FLOATING AN IDEA

BY

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This is the second of two articles on the subject of airships, and deals with their technical history, problems, and possible developments.

Principles

Airships are nothing more than airborne submarines. Both use Archimedes principle. Both float fully submerged in a fluid. Both change their buoyancy by altering their gas volume. Each obeys similar stability and control laws. Externally at least one resembles the other. While they share common principles, the submarine and airship work in entirely different environments. Water is 850 times more dense and 100 times more viscous than air at sea level. Although the pressure increases with depth, water density remains virtually constant. In air, both pressure and density are interdependent and both decrease with altitude. In the depths of the sea, there is no wind, sunlight, rain, frost, lightning, or any of the other elements listed in the *Benedicite*. Above the waters, they are found in abundance and are for ever changing. This article looks at how airships can be made to work in our atmosphere.

In the Beginning

Airships developed from balloons and the history of balloons started one day in 1782 when two brothers, Joseph and Etienne Montgolfier, were in a hostelry near Paris watching the hot air from a fire lift the skirts of a serving wench. Doubtless they admired her ankles but also applied the principles they observed and so, in December 1782, launched their first balloon, made of papier mâché, to a height of 300 metres. The following year on 27th August, another Frenchman, Jacques Charles, floated the first gas balloon. The gas was hydrogen made by pouring sulphuric acid on iron filings. Although bigger and better balloons were subsequently made no major technical advance was achieved for another hundred years—not until the invention of the internal combustion engine which at last gave aeronauts a light, dependable source of power. Balloons could now be steered—they were dirigible. Spherical balloons, however, were almost impossible to control and so a cigar shaped ellipsoid was soon developed. This advance brought a new problem for, if a load was hung at the centre of the balloon, the ends would fold up. By the beginning of the twentieth century, three solutions to this problem had been found: these gave rise to three distinctive designs which were to be known as the semi-rigid, the non-rigid or blimp, and the rigid or Zeppelin. These three designs have remained virtually unaltered to this day and so it is worth looking at each in more detail.

The Semi-Rigid

This was the earliest of the three designs. Its solution was to have a beam underslung along the length of the balloon. On this beam was placed the load, distributed in such a way that the lift and load counteracted each other and so removed the bending moment. Eventually the beam became hollow and the load was placed inside it. It was also reshaped to fit onto the underside of the balloon rather like a keel on a ship. Probably the best known and most notorious of this type of airship were the Norge and Italia, both designed by General Umberto Nobile. As it has been so far described, this design could not have climbed very high for if it did so the pressure differential between the gas and the air would have eventually become sufficient to rupture the envelope. Partially filling the balloon on the ground to allow for expansion was no answer either, for the balloon would have been flaccid at low levels. Some means was needed to keep the pressure differential the same at all heights. The answer was found in a device called the ballonet. This was an air sack inside the balloon which could be filled or deflated by the pilot. Usually it was filled with pressurized air scooped from the propeller slip stream and deflated by exhausting the air to atmosphere. In practice there were usually two or more ballonets and they worked in this manner. On the ground the balloon was partially inflated and the ballonets were then pumped up to make the balloon firm. As the airship ascended, the gas tried to expand and so the ballonets were allowed to deflate. When the ballonets were completely exhausted the airship was said to be at its 'pressure height': climbing higher would mean either bursting the envelope or exhausting gas. To descend, the reverse process was applied. The rate of climb or descent depended upon how quickly the ballonets could be deflated or inflated.

The semi-rigid was never a popular design outside Italy probably because it had some of the worst faults of both the other two types of airships without showing any of their virtues. A diagrammatic layout of this type of airship is shown in FIG. 1.

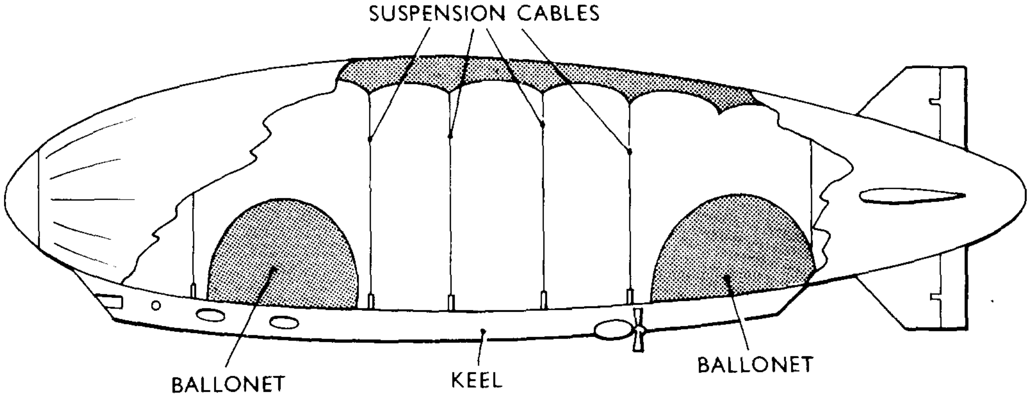

FIG. 1—DIAGRAMMATIC LAYOUT OF SEMI-RIGID

The Non-Rigid

In the non-rigid or blimp (so called because of the noise it made if flicked with the forefinger) the problem of bending was solved by pressurizing the balloon to make it a pneumatic beam. The pressure required was surprisingly low, being no more than 1/100th to 1/200th atmosphere. The load was hung on cables inside the balloon which were attached to the top of the envelope and fanned out along its length to help distribute the load. Like the semi-rigid this design also needed ballonets. The diagrammatic layout is shown in FIG. 2. This design had three advantages and two disadvantages. The first advantage was that it could be made smaller than either of the other types. Useful craft as small as 60 000 cubic feet (3720 lb lift) have been built. The second was that it was a very forgiving design. If it experienced an excessive load from say a side gust or by hitting the ground, then the balloon would temporarily deform only to resume its original shape once the load was removed. The third advantage was that it was cheap and easy to build. The first of the disadvantages was that it was less aerodynamically efficient than the rigid. This was because the designers had to compromise between the craft being a pressure vessel, where the ideal shape would be a sphere, and the long thin aerodynamically efficient configuration. The compromise resulted in a dumpy

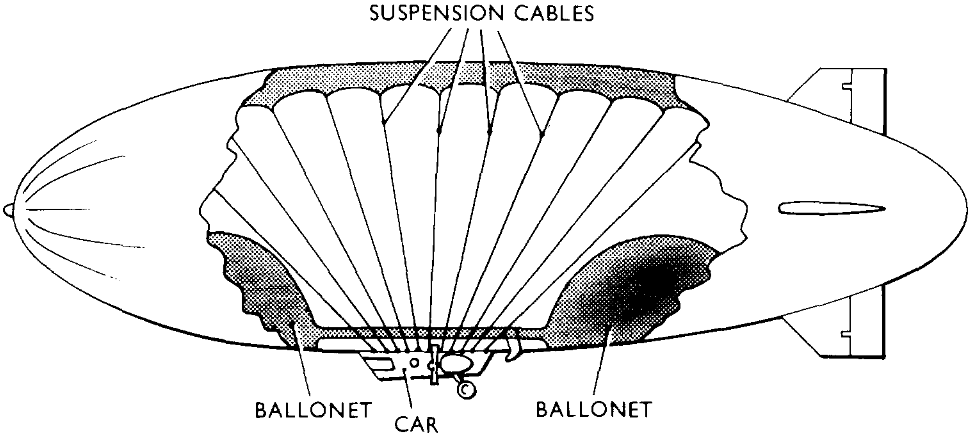

FIG. 2—DIAGRAMMATIC LAYOUT OF NON-RIGID

craft with a length to diameter ratio of about four. The second disadvantage was that it had an upper size limitation created by hoop stresses. As the size increased then so did the diameter. A 1·5 million cubic foot craft, for example, had a diameter of nearly 100 feet. Thus, although the pressures may be low, these large diameters gave rise to large hoop stresses. The major point of weakness was not the fabric itself but the bonding between the fabric sheets. The better the bond then the bigger could be the airship. Currently the maximum theoretical size for non-rigids is about 2·5 to 3 million cubic feet (155 000 to 186 000 lb lift).

The Rigid

This design was the brain child of Count Ferdinand von Zeppelin. His solution was to build a rigid, aerodynamically-shaped cage of longitudinals and circular frames into which were placed a number of roughly cylindrical balloons graduated to fill the available space. The rigid structure took the loads and the balloons provided the lift. The whole was covered with fabric. Ascent was achieved by dumping ballast and to descend again the pilot vented gas. FIG. 3 shows a diagrammatic layout. The advantages of this design were that it was more aerodynamically efficient than either of the other designs and, in theory at least, could be built to any size. The disadvantages were that

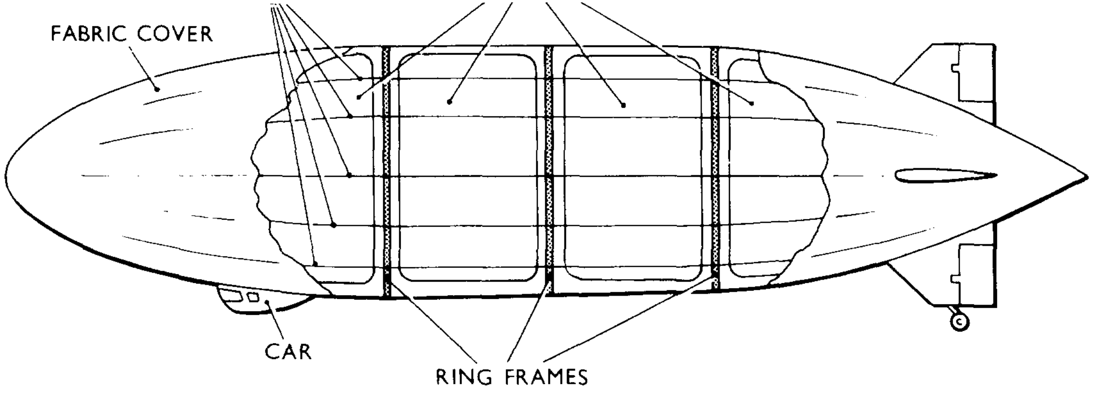

FIG. 3—DIAGRAMMATIC LAYOUT OF RIGID

it was structurally heavy and was uneconomical below about 600 000 cubic feet (37 000 lb lift). It was also a wasteful design in that it dumped gas and had to carry extra ballast to the detriment of the payload. To be at all efficient airships of this design had to be constant altitude machines, releasing ballast on the initial ascent and venting gas only when they eventually had to land. A much more important defect was that this design was structurally unsound. It was too inflexible and the longitudinals were prone to Euler failure. Airships, such as the R38, R101, the Akron, Macon, and Hindenburg, were all of this design. It must be stressed that not all of these crashed because of structural failure; that so many of them did, however, highlights a fundamental weakness in the design.

The Legacy

When these three types of airships last flew—the semi-rigids in 1928, the rigids in 1938, and the non-rigids in 1961 (although to be accurate Goodyears still operate small non-rigids, such as the 'Europa')—they left a legacy of unsolved or, at best, only partially solved problems. These could be listed under the following headings:

Drag
Stability and control
Buoyancy and lift
Structures
Weight
Production
Ground handling
Hangarage

During the intervening years, there have been significant technical advances. Modern technology can be used either to remove many of those old problems or, at least, to reduce them to a point where they are acceptable. Some problems, of course, can never be solved because of the very nature of the airship which will always be large, slow, and operate best at low altitudes.

Drag

Although airship designers were well aware of the advantages of streamlining, they had problems in maximizing lift whilst keeping drag to a minimum. Lift was proportional to volume, while structural weight varied with surface area. To get the maximum useful lift, it was important to keep the surface area to a minimum; yet the aerodynamists called for long thin shapes which had large surface areas. The result was a compromise with a length to diameter (fineness) ratio of about 8 for rigids and 4 for non-rigids. With this shape, it was found that the airflow was linear for the front 15 per cent. of its length, turbulent over the next 70 per cent., and separated over the last 15 per cent. Minor improvements to the drag could be obtained by improving the design of the overall shape, but any significant reductions can be found only by inducing the air flow not to separate over the tail end. Now, there are a variety of methods available. The simplest of these is to re-excite the air with vortex generators or, alternatively, the air flow may be induced to the surface by use of sucking or blowing devices. Probably the most fruitful method, however, is to fit a tail propeller. Experiments suggest that a tail propeller could reduce the fuel usage by up to 15 per cent. and good body design could reduce it by a further 5 per cent., making a total saving of 20 per cent. There is a price to pay, however. In order to keep the airship trimmed, the load would have to be redistributed to counter the weight of the tail propeller. This in turn would increase the bending moment and hence structural weight. Whether it is worth fitting a tail propeller or not depends upon whether the fuel weight saved by so doing is greater than the increased structural weight.

Stability and control

Past airships had some rather nasty stability and control idiosyncrasies. For a start, they were usually uncontrollable at speeds below 15 knots. This made take-off and landing a risky affair. A tail propeller would improve the air flow over the tail surfaces, but it would still not give the control in the hover essential for future naval airships. This can be provided by fitting vectoring-thrust variable-pitch propellers on either side of the craft at about the centre of gravity. Fortunately, a large amount of work was carried out on vectored propellers during the 1960s and 1970s and results are readily available.

Another idiosyncrasy was the airship's response to control movements. Designers, to keep the weight down, made the tail surfaces as small as possible and at the same time put them well aft to gain the maximum authority. The result was that they were partially buried in the separated air-flow cone. As a result, airships were seldom, if ever, statically stable although they were dynamically stable. The control surfaces also were partially buried in the separated air-flow cone; thus, even if the pilot applied full rudder, the ship's movement was initially sluggish. As the craft turned, however, more of the control surface was exposed to the free air flow and so became more authoritative. Indeed, its authority could eventually be so great that the airship's structure was endangered. The pilot had therefore initially to apply full rudder and then ease off as the turn progressed. The airship's behaviour varied with height, speed, and load, and, needless to say, no two aircraft behaved the same. Pilots could only learn about a particular aircraft's behaviour by experience. This idiosyncrasy can be eliminated by again fitting a tail propeller and so removing the separated air cone.

Buoyancy and Lift

In one respect airships are the ideal aircraft because a given quantity of gas will lift a specified weight to any height up to the stratosphere, provided the gas is allowed to expand freely. Regrettably, infinitely expanding envelopes have yet to be invented and, if they were, they would present horrific stability and control problems. For the time being, we are stuck with fixed volume airships.

Buoyancy and lift problems are created by a large number of outside influences, most of which are beyond the pilot's control. The weight of the aircraft itself will vary with loss of fuel or accretions of snow. Ambient pressures, temperatures, and densities change not only with height but also with the changing cyclonic weather. Solar radiation will heat the gas and try to expand it. There are thermals and vertical airflows associated with thunderstorms and fronts. The best that can be done is to fit the airship with a variety of methods of counteracting these influences. Fortunately, there are a variety at hand.

The first problem is the change in all-up weight caused mainly by fuel usage. There have been many solutions put forward in the past, not all of them practicable. One was to condense the water from the diesel exhaust but the equipment to do this was heavy. Another was to condense water from out of the clouds but this had its disadvantages in fine weather. Yet another was to use a fuel/gas mixture, called Blaugas, which had the same density as air. One of the more popular methods was to take on water ballast from the sea or some convenient lake but this took time and presupposed that the craft was at low altitudes. A more serious contender for weight compensation was to 'fly' the airship. The airship hull is a crude aerofoil, but it is very large and so a substantial lift could be gained by inclining it to the air flow. Increases in lift of up to 10 per cent. of its static value were possible. The advantage was that the extra lift could be varied in flight; the disadvantages were that extra drag was generated and a short running take-off was necessary. Vectored thrust would be a modern method of lift control and another would be to heat the gas, from the turbo-prop. efflux, and so decrease its density.

The second main problem was that of height control. The airship's pressure height could be varied by the amount of gas put into the balloon whilst it was on the ground. If the balloon was almost filled with gas, it could lift a large load but not very high. Alternatively, if the balloon were only partially filled, it could fly higher but lift less. The ultimate height to which it could fly depended on the size of the ballonets in relation to the balloon. The trouble with this method was that once the airship was airborne the pilot had no means of trading off altitude against lift. It was suggested that compressors and gas bottles could be fitted but this method proved to be too heavy. Another, though less versatile method, may be to use the fact that the gas is naturally compressed or expanded as the airship changes altitude. If there were a large container in the hull that could be filled with some of the gas at sea level, then this gas could be contained and restricted from expanding during ascent. Thus, greater heights could be achieved with no loss of lift at sea level. Where to find a suitable container will be explained in the next section.

It is now possible to visualize a complete sortie pattern. As the airship descends to refuel, it fills its ballonets. Once refuelling starts, the gas is heated and the ballonets exhausted. Any differences between lift and load can be compensated by using the vectored thrusters. Once refuelling is complete, the airship climbs away to its operating altitude and, as it does so, simultaneously allows the gas to cool and uses aerodynamic lift to take up the load. Changes of air density during the sortie can be compensated by heating the gas, and vertical air currents can be counteracted using the vectored thrusters.

Structures

None of the three types of airships—neither the rigid, the semi-rigid, nor the non-rigid—were structurally ideal for each had good and bad points. The aim would be to remove the bad points and achieve a design that was aerodynamically efficient, strong, lightweight, and cheap. Probably there are many answers but, for demonstration, just one is suggested. Start by rejecting all three designs and return to basic principles. Strong lightweight designs concentrate the compression, bending, and torsion loads into one set of members and the tension loads into another set. For our purposes, probably the most efficient structure for the compression, bending, and torsion loads is a thin-walled column strengthened with transverse frames to reduce Euler buckling. The best members for tension loads are ropes. Returning to the thin-walled column, there is considerable knowledge about these gained from the study of aircraft fuselages. It is also known that there is an optimum diameter for minimum weight. For airships this diameter is large but not as large as the hull has to be to contain the gas. Thus the column can be inserted into the envelope to become, as it were, a backbone. The shape of the outer hull could be made aerodynamically efficient by building a structure of longitudinals, using ropes, and hoops attached to the central column, again using ropes, rather like bicycle wheels. The envelope covers and is attached to this outer structure so that it too can take some of the tension loads. The result should be a strong internal structure with a flexible exterior. The gas pressure need be kept no greater than ambient and is controlled by use of ballonets. This structure is shown at FIG. 5. It is unlikely that this design will be as structurally efficient as the smaller non-rigids and so the blimp may still be the best answer up to about 1 million cubic feet (62 000 lb lift). Incidentally, referring back to the previous section, we now have a gas container in the form of the central compression column.

Weight

Advocates of the airship point to the many ways in which modern technology could reduce the weight of 1930's craft. Heavy diesels have lightweight counterparts or turbo props to replace them. There are new metals and structural materials with far better strength to weight ratios than anything known half a century ago. There are improved fabrics and better methods of reducing gas losses. Fly-by-wire systems will replace the old control runs. There are better instruments and lighter components, automatic control methods and a whole list of other improvements. Optimists suggest that future structures would be up to 30 per cent. lighter than their counterparts of fifty years ago. But a word of warning: many modern materials and components are expensive and any ultra-light structure would be costly. Whether it is cost effective to fit these items depends partly on operational requirements and partly on whether the savings in fuel costs justify the initial expenditure. When fuel was cheap it was difficult to justify the use of expensive materials but as fuel costs rise then it is less difficult so to do.

Production

Airships in the past were hand crafted as were aircraft of the same period. Manufacture was long and expensive, even in a period when skilled labour was relatively cheap. Production methods have come a long way since then. Good design will mean that parts can be precut ready to fit and components can be pre-fabricated rather than being built up in the stocks. The use of modular parts can cut down costs even further. In short, current production methods and design should radically reduce costs, building times, and the need for skilled labour.

Ground Handling

The spectacle of handling parties of hundreds are a thing of the past. By the 1950s handling teams in the United States had been reduced to about a dozen or so, depending upon the weather. They invented the mobile mooring masts and heavy tractors, rather like flight-deck tractors, fitted with constant tension winches. Once an airship was moored to its mast it was usual to move the airship and mooring mast together and so further reduce the size of handling parties. In the future vectored thrust will make airships even easier to handle during take-off and landing. Most of the ground handling problems, remarkably enough, will be as a result of the airship's good serviceability. If past experience is to be a guide, future availability will be in the order of 80 per cent. and there will be no need for frequent movements of craft in and out of hangars. Most work will be in the open. This will mean that suitable ground equipment will have to be developed to reflect this style of maintenance. Hopefully this should present no major difficulties but it will require some thought. Most civilian air lines maintain their large aircraft in the open and thus much of their ground equipment should easily adapt to airship maintenance. The only major difference between the alfresco maintenance of aircraft and airships is that the latter, because they are at mooring masts, will be always moving. Special equipment and routines will be needed for replenishment, provision of ground supplies, and removal or replacement of large components.

Hangars

It should be necessary to hangar airships only for major repairs and major routine maintenance. This will probably be about as frequent as ships go into dry dock. It will not be necessary to have large numbers of hangars, and these can be concentrated at second line repair bases. The process of hangaring airships has normally been beset with dangers, especially when there are side winds or the conditions are gusty. Besides which, hangars themselves, because they are large, invariably create their own fluctuating eddies which only add to existing dangers. One way to reduce the dangers would be to winch the airships down through the top of the hangar and so reduce the transit times. Such hangars would have retractable roofs. Eddies and local turbulence may be reduced by partially burying the hangars themselves and having high earth banks around them, or alternatively even convert disused dry docks.

Future Operational Airships

Many of the problems which bedevilled previous designers, maintainers, and operators can now be solved and practicable airships could be produced without the need of very much research and development effort. This is not to say research and development is not necessary, but it need not be applied until after airships have demonstrated their worth (unlike most new ideas where the R. and D. bill comes first). The process of introduction will be first to build a trials craft to demonstrate the airship's effectiveness in different roles. This can be of a relatively simple design based on the non-rigid construction. This stage will need almost no R. and D. at all since it will be resuming development from where it ended over twenty years ago. The next stage will be to build airships for specific roles. As far as the designer is concerned, these would be divided into three separate classes. The high-altitude airship for use in AEW roles, the low-level airship for anti-submarine and mine-warfare roles, and a general-purpose craft for most of the other roles, including logistic support and off-shore policing. The general-purpose airship should not present any special design difficulties but the other two might, and these are now discussed more fully.

The High Altitude Airship

This craft will tax the designer to his limits. The probable requirement would be for it to operate at about 15 000 feet. At this height, the air density is 63 per cent. of its sea level value, winter temperatures can drop to -20°F, and winds sometimes gust to 150 knots (95 knots IAS). These conditions call for a large, strong, powerful lightweight craft that is not easily detectable by radar. Sophisticated non-metallic materials would probably be used and it is likely that it would have a central beam of Kevlar composite with Kevlar ropes and fabric covering. It will also probably have a tail propeller to give it

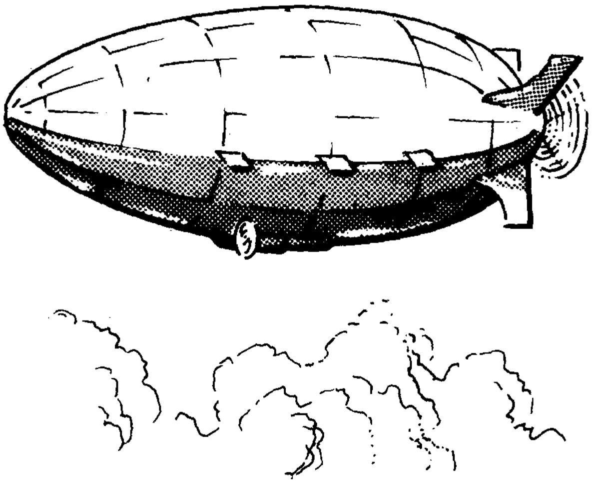

FIG. 4—ARTIST'S IMPRESSION OF HIGH-ALTITUDE AIRSHIP

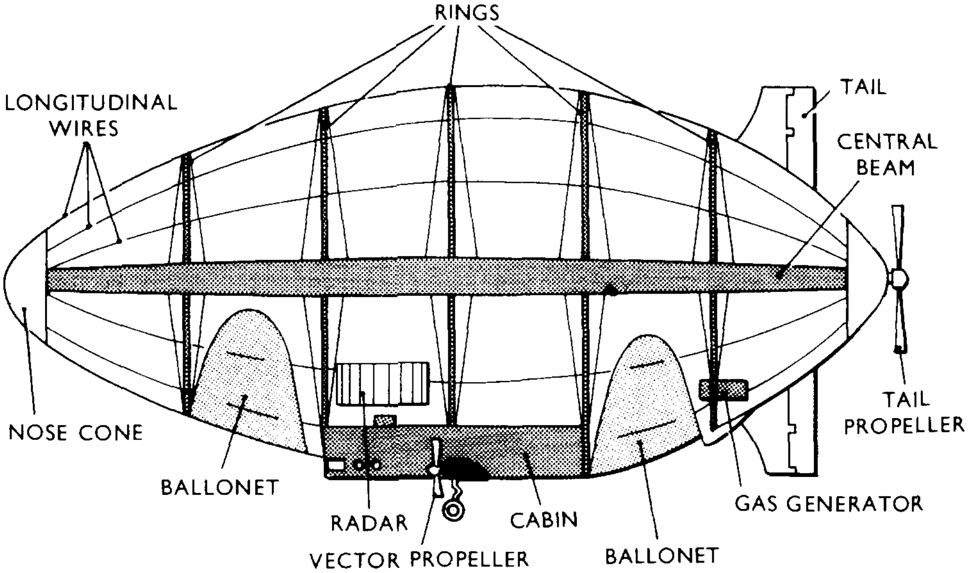

FIG. 5—DIAGRAMMATIC LAYOUT OF HIGH-ALTITUDE AIRSHIP

the necessary aerodynamic efficiency (to combat the high winds) together with vector thrusters on either side (to give additional boost at high speeds and control whilst replenishing). The radar, whose aerial can be far larger than anything carried in an aircraft, can be slung underneath but immersed in dry inert helium. FIG. 4 shows an artist's impression and FIG. 5 shows a diagrammatic layout.

The Low Level Airship

This craft will operate over the sea at heights only a fraction of its length. The main problem will be to prevent it hitting the water. There are four devices which could be used: two passive and two active. The first of the passive methods is to give the hull a flat base, which will act like a pneumatic cushion. The closer it gets to the surface the greater will be the resistance to it sinking further. The second of the passive devices is to fit long hollow columns vertically under the craft. Normally these would be clear of the water but should the craft get too low the columns would come into contact with the water and so exert an upward buoyancy force. Of the active methods, vectored thrust is an obvious candidate but sometimes this may be too slow and a second method might be necessary. One possible answer would be to fit large control surfaces into the slip stream of the vector thrust propellers which can deflect this flow by Coanda effect and so give the fast response necessary for minor alterations. An artist's impression and layout of this type of craft are shown in FIGS. 6 and 7.

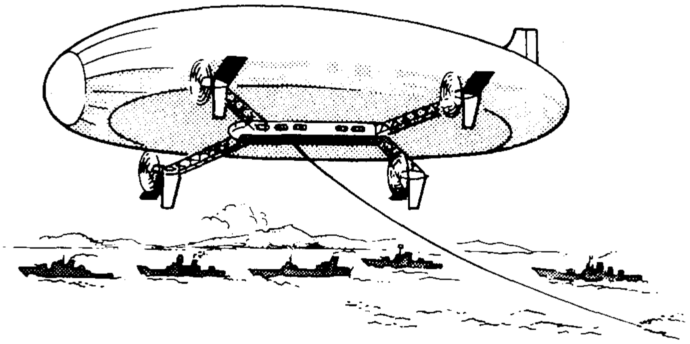

FIG. 6—ARTIST'S IMPRESSION OF LOW-LEVEL AIRSHIP

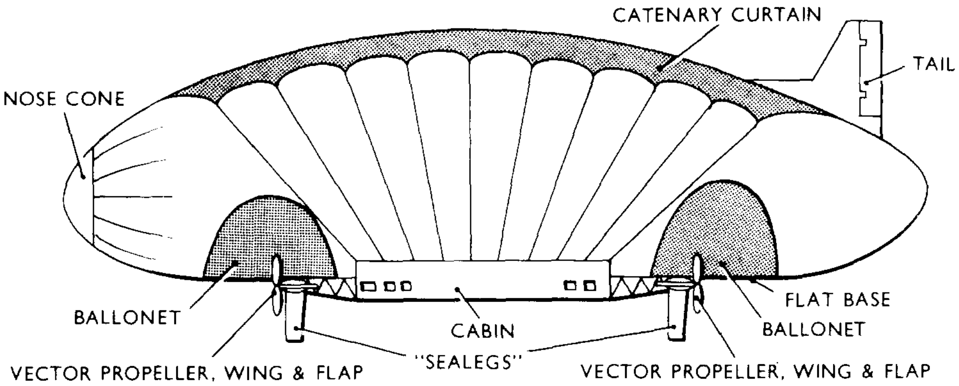

FIG. 7—DIAGRAMMATIC LAYOUT OF LOW-LEVEL AIRSHIP

Conclusions

These two articles have unashamedly advocated the airship. They have proposed a variety of roles, have shown that airships should be capable of operating with the Fleet, that many of the technical problems which beset it fifty years ago can now be resolved, and ended by showing that the airship is adaptable and can be designed to meet a variety of operational needs. On the other hand, these two articles have also highlighted the airship's shortcomings and limitations. The purpose has not been to eulogize this craft but to give it its proper place along with other aircraft. Each type of aircraft has its advantages and drawbacks. If speed and altitude are important then choose an aeroplane but in so doing one must accept its poor endurance and pay the cost of long runways and expensive maintenance. Should agility, the ability to hover, and to operate out of confined areas be paramount requirements, then select the helicopter but acknowledge too that it has poor endurance and poor pay load, and can not fly very high. On the other hand, if endurance and good pay load are essential, then the airship is the best option albeit it is slow and has a limited altitude. Each craft has its own unique characteristics, its own value, its own place to fill in the vehicle spectrum. With so few types of craft from which to choose, it would be foolish to reject any of them.

Postscript

So far the discussions have been confined to ways in which the Royal Navy can use airships. But there are others who may also find a use for them. They may be conveniently divided into Government Agencies and Commercial interests.

The police would probably find the greatest use of airships. They could be used for overhead patrolling of difficult areas such as are found in Northern Ireland. Crowd and traffic control would be another use. Disaster relief is yet another and it is here that Japan are showing particular interest. The Coast Guards would find uses for them in shipping lane control and for checking ships violating oil pollution laws. Immigration authorities could use them for patrolling in places such as Hong Kong and on the Mexico/USA border. MAFF might find them convenient to patrol forests, survey crops for disease, or to enforce fishing laws. Many of these tasks could be done with small remotely controlled craft fitted with TV cameras and light itensifiers.

Commercial uses are just as varied. Airships could be used to survey inaccessible areas or to take men and equipment to them. Bulky or difficult loads could be taken directly to their destination rather than suffer delays by ship, rail, and road, or the expense of carriage by aircraft. They could be used for TV coverage of sporting and ceremonial events. Indeed the Goodyears blimps have been used for TV coverage of golfing championships in preference to helicopters because they are a more stable platform, cheaper, and quieter. Tourism may be another market. Weather willing, a three-day tour of the British Isles at 2000 feet could be an attractive idea. Some people are now suggesting that, with the rising price of fuel, more people would be willing to sacrifice the speed offered by the aircraft for the economy given by the airship. Yet other people are looking to the airship as an alternative form of transport in already congested areas, such as exists around docks. Their uses are endless.

With so many uses, why are there no airship industries? The answer is to be found by re-examining the list of potential users. No one group would want a large number of craft and each would want the craft to be to its own specification. Police would look for small unmanned craft while a tourist company would seek for something that can carry a hundred people and their luggage. Some, such as disaster authorities, would be reluctant to buy an airship at all but would be happy to hire one when an emergency arose. The market is potentially large but very fragmented and no one group has a big enough demand to justify 'going it alone'. This is a familiar situation. There have been many good ideas stuck on the shelf awaiting money to develop them. When the money eventually comes the ideas suddenly become financial successes. This may well be true of airships.