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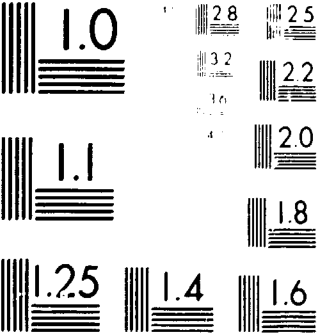

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THE AIRSHIP: PAST, PRESENT AND POSSIBLE FUTURE*

by

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INTRODUCTION

1. This paper has been prepared as a background document for the UNIDO exchange of views meeting on the implications of technological advances in lighter-than-air systems technology for developing countries, Vienna, 19-22 October 1981.

2. It is designed to present those who may not be too familiar with past and present LTA developments with a short overview and to list some of the problems and opportunities associated with the development of operational airships.

3. The paper has five parts. Part 1 is devoted to the definition of essential concepts and to the main distinctions used in classifying airship types. Part 2 contains a short history of important LTA developments from the first use of the balloon for free flight in the 18th century up to the late 1950s. The experience gained in this period is briefly reviewed in part 3 as is some of the mainly theoretical work which was undertaken on airship development after the Second World War. The main attributes on the airship are defined in section 4 and the possible range of applications of LTA technologies are briefly discussed as are some of the development programmes now planned or underway. The paper is concluded with a short discussion on the possible relationships between developing countries and advances in LTA technologies.

4. The paper has no pretentions as to completeness but is rather deliberately selective in its treatment of some of the themes covered.

I. SOME DEFINITIONS

5. An *airship* consists of an elongated gas-filled streamlined hull with propulsive power, stabilizing surfaces and altitude and directional control. To distinguish the airship from a simple balloon, which has similar aerostatic characteristics but no propulsion or steering system, it is known as a dirigible balloon, or simply a *dirigible*. Dirigibles are classified according to their structural type as non-rigid, semi-rigid or rigid.

6. *Non-Rigid Airship:* the body consists of a highly impervious fabric envelope of lifting gas and air. The envelope maintains its form by the interior pressure of both the lifting gas and air, the latter being contained in variable volume compartments called *ballonets* which can be inflated and deflated to compensate for changes in lifting gas volumes.

7. *Semi-Rigid Airship:* similarly depends upon internal gas and air pressure to maintain its envelope form but has, in addition, a supporting structural keel extending longditudinally along the bottom of the envelope.

8. *Rigid Airship:* maintains its shape through a rigid structural framework indepedent of internal gas pressure. The framework has an outer cover (generally an impervious fabric) and, on the inside, individual lifting gas cells are placed throughout the ship's length, an installation comparable to the watertight compartmention of water borne vessels.

9. Non-rigid airships are frequently referred to as *'blimps'*. Blimps and semi-rigids are known as *pressure airships* because of the pressure differential used to maintain envelope rigidity. This distinguihes them from the rigid airship which maintains its shape through a rigid structural framework independent of internal gas pressure.

10. Contol over flight in pressure airships is usually achieved by filling or emptying the ballonets contained in the craft's hull. The ballonets are usually full when the airship is on the ground. As the craft ascends, air escapes through valves, deflating the ballonets to make room for the expanding gas - today usually the inert helium - within the envelope. Ballonets permit control of an airship without consumption of gas and their capacity dictates the maximum altitude which can be reached. Even quite small vehicles, in which the ballonets occupy a relatively small part of the hull volume, have a ceiling, or *pressure altitude*, of some 2,600 metres (10,000 ft).

11. Balloons and airships are frequently referred to generically as lighter-than-air *(LTA)* vehicles to distinguish them from heavier-than-air craft which, like the aeroplane, do not derive their performance from aerostatic principles.

II. HISTORICAL SKETCH (1)*

12. The lighter-than-air adventure started in the second half of the 18th century. In April 1783, some 70 years after the Brazilian priest Bartolomeu de Gusmão had first demonstrated the feasibility of hot air flight at the court of King John V of Portugal, Etienne and Joseph Montgolfier first tested a hot air balloon. They demonstrated it publicly two months later, their *Montgolfière* rising to about 1800 m. Their success resulted in a summons to Paris where King Louis XVI could see the Montgolfiers' invention for himself. In September the first living creatures ever to take to the air - a sheep, a duck and a cock - were loaded into the balloon's basket and, under the royal gaze, launched into the wind. They climbed to approximately 550 m and travelled some 3 km in 8 minutes. History does not record the reactions of the first air travellers although the cock looked distinctly the worse for wear, possibly the result

* Figures in parentheses refer to references at the end of this paper.

of having been trampled on by the sheep.

13. The Montgolfier brothers constructed another balloon, emblazoned with the Royal cypher. In this vehicle François Pilâtre de Rozier made a tethered flight of 26 m in October 1783, remaining airborne for about 4½ minutes. A month later the young Rozier and the Marquis d'Arlandes became the first men to be carried by free flight in a balloon. They rose from the Bois de Bologne and were airborne for 25 minutes. Reaching a height of 450 m, they covered a distance of 8.5 km. Rozier also has the distinction of becoming the first man to be killed in balloon flight when the vehicle that was carrying him and a companion burst into flames while attempting to cross the Channel in June 1785.

14. The military applications of the balloon were immediately obvious. The French Republican army became the first to use them for this purpose when it employed them for reconaissance duties in Belgium in 1794. During the 19th century, a period which saw the widespread use and rapid development of balloons, they were used by the Austrians (the first to use the vehicle for bombardment), by U.S. forces during the Civil War, by the Brazilians in the Paraguyan War, and by the British in the Boer War and in the Sudan. They were to play a special role in the Siege of Paris during the Franco-German War of 1870-1871. Cut off from the rest of France, the nation's beleagured leadership used balloons to communicate with the outside world. When the siege started, Paris had only five balloons. Steps were quickly taken to mass produce them. By the end of the siege the mass produced balloons, piloted by circus acrobats and sailors selected by virtue of their head for heights, had made 66 flights and carried 155 passengers and crew and some 2.5-3 million letters. Infuriated by the success of the balloons, the Prussians went on the develop the first anti-aircraft gun.

15. As useful as the balloons were, they remained victims of the wind. Between 1783 and 1850 numerous unsuccessful attempts were made to steer and propel balloons using primitive forms of manual power. The breakthrough came in 1851 when Henri Giffard, the French inventor of the steam engine, developed a 3 h.p. engine which could drive a propellor. The following year he mounted it on a 43 m long envelope. He succeeded in travelling 27 km at 8k.p.h. in what was to be the first true airship flight.

16. Developments followed fast. In 1872 Austrian Paul Haenlin made the first flight in an airship powered by an internal combustion engine. The four cylinder Lenoir gas engine he used drew its fuel from the craft's envelope. In 1883 Albert and Gaston Tissander built and flew the first electrically powered airship. Charles Renard and Arthur Krebs followed a year later. They attached an 8 h.p. electric motor to a 50 m bamboo trelliswork envelope covered in Chinese silk and completed a circular course of 8 km at 23 k.p.h. in the first fully controlled power flight in airship history.

17. A few years later, in 1887, David Schwarz built the first rigid airship, consisting of an aluminium frame covered by aluminium sheeting. His was also the first airship to be powered by a gasoline engine. A year later Karl Wölfert built and flew another gasoline powered airship, making use of a Daimler motorcycle engine.

18. France and Germany became the leaders in airship design and construction. In 1898, Alberto Santos-Dumont, a Brazilian who lived in Paris, completed the first of 14 non-rigid, gasoline powered airships. These he used to make a number of record breaking and unusual flights - he was the first to pilot a craft around the Eiffel Tower - which gained him international acclaim.

19. At the same time, Count Ferdinand von Zeppelin, perhaps the most legendary name in the history of airships, started to build rigid airships in a floating hanger on Lake Constance, near Friedrichshafen. Zeppelin visited the United States at the turn of the century and took to the air for the first time in a U.S. Army balloon. Impressed by the flight and the success of especially Renard and Krebs he saw it as his duty to provide Germany with a fleet of military airships. He began construction of his first rigid vessel, the *LZ-1*. It was the giant of its day. Measuring 128 m long its 11,300 cu.m of gas was contained in 17 separate cells. Its engines, by comparison, were tiny: two Daimlers together producing 30 h.p. for a weight of 770 kg. When it made its first 20 minute flight in July 1900 it was obvious that the vessel was hopelessly underpowered. It was scrapped a year later and Count von Zeppelin went back to the drawing board. Four years later he began construction of the *LZ-2*.

20. The early 1900s had, however, witnessed the emergence of the first practical airships. In 1903 the Lebaudy Brothers in France made the first ever journey in a fully controlled airship, travelling a predetermined distance of 61 km. The ship was handed over to the French Government and others were built for the French Army, and Britain, Russia and Austria, aware of its military applications, each acquired one. The first regular passenger services were introduced in 1910 in Germany. Five airships, built by the Delag Company, were used to connect a network of towns. When they were taken out of service in 1914 they had made nearly 1600 flights and carried 34,000 passengers without a single injury.

21. By the outbreak of the First World War Britain, France, Germany, Italy and the U.S. all had airship development programmes. The Great War gave an enormous impetus to their further development, when great strides were made

in disposable weight, speed and range. Nowhere was this more so than in Germany where, thanks to the work of August von Parseval (who built 28 pressure airships for the German Navy), Johan Schütte, Heinrich Lanz and, of course, Ferdinand von Zeppelin, the airship was seen as the most destructive weapon ever invented. During World War I Germany standardized the Zeppelin type, choosing it in preference to the designs of Zeppelin's competitors. At 4 plants 88 Zeppelins were built, a production rate of one vessel every two weeks. The ships were operated by both the German Army and Navy for both bombardment and naval patrol duties.

22. During the war, the Zeppelins were intensively developed. The German Navy started the war with the *L-3* and ended it with the *L-71*. The *L-3* was 158 m long, had a volume of 22,500 cu.m, and a top speed of 75 k.p.h. The *L-70* was 211 m long, had a volume of 62,000 cu.m and its 1715 h.p. engines gave it a top speed of 130 k.p.h. The last of the wartime Zeppelins had a useful lift of 50 tons and their ceiling had been increased to over 6,000 m to keep them out of range of enemy anti-aircraft fire. The ships developed a fearsome reputation in England with their bombing raids. Equipped with machine guns in the cars and on top of the hull to protect them against enemy aircraft, they also had a car, or 'spy basket', which could be lowered beneath the clouds to permit the observer in his car to navigate or direct bombing while the airship remained hidden above. The longest flight during the war was made by Naval Zeppelin *L-59* which flew 6700 km, much of it in a tropical climate, and remained in the air for 95 hours.

23. Whereas Italy also developed new types of airships for bombing missions, Britain, France and the U.S. saw and used the airship as a patrol vessel rather than a war-winning weapon. In this role it performed extremely well.

24. The French Navy had 60 airships during the last year of the war which were mainly used for patrols over the Mediterranean Sea. They performed more than 3,300 flights, attacking about 60 U-boats and sighting about 100 mines. The British began the war with 3 airships. An experimental craft was quickly built for coastal antisubmarine patrols and proved so successful that it was to result in a family of related non-rigid airships - the Sea Scout, Coastal and N.S. being the main variations. The most successful of all was the N.S. class which was 80 m long and had a volume of 10,000 cu.m. Its enclosed gondola could accommodate a crew of 10. With a maximum speed of over 90 k.p.h. it proved very effective in tracking U-boats and calling up surface vessels to harass or destroy them. Altogether, more than 9000 patrol and 2200 escort missions were flown by British airships in the First World War, operating from 17 airship stations and 12 mooring-out sites. The U.S. Navy similarly moved to develop non-rigid vessels for antisubmarine and coastal control. In 1917 it ordered 15 B-type airships and 30 larger C-types (reduced to 10 after the Armistice) from three manufacturers, including the Goodyear Tire and Rubber Company which has continued to play a prominent role in airship developments ever since. By 1919 the Navy was ordering G-type airships of 11,4000 cu.m.

25. After the First World War airship developments continued apace. The limitations of the airship as a strategic weapon had been clearly demonstrated during the hostilities and attention turned to their potential role as commercial vehicles, at that time superior in every way to the aeroplane, and to further developing their usefulness for surveillance and monitoring missions. Keen rivalry existed between the proponents of rigid and non-rigid systems. The former believed that their ships had speed and range, while the latter believed that rigids were clumsy and dangerous to handle.

26. The British soon built the *R-33* and *R-34*, rigid airships modelled along the lines of the captured Zeppelin *L-33*. The *L-34* became the first airship in 1919 to cross the Atlantic. With a crew of 10 it made the westward journey in 108 hours, and the return trip in 75 hours. Several other rigid airships were built, including the 2100 h.p. *R-38*, a vessel 212 m long, which was to be purchased by the U.S. Navy. On its fourth flight in 1921 it broke into two in severe handling conditions and fell into the Humber, killing 44 British and U.S. officers and men. This disaster put a temporary stop to British airship efforts. Another disaster, the loss of the *Dixmunde* over the Mediterranean, one of 3 Zeppelins acquired by France as war reparations, put an end to French rigid airship developments some two years later, although the country was to continue non-rigid and semi-rigid development until 1937.

27. Germany entered the 1920s with virtually no operational airships. Many of the vessels in its armada of airships had been destroyed by their own crews to prevent them being surrendered to the Allies, a condition of the Armistice. The Delag company lost no time in constructing new airships. In 1919, a new purpose-built passenger vehicle, the *Bodensee*, started to operate between Friedrichshafen and Berlin. So successful was this service that the company built a second vessel, the *Nordstern*. Before it could enter service, however, the Allies put a stop to the operation since Germany was forbidden under the Treaty of Versailles to build airships.

28. Count von Zeppelin had died in 1917. His factory, whose financial fortunes were at a low ebb, was taken over by Hugo Eckner, the Count's close associate. Convinced that the airship was unsurpassed as a long-distance passenger carrier, Eckner suggested to the U.S. that it build it a new airship to replace the vessel which it should have received as reparations but which had been destroyed.

29. The U.S. agreed and this decision helped ensure that the Zeppelin company reestablish its position in the forefront of airship development. The resulting *LZ-126* began flight tests in early 1924 and in October of that year, it was flown to Lakehurst, New Jersey, becoming the first German airship to cross the Atlantic. Designated *ZR-3* by the U.S. Navy and christened the *USS Los Angeles*, it went on to accumulate 5,368 flight hours in 330 flight before being retired in 1932. Although occasionally recommissioned, it was finally scrapped in 1939.

30. By 1924 rigid airship development had recommended in Britain. In that year design started of two ships - the *R-100* and *R-101* - for passenger services to the Dominions. The disaster of the *R-38* led to a greater emphasis on safety factors and consequently to heavier airships, a decision which proved to be fraught with grave consequences. Spurred on by an Imperial mission, and, more mundanely, by the development of the mooring mast which was held by the British to be the solution to the intractable problem of handling large craft on the ground, the two vessels were completed in 1929. The *R-100*, designed by the distinguished inventor Barnes Wallis, was built on a modified Zeppelin design, an unconventional geodetic construction replacing unbraced transverse frames. With accommodation for 100 passengers, its 6 gasoline engines gave it a top speed of 130 k.p.h. Its two year life was relatively uneventful. In July 1930 it flew from England to Canada in 78 hours, returning in 58 hours. The *R-101*, lengthened after completion to increase its lifting capacity, could accommodate 50 passengers. It deviated more from conventional Zeppelin practice. Political pressures had led to a curtailment of the trials of both the *R-100* and *R-101* and, with the unreadiness of the vessel no secret, the *R-101* left England on a proving flight to India via Egypt. It crashed into a hill near Beauvais, France, killing 48 passengers. Following this disaster the British Government

scrapped the *R-100* and abandoned all further airship activity.

31. While the British were building the *R-100* and *R-101*, the Zeppelin company was building perhaps the most famous of all airships, the *LZ-127*, known as the *Graf Zeppelin*. Some 240 m long, the *LZ-127* had a volume of 3.3 million cu.m, of which nearly a third was filled with blaugas fuel and the remainder with hydrogen, the lifting gas. Powered by five engines capable of developing 2650 h.p. it provided luxury accommodation for 20 passengers and could carry 12 tons of mail and cargo. First flown in September 1928, the *Graf Zeppelin* made a much publicized round the world flight in 21 days in 1929. It saw nine years of continuous and successful service. When decommissioned in 1937, it had made 590 flights, including more than 140 transAtlantic crossings, carried 13,000 passengers and more than 100 tons of mail and freight, and travelled 1.7 million km.

32. The development of rigid airships was also well underway in the U.S. in the same period. Before it received the *LZ-126* from Germany, the U.S. Navy had already acquired a rigid airship, the *LZ-1*, christened the *USS Shenandoah*, a copy of the German Zeppelin *L-49*, modified mainly for helium and mooring mast operation. First flown in 1923 it went on to make a number of noteworthy flights, including a 14,000 km transcontinental roundtrip in 1924. The ship was, however, destroyed in a thunderstorm in September 1925 when it failed structurally. Being inflated with helium it did not catch fire, although 14 members of its crew of 43 were killed. The disaster has been attributed to crew inexperience as much as to faults in construction.

33. Further development of rigid airships in the U.S. was prompted by the arrival from Germany of the *LZ-126* and the acquisition by Goodyear, also in 1924, of Zeppelin patents

and processes as well as a small group of expert Zeppelin engineers who had been persuaded to emigrate to the U.S. Goodyear formed a subsidiary, the Goodyear-Zeppelin corporation, in Akron, Ohio which remains the home of the Goodyear Airship Co. In 1928 it began construction of two giant rigid airships - the *ZRS-4*, christened the *USS Akron*, and the *ZRS-5*, christened the *USS Macon* - for the U.S. Navy. Both were 240 m long and had a volume of 185,000 cu.m. Built for long-range reconnaissance missions, the vessels had a cruising range of more than 10,000 km and a maximum speed of 72 knots. They were in many respects ingenious designs. They departed from the traditional Zeppelin design, being based upon a light weight wire bracing construction rather than heavy unbraced transverse frames. The power plant installation consisted of eight 560 h.p. Maybach engines mounted in separate engine rooms within the hull driving propellors which could be swivelled to produce vertical lift. Each had an internal hangar for five scouting planes which could be launched and landed from a special trapeze.

34. The *Akron* was completed in 1931 but, after about 1700 hours of service, crashed with the loss of 73 lives, in a storm off the New Jersey coast in 1933. The *Macon* was launched at the same time. In 1935, after 1800 hours of service, the upper fin structure failed and the ship fell to the sea and sank off the coast of California with the loss of two lives.

35. The loss of the *Akron* and *Macon* was, like the *Shenandoah*, probably due more to crew inexperience than to defects in their lightweight construction. The loss, however, left the U.S. Navy without a rigid airship and further activity was limited to semi-rigid designs.

36. Airship activity started in earnest in the Soviet Union in 1931, the year that the *Akron* and *Macon* made their maiden flights. In that year, a public subscription of 15 million rubles towards an airship programme was announced. The Second Five Year Plan provided for the operation of airships on civil air routes within the country. Spurred on by the arrival of Umberto Nobile, who had attained considerable fame by building and flying the first airship - the *Norge* - to cross the North Pole in 1926 and was later compelled to leave Fascist Italy, the programme made rapid strides. By the outbreak of World War II the Soviet Union reportedly had a fleet of 15 non-rigid and semi-rigid airships and was seriously considering building larger ships of the rigid type. In 1937 it expressed an interest in purchasing the German built *USS Los Angeles* and was operating regular airline services using small airships that connected Moscow and Sverdlovsk.

37. It was in the 1930s that the Zeppelin company built their two largest rigid airships, the *LZ-129*, known as the *Hindenburg* and the *LZ-130*, known as the *Graf Zeppelin II*. Both were to be bigger and better than the *Graf Zeppelin* that had impressed all who had seen it. Both were designed for helium instead of hydrogen operation to prevent an occurence of the *R-101* disaster. The United States, however, the only large-scale producer of helium, refused to sell the gas to Germany, fearing that it would find an application in military airships.

38. The failure to acquire helium did not stop the Zeppelin company. In 1936 it launched the *Hindenburg*, a vessel 245 m long and a volume of 200,000 cu.m. Its four Daimler diesel motors developing 1000 h.p. gave the ship a top speed of 130 k.p.h. It could accommode 75 passengers in unsurpassed luxury and a crew of 25. It entered service in the summer of 1936 and made ten trans Atlantic round trip flights, carrying 1000 passengers in the process.

39. On May 6, 1937 the hydrogen inflated craft burst into flames while landing at Lakehurst, New Jersey. 36 of the 97 persons on board lost their lives, the first passenger fatalities in the history of commercial airship operation. While the fire is generally attributed to a discharge of atmospheric electricity in the vicinity of a hydrogen leak, the possibility of sabotage has never been ruled out.

40. The *Graf Zeppelin II* was commissioned and tested in 1938. It too was inflated with hydrogen. It went on to make 30 exhibition and test flights but saw no commercial or war service. At the outbreak of the Second World War the German Government directed the Zeppelin company to discontinue all lighter-than-air manufacture. The *LZ-127* and *LZ-130* were dismantled for duralumin and aluminium for use in warplane production. This marked the end of German attempts to build a world-wide fleet of commercial transport airships. With the cancellation of a U.S. design for a rigid airship for the U.S. Navy in 1939, the development of the rigid airship finally came to an end.

41. The Second World War did not, however, witness the end of all airship development. Rather it gave a new impetus, especially in the U.S., to the development of non-rigid and semi-rigid designs for the role they had performed so well in the First World War - coastal patrol and surveillance. Only Japan persevered with the airship as a weapon of war. In the early 1940s it despatched about 9000 ingeniously constructed unmanned bomb-carrying balloons across the Pacific aimed at the not inconsiderable target of North America. About 11-12% survived the crossing, killing 6 persons upon reaching their destination.

42. The U.S. Navy, which had continued non-rigid and semi-rigid development throughout the 1920s and 1930s, was operating 4 patrol airships and 3 small trainers as well

as a few ex-Army craft at the time of the Pearl Harbor attack. It quickly expanded its fleet as the airship building programme accelerated. During the war the Navy operated 138 patrol vessels (mainly the 12,000 cu.m K-type first built in 1931) and had 22 training ships operating from more than 50 bases. They performed antisubmarine and patrol and escort operations in a 3 million sq.mile area along the Atlantic, Gulf and Pacific coasts, in the Caribbean, along the South American coast from Panama to Rio, and in the Mediterranean. They also successfully performed a number of other tasks, including shipping control, torpedo recovery, aerial photography, observation, special equipment calibration, search and rescue operations, as well as other services requiring low-speed and low-altitude operations. In the Mediterranean they fulfilled a valuable role in minesweeping operations by spotting and marking undetected minefields. This undoubtedly prevented a number of minesweepers from being destroyed.

43. Operating from 5 bases along the Atlantic seaboard, U.S. Navy blimps flew a total of 55,900 flights for 550,000 hours and escorted 89,000 ships without the loss of a single craft to enemy action. Of the blimps assigned to fleet units, 87% were in operational readiness at all times, thereby establishing a World War II record availability for military aircraft. It was a U.S. Navy blimp which became the first non-rigid airship to cross the Atlantic in 1944.

44. The U.S. Navy continued non-rigid airship development after the Second World War. Various configurations of the successful K-type were evolved, with increased volumes of up to 19,000 cu.m. In 1953, the first N-type blimp was placed into service. This 29,000 cu.m craft had considerably improved lifting performance. The *ZPG-2W* was developed for airborne early warning at sea and, introduced

in service in 1957, quickly demonstrated its all weather reliability, economy and high technical efficiency. In 1957, the *ZPG-2*, a sister ship, completed an unrefuelled flight of over 264 hours for a new record distance of over 15,000 km over the North Atlantic and Caribbean, beating the one set up in 1929 by the rigid *Graf Zeppelin* when it flew 11,000 km non-stop from Friedrichshafen to Tokyo. In 1958 the first of the Navy 42,000 cu.m *ZPG-W* type, the larget blimp ever built, entered service. Equipped with a large radar antenna within its envelope it proved a very useful early warning device.

45. In 1961 the U.S. Navy terminated airship operations, effectively bringing to a close a period of airship development which stretched over more than a century.

III. MARKING TIME (2)

46. The appellation airship remains coloured by the spectacular disasters which brought the development of rigid vehicles to a close in the 1930s: the loss of the *R-38*, the *Shenandoah*, the *R-101*, the *Akron*, the *Macon* and the *Hindenburg*, all giants of their day, seems to have left an indelible imprint in our collective subconscious and has prevented a full appreciation of the performance of the airship.

47. As we have seen, there was no single reason for the disasters. In many respects they were a consequence of the fact that the airship was ahead of its time, demanding technologies which only later become or only today are becoming available. Some disasters were unnecessary. The *R-101* and *Hindenburg* were lost to fire because they were inflated with highly inflammable hydrogen unlike U.S. ships which used the inert, but heavier, helium. The Germans, as we have seen, designed their 1930s vehicles for

helium operation but were unable to attain it from the U.S., the world's only large-scale producer, because, in the tense political climate of the 1930s, the U.S. Government feared the development by Germany of military aircraft.

48. Other disasters were due to defects in structural design and, in the case of several U.S. accidents, crew inexperience. Some other ships, like the *R-101*, were forced, under political pressure, to take to the air before they were really ready to do so. It is also worth noting that the giants of yesterday, never the most maneuverable of craft, were compelled to fly with only the most primitive of radar and navigation aids.

49. Given the limitations and constraints faced by the pioneers of airship design it can be considered surprising that so few accidents actually occured. For every rigid giant that crashed among front-page headlines, there were scores of non-rigid and semi-rigid airships leading uneventful lives, engaged in a wide range of military and civilian work. The history of the airship is in fact a story of performance and safety. Consider the record of the Delag airships in pre World War I Germany and the performance of British, French and U.S. naval airships in the two world wars. The U.S. Navy flew 30 million km with airships in the Second World War with only one fatality and that was due to enemy action. Hardly less impressive was the performance of Goodyear airships which, up to 1960, carried nearly half a million passengers and made 180,000 flights without a single passenger injury. The safety record of the airship was in fact at least as good if not considerably better than that of heavier-than-air craft in the same period.

50. Throughout their development airships served as a laboratory for technological innovation. Propulsion systems and construction technologies were pioneered which were subsequently put to good use in other fields and other aircraft. The geodetic construction technique developed by Barnes Wallis for the British *R-100*, for example, was later successfully used in the construction of the Vickers Wellesley and Wellington bombers, Britain's most successful bombers in the early years of the Second World War.

51. The existence of new technologies - technologies which virtually rule out the kinds of disaster which brought the first round of airship developments to a close - have brought about a renewed interest in lighter-than-air vehicles for use in a wide range of fields. The development of airships has always taken place around a theme. Count von Zeppelin was determined, for example, to build Germany a fleet of warwinning machines. Eckner used the airship to restore German prestige after the First World War. The British developed airships for purposes of keeping their empire intact.

52. Today, there is no shortage of new themes to which the new technologies can be applied. The search for fuel-efficient forms of transportation, the need to develop suitable craft for monitoring the exclusive economic zones afforded coastal states by the U.N. Law of the Sea Conference, and the need to find cost effective ways of opening up remote areas in and exploiting the natural resources of developing countries are all examples of such themes. These and others have given a new impulse to LTA developments in the past decade.

53. In a way the airship never really died. The tradition was kept alive in the 1950s and '60s by men of imagination and by ambitious drawing board designs in both the U.S. and Europe. No sooner had World War II ended the Good-

year Airspace Corporation advocated the construction of a rigid airship of 280,000 cu.m capacity, with accommodation for 112 passengers who were to travel in standards comparable to an ocean liner. By eliminating a dining room designed to seat 60 passengers and converting the whole interior to Pullman-type compartments, the Goodyear vessel was capable of carrying 232 passengers. The use of reclining chairs similar to those used in civil aeroplanes gave the airship a capacity of 288 passengers. Designed to compete with aeroplanes which in the early past war years were spartan in their standards of comfort, the airship was to cruise at 120 k.p.h., although Goodyear believed that, with stern propulsion and other developments, cruising speeds of over 150 k.p.h. would be possible.

54. In the 1950s other designers optimistically turned their attention to the possibility of nuclear powered airships. Francis Moore of Boston University designed a nuclear powered airship to be used either as a cargo carrier or a passenger vehicle with accommodation for 400 passengers. His ship, 300 m long, was to have a useful lift of 140 tons and a payload capacity of nearly 90 tons. The nuclear power plant was to drive three rear mounted engines - a 4000 h.p. gas-turbine revolving 20 m long dual-rotation propellers and two 1000 h.p. turbofans designed to help overcome the problem of drag. The airship was to be equipped with a hotel containing a dining room for 200 persons as well as a cinema and promenades. Like the *Akron* and *Macon*, the vessel was to have its own aeroplane: an 18 seat shuttle plane was to ferry passengers to and from the ship while in flight.

55. In Austria, Erich von Veress designed an ever larger nuclear powered airship. Known as the *ALV-1*, it was to have a volume of some 400,000 cu.m, carry 500 passengers and 100 crew, and handle 100 tons of freight. The vessel was to be propelled by a nuclear powered turbine with two

propellers placed in tandem inside the hull near the bow. To be furnished to high levels of passenger comfort, the planned speed would have enabled it to make a Westerly crossing of the Atlantic in 22 hours, the return trip to take 18 hours.

56. These nuclear-powered airships were more drawing board designs than practical propositions and, in retrospect, it is perhaps fortunate that funds were never found to turn them into reality. More realistic but no less ambitious were the proposals developed in the U.K. in 1971 by Airfloat Transport Ltd. for freight carrying rigid airships. Designed to carry a payload of 400 tons in varying weather conditions, the airship required a length of 390 m - 100 m longer than the Queen Elizabeth II - and a volume of over 1.1 million cu.m - nearly 6 times that of the *Hindenburg*. Power was to be provided by six Proteus gas turbines driving 7 m propellers. All the engines were to be self-reversing and four were designed to provide thrust in any direction. All operation was to be automatic, with sensors supplying information to a computer which would control, among other things, lift-and-trim operations and gust evasion.

57. In the early 1970s another British company, Aerospace Developments Ltd., began investigating, at the request of Shell, the feasibility of using airships for transporting natural gas. Aerospace Developments proposed huge vehicles 550 m long and 90 m in diameter capable of transporting 2.8 million cu.m of liquified gas. This aerial tanker was to be powered by four fanjet gas turbines, each developing 12,000 h.p., driving 9 m reversible propellers hung in pods from the horizontal tail fins on either side of the hull.

58. The U.S. Navy, that had terminated airship operations in 1961, reentered the LTA field in the mid 1970s, commiting $ 4 million to a new series of studies of naval airships. Studies conducted to date have included the *ZPG-X* project, a VTOL/hover derivative of the Navy's *ZPG-3W* nonrigid airship, designed for a 90 knot top speed, a 1500 m normal cruising altitude and a 4000 nautical mile ferry range. Goodyear Aerospace, which examined the feasibility of the proposal for the Navy, concluded that, given present technology levels, the *ZPG-X* could be operational by 1985. More ambitious was the Navy's investigation of an airship for the 1990s capable of carrying some 50 tons of surveillance, attack and defence equipment to an area 3000 km distant and patrolling the area for 8 days at an altitude of 3000 m. The airship was required to be able to land, moor and launch without external aid. Studies showed that such a vehicle could be constructed. With a length of 200 m and a weight of 188 metric tons, it would be smaller than many of the airships built in the 1930s.

59. In addition to these ambitious studies, a number of modest airships were built. In the U.S., John Fitzpatrick, an ex-U.S. Navy airship officer, built a catamaran airship with 3 hulls. With a volume of 10,000 cu.m and a length of 25 m, the airship, known as *Aereon III*, was propelled by a two-bladed helicopter type rotor. Essentially a buoyant wing, the craft had an ingenious controlled lift system and carried its own mooring mast in the form of a 6 m retrackable strut which carried the front landing wheel. Developed at the request of religious authorities to help bring assistance to developing countries, the *Aereon III* was unfortunately destroyed by wind while being handled outside her shed. Other airships constructed in the U.S. include a number of Goodyear blimps, built for advertising and television work, the *Hov-Air-Ship HX-1*, a 6 m long remotely controlled experimental airship, and the Tucker Airship Company's *TX-1*, 28 m semi-rigid which made its

first flight in the late 1970s.

60. In the U.K., Anthony Smith constructed a 23 m helium-filled semi-rigid, christened *Santos-Dumas*, which was first flown in 1974. Aerospace Developments built and flew its *AD 500* semi-rigid airship which was ordered by Colombian and Venezuelan operators for a variety of uses. The loss of the prototype ship in gusty conditions in 1979, however, led to the bankrupty of the company.

61. In Germany, non-rigid airships were built in the early '60s by the West Deutsche Luftwerbung (WDL). Two helium inflated ships with a volume of 6,000 cu.m powered by 400 h.p. engines were constructed. One of these was destroyed in a gale in 1972 when it was struck by flying debris from its hanger while it was riding out the gale at its mooring mast. WDL, however, was able to continue airship development.

62. In Japan Fuji built a small research ship, the *500*, which underwent flight trials in the mid 1970s. Other versions of the 500 were planned.

63. The Soviet Union is also believed to have developed a number of airships in the post-war period, despite apparent opposition from the Ministry of Aviation. It is reported to have used semi-rigid airships for a variety of purposes, including mineral resource surveys, in the developing regions of Siberia and on its eastern frontier.

IV. PRESENT AND POSSIBLE FUTURE DEVELOPMENTS

64. Airship history and the studies conducted in recent years have clearly pointed to the main attributes of the LTA vehicle. They include:

• *Fuel efficiency.* Airships do not require fuel to become airborne and have a low power to weight ratio. As a general rule an airship uses a quarter of the fuel required by an aeroplane to carry the same payload, an important consideration in a world in which the price of jet fuel has increased tenfold in the past seven years. (3)

• *Endurance.* An airship can remain in active service for days or even weeks and months on end compared to the few hours of conventional aeroplanes

• *Low environmental impacts.* Airships have extremely low vibration, noise, acceleration and pollution levels. They do not require space consuming airports.

• *Speed range.* The speed range of an airship varies from precision hover to up to 40-50 metres per second (140-180 k.p.h.), faster than the fastest surface vessels.

• *Payload capacity.* An airship has a large load and space capability. Airships are now being developed which will be capable of transporting loads of up to 400 tons. Large hull structures make it possible to accommodate all manner of things. Naval patrol and surveillance airships, for example, could carry small surface vessels which could be lowered into the water as and when required.

• *Radar transparency.* Airships are difficult to detect with conventional radar, important when airships are used, for example, in tracking illegal operations (pollution discharges, smuggling) and antisubmarine warfare.

• *Safety.* Should their engines fail, airships, unlike other aircraft, do not fall from the sky. They have, as noted above, a safety record which is at least as good as commercial aeroplanes.

- *Serviceability*. Airships offer the possibility for in-flight maintenance and the repair of equipment.

65. These attributes can be put to a wide variety of uses. Areas in which airships have a proven or potential capability include: marine patrol and surveillance; antisubmarine warfare; minesweeping; search and rescue; the transport of bulk commodities into and out of inaccessible areas; the transport of bulky machinery too large to move over normal highways and rail rights-of-way and too heavy for existing bridges; the transport of volatile commodities (gasses or cryogenic liquids); the transport of heavy equipment to offshore oil platforms; photographic, magnetic and geosurveys; pipeline construction; the loading and unloading of ships in areas without port or harbour facilities; firefighting; logging operations; emergency and disaster relief; modular housing construction; urban traffic management; traffic control in busy sealanes; the repositioning of crawler coal shovels; industrial security; and fish and animal migration studies. The list is long but far from complete.

66. These possibilities are now being actively explored. Governmental organizations in Brazil, Canada, Ghana, Japan, Peru, Soviet Union, Upper Volta and Venezuela are reportedly studying the feasibility of airships for local conditions. While only 6 airships were known to be flying in the West in the late 1970s, most owned by Goodyear and used for advertising purposes, several new types are under construction in Canada, France, the Federal Republic of Germany, Japan, U.K. and U.S.A. In the U.S. alone, 27 companies are known to be interested in building airships.(4) All these countries are considering expanding their rules for airworthiness certification, operation, regulation and pilot licensing.

67. A few U.S. companies are seeking to develop high-speed airships. Airships International of California, for example, has a design for an aluminium airship which, equipped with rotating thrusters on bow, stern and underside, would be cap ·le of speeds of over 300 k.p.h. Most of the work currently being undertaken, however, is aimed at operationalizing heavy lift and naval patrol craft. Among those developing heavy lift airships in the U.S. are Goodyear Aerospace and the Piasecki Aircraft Corporation. Both are adopting the same approach to heavy lifting, the linking of helicopters to airships in an attempt to combine the controlability and maneurability of rotor craft with the aerostatic lift of the airship.

68. Goodyear, which has built more than 300 airships including all the significant ones constructed in the U.S. in the last 60 years, is using four helicopters attached to an envelope to develop a vehicle able to transport 60 tons over 500 km. It also has a design for a heavy lift vehicle which would be capable of lifting up to 160 tons - almost the weight of a fully loaded Boeing 707.

69. The Piasecki Aircraft Corporation has linked a 100 m long former U.S. Navy airship to an interconnecting structure of four helicopters. The controls of the 1525 h.p. helicopter rotors are interconnected to one pilot seated in the helicopter located on the port side of the airship aft of its centre. The three other craft each have a flight engineer. The vehicle, known as the *Heli-Stat* heavy vertical air lifter has been inflated at its hangar in Lakehurst, New Jersey. Being built for the U.S. Forestry Service to demonstrate the feasibility of timber harvesting in inaccessible areas, work on the *Heli-Stat* began in 1974 and the vehicle is due for delivery in 1982. It is designed to carry loads of up to 24 tons at a forward speed of 60 knots. A larger version, designed to lift 75 tons at 73 knots, is under development. The Piasecki Corporation has

recently established a Canadian operation and a number of Canadian oil and pipeline construction companies have reportedly expressed an interest in the *Heli-Stat* design. Goodyear Aerospace has also recently been invited to build and test a heavy lift prototype airship for Canadian conditions and to cooperate in the building of an airship manufacturing plant in Alberta. (5)

70. Canada already has an airship manufacturer - the Montreal based Aerostat Airship Company - which is developing heavy lift vehicles designed to transport men and vehicles into the country's remote but mineral rich Arctic. The company reportedly has customers in Argentina, Colombia and Peru.

71. In Europe, the activities of Airship Industries is attracting considerable attention. Formerly known as Thermo-Skyships, the company has developed a number of interesting designs. These have included a new generation of short- and medium-range circular airships, similar in conception to those developed in France by Pierre Balaskovic, which have performed very well in wind tunnel tests. They are designed to take-off and land from very small areas in almost all weather conditions without the need for mooring masts. A European transport company - European Ferries - has reportedly ordered 6 such skyships for a passenger service between London and Amsterdam, a service whereby 60 passengers could travel at speeds of up to 170 k.p.h. from city centre to city centre (from terminals in dock areas in both cities) at fares similar to those paid on hovercraft services across the English Channel. With a still air range of 1000 km the ship would also have a disposable payload of about 6 tons. (6)

72. Airship Industries also plans to develop cargo airships. Recently, Redcoat Cargo Airlines, a small British independent which operates a fleet of ageing Brittanias, placed an order for four more conventional, long-range, cigar-

shaped airships, each 200 m long, capable of carrying a payload of 40 tons at 120 k.p.h. The airline plans to abandon its conventional aircraft operations which it believes are becoming untenable in the face of ever-rising fuel costs. Its airships, the first of which it hopes to receive in 1984, are planned to fly to West Africa, the Middle East and Central America.(7) More recently the U.S. airline Federal Express, the largest carrier of parcel post and one of the most successful airlines in the U.S. in recent years, has also expressed an interest in the cargo airships under development by Airship Industries. The company hopes to obtain orders from the British Ministry of Defence for the transport of heavy equipment to Germany and is currently examining the feasibility of a heavy lift airship capable of carrying 400 tons - considerably more than a fully laden Boeing 747.

73. The only airship so far to come off Airship Industries' drawing board is the *Skyship 500*, a model based upon the Aerospace Developments *AD 500* acquired by the company when Aerospace Developments went into liquidation following the partial loss of the *AD 500* in gusty conditions in 1979. The *Skyship 500* is the product of the AD 500 design team. It has been designed specifically for maritime patrol duties, but commercial use is also considered possible.(8)

74. The *Skyship 500* is designed and tooled up for mass production. Its advanced technology design includes honeycomb sandwich materials for tailfin structure, gondola bulkheads and flooring and the use of titanium and aluminium instead of steel in engine design,all of which help reduce weight and thus maximize payload. It also incorporates advanced avionics and navigational aids. Two Porsche 3 cylinder motors give the vessel a maximum take-off power of 200 h.p. The engines drive twin-ducted fan units which have four pitch conditions (for course pitch, flight fine, zero pitch and reverse pitch). The vessel will have a

top speed of 64 knots and, in addition to its 10 seat gondola, can carry a two ton payload. With a length of 50 m and a diameter of 14 m it is modest when measured by airship standards. But such modesty may make it the first low-cost airship.

75. The vessel made a two hour maiden flight on 28 September 1981 when it reportedly performed well. About 40 hours of flight testing is required before the Skyship 500 can gain Special Category certification by the British Civil Aviation Authority, which will allow military evaluations to be made. Once it receives Aerial Work Category Status, which will require 4 months of additional flight trials, it can be hired out to operators. Already, UNCTAD has requested Airship Industries to consider making a *Skyship 500* available for monitoring and surveillance and inter-island travel testing in the South Pacific.

76. All these developments are helping to bring the real age of the airship so much closer. Advances in technology have already solved some of the problems which confronted airship designers in the 1920s and '30s. The application of modern sensors and variable thrust and direction engines, for example, have greatly improved performance and low speed maneuvrability. Modern light-weight, low-consumption gas turbine engines have also shown to lend themselves to airship application, as have light-weight helicopter blade systems, high strength and corrosion-resistant titanium and aluminium alloys, glass fibre and carbon fibre composites, and low permeability synthetic fabrics.

77. Helium is now more widely available and cheaper than it was in the 1930s. It is today widely used in space and nuclear energy programmes and has been discovered in Algerian and North Sea gas. The long-term viability of airships may also be increased by recent advances in the development of liquid hydrogen technologies. Liquid hydrogen

burns clearly and, since it is made from water, it is a potentially unlimited source of fuel. Boeing, Lockheed and McDonell Douglas are already studying the feasibility of liquid hydrogen powered heavier-than-air craft. But when used in aeroplanes, the fuel requires about three times more space than kerosene, which means that hydrogen powered planes would carry fewer passengers than today's airframes. Since space is not at a premium, this would not be a problem in airships.

78. Despite the recent technological advances, there remains some way to go. Among the problems awaiting a satisfactory solution are the provision of a low-weight, low-cost envelope that is durable, maintenance free and gas tight, the development of equipment for monitoring the state of structures and sub-systems, the development of cost effective means of fabricating and assembling large hull structures, and the development of practical groundhandling and mooring techniques in severe weather. Problems also still exist with respect to the control of aerostatic lift and precision hovering, especially when loading or discharging heavy loads.

79. The solution to many of these problems is clearly in sight. The greatest obstacle to further airship development is unlikely to be the absence of appropriate technologies but rather a lack of research and development funds. Investments in airships are essentially long-term investments and because they are long-term all airship companies in the Western world are experiencing difficulties in raising money. The amounts required are considerable. The commercialization of production typically requires between $ 50-100 million. These are large sums of money although, it should be noted, small in comparison to the R&D costs of small passenger aeroplanes and even to the costs of introducing relatively minor style changes to automobiles. (9) The costs are such, however, that government involve-

ment in the funding of airship development programmes may well be necessary. The Belgian Government has been reported to be interested in backing Airship Industries and the Company has considered approaching the European Community. The Federal and Provincial Governments in Canada have also been requested to back airship development. The U.S. and France, through their space agencies, have already put money into airship research.

80. Such funds may well become available when governments realize that the airship is no longer a competitor to the aeroplane but an intrinsically safe and rugged vehicle able to perform a wide range of tasks which other vehicles are unable to do or unable to do as well at a potentially significantly lower cost.

V. THE DEVELOPING COUNTRIES AND LTA TECHNOLOGIES

81. The potential of the airship will increasingly become recognized and the start of the race to develop them has been signalled. Where this race will take us is impossible to say. But given the wide range of uses to which the airship can be put as well as its many attributes, common sense suggests that this is one race in which the developing countries must actively participate, not only as a user of airships but also as a constructor. The design and construction of operational airships would take the developing countries into the mainstream of technological advance. The search for appropriate technological solutions to the problems posed by LTA transport could, because it would lead to the acquisition of knowledge and skills in 'avant-garde' areas, serve to promote the process of technological innovation and to strengthen the development of indigenous technological capabilities. LTA development might constitute an interesting basis for pioneering new forms of TCDC, especially among the technologically most advanced devel-

oping countries some of which, like Brazil, Mexico and India, will soon be faced with the problem of monitoring exclusive economic zones of between half a million and one million square nautical miles.

82. There is no reason, however, why developing countries should seek to go it alone. To do so would be to deny the existence of relevant LTA skills and experience accumulated over more than a century in the industrialized world. The field of LTA technologies is large and it would be neither necessary nor desirable for the developing countries interested in developing operational airships to isolate themselves from the R and D capacities of the industrialized nations. Indeed, the development of a new generation of airships could prove an area in which it is possible to develop innovative cooperative programmes which bring together both developed and developing countries. The essential context for such programmes would need to be the furtherance of mutual interest through the development of technologies from which both developed and the developing countries could benefit. And because the interests would be shared interests, the programmes could be organized on a 'partnership' basis.

References

(1) This section draws upon a number of published sources, notably Guy Hartcup, *The Achievement of the Airship*, David and Charles, London, 1974; David Morley (editor), *Aviation: The Complete Book of Aircraft and Flight*, Octopus Books, London, 1980, viz. pp. 290-317; and appropriate sections of *Encyclopaedia Brittanica*, 1967 edition.

(2) This section draws upon Hartcup, op.cit., and Morley, op.cit., the papers contained in Joseph F.Vittek jr. (editor), *Proceedings of the Interagency Workshop on Lighter-than-Air Vehicles*, Flight Transportation Laboratory, MIT, Cambridge, Mass., January 1975, and the papers contained in American Institute of Aeronautical Engineers, *Collection of Technical Papers*, AAIA Ligher-than-Air Systems Technology Conference, Melborne, Fla., 11-12 August, 1977.

(3) It might be noted here that in recent years considerable progress has been made in the development of solar-powered balloons. One such balloon successfully crossed the English Channel in 1981.

(4) For a short review of activities in the airship field see the Earthscan features document *Airships Again?* prepared by Robert Lamb(Earthscan, London, 1980).

(5) See 'Proposal Forwarded for Airship Manufacturing Plant', *The Citizen*, Ottawa, March 27, 1981.

(6) Reported in 'Brit: Zeppelin Heeft Weer Grote Toekomst', *NRC* (Netherlands), August 8, 1980.

(7) Reported in 'Vracht per Luchtship', *De Volkskrant* (Netherlands), November 5, 1890.

(8) For a description of the Skyship 500 see *Flight International*, September 26, 1981, p.938. The AD 500, the Skyship 500's predecessor, is described in *Flight International*, February 24, 1979, pp. 539-544.

(9) It is worth noting in this respect that General Motors, according to its own estimates, spent $ 2.7 billion in the development of a front-wheel drive model incorporating no radically new technology which it introduced in 1979. See Lester R.Brown, Christopher Flavin and Colin Norman, *The Future of the Automobile in an Oil-Short World*, Worldwatch Paper 32, Worldwatch Institute, Washington D.C., September 1979, viz. p. 30.