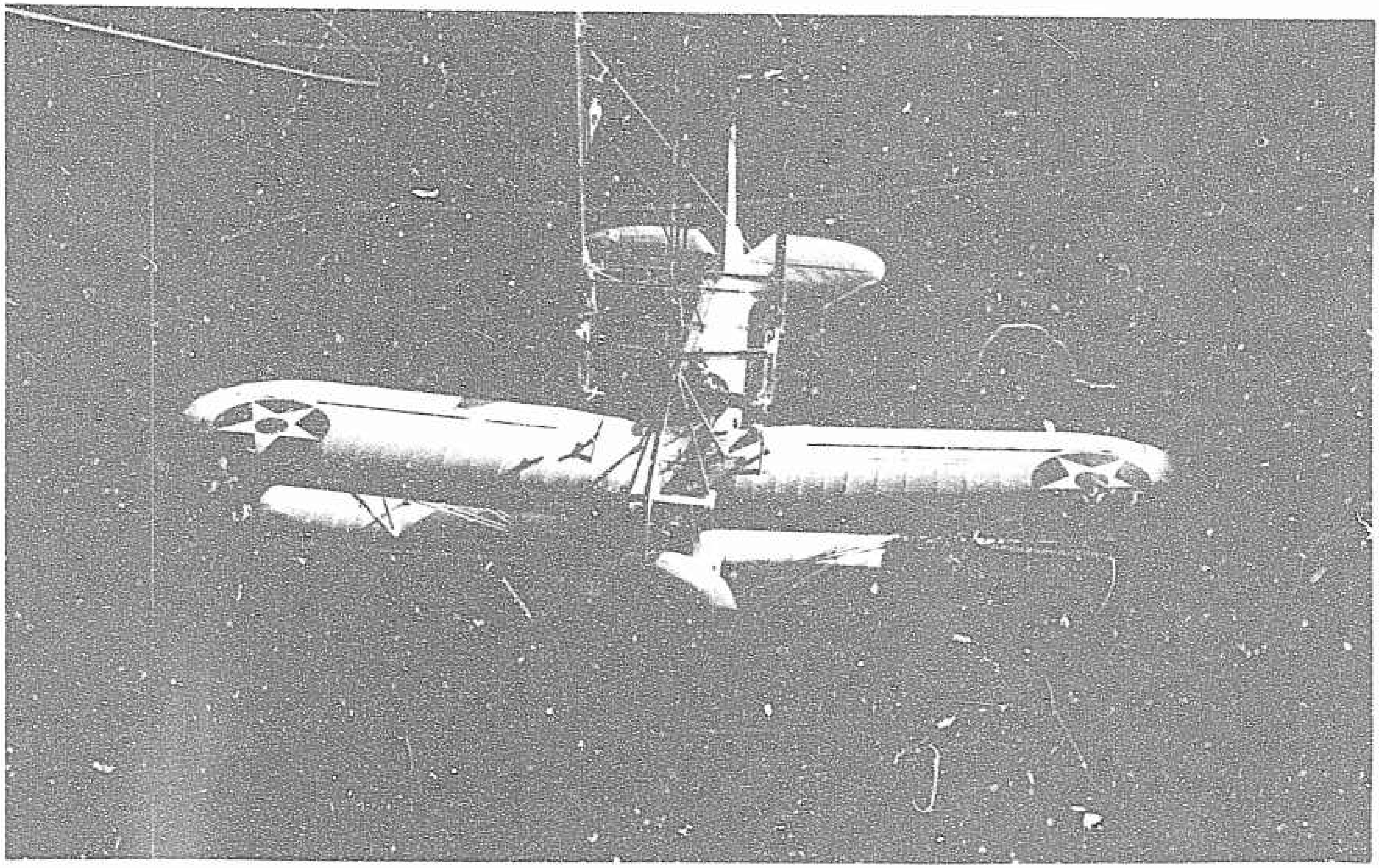

Fig. 3 - Scout airplane hooking on to Trapeze, ZRS5 "Macon." The hangar door is partially opened. When the airplane has been secured to the trapeze, the hangar door will be completely opened and the scout will be lifted into the hangar space.

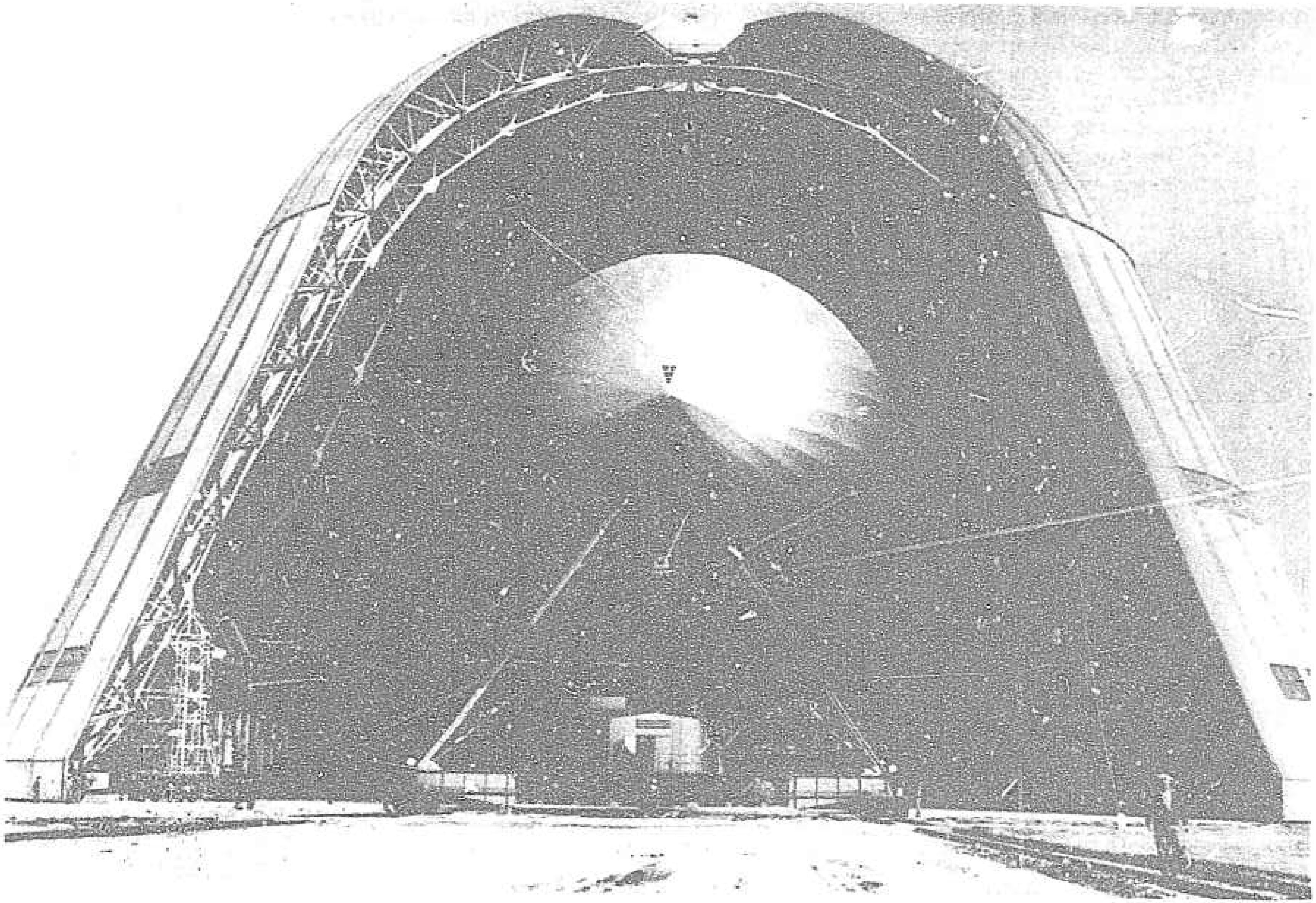

Fig. 4 - ZRS5 ''Macon'' in Hangar. ''Macon'' is about to leave Hangar No.1, Moffett Field. Note the mooring post to which the craft is attached.

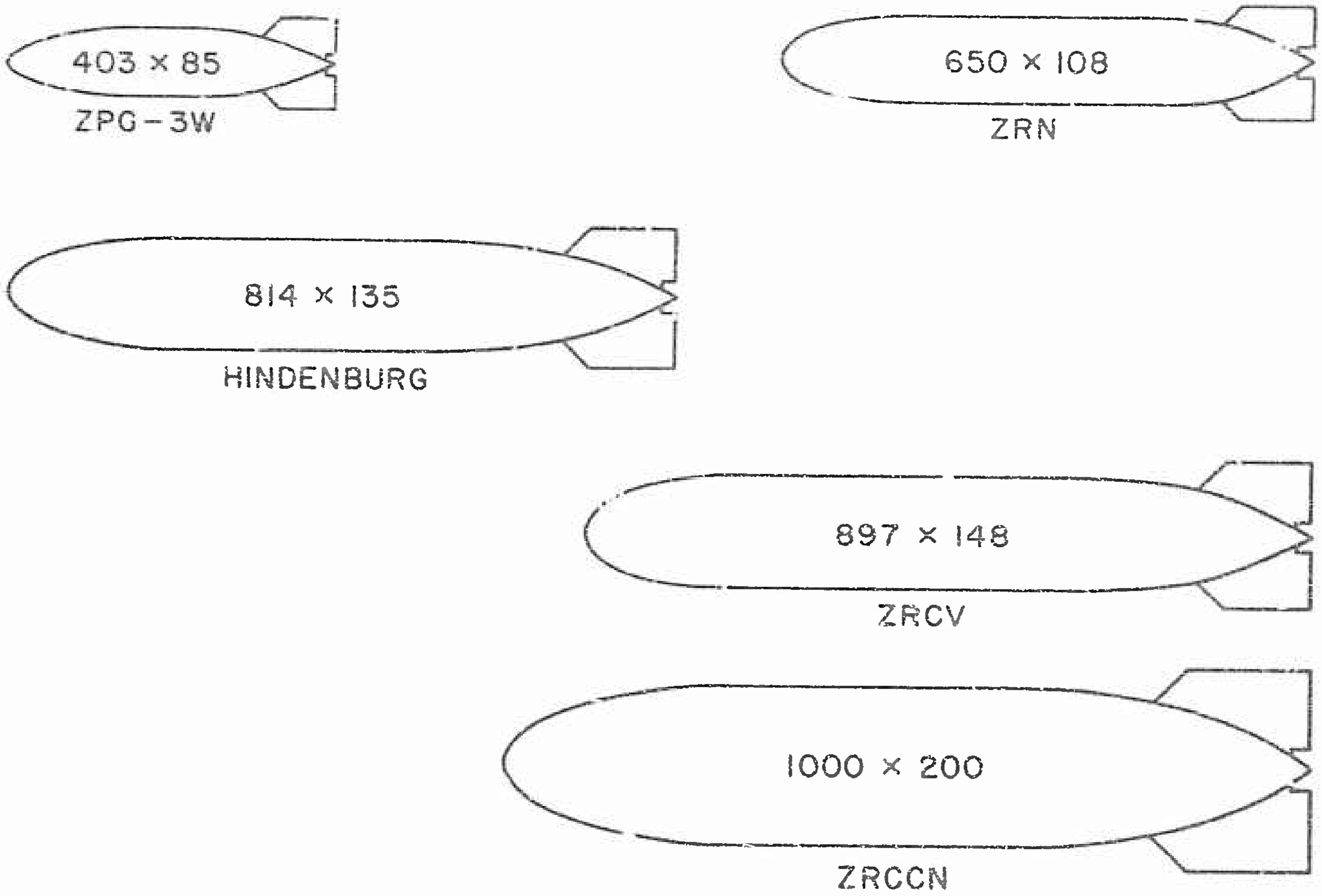

Fig. 5 - Comparative Sizes of Airships Discussed. Lengths and diameters (numbers shown in each outline) are shown to scale, but hull forms and fin details are approximate. The two on the left are airships of the past: the ZPG-3W was the largest non-rigid (blimp) ever constructed, the "Hindenburg" the largest rigid, being slightly larger than "Akron" and "Macon." The three on the left, "ZRN," "ZRCV" and "ZRCCN" are the three models discussed in this report in connection with a practical construction program.

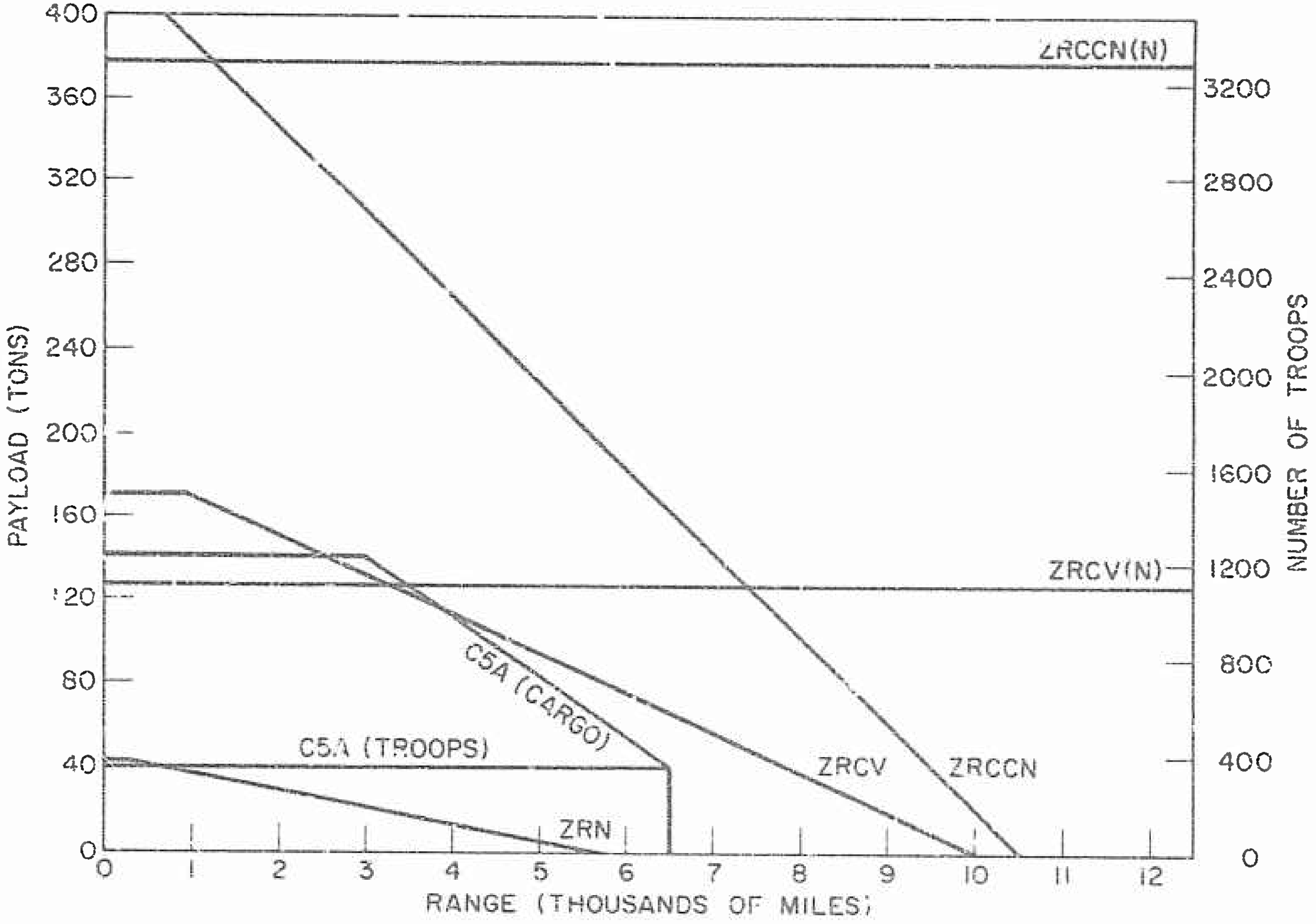

Fig. 6 - Single Trip Payload Capacities of Rigid Airships. The left-hand ordinate gives the payload in tons, and the right-hand ordinate the alternative number of troops, which can be carried for the distances given on the abscissa. The same curves apply to each ordinate except for the C5A, where the number of troops is limited by the geometry of the aircraft. The parenthesized suffix (N) indicates the nuclear-powered version of the ZRCV or ZRCCN.

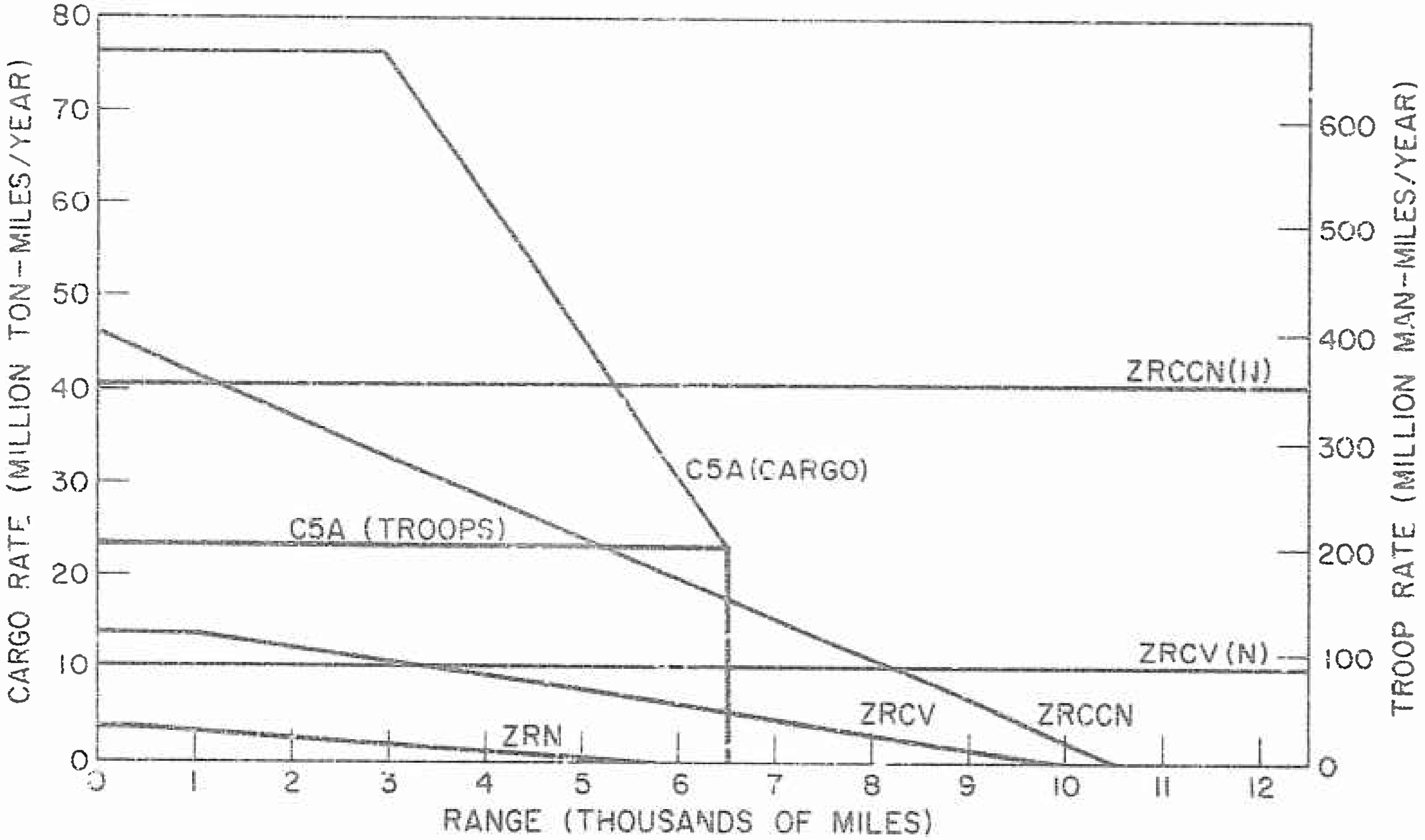

Fig. 7 - Total Material Transported per Year. The left-hand ordinate gives the payload in tons, and the right-hand ordinate the alternative number of troops, which can be carried for the distances given on the abscissa. The same curves apply to each ordinate except for the C5A, where the number of troops is limited by the geometry of the aircraft. The parenthesized suffix (N) indicates the nuclear-powered version of the ZRCV or ZRCCN. It is assumed that operations result in an equivalent full-load flight time of 1,073 hrs per year per aircraft.

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13. ABSTRACT

Lighter-than-air (LTA) craft were used with great success by the Navy for some fifty years. Consideration of the unique capabilities of these craft, particularly rigid airships, suggests that they would be well suited to some present-day Navy missions. This memorandum presents a resume of past experience with rigid airships and outlines their performance characteristics. The most prominent of these include the ability to remain airborne for great lengths of time carrying large payloads, the ability to land and take off vertically and hover, and their apparent compatibility with nuclear propulsion. In view of the considerable technical potential, a mission-oriented systems analysis of updated rigid airship designs is recommended.

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LTA - lighter-than-aircraft						