

Encyclopedia of
Airships



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Chapter- 1

Introduction to Airship



A modern airship

An **airship** or **dirigible** is a type of aerostat or "lighter-than-air aircraft" that can be steered and propelled through the air using rudders and propellers or other thrust mechanisms. Unlike aerodynamic aircraft such as fixed-wing aircraft and helicopters, which produce lift by moving a wing through the air, aerostatic aircraft, such as airships and hot air balloons, stay aloft by filling a large cavity with a lifting gas.

The main types of airship are non-rigid (or blimps), semi-rigid and rigid. Blimps are small airships without internal skeletons. Semi-rigid airships are slightly larger and have some form of internal support such as a fixed keel. Rigid airships with full skeletons, such as the huge Zeppelin transoceanic models, have nearly disappeared after several high-profile catastrophic accidents during the mid-20th century.

Airships were the first aircraft to enable controlled, powered flight, and were widely used before the 1940s, but their use decreased over time as their capabilities were surpassed by those of airplanes. Their decline continued with a series of high-profile accidents, including the 1937 burning of the hydrogen-filled *Hindenburg* near Lakehurst, New Jersey, and the destruction of the USS *Akron*. Airships are still used today in certain niche applications, such as advertising, freight transportation, tourism, camera platforms for sporting events, and aerial observation and interdiction platforms, where the ability to hover in one place for an extended period outweighs the need for speed and maneuverability.

Terminology

In some countries, airships are also known as *dirigibles* from the French (*diriger* to direct plus *-ible*), meaning "directable" or steerable. The first airships were called *dirigible balloons*. Over time, the word *balloon* was dropped from the phrase. In modern usage, balloon refers to any buoyant aircraft that generally relies on wind currents for horizontal movement, and usually has a mechanism to control vertical movement.



USS *Akron* (ZRS-4) in flight on 2 November 1931

The term *zeppelin* is a genericised trademark that originally referred to airships manufactured by the German Zeppelin Company. The word *Luftschiff*, German for "airship", usually prefixed their crafts' names.

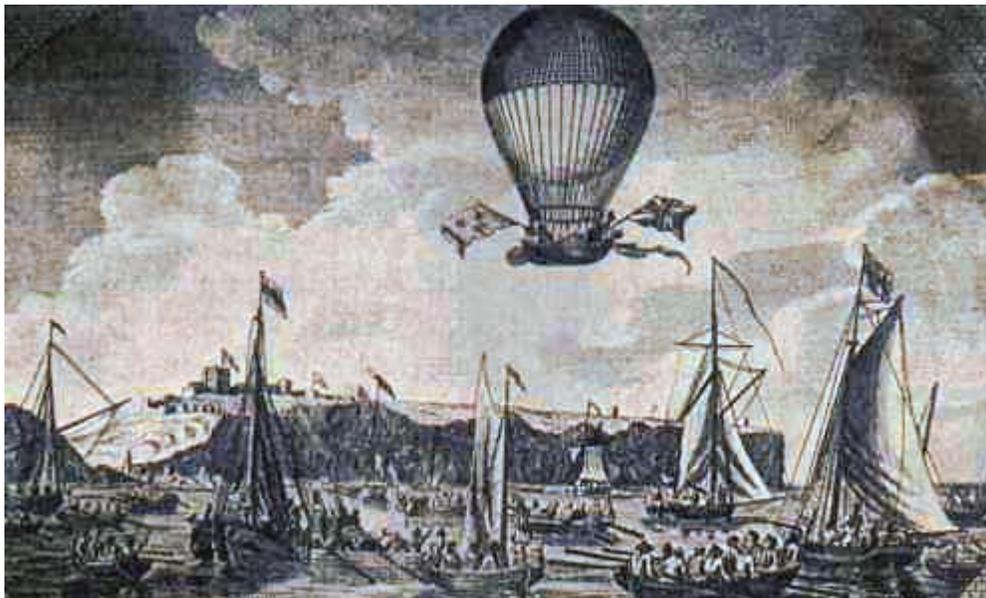
In modern common usage, the terms *Zeppelin*, *dirigible* and *airship* are used interchangeably for any type of rigid airship, with the term *blimp* alone used to describe non-rigid airships. Although the blimp also qualifies as a "dirigible", the term is seldom used with blimps. In modern technical usage, *airship* is the term used for all aircraft of this type, with *Zeppelin* referring only to aircraft of that manufacture, and *blimp* referring only to non-rigid airships.

There is some confusion around the term *aerostat* with regard to airships. This confusion arises because *aerostat* has two different meanings. One meaning of *aerostat* refers to all craft that remain aloft using buoyancy: here, airships are a type of *aerostat*. The narrower and more technical meaning of *aerostat* refers only to tethered or moored balloons: here, airships are distinct from *aerostats*. This airship/aerostat confusion is often exacerbated by the fact that both airships and aerostats have roughly similar shapes and comparable tail-fin configurations, although only airships have engines.

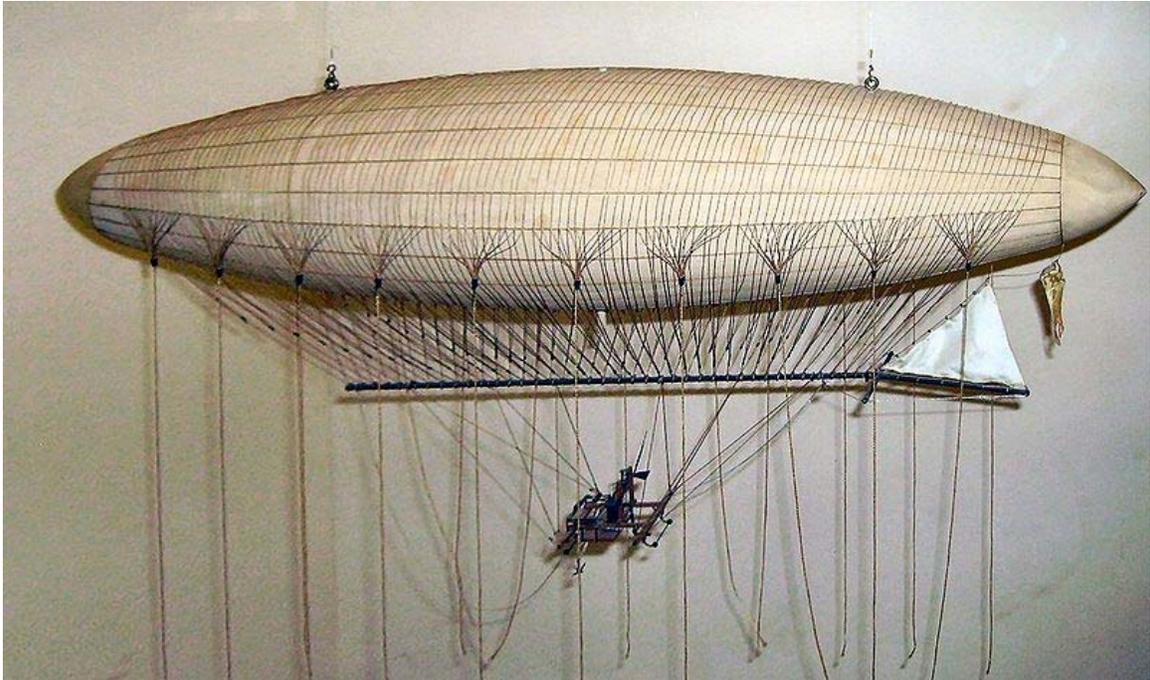
The term **gondola** is used to describe the passenger/instrument area of an airship. There may be one or more.

History

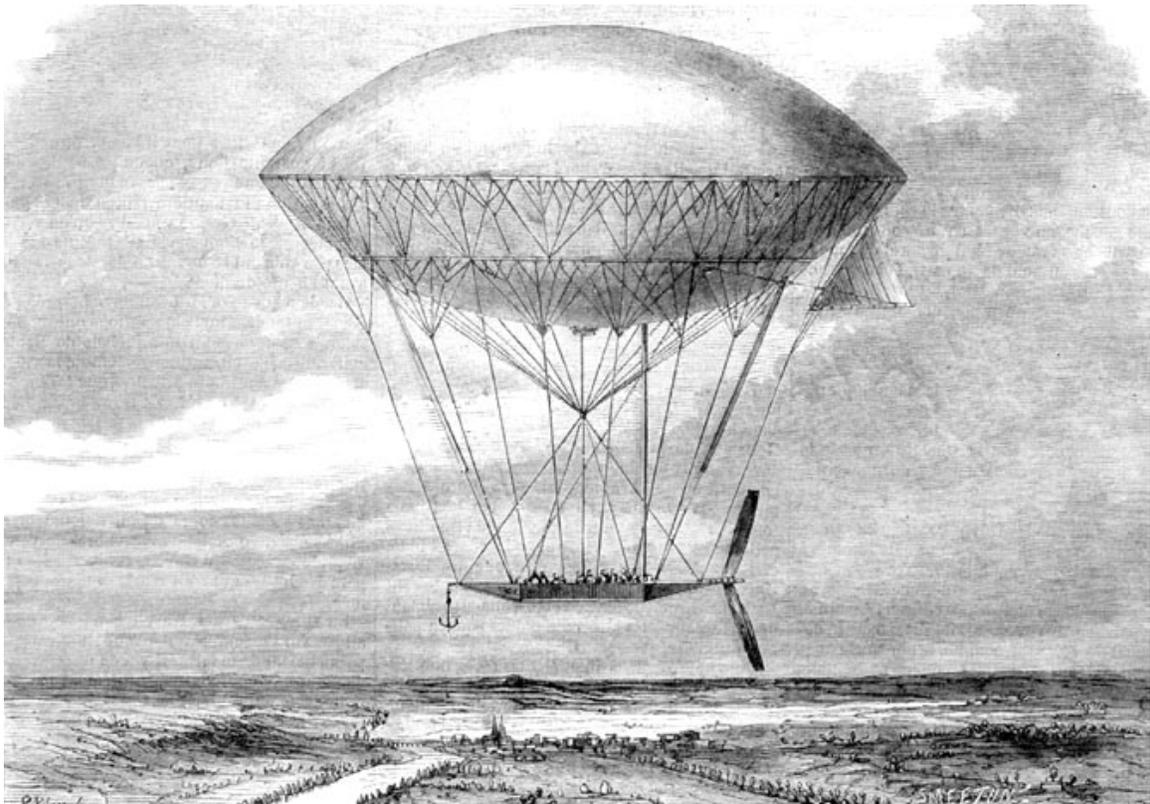
Early pioneers



Crossing of the English Channel by Blanchard in 1785



A model of the Giffard Airship at the London Science Museum



The navigable balloon developed by Henri Dupuy de Lôme in 1872

Francesco Lana de Terzi is referred to as the "Father of Aeronautics" in part for his theoretical design of a Vacuum airship circa 1670. Structural limitations have prevented this concept from taking flight.

The father of the dirigible was Lieutenant Jean Baptiste Marie Meusnier (1754–93). On 3 December 1783, he presented a historic paper to the French Academy: "*Memoire sur l'equilbre des Machines Aerostatique*" (Memorandum on the balance of aerostatic machines). The 16 water-colour drawings published the following year depicted a 260-foot-long (79 m) envelope with internal ballonets that could be used for regulating lift, and this was attached to a long carriage that could be used as a boat if the vehicle was forced to land in water. The airship was designed to be propelled in the air by three airscrew propellers and steered with a sail-like aft rudder. In 1784, Jean-Pierre Blanchard fitted a hand-powered propeller to a balloon, the first recorded means of propulsion carried aloft. In 1785, he crossed the English Channel with a balloon equipped with flapping wings for propulsion, and a bird-like tail for steerage.

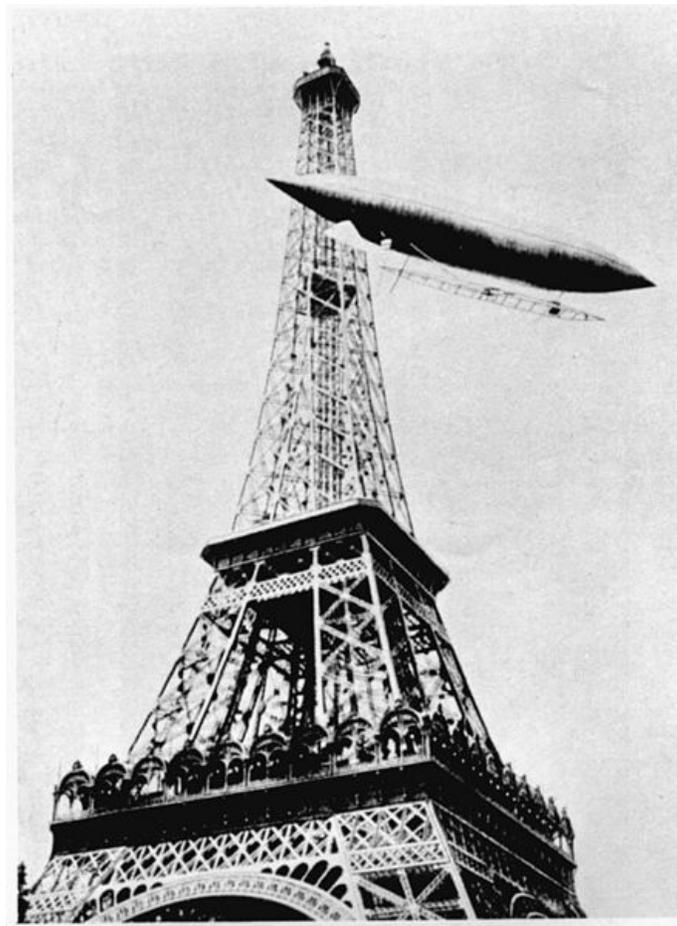
The 19th century saw continued attempts at adding propulsion to balloons. The first aviation pioneer of Australia was Dr William Bland, a naval surgeon who was sentenced to seven years transportation in a Calcutta court after a duel in Bombay in 1813. In March 1851, Bland sent designs for his 'Atmotic Airship' to the Great Exhibition at the Crystal Palace in London where a model was displayed, this was the year before Henri Giffard flew the first steam-powered dirigible. His idea was to supply power to an elongated balloon with a steam engine installed in a car, Since the lift of the balloon was estimated at 5 tons and the car with the fuel weighed 3.5 tons, the payload was estimated at 1.5 tons. Bland believed that with two airscrews the machine could be driven at 80 km/h (50 mph) and could fly from Sydney to London in less than a week. The first person to make an engine-powered flight was Henri Giffard who, in 1852, flew 27 km (17 mi) in a steam-powered airship. Airships would develop considerably over the next two decades: there were reports that on 1 June 1863 Dr. Solomon Andrews had launched the *Aereon* comprising two horizontal cylindrical gas bags with no motor that "wheeled gracefully and headed back towards them" and that later, pilotless after Andrews had released all ballast, flew in "ascending spirals" and during this ascent that it "was apparent to everyone that the ship was moving with the wind and then against it" with a Herald reporter estimating the speed at 120 mph. In 1872, the French naval architect Dupuy de Lome launched a large limited navigable balloon, which was driven by a large propeller and the power of eight people. It was developed during the Franco-Prussian war, as an improvement to the balloons used for communications between Paris and the countryside during the Siege of Paris by German forces, but was completed only after the end of the war.

Paul Haenlein flew an airship with an internal combustion engine running on the coal gas used to inflate the envelope over Vienna, the first use of such an engine to power an aircraft in 1872. Charles F. Ritchel made a public demonstration flight in 1878 of his hand-powered one-man rigid airship, and went on to build and sell five of his aircraft.

In the 1880s a Serb named Ognoslav Kostovic Stepanovic also designed and built an airship. However, the craft was destroyed by fire before it flew. In 1883, the first electric-powered flight was made by Gaston Tissandier who fitted a 1.5 hp (1.1 kW) Siemens electric motor to an airship. The first fully controllable free-flight was made in a French Army airship, *La France*, by Charles Renard and Arthur Constantin Krebs in 1884. The 170 ft (52 m) long, 66,000 cu ft (1,900 m³) airship covered 8 km (5.0 mi) in 23 minutes with the aid of an 8.5 hp (6.3 kW) electric motor, and a 435 kilograms (960 lb) battery. In 1884 and 1885, it made seven flights.

In 1888, the Novelty Air Ship Company made the Air Ship for Professor Peter C. Campbell which was known as the Campbell Air Ship. The air ship was lost at sea in 1889 while being flown by Professor Hogan during an exhibition Flight.

In 1888–97, Dr. Frederich Wölfert built three airships powered by Daimler Motoren Gesellschaft-built petrol engines, the last of which caught fire in flight and killed both occupants in 1897. The 1888 version used a 2 hp one cylinder Daimler engine and flew 10 km (6 mi) from Canstatt to Kornwestheim.



Santos-Dumont#6 rounding the Eiffel Tower, winning the Deutsch Prize in 1901

In 1896, a rigid airship created by the Croatian engineer David Schwarz made its first flight at Tempelhof field in Berlin. After Schwarz's death, his wife, Melanie Schwarz, was paid 15,000 marks by Count Ferdinand von Zeppelin for information about the airship.

The wealthy Brazilian Alberto Santos-Dumont in France had a passion for flying. He designed 18 examples of balloons and dirigibles, and created 18 different examples of the latter before turning his attention to fixed winged aircraft in 1907. In 1901, in his airship *Number 6*, a small blimp, he won the Deutsch de la Meurthe prize of 100,000 francs for flying from the Parc Saint Cloud to the Eiffel Tower and back in under thirty minutes. Many inventors were inspired by Santos-Dumont's small airships and a veritable airship craze began worldwide. Many airship pioneers, such as the American Thomas Scott Baldwin financed their activities through passenger flights and public demonstration flights. Others, such as Walter Wellman and Melvin Vaniman set their sights on loftier goals, attempting two polar flights in 1907 and 1909, and two trans-atlantic flights in 1910 and 1912.

"The Golden Age"

The "Golden Age of Airships" began in July 1900 with the launch of the Luftschiff Zeppelin LZ1. This led to the most successful airships of all time: the Zeppelins. These were named after Count von Zeppelin who began experimenting with rigid airship designs in the 1890s leading to the badly-flawed *LZ1* (1900) and the more successful *LZ2* (1906). At the beginning of World War I the Zeppelin airships had a framework composed of triangular lattice girders, covered with fabric and containing separate gas cells. Multi-plane, later cruciform, tail fins were used for control and stability, and two engine/crew cars hung beneath the hull driving propellers attached to the sides of the frame by means of long drive shafts. Additionally, there was a passenger compartment (later a bomb bay) located halfway between the two cars.

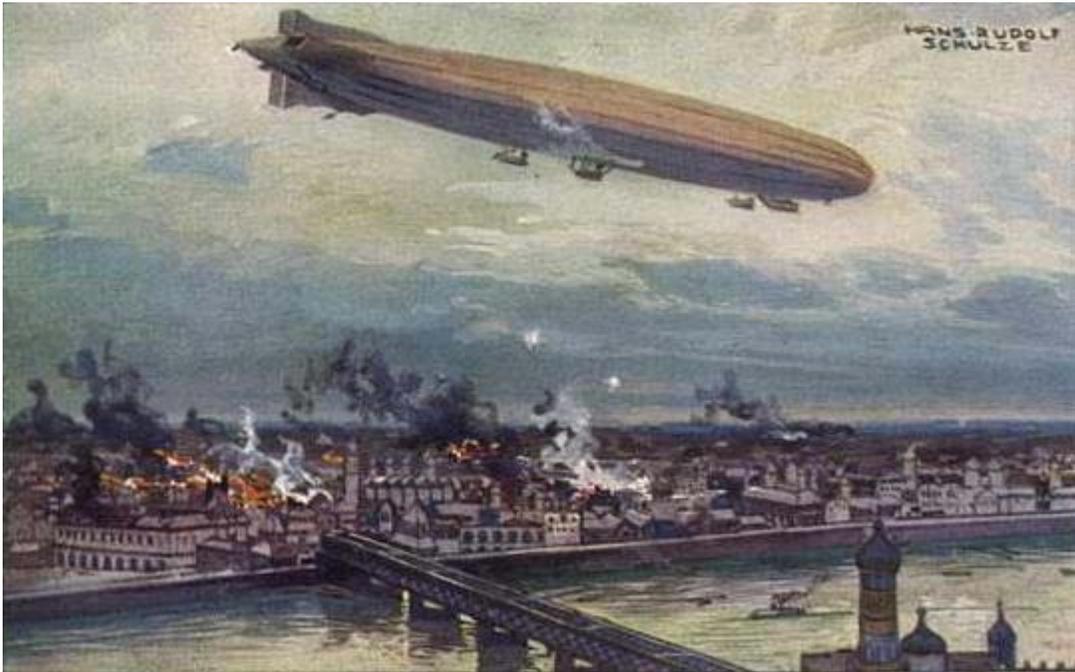
Other airship builders were also active before the war: The French company Lebaudy Frères specialised in semi-rigid airships from 1902 (e.g. the *Patrie* and the *République*), designed by their engineer Henri Julliot, who later worked for the American company Goodrich; the German firm Schütte-Lanz built the SL series from 1911; another German firm Luft-Fahrzeug-Gesellschaft built the *Parseval-Luftschiff* (PL) series from 1909, and Italian Enrico Forlanini's firm had built and flown the first two Forlanini airships.

In 1910 Walter Wellman unsuccessfully attempted the first aerial crossing of the Atlantic Ocean on airship *America*.

World War I

The prospect of airships as bombers had been recognised in Europe well before the airships were up to the task. H. G. Wells' *The War in the Air* (1908) described the obliteration of entire fleets and cities by airship attack. On 5 March 1912, Italian forces became the first to use dirigibles for a military purpose during reconnaissance west of

Tripoli behind Turkish lines. It was World War I, however, that marked the airship's real debut as a weapon.



German airship Schütte Lanz SL2 bombing Warsaw in 1914

Albert Caquot designed an Observation balloon for the French army in 1914. The tethered Type R Observation balloon was used by all the allied forces, including the British and United States Armies, at the end of the World War.

The Germans, French and Italians all operated airships in scouting and tactical bombing roles early in the war, and all learned that the airship was too vulnerable for operations over the front. The decision to end operations in direct support of armies was made by all in 1917.



Type "R" observation balloon at Arcadia Balloon School, Arcadia, Calif. 1921

Count Zeppelin and others in the German military believed they had found the ideal weapon with which to counteract British Naval superiority and strike at Britain itself. More realistic airship advocates believed the Zeppelin was a valuable long range scout/attack craft for naval operations. Raids began by the end of 1914, reached a first peak in 1915, and then were discontinued in August 1918. Zeppelins proved to be terrifying but inaccurate weapons. Navigation, target selection and bomb-aiming proved to be difficult under the best of conditions. The darkness, high altitudes and clouds that were frequently encountered by Zeppelin missions reduced accuracy even further. The physical damage done by the Zeppelins over the course of the war was trivial, and the deaths that they caused (though visible) amounted to a few hundred at most. The Zeppelins were initially immune to attack by aircraft and anti-aircraft guns: as the pressure in their envelopes was only just higher than ambient, holes had little effect. But once incendiary bullets were developed and used against them, their flammable hydrogen lifting gas made them vulnerable at lower altitudes. Several were shot down in flames by British defenders, and others crashed *en route*. They then started flying higher and higher above the range of other aircraft, but this made their bombing accuracy even worse and success harder to achieve.

In retrospect, advocates of the naval scouting role of the airship proved to be correct, and the land bombing campaign proved to be disastrous in terms of morale, men and material.

Many pioneers of the German airship service died in what was the first strategic bombing campaign in history.

Countermeasures by the British were sound detection equipment, search lights and anti-aircraft artillery, followed by night fighters in 1915. One method used early in the war when short range meant the airships had to fly from forward bases, and when the only Zeppelin production facilities were in Friedrichshafen, was bombing of airship sheds by the British Royal Naval Air Service. Late in the war, the development of the aircraft carrier led to the first successful carrier air strike in history. The morning of 19 July 1918, seven Sopwith 2F.1 Camels were launched from HMS *Furious* and struck the airship base at Tondern, destroying the Zeppelins *L 54* and *L 60*.



View from a French dirigible approaching a ship in 1918

Before the World War, the British Army was interested in blimps for scouting purposes. The Royal Navy, recognizing the potential threat that scouting Zeppelins might pose, decided in 1908 to produce an example of rigid airship so that the threat might be evaluated in practice instead of theory. The Royal Navy was to continue development of rigid airships until the end of the war. The British Army abandoned airship development in favour of aeroplanes by the start of the war, but the Royal Navy had recognised the need for small airships to counteract the submarine and mine threat in coastal waters. Beginning in February 1915, they began to deploy the SS (Sea Scout) class of blimp. These had a small envelope of 1,699-1,982 m³ (60–70,000 ft³) and at first used standard single engined planes (BE2c, Maurice Farman, Armstrong FK) shorn of wing and tail surfaces as control cars, as an economy measure. Eventually more advanced blimps with purpose built cars, such as the C (Coastal), C* (Coastal Star), NS (North Sea), SSP (Sea Scout Pusher), SSZ (Sea Scout Zero), SSE (Sea Scout Experimental) and SST (Sea Scout Twin) classes were developed. The NS class, after initial teething problems, proved to be

the largest and finest airships in British service. They had a gas capacity of 360,000 cu ft (10,000 m³), a crew of 10 and an endurance of 24 hours. Six 230 lb (100 kg) bombs were carried, as well as three to five machine guns.

British blimps were used for scouting, mine clearance, and submarine attack duties. During the war, the British operated 226 airships, mostly non-rigid, most of which were of indigenous construction, though some non-rigid airships operated were purchased from France and even Germany (before the war). Of that number several were sold to Russia, France, the US and Italy. Britain, in turn, purchased one M-type semi-rigid from Italy whose delivery was delayed until 1918. Nine rigid airships had been completed by the armistice, although several more were in an advanced state of completion by the war's end. The large number of trained crews, low attrition rate and constant experimentation in handling techniques meant that at the war's end Britain was the world leader in non-rigid airship technology.

Both France and Italy continued airships throughout the war. France preferred non-rigid types while Italy operated 49 semi-rigid airships in both the scouting and bombing roles.

Airplanes had essentially replaced airships as bombers by the end of the war, and Germany's remaining zeppelins were scuttled by their crews, scrapped or handed over to the Allied powers as spoils of war. The British rigid airship program, meanwhile, had been largely a reaction to the potential threat of the German one and was largely, though not entirely, based on imitations of the German ships.

Inter-war period

A number of nations operated airships between the two world wars. Many operated blimps. Britain, the United States and Germany were the main operators of rigid airships with Italy and France using them to a lesser extent. Italy, the Soviet Union, United States and Japan mainly concentrated on semi-rigid airships. On May 12, 1926, The Italian *Norge*, a semi-rigid airship, was the first aircraft confirmed to fly over the North Pole.

Photo # NH 69230 Rescuers working on wreckage of Airship R-38 (U.S. Navy ZR-2), 24 August 1921



Rescuers scramble across the wreckage of British R-38/USN ZR-2, 24 August 1921

The British *R33* and *R34* were near-identical copies of the German *L 33*, which crashed virtually intact in Yorkshire on 24 September 1916. Despite being almost three years out of date by the time they were launched in 1919, they were two of the most successful in British service. The creation of the Royal Air Force (RAF) in early 1918 created a hybrid British airship program. The RAF was not interested in airships and the Admiralty was, so a deal was made where the Admiralty would design any future military airships while the RAF would handle manpower, facilities and operations.

After the armistice, the airship program was rapidly wound down, and rigid airship operations were curtailed. On 2 July 1919, *R34* began the first double crossing of the Atlantic by an aircraft. It landed at Mineola, Long Island on 6 July after 108 hours in the air. The return crossing began on 8 July because of concerns about mooring the ship in the open, and took 75 hours. Impressed, British leaders began to contemplate a fleet of airships to link Britain to its far-flung colonies. But post-war economic conditions led to the scrapping of most airships and dispersion of trained personnel, until starting construction of the *R-100* and *R-101* in 1929. The major consequence of Britain's interest in establishing airship service to the empire was the effort to use the Allies' seizure of German airships and airship sheds to avoid competition from Germany. The US Navy

contracted to buy the British built R-38, but before that airship was turned over to the US, it was lost to structural failure due to both improper design and operation.



Construction of USS *Shenandoah* (ZR-1), 1923

The first American-built rigid airship was USS *Shenandoah*, christened on 20 August in Lakehurst, New Jersey. It flew in 1923, while the *Los Angeles* was under construction. It was the first ship to be inflated with the noble gas helium, which was still so rare that the *Shenandoah* contained most of the world's reserves. When the *Los Angeles* was delivered, the two airships had to share the limited supply of Helium, and thus alternated operating and overhauls.



US Navy Zeppelin USS *Macon* (ZRS-5) over Moffett Field in 1933

The United States Navy purchased what became the USS *Los Angeles* and paid with "war reparations" money, owed according to the Versailles Treaty, thus saving The Zeppelin works. The success of the *Los Angeles* encouraged the US Navy to invest in its own, larger airships. The *Los Angeles* flew successfully for 8 years.

Meanwhile Germany was building the *Graf Zeppelin* (LZ 127), the largest airship that could be built in the company's existing shed, and intended to stimulate interest in passenger airships. The *Graf Zeppelin* burned *blau gas*, similar to propane, stored in large gas bags below the hydrogen cells, as fuel. Since its density was similar to that of air, it avoided the weight change when fuel was used, and thus the need to valve hydrogen. The "Graf" was a great success and compiled an impressive safety record, flying over 1,600,000 km (990,000 mi) (including the first circumnavigation of the globe by air) without a single passenger injury.



USS *Akron* over Manhattan island circa 1932

The US Navy developed the idea of using airships as airborne aircraft carriers, although the British had experimented with a plane trapeze on their *R33* many years before. The USS *Los Angeles* was used to experiment with the project, followed by two other airships, the world's largest at the time, to test the principle—the USS *Akron* and *Macon*. Each carried four F9C Sparrowhawk fighters in its hangar, and could carry a fifth on the trapeze. The idea had mixed results. By the time the Navy started to develop a sound doctrine for using the ZRS-type airships, the last of the two built, USS *Macon*, was lost. The seaplane had become more mature, and was considered a better investment.

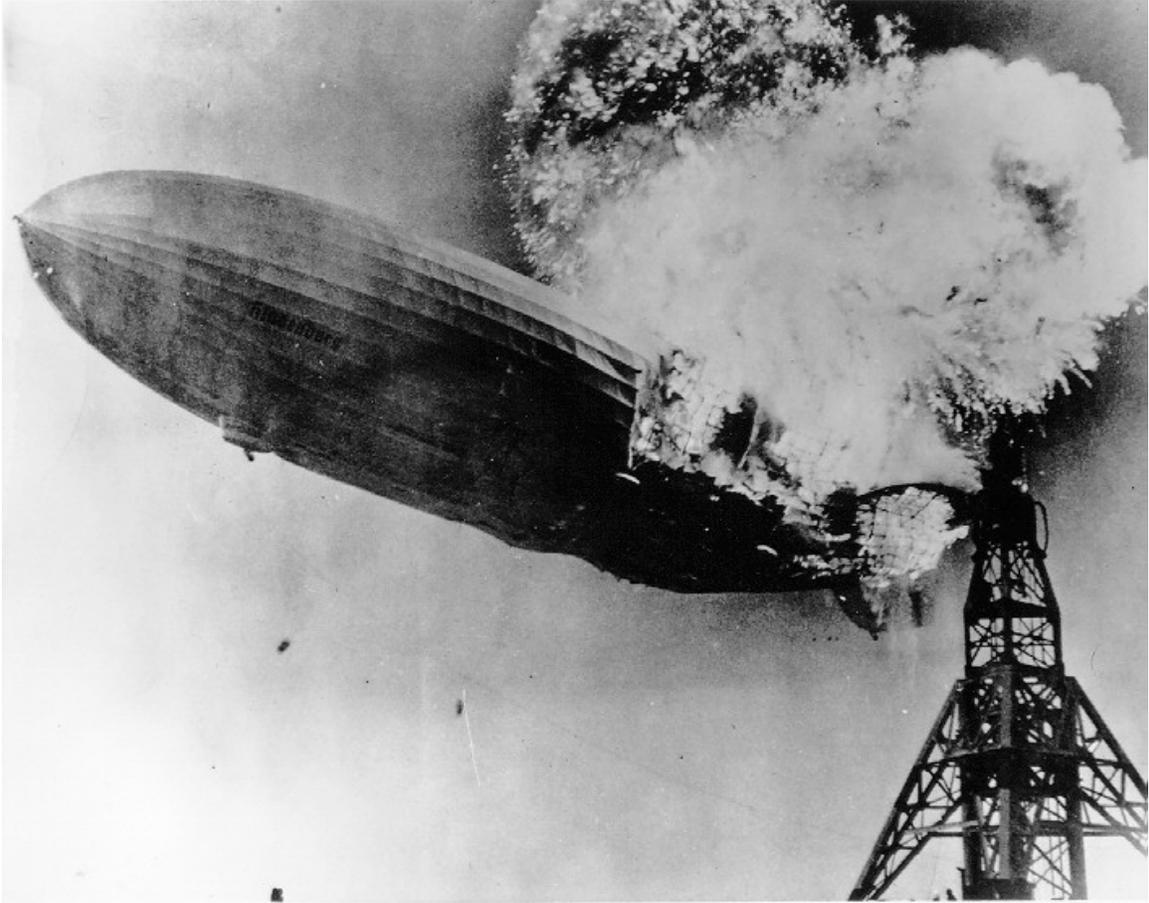
Eventually the US Navy lost all three American-built rigid airships to accidents. USS *Shenandoah* on a poorly planned publicity flight flew into a severe thunderstorm over Noble County, Ohio on 3 September 1925. It broke into pieces, killing 14 of its crew. USS *Akron* was caught in a severe storm and flown into the surface of the sea off the shore of New Jersey on 3 April 1933. It carried no life boats and few life vests, so 73 of its crew of 76 died from drowning or hypothermia. USS *Macon* was lost after suffering a structural failure off the shore of Point Sur Lightstation State Historic Park on 12 February 1935. The failure caused a loss of gas, which was made much worse when the aircraft was driven over pressure height causing it to lose too much helium to maintain

flight. Only 2 of its crew of 83 died in the crash thanks to the inclusion of life jackets and inflatable rafts after the *Akron* disaster.

Britain's Burney Scheme and decline in airships

In Britain during the 1920s, Sir Dennistoun Burney suggested a plan for air service throughout the Empire by airships (the Burney Scheme). Following the election of Ramsay MacDonald, the Burney scheme was transformed into a government-controlled program, the Imperial Airship Scheme, which contracted for two airships, one to be developed by the Airship Guarantee Company, the other by the Royal Airship Works. The two designs were radically different. The "capitalist" ship, the *R100*, was conservative, while the "socialist" ship, the *R101*, was wildly innovative. Construction was delayed, and the airships did not fly until 1929. Neither airship was capable of the service intended, though the *R100* did complete a proving flight to Canada and back in 1930, while the *R101* crashed on its maiden voyage to France at great loss of life.

In October 1930 there were rushed preparations to fly the *R101*, which had not been adequately tested and had serious deficiencies, on a flight to India carrying the Air Minister of the MacDonald government, Christopher Birdwell, Lord Thompson for an important Imperial conference. An air worthiness certificate was issued at the last moment. The *R101* left on the flight on 5 October but hours later crashed in France killing 48 of the 54 people aboard. Because of the bad publicity surrounding the crash, the Air Ministry grounded the competing *R100* in 1930 and sold it for scrap in 1931, ending the era of British rigid airships. The Empire State Building was completed in 1931 with a dirigible mast, in anticipation of passenger airship service. Various entrepreneurs experimented with commuting and shipping freight via airship.



The *Hindenburg* — moments after catching fire, 6 May 1937



Zeppelin Tower in Recife - The only one in the world preserved in its original structure.
2007 photo

By the mid-1930s only Germany still pursued the airship. The Zeppelin company continued to operate the *Graf Zeppelin* on passenger service between Frankfurt and Recife in Brazil, taking 68 hours. Even with the small *Graf Zeppelin*, the operation was almost profitable. In the mid-1930s work started to build an airship designed specifically to operate a passenger service across the Atlantic. The *Hindenburg* (LZ 129) completed a very successful 1936 season carrying passengers between Lakehurst, New Jersey and Germany. But 1937 started with the most spectacular and widely remembered airship accident. Approaching the mooring mast minutes before landing on 6 May 1937, the *Hindenburg* burst into flames and crashed. Of the 97 people aboard, 36 died: 13 passengers, 22 aircrew, and one American ground-crewman. The disaster happened

before a large crowd, was filmed and a radio news reporter was cutting a recording of his coverage of the arrival. This was a disaster which theater goers could see and hear the next day. On that same next day, the *Graf Zeppelin* landed at the end of its flight from Brazil, ending intercontinental passenger airship travel.

Hindenburg's sister ship, the *Graf Zeppelin II* (LZ 130), could not perform commercial passenger flights without helium, which the United States refused to sell. The *Graf Zeppelin* flew some test flights and conducted electronic espionage until 1939 when it was grounded due to the start of the war. The last two Zeppelins were scrapped in 1940.

Development of airships continued only in the United States, and in a small way, the Soviet Union. The Soviet Union had several semi-rigid and non-rigid airships. The semi-rigid SSSR-V6 OSOAVIAKhIM was among the largest of these craft, and set the longest endurance flight at the time of over 130 hours. However, it crashed into a mountain in 1938, killing 13 of the 19 people on board. While this was a severe blow towards the Russian airship programme, they continued to operate non-rigid airships until 1950.

World War II

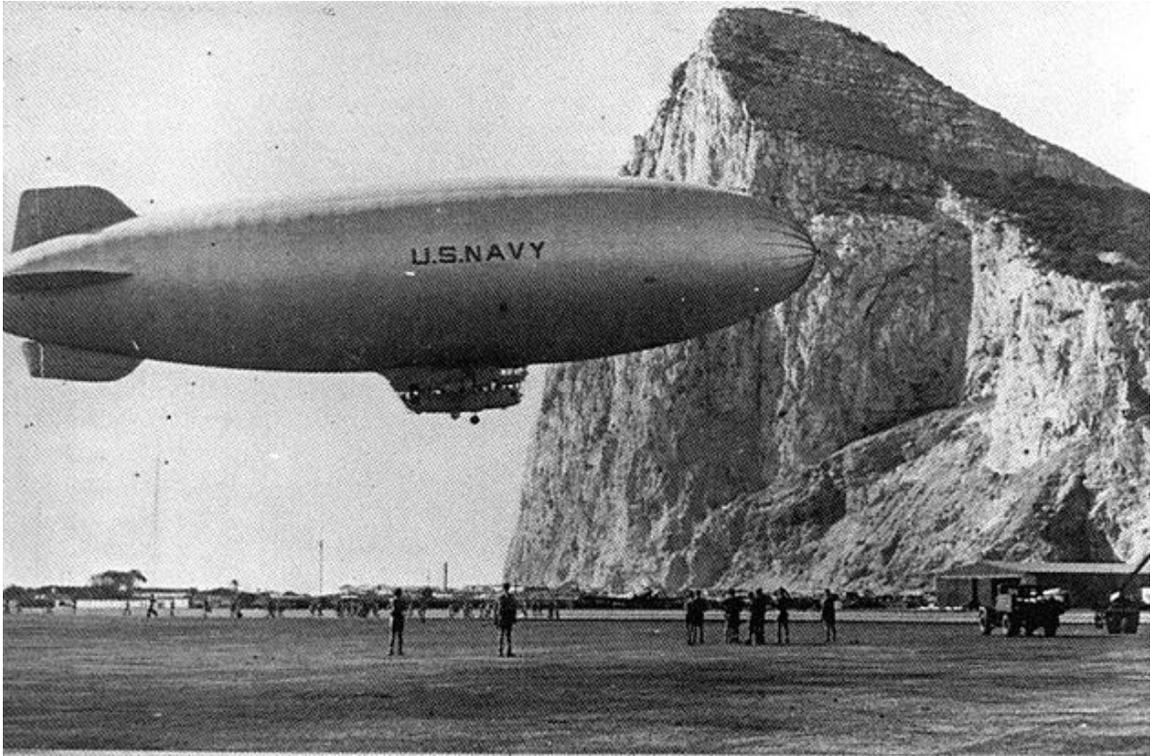
While Germany determined that airships were obsolete for military purposes in the coming war and concentrated on the development of airplanes, the United States pursued a program of military airship construction even though it had not developed a clear military doctrine for airship use. At the Japanese attack on Pearl Harbor on 7 December 1941 that brought the United States into World War II, it had 10 non-rigid airships:

- 4 *K*-class: *K-2*, *K-3*, *K-4* and *K-5* designed as patrol ships built from 1938.
- 3 *L*-class: *L-1*, *L-2* and *L-3* as small training ships, produced from 1938.
- 1 *G*-class built in 1936 for training.
- 2 *TC*-class that were older patrol ships designed for land forces, built in 1933. The US Navy acquired them from the United States Army in 1938.



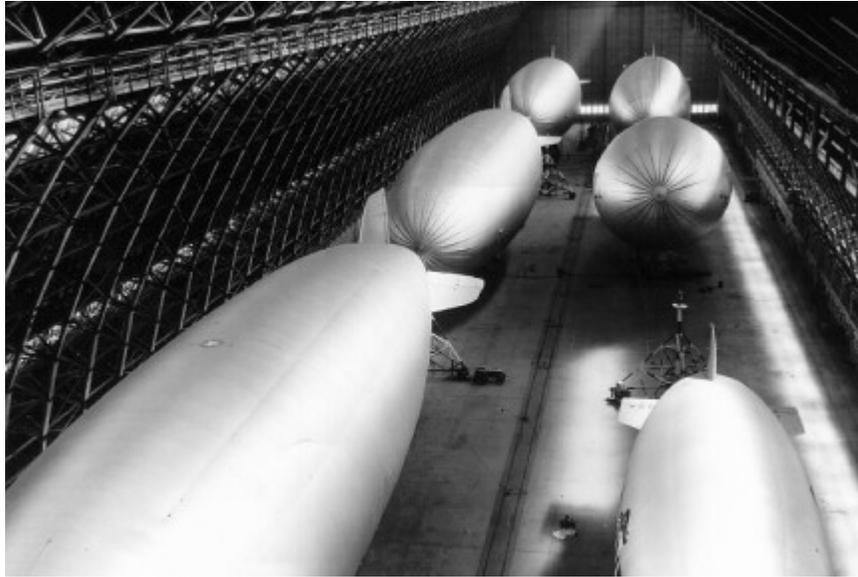
Control car of the Goodyear ZNP (K-28) Puritan

Only *K*- and *TC*-class airships were suitable for combat and they were quickly pressed into service against Japanese and German submarines which were then sinking US shipping within visual range of the US coast. US Navy command, remembering the airship anti-submarine success from World War I, immediately requested new modern anti-submarine airships and on 2 January 1942 formed the ZP-12 patrol unit based in Lakehurst from the four *K* airships. The ZP-32 patrol unit was formed from two *TC* and two *L* airships a month later, based at NAS Moffett Field in Sunnyvale, California. An airship training base was created there as well. In December 1941 and the first months of 1942, the Goodyear blimp *Resolute* was operated as an anti-submarine privateer based out of Los Angeles. As the only US craft to operate under a Letter of Marque since the War of 1812, the *Resolute*, armed with a rifle and flown by its civilian crew, patrolled the seas for submarines.



This is the K-112--the first K-type airship to land on continental Europe. Commander Sullivan made two landings at Gibraltar 18 July in the initial service test of facilities established there for handling airships. The 1,396-foot "Rock" with its attendant wind "spill" coupled with the rudderman's ticklish job of avoiding neutral Spanish territory during the approach makes a Gibraltar landing a task for seasoned pilots. Fifty ratings from R.A.F. activities directed by an airship pilot and three L.T.A. enlisted men ground handled the ship. The landings were made successfully in a 19-knot cross-"Rock" wind and a British Vice Air Marshal taken for a short hop. A duty Blimp pilot is kept at Gibraltar for liason purposes.

K-class blimps of USN Blimp Squadron ZP-14 conducted antisubmarine warfare operations at the Strait of Gibraltar in 1944-45.



A view of six helium-filled blimps being stored in one of the two massive hangars located at NAS Santa Ana, during World War II.

In the years 1942–44, approximately 1,400 airship pilots and 3,000 support crew members were trained in the military airship crew training program and the airship military personnel grew from 430 to 12,400. The US airships were produced by the Goodyear factory in Akron, Ohio. From 1942 till 1945, 154 airships were built for the US Navy (133 *K*-class, 10 *L*-class, seven *G*-class, four *M*-class) and five *L*-class for civilian customers (serial numbers *L-4* to *L-8*).

The primary airship tasks were patrol and convoy escort near the US coastline. They also served as an organisation center for the convoys to direct ship movements, and were used in naval search and rescue operations. Rarer duties of the airships included aerophoto reconnaissance, naval mine-laying and mine-sweeping, parachute unit transport and deployment, cargo and personnel transportation. They were deemed quite successful in their duties with the highest combat readiness factor in the entire US air force (87%).

In 1944-45, the United States Navy moved an entire squadron of eight Goodyear K class blimps (K-123, K-130, K-109, K-134, K-101, K-112, K-89, & K-114) with flight and maintenance crews from Weeksville Naval Air Station in North Carolina to Port Lyautey, French Morocco. Their mission was to locate and destroy German U-boats in the relatively shallow waters around the Strait of Gibraltar where magnetic anomaly detection (MAD) was viable. PBV aircraft had been searching these waters but MAD required low altitude flying that was dangerous at night for these aircraft. The blimps were considered a perfect solution to establish a 24/7 MAD barrier (fence) at the Straits of Gibraltar with the PBVs flying the day shift and the blimps flying the night shift. The first two blimps (K-123 & K-130) left South Weymouth NAS on 28 May 1944 and flew to Argenta, Newfoundland, the Azores, and finally to Port Lyautey where they completed the first transatlantic crossing by non-rigid airships on 1 June 1944. The blimps of USN Blimp Squadron ZP-14 (Blimpron 14, aka *The Africa Squadron*) also

conducted mine-spotting and minesweeping operations in key Mediterranean ports and various escorts including the convoy carrying United States President Franklin D. Roosevelt and British Prime Minister Winston Churchill to the Yalta Conference in 1945.

During the war some 532 ships without airship escort were sunk near the US coast by enemy submarines. Only one ship, the tanker *Persephone*, of the 89,000 or so in convoys escorted by blimps was sunk by the enemy. Airships engaged submarines with depth charges and, less frequently, with other on-board weapons. They were excellent at driving submarines down, where their limited speed and range prevented them from attacking convoys. The weapons available to airships were so limited that until the advent of the homing torpedo they had little chance of sinking a submarine.

Only one airship was ever destroyed by U-boat: on the night of 18/19 July 1943, a K-class airship (*K-74*) from ZP-21 division was patrolling the coastline near Florida. Using radar, the airship located a surfaced German submarine. The K-74 made her attack run but the U-boat opened fire first. *K-74's* depth charges did not release as she crossed the U-boat and the *K-74* received serious damage, losing gas pressure and an engine but landing in the water without loss of life. The crew was rescued by patrol boats in the morning, but one crewman, Aviation Machinist's Mate Second Class Isadore Stessel, died from a shark attack. The U-Boat, *submarine U-134*, was slightly damaged and the next day or so was attacked by aircraft sustaining damage that forced it to return to base. It was finally sunk on 24 August 1943 by a British Vickers Wellington near Vigo, Spain

Fleet Airship Wing One operated from Lakehurst, NJ, Glynco, GA, Weeksville, NC, South Weymouth NAS Massachusetts, Brunswick NAS and Bar Harbor ME, Yarmouth, Nova Scotia, and Argentia, Newfoundland.

Some US airships saw action in the European war theatre. The ZP-14 unit operating in the Mediterranean area from June 1944 completely denied the use of the Gibraltar Straits to Axis submarines. Airships from the ZP-12 unit took part in the sinking of the last U-Boat before German capitulation, sinking *U-881* on 6 May 1945 together with destroyers Atherton and Mobery.

Other airships patrolled the Caribbean, Fleet Airship Wing Two, Headquartered at NAS Richmond, Florida, covered the Gulf of Mexico from Richmond and Key West, FL, Houma, Louisiana, as well as Hitchcock and Brownsville, Texas. FAW 2 also patrolled the northern Caribbean from San Julian, the Isle of Pines (now called Isla de la Juventud) and Guantanamo Bay, Cuba as well as Vernam Field, Jamaica.

Navy blimps of Fleet Airship Wing Five, (ZP-51) operated from bases in Trinidad, British Guiana and Paramaribo, Dutch Guiana. Fleet Airship Wing Four operated along the coast of Brazil. Two squadrons, VP-41 and VP-42 flew from bases at Amapá, Igarape Assu, Sao Luiz, Fortaleza, Fernando de Noronha, Recife, Maceió, Ipitanga (near Salvador, Bahia), Caravellas, Vitoria and the hangar built for the *Graf Zeppelin* at Santa Cruz, Rio de Janeiro.

Fleet Airship Wing Three operated squadrons, ZP-32 from Moffett Field, ZP-31 at NAS Santa Ana, and ZP-33 at NAS Tillamook, Oregon. Auxiliary fields were at Del Mar, Lompoc, Watsonville and Eureka, CA, North Bend and Astoria, Oregon, as well as Shelton and Quillayute in Washington.

From 2 January 1942 till the end of war airship operations in the Atlantic, the airships of the Atlantic fleet made 37,554 flights and flew 378,237 hours. Of the over 70,000 ships in convoys protected by blimps, only one was sunk by a submarine while under blimp escort.

The Soviet Union used a single airship during the war. The *W-12*, built in 1939, entered service in 1942 for paratrooper training and equipment transport. It made 1432 runs with 300 metric tons of cargo until 1945. On 1 February 1945, the Soviets constructed a second airship, a *Pobeda*-class (*Victory*-class) unit (used for mine-sweeping and wreckage clearing in the Black Sea) which crashed on 21 January 1947. Another *W*-class - *W-12bis Patriot* - was commissioned in 1947 and was mostly used for crew training, parades and propaganda.

Modern use

Although airships are no longer used for passenger transport, they are still used for other purposes such as advertising, sightseeing, surveillance and research.



One of The Goodyear Tire and Rubber Company's blimp fleet

In the 1980s, Per Lindstrand and his team introduced the *GA-42* airship, the first airship to use fly-by-wire flight control which considerably reduced the pilot's workload.

The world's largest thermal airship (300,000 cubic feet/8,495 m³) was constructed by the Per Lindstrand company for French botanists in 1993. The *AS-300* carried an underslung raft, which was positioned by the airship on top of tree canopies in the rain forest, allowing the botanists to carry out their treetop research without significant damage to the

rainforest. When research was finished at a given location, the airship returned to pick up and relocate the raft.

In the spring of 2004, Lindstrand Technologies supplied the world's first fully-functional unmanned airship to the Ministry of Defense in Spain. This airship carried a 42 kilograms (93 lb) classified payload and its surveillance mission was also classified. Four years later, this airship, which is designated *GA-22*, still flies on an almost daily basis.

In June 1987, the US Navy awarded a US\$168.9 million contract to Westinghouse Electric and Airship Industries of the UK to demonstrate whether a blimp could be used as an airborne platform to detect the threat of sea-skimming missiles, such as the Exocet. At 2.5 million cubic feet, the Westinghouse/Airship Industries Sentinel 5000 (Redesignated YEZ-2A by the U. S. Navy) prototype design was to have been the largest blimp ever constructed. However, additional funding for the Naval Airship Program was killed in 1995 and development was discontinued.

The *CA-80* airship, which was launched in 2000 by Shanghai Vantage Airship Manufacture Co., Ltd., had a successful trial flight in September 2001. This model of airship was designed for the purpose of advertisement and propagation, air-photo, scientific test, tour and surveillance duties. It was certified as a grade 'A' Hi-Tech introduction program (No.20000186) in Shanghai, China. The CAAC authority granted a type design approval and certificate of airworthiness for the model CA-80 airship, which has been published in the Jane's All the World's Aircraft for five times (2003–2008).

In recent years, the Zeppelin company has reentered the airship business. Their new model, designated the Zeppelin NT made its maiden flight on 18 September 1997. There are currently four NT aircraft flying, a fifth completed in March 2009 and an expanded NT-14 (14,000 cubic meters of helium, capable of carrying 19 passengers) also under construction. One was sold to a Japanese company, and was planned to be flown to Japan in the summer of 2004. But due to delays getting permission from the Russian government, the company decided to transport the airship to Japan by ship. One of the four NT craft is in South Africa carrying diamond detection equipment from De Beers, an application at which the very stable low vibration NT platform excels. Some adaptations to the design for high heat operation and desert climate were part of that project. A separate mooring mast and a very heavy truck to moor the vehicle is also part of the technology. NT-4 belongs to Airship Ventures of Moffett Field, Mountain View in the San Francisco Bay Area, and provides sight-seeing tours

Blimps are used for advertising and as TV camera platforms at major sporting events. The most iconic of these are the Goodyear blimps. Goodyear operates three blimps in the United States, and The Lightship Group operates up to 19 advertising blimps around the world. Airship Management Services owns and operates three Skyship 600 blimps. Two operate as advertising and security ships in North America and the Caribbean.

Skycruise Switzerland AG owns and operates two Skyship 600 blimps. One operates regularly over Switzerland used on sightseeing tours.



The Spirit of Dubai approaches its motorised mooring mast

The Switzerland-based Skyship 600 has also played other roles over the years. For example, it was flown over Athens during the 2004 Summer Olympics as a security measure. In November 2006, it carried advertising calling it "The Spirit of Dubai" as it began a publicity tour from London to Dubai, UAE on behalf of The Palm Islands, the world's largest man-made islands created as a residential complex.

Los Angeles-based Worldwide Aeros Corp. produces FAA Type Certified Aeros 40D Sky Dragon airships.

In May 2006, the US Navy began to fly airships again after a hiatus of nearly 44 years. The program uses a single American Blimp Company A-170 non-rigid airship, with designation MZ-3A. Operations focus on crew training and research, and the platform integrator is Northrop Grumman. The program is directed by the Naval Air Systems Command and is being carried out at NAES Lakehurst, the original center of US Navy lighter-than-air operations in previous decades.

In November 2006, the US Army bought an A380+ airship from American Blimp Corporation through a Systems level contract with Northrop Grumman and Booz Allen Hamilton. The airship started flight tests in late 2007 with a primary goal of carrying 2,500 lb (1,100 kg) of payload to an altitude of 15,000 ft (4,600 m) under remote control and autonomous waypoint navigation. The program will also demonstrate carrying 1,000 lb (450 kg) of payload to 20,000 ft (6,100 m) The platform could be used for Multi-Intelligence collections. Northrop Grumman (formerly Westinghouse) has responsibility for the overall program.

In 2008 the *CA-150* airship was launched by Vantage Airship. This is an improved modification of model *CA-120* and completed manufacturing in 2008. With larger volume and increased passenger capacity, it is the largest manned non-rigid airship in China at present.

In 2010, the U.S. Army awarded a \$517 million (£350.6 million) contract to Northrop Grumman, to develop Long Endurance Multi-Intelligence Vehicle (LEMV) systems.

An airship starred in the *James Bond* 1985 film "*A view to a kill*" The airship had the livery of Zorin Industries.

Recent developments

In the 1930s, Zeppelins successfully competed with other means of transatlantic transport. Their advantages included the ability to carry significantly more passengers than other contemporary aircraft in greater comfort with less engine noise, vibration and turbulence, while providing amenities similar to those on ocean liners, such as private cabins, observation decks, dining rooms, and even a smoking lounge on the *Hindenburg*. Less importantly, the technology was potentially more energy-efficient than heavier-than-air designs. Zeppelins were also faster than ocean liners. On the other hand, operating the giants was quite involved, especially in terms of personnel. Often the crew would outnumber passengers on board, and on the ground large teams were necessary to assist starting and landing. Also, to accommodate Zeppelins like *Hindenburg* (which was more than five times as long as the height of the Statue of Liberty without the pedestal), very large hangars were required at airports.

Today, with large, fast, and more cost-efficient fixed-wing aircraft, it is unknown whether huge airships can operate profitably in regular passenger transport though, as energy costs rise, attention is once again returning to these lighter than air vessels as a viable alternative. At the very least, the idea of comparatively slow, "majestic" cruising at relatively low altitudes and in comfortable atmosphere certainly has retained some appeal. There have been some niches for airships in and after World War II, such as long-duration observations, antisubmarine patrol, platforms for TV camera crews, and advertising; these, however, generally require only small and flexible craft, and have thus generally been better fitted for cheaper blimps.

Heavy lifting

It has periodically been suggested that airships could be employed for cargo transport, especially delivering extremely heavy loads to areas with poor infrastructure over great distances. This has also been called roadless trucking. Also, airships could be used for heavy lifting over short distances (e.g. on construction sites); this is described as heavy-lift, short-haul. In both cases, the airships are heavy haulers. One recent enterprise of this sort was the *Cargolifter* project, in which a hybrid (thus not entirely Zeppelin-type) airship even larger than *Hindenburg* was projected. Around 2000, this idea was realized, when the CargoLifter AG constructed the world's largest cantilever shop hall measuring 360 m (1,180 ft) long, 210 m (690 ft) wide and 107 m (351 ft) high about 60 km (37 mi) south of Berlin. In May 2002, the project was stopped for financial reasons; the company had to file bankruptcy. Although no rigid airships are currently used for heavy lifting, hybrid airships are being developed for such purposes. John McPhee's *The Deltoid Pumpkin Seed* is the story of one company attempting this.

Passenger transport



A Zeppelin NT airship

In the 1990s, the successor of the original Zeppelin company in Friedrichshafen, the *Zeppelin Luftschifftechnik GmbH*, reengaged in airship construction. The first experimental craft (later christened *Friedrichshafen*) of the type *Zeppelin NT* flew in September 1997. Though larger than common blimps, the *Neue Technologie* (new technology) Zeppelins are much smaller than their giant ancestors and not actually Zeppelin-types in the classical sense; they are sophisticated semi-rigids. Apart from the greater payload, their main advantages compared to blimps are higher speed and excellent maneuverability. Meanwhile, several *Zeppelin NT* have been produced and operated profitably in joyrides, research flights and similar applications.

In June 2004, a Zeppelin NT was sold for the first time to a Japanese company, Nippon Airship Corporation, for tourism and advertising mainly around Tokyo. It was also given a role at the 2005 Expo in Aichi. The aircraft began a flight from Friedrichshafen to Japan, stopping at Geneva, Paris, Rotterdam, Munich, Berlin, Stockholm and other European cities to carry passengers on short legs of the flight. However, Russian

authorities denied overflight permission so the airship had to be dismantled and shipped to Japan rather than following the historic *Graf Zeppelin* flight from Germany to Japan.

In 2008, Airship Ventures Inc. began operations from Moffett Federal Airfield near Mountain View, California and currently offers tours of the San Francisco Bay Area for up to 12 passengers.

Use in exploration

In November 2005, De Beers, the diamond mining company, launched an airship exploration program over the remote Kalahari desert. A Zeppelin, loaded with high-tech equipment, is used to find potential diamond mines by scanning the local geography for low-density rock formations - so-called kimberlite pipes. On 21 September 2007, the airship was severely damaged by a whirlwind while in Botswana. One crew member, who was on watch aboard the moored craft, was slightly injured but released after overnight observation in hospital.

Thermal Airships and Remotes



Thermal airship (manufacturer GEFA-FLUG/Germany)

Several companies, such as Cameron Balloons in Bristol, United Kingdom, build hot-air airships. These combine the structures of both hot-air balloons and small airships. The envelope is the normal 'cigar' shape, complete with tail fins, but is inflated with hot air (as in a balloon) to provide the lifting force, instead of helium. A small gondola, carrying the pilot and passengers, a small engine, and the burners to provide the hot air are suspended below the envelope, below an opening through which the burners protrude.

Hot-air airships typically cost less to buy and maintain than modern helium-based blimps, and can be quickly deflated after flights. This makes them easy to carry in trailers or trucks and inexpensive to store. They are usually very slow moving, with a typical top speed of 25–30 km/h (15–20 mph, 6.7–8.9 m/s). They are mainly used for advertising, but at least one has been used in rainforests for wildlife observation, as they can be easily transported to remote areas.

Remote controlled (RC) airships, a type of Unmanned Aerial System (UAS), are sometimes used for commercial purposes such as advertising and aerial video and photography as well as recreational purposes. They are particularly common as an advertising mechanism at indoor stadiums. While RC airships are sometimes flown outdoors, doing so for commercial purposes is illegal in the US. In particular, Docket FAA-2006-25714 states that: "The FAA recognizes that people and companies other than modelers might be flying UAS with the mistaken understanding that they are legally operating under the authority of AC 91-57. AC 91-57 only applies to modelers, and thus specifically excludes its use by persons or companies for business purposes." The same docket item identifies 14CFR121 as the appropriate certification basis for experimental unmanned aircraft, which would include unmanned airships operating for commercial purposes, so commercial use of a unmanned airship is not prohibited - instead it must be certified under part 121 not 91.

A total of 4,700 total airships and blimps exist across the world.

Present-day research

Prototypes and experimental models

Hybrid designs such as the Heli-Stat airship/helicopter, the Aereon aerostatic/aerodynamic craft, and the CycloCrane (a hybrid aerostatic/rotorcraft), have struggled to take flight. The CycloCrane was also interesting in that the airship's envelope rotated along its longitudinal axis.

CL 160 was a very large semi-rigid airship to be built by the start-up Cargolifter, but funding ran out in 2002 after a massive hangar was built. The hangar, built just outside Berlin, has since been converted into a resort called Tropical Islands.

In 2005, a short-lived project of the US Defense Advanced Research Projects Agency (DARPA) was WALRUS HULA which explored the potential for using airships as long-distance, heavy lift craft. The primary goal of the research program was to determine the

feasibility of building an airship capable of carrying 500 short tons (450 t) of payload a distance of 12,000 mi (19,000 km) and land on an unimproved location without the use of external ballast or ground equipment (such as masts). In 2005, two contractors, Lockheed Martin and US Aeros Airships were each awarded approximately \$3 million to do feasibility studies of designs for WALRUS. In late March 2006, DARPA announced the termination of work on WALRUS after completion of the current Phase I contracts.

The US government is funding two major projects in the high altitude arena. The Composite Hull High Altitude Powered Platform (CHHAPP) is sponsored by US Army Space and Missile Defense Command. This aircraft is also sometimes called *HiSentinel High-Altitude Airship*. This prototype ship made a five-hour test flight in September 2005. The second project, the high-altitude airship (HAA), is sponsored by DARPA. In 2005, DARPA awarded a contract for nearly \$150 million to Lockheed Martin for prototype development. First flight of the HAA is planned for 2008.

Many companies are working on high-altitude airships.

In 1999 Lindstrand Technologies, in partnership with Daimler Chrysler Aerospace of Germany, was awarded a design contract by the European Space Agency (ESA) to develop a High Altitude Long Endurance airship for possible use in the telecommunications market. As a result of this, Per Lindstrand was awarded the German-based Körber Prize for engineering excellence. These stratospheric long endurance platforms inhabit the calm upper atmosphere at usually 21 km (69,000 ft) where airspace is uncontrolled, in a geo-synchronous position and remain in the same place by motoring into the prevailing wind. About 60 and 90 m (295 ft) long, they are intended to stay up for a period of three to five years without maintenance. Applications include cellular phone (S-UMTS) base station, passenger information system, digital broadcast, remote monitoring, metropolitan area network and emergency response network.

E-Green Technologies, Inc., is developing a high-altitude version of their spherically and bullet shaped airships. JP Aerospace has discussed its long-range plans that include not only high altitude communications and sensor applications but also an "orbital airship" capable of lifting cargo into low Earth orbit with a marginal transportation cost of \$1 per short ton per mile of altitude (0.70 US\$/t-km).

On 31 January 2006 LockheedMartin made the first flight of their secretly built hybrid airship designated the P-791. The design is very similar to the SkyCat, unsuccessfully promoted for many years by the now financially troubled British company Advanced Technology Group. Although Lockheed Martin is developing a design for the DARPA WALRUS HULA project, it claimed that the P-791 is unrelated to WALRUS. Nonetheless, the design represents an approach that may well be applicable to WALRUS. Some believe that Lockheed Martin had used the secret P-791 program as a way to get a "head start" on the other WALRUS competitor, US Aeros Airships.

A privately funded effort to build a heavy-lift aerostatic/aerodynamic hybrid craft, called the Dynalifter, is being carried out by Ohio Airships. Test flights are to begin in Spring 2006.

The research and development company for airship technologies, 21st century Airships Inc., has developed a spherical-shaped airship, and airships for high altitude, environmental research, surveillance and military applications, heavy lift and sightseeing. Its airships have set numerous world records.

In Russia, AUGUR-RosAerosystems Group is manufacturing non-rigid multi-functional airships for up to ten passengers, as well as patrol airships including the Au-12 and Au-30. They are also working on developmental programs for heavy-lift cargo models and high-altitude stratospheric ships.

Airships in Planetary Exploration

Several proposals have been made for the use of airships in the robotic exploration of those planets (and one moon, Titan) which have atmosphere thick enough to provide buoyancy. Some of these applications are discussed under Aerobots.

Hybrid Airship

A Hybrid airship is a general term for an aircraft that combines characteristics of heavier-than-air (airplane or helicopter) and lighter-than-air technology. Examples include helicopter/airship hybrids intended for heavy lift applications and dynamic lift airships intended for long-range cruising. It should be noted that most airships, when fully loaded with cargo and fuel, are usually ballasted to be heavier than air, and thus must use their propulsion system and shape to create aerodynamic lift, necessary to stay aloft. All airships can be operated to be slightly heavier than air at periods during flight (descent). However, the term 'hybrid airship' refers to craft that obtain a significant portion of their lift from aerodynamic lift or other kinetic means.

For example, the Aeroscraft is a buoyancy assisted air vehicle that generates lift through a combination of aerodynamics, thrust vectoring and gas buoyancy generation and management, and for much of the time will fly heavier than air. Aeroscraft is Worldwide Aeros Corporation's continuation of DARPA's now canceled Walrus HULA(Hybrid Ultra Large Aircraft) project.

Practical comparison with heavier-than-air aircraft

The advantage of airships over airplanes is that static lift sufficient for flight is generated by the lifting gas and requires no engine power. This was an immense advantage before the middle of World War I and remained an advantage for long distance, or long duration operations until World War II. Modern concepts for high altitude airships include photovoltaic cells to reduce the need to land to refuel, thus they can remain in the air until consumables expire.

The disadvantages are that an airship has a very large reference area and comparatively large drag coefficient, thus a larger drag force compared to that of airplanes and even helicopters. Given the large flat plate area and wetted surface of an airship, a practical limit is reached around 80–100 miles per hour (130–160 km/h). Thus airships are used where speed is not critical.

The gross lift capability of an airship is equal to the buoyant force minus the weight of the airship. This assumes standard air temperature and pressure conditions. Corrections are usually made for water vapor and impurity of lifting gas, as well as percentage of inflation of the gas cells at liftoff. Based on specific lift (pounds of lift per thousand cubic feet of lifting gas), the greatest static lift is provided by hydrogen (71 lbs. lift/1000 cubic feet of gas) with helium (66 lbs. lift/1000 cubic feet of gas) a close second. At 39 lbs./1000 cubic feet, steam is a distant third. Other gases, such as methane, carbon monoxide, ammonia and natural gas have even less lifting capacity and are flammable, toxic, corrosive, or all three. Operational considerations such as whether the lift gas can be economically vented and produced in flight for control of buoyancy (as with hydrogen) or even produced as a byproduct of propulsion (as with steam) affect the practical choice of lift gas in airship designs.

Considering the *Hindenburg* disaster, one may question why such a flammable gas as hydrogen was used in the first place, when it is only marginally better than helium as a lifting gas. The answer to this lies in the availability of the gas. Hydrogen can be produced easily and economically through the electrolysis of water, or by chemical reactions, whereas helium exists only in trace amounts and can only be extracted from a few natural gas wells.

In addition to static lift, an airship can obtain a certain amount of dynamic lift from its engines. Dynamic lift in past airships has been about 10% of the static lift. Dynamic lift allows an airship to "take off heavy" from a runway similar to fixed-wing and rotary-wing aircraft. However, this requires additional weight in engines and fuel, negating some of the static lift capacity.

The altitude at which an airship can fly largely depends on how much lifting gas it can lose due to expansion before stasis is reached. The ultimate altitude record for a rigid airship was set in 1917 by the L-55 under the command of Hans-Kurt Flemming when he forced the airship to 24,000 ft (7,300 m) attempting to cross France after the "Silent Raid" on London. The L-55 lost lift as the descent to lower altitudes over Germany compressed the gas left in the cells, and thus the weight of air displaced. L-55 crashed due to loss of lift. While such waste of gas was necessary for the survival of airships in the later years of WW I, it was impractical for commercial operations, or operations of helium-filled military airships. The highest flight made by a hydrogen filled passenger airship was 5,500 ft (1,700 m) on the *Graf Zeppelin's* around the world flight. The practical limit for rigid airships was about 3,000 feet (900 m), and for pressure airships around 8,000 ft (2,400 m).

Modern airships use dynamic helium volume. At sea level altitude, helium only takes up a small part of the hull, while the rest is filled with air. As the airship ascends, the helium inflates with reduced outer pressure, and air is pushed out and released from the downward valve. This allows an airship to reach any altitude with balanced inner and outer pressure if the buoyancy is enough. Some civil aerostats could reach 100,000 ft (30,000 m) without explosion due to overloaded inner pressure.

The greatest disadvantage of the airship is size, which is essential to increasing performance. As size increases, the problems of ground handling increase geometrically. As the German Navy transitioned from the "p" class Zeppelins of 1915 with a volume of over 1,100,000 cu ft (31,000 m³) to the larger "q" class of 1916, the "r" class of 1917, and finally the "w" class of 1918, at almost 2,200,000 cu ft (62,000 m³) ground handling problems reduced the number of days the Zeppelins were able to make patrol flights. This availability declined from 34% in 1915, to 24.3% in 1916 and finally 17.5% in 1918.

So long as the power-to-weight ratios of aircraft engines remained low and specific fuel consumption high, the airship had an edge for long range or duration operations. As those figures changed, the balance shifted rapidly in the airplane's favor. By mid-1917 the airship could no longer survive in a combat situation where the threat was airplanes. By the late 1930s, the airship barely had an advantage over the airplane on intercontinental over-water flights, and that advantage had vanished by the end of WW II.

This is in face-to-face tactical situation, current High Altitude Airship project is planned to survey hundreds of kilometers as their operation radius, often much farther than normal engage range of a military airplane. This provides better early warning, even farther than the Aegis system. The current Aegis system is often based on a sea vessel like Ticonderoga Class and Burke Class, which have restricted radio horizon and line of sight. For example, a radar mounted on a vessel platform 30 m (100 ft) high has radio horizon at 20 km (12 mi) range, while a radar at 18,000 m (59,000 ft) altitude has radio horizon at 480 km (300 mi) range. This is significantly important for detecting low-flying cruise missiles or fighter-bombers.

The blimp remained a viable military system only until the conventional submarine was replaced by the nuclear submarine. Today, airships are used primarily for command, control and as a communication platform; to establish and maintain reliable and secure connectivity among all forces, provide transparent data across the echelons; precisely locate friendly and enemy forces; detect targets on an extended battlefield at a minimal exposure to enemy forces; real time targeting; navigation assistance; battle management; monitor radio conversations, etc.

Safety

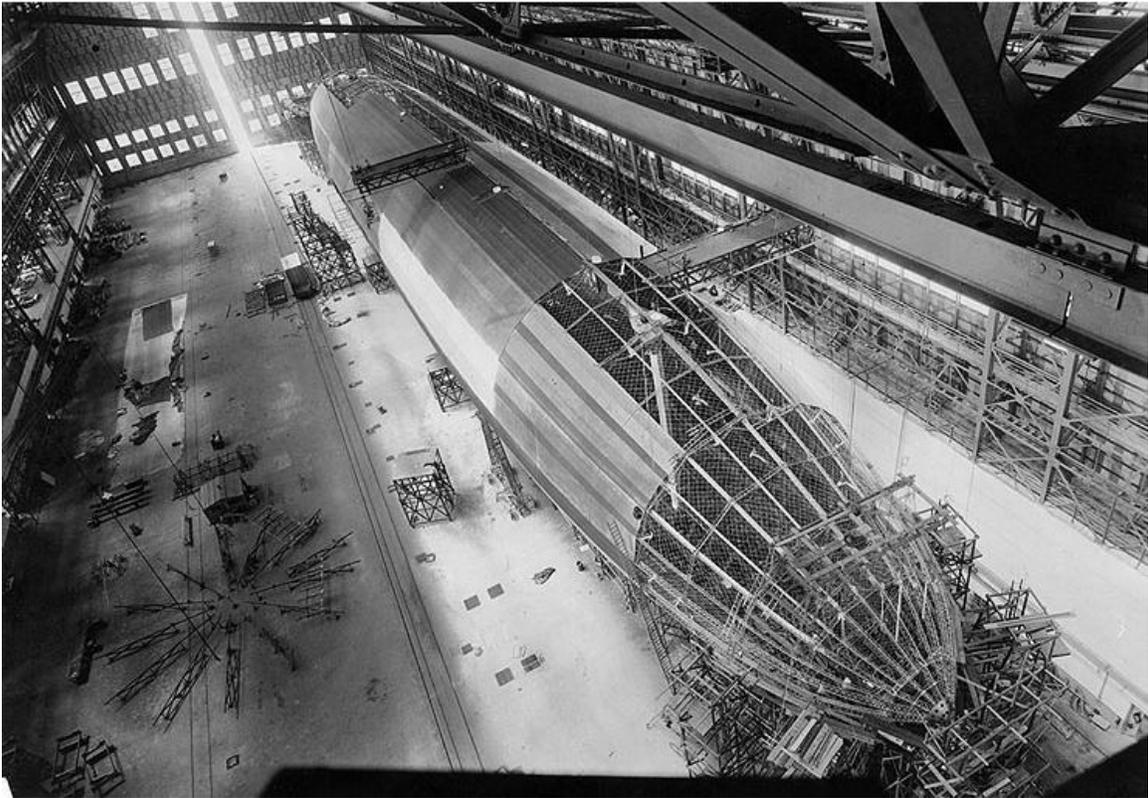
The most commonly used lift gas, helium, is not merely inert but acts as a fire extinguisher, since it is non-flammable. Modern airships have a natural buoyancy and special design that offers a virtually zero catastrophic failure mode. While on long-haul flights weather patterns would be flown to avoid bad weather, the hull's mass largely

dampens the effect of turbulence, just as a large tanker rides through rough seas. An airship is usually a poor lightning target, as it is constructed mainly from composite materials. If it is struck, built-in protection devices minimise the risk to the vehicle and its cargo.

A series of structural vulnerability tests were done by the UK Defence Evaluation and Research Agency DERA on a Skyship 600, an earlier airship built by the Munk team to a similar pressure-stabilised design. Several hundred high-velocity bullets were fired through the hull, and even two hours later the vehicle would have been able to return to base. The airship is virtually impervious to automatic rifle and mortar fire: ordnance passes through the envelope without causing critical helium loss. In all instances of light armament fire evaluated under both test and live conditions, the vehicle was able to complete its mission and return to base. The internal hull pressure is maintained at only 1–2% above surrounding air pressure, the vehicle is highly tolerant to physical damage or to attack by small-arms fire or missiles.

Chapter- 2

Rigid Airship



Construction of USS *Shenandoah* (ZR-1), 1923, showing the framework of a rigid airship

A **rigid airship** was a type of airship in which the envelope retained its shape by the use of an internal structural framework rather than by being forced into shape by the pressure of the lifting gas within the envelope as used in blimps (also termed pressurized airships) and semi-rigid airships.

Rigid airships were produced and relatively successfully employed from the beginning of the 1900s to the end of the 1930s; their heyday ended when the Hindenburg ignited on May 6, 1937.

Terminology

Although "rigid airship" is the proper formal term, these aircraft are often casually referred to by several other names such as *dirigibles*, *zeppelins* (after the most successful ships of this type built by the Zeppelin Company) or the *big rigids*.

Early days

By 1874 several people had conceived of a rigid dirigible (in contrast to non-rigid powered airships which had been flying since 1852). Frenchman Joseph Spiess had published a rigid airship proposal in 1873 but failed to get funding. Count Zeppelin had outlined his thoughts of a rigid airship in diary entries from 25 March 1874 through to 1890 when he resigned from the military. David Schwarz had thought about building an airship in the 1880s and had likely started design work in 1891, definitely by 1892 he was starting construction. It was not until after Schwarz's death in 1897 that his all-aluminium airship, built with help from with Carl Berg and the Prussian Airship Battalion, was test flown. Schwarz and Berg had an exclusive contract and Count Zeppelin was obliged to come to a legal agreement with Schwarz's heirs to obtain aluminium from Carl Berg, although the two men's designs were different and independent from each other. With Berg's aluminum, Zeppelin was able in 1899 to start building and, in 1900 July, to fly the Zeppelin LZ1.

Great Britain

Great Britain and the USA lagged behind Germany in rigid airship technology. According to a 2001 PBS documentary, much of Britain's knowledge was based on reverse engineered technology from World War I German zeppelin crashes. After several crashes of experimental airships, the British ceded this field to the Germans.

France

France's only rigid airship was built by Alsatian Joseph Spiess using a wooden framework and it flew on April 13, 1913. It was 146 metres (479 ft) long, with a diameter of 13.5 metres (44.3 ft) and a gas volume of 16,400 cubic metres (579,161 cubic feet). Joseph Spiess is buried in the famous Cimetiere du Pere-Lachaise in Paris. His gravestone celebrates his achievements with a bronze frieze of his rigid airship.

Germany

In 1900, Count Ferdinand von Zeppelin began trials with a rigid airship based on the theories of Austrian engineer David Schwartz. Germany had over twenty very large lighter-than-air rigid airships by the beginning of World War I, seven owned by the company Luftschiffbau Zeppelin. In the five years prior to the outbreak of war, his airline carried 32,722 passengers on over 1,588 flights totalling 172,530 kilometres (107,205 miles). The German war ministry took over two of them in 1909 and one crashed.

Commercial airlines ended in Germany at the outbreak of the War, during which Zeppelin's company built 95 giant military airships. German military airship stations had been established before the War and on September 2–3, 1914, the Zeppelin LZ 17 dropped three 200 lb bombs on Antwerp in Belgium. On January 19, 1915, two further airships dropped bombs on Norfolk, England, killing numerous people; the third ship in the air raid returned to Germany with engine trouble before reaching England. On May 31, 1915, the first bombs fell on London. The night of September 2–3, 1916 was when the first German airship was shot down over English soil; it was done using a small heavier-than-air aircraft. Further bombs were dropped on London during the night of November 27–28, 1916, this time by a winged aircraft. However, the build-up of England's defences against such aircraft led to the discontinuation of airship raids by Germany. The last casualties occurred on April 12, 1918.

United States

The United States rigid airship program was mostly stationed in Lakehurst Naval Air station, New Jersey. The ZR-1 Shenandoah was one of the first, serving from 1923 to 1925. The ZR-2 was a British airship intended to join the naval fleet, but it crashed in 1921. The ZR-3 was a German airship, sold to the United States in 1924 and named Los Angeles. The ship was grounded in 1931, due to the Depression, but was not dismantled for over 5 years. The sister ships Akron and Macon both crashed after technical failure. These crashes ended the rigid airship program.

Production

As well as the Zeppelin Company, Schütte-Lanz also manufactured them. Both America and Britain have manufactured rigid airships at some point.

Demise

Following the Hindenburg disaster in 1937, Germany grounded its airship fleet with the intention of replacing their hydrogen gas with non-flammable helium. By this time, however, Europe was well on the path to World War II, and the United States, the only country with substantial helium reserves, refused to sell the necessary gas. International travel was crippled during the war, and commercial aircraft - able to fly much faster than rigid airships - soon became the favored method of international air travel.

Some famous rigid airships

- *R34*, British airship and the first aircraft to traverse the Atlantic Ocean from east to west, in 1919.
- USS *Shenandoah*, American naval airship which served the U.S. Navy from 1923 until its crash in Ohio in 1925.
- *R38 (ZR-2)*, British airship intended to join the American naval fleet, but crashed during testing in 1921.

- USS *Los Angeles*, German airship sold to the United States in 1924 as part of German reparations from World War I. The ship served with distinction from 1924 to 1931.
- LZ 127 *Graf Zeppelin*, German passenger airship designed and piloted by Hugo Eckener. It circumnavigated the globe in 1929 and had a spotless safety record. It was ultimately dismantled by the Nazis at the outset of World War II.
- R-100, British airship built by the Airship Guarantee Company, a private company created solely for the construction of this airship, as a subsidiary of the armaments firm, Vickers.
- R-101, British airship designed and built by the British government in a kind of competition with the R-100. The R-101 crashed on its maiden flight in 1930 in France, with considerable loss of life. Its crash effectively ended British participation in rigid airship construction.
- USS *Akron*, American naval airship designed and built by the Goodyear Tire and Rubber Company in Ohio in 1931. Deployed as an airborne aircraft carrier, it was lost at sea in a storm off New Jersey in 1933 with considerable loss of life.
- USS *Macon*, sister ship to the *Akron*, it was a near carbon-copy of her. Though it suffered only 2 deaths, its crash in 1935 off the coast of California ended American participation in rigid airship development.
- LZ 129 *Hindenburg*, German passenger airship also designed and built by Hugo Eckener. The airship was lost in a famous fire in New Jersey in 1937. With its end came the end of the age of the Great Rigid Airships.

Modern rigids

There are no rigid airships flying today. The Zeppelin company refers to their NT ship as a rigid but this is a misnomer. The envelope shape is retained in part by super-pressure of the lifting gas, and so the NT is more correctly classified as a semi-rigid.

Chapter- 3

Blimp



An American Blimp Corporation A-60+, the MetLife Snoopy Two



Steerable ducted fans on a Skyship 600 provide thrust, limited direction control, and also serve to inflate the ballonets to maintain the necessary overpressure

A **blimp**, or **non-rigid airship**, is an airship without an internal supporting framework or keel. A non-rigid airship differs from a semi-rigid airship and a rigid airship (e.g., a Zeppelin) in that it does not have any rigid structure, neither a complete framework nor a partial keel, to help the airbag maintain its shape. Rather, these aircraft rely on both a higher pressure of the lifting gas (usually helium) inside the envelope and the strength of the envelope itself.

The term "blimp" refers only to free-flying aircraft. The term is sometimes erroneously used to refer to the tethered craft known as moored balloons. While often very similar in shape, moored balloons have no propulsion and are tethered to the ground.

Principle

Since blimps keep their shape with internal overpressure, typically the only solid parts are the passenger car (gondola) and the tail fins. A non-rigid airship that uses heated air instead of a light gas (such as helium) as a lifting medium is called a hot-air airship.



A modern blimp from Airship Management Services showing a strengthened nose, ducted fans attached to the gondola under the hull, and cable-braced fins at the tail

Volume changes of the lifting gas, due to temperature changes, is balanced using ballonets (air bags), in order to maintain the overpressure. Without sufficient overpressure, the blimp loses its ability to be steered and top speed is degraded. The propeller air stream can be used to inflate the hull. In some models, such as the Skyship 600, differential ballonet inflation can provide a measure of pitch trim control.

The engines driving the propellers are usually directly attached to the gondola, and in some models are partly steerable.

Blimps are the most commonly built airships, because they are relatively easy to build and easy to transport once deflated. However, because of their unstable hull, their size is limited. A blimp with too long a hull may kink in the middle when the overpressure is insufficient or when maneuvered too fast (this has also happened with semi-rigid airships with weak keels). This led to the development of semi-rigids and rigid airships.

Modern blimps launch somewhat heavier than air (overweight), in contrast to historic blimps. The missing lift is provided by lifting the nose and using engine power. Some types also use steerable propellers or ducted fans. Operating in a state heavier than air avoids the need to dump ballast at lift-off and also avoids the need to lose costly lifting gas on landing.

Etymology



The Spirit of Goodyear, one of the iconic Goodyear Blimps

The term "blimp" is reportedly onomatopoeic, the sound the airship makes when one taps the envelope (balloon) with a finger. Although there is some disagreement among historians, credit for coining the term is usually given to Lt. A.D. Conningham of the British Royal Navy in 1915.

A 1943 etymology published in the *New York Times* confirms the British origin during the first World War when the British were experimenting with lighter-than-air craft. The initial non-rigid aircraft was called the A-limp; and a second version called the B-limp was deemed more satisfactory.

A different derivation is given by Barnes & James in *Shorts Aircraft since 1900*:

"In February 1915 the need for anti-submarine patrol airships became urgent, and the Submarine Scout type was quickly improvised by hanging an obsolete B.E.2c fuselage from a spare Willows envelope; this was done by the R.N.A.S. at Kingsnorth, and on seeing the result for the first time, Horace Short, already noted for his very apt and original vocabulary, named it 'Blimp', adding, 'What else would you call it?'"

An oft-repeated, but false, alternative explanation for the term says that at some time in the early 20th century, the United States military had two classes for airships: Type A-rigid and Type B-limp (hence "blimp"). In fact,

"there was no American 'A-class' of airships as such—all military aircraft, heavier or lighter-than-air were designated with 'A' until the appearance of B-class airships in May 1917. There was an American B airship—but there seems to be no record of any official designation of non-rigids as 'limp'. Further, according to the Oxford Dictionary, the first appearance of the word in print was in 1916, in England, a year before the first B-class airship." ("Etymology of 'Blimp'" by Dr. A. D. Topping, AAHS Journal, Winter 1963.)

The perpetuation of this erroneous explanation is an example of false etymology.

Examples of non-rigid airships

There are several blimps worldwide. Some examples include:

- TC-3 and Tc-7, two US Army Corps non-rigid blimps used for parasite fighter trials during 1923–24.
- SS, SSP, SST, SSZ and NS class blimps, convoy escort blimps used by the UK in World War I.
- G class blimp and L class blimp, US training blimps built by Goodyear during World War II.
- K class blimp and M class blimp, US anti-submarine blimps operated during World War II.
- N class blimp (the "Nan ship"), used for anti-submarine and as a radar early-warning platform during the 1950s.
- Goodyear Blimps, a fleet of blimps operated for advertising purposes and as a television camera platform.
- Skyship 600, a private blimp used by advertising companies
- P-791, an experimental aerostatic/aerodynamic hybrid airship developed by Lockheed-Martin corporation.
- SVAM CA-80, an airship manufactured by the Shanghai Vantage Airship Manufacture Co in China

Chapter- 4

Semi-rigid Airship



Explorer Roald Amundsen crossed the North Pole in the semi-rigid airship *Norge* in 1926

Semi-rigid airships are airships with a partial framework. These often consist of a rigid, or occasionally, flexible, keel frame along the long axis under the aerodynamic hull envelope. The partial framework can also be located inside the hull. Semi-rigids were built in quantity from the late 19th century but since the 1930s they fell out of favour until the development of the Zeppelin NT

Principle

More or less integrally attached to the hull are the gondola, engines and sometimes the empennage (tail). The framework has the task of distributing the suspension loads of these attachments and the lifting gas loads evenly throughout the whole hull's surface and may also partially relieve stresses on the hull during manoeuvres. In early airships which relied on nets, fabric bands, or complicated systems of rope rigging to unite the lifting envelope with the other parts of the ship, semi-rigid construction was able to achieve improvements in weight, aerodynamic, and structural performance. The boundary

between semi-rigid and non-rigid airships is vague. Especially with small types, it is unclear whether the structure is merely an extended gondola or a proper structural keel.

As in non-rigid airships, the hull's aerodynamic shape is maintained by an overpressure of the gas inside and light framework at the nose and tail. Changes in volume of the lifting gas is balanced using ballonets (air filled bags). Ballonets also may serve to provide pitch control. For small types the lifting gas is sometimes held in the hull itself, while larger types tend to use separate gas cells which mitigates the consequences of a single gas cell failure and helps reduce the amount of overpressure needed.

History

In the first decade of the twentieth century, semi-rigid airships were considered more suitable for military use because, unlike rigid airships, they could be deflated, stored and transported by land or by sea. Non-rigid airships had a limited lifting capacity due to the strength limitations of the envelope and rigging materials then in use.

An early successful example is the Groß-Basenach design made by Major Hans Groß from the *Luftschiffer-Bataillon Nr. 1* in Berlin, the experimental first ship flying in 1907. It had a rigid keel under the envelope. Four more military airships of this design were built, and often rebuilt, designated M I to M IV, up to 1914.

The most advanced construction of semi-rigid airships between the two World Wars took place in Italy. There, the state-factory *Stabilimento di Costruzioni Aeronautiche* (SCA) constructed several. Umberto Nobile, later General and director, was its most well-known member, and he designed and flew several semi-rigid airships, including the *Norge* and *Italia*, for his overflights of the North Pole, and the *W6 OSOAVIAKhIM*, for the Soviet Union's airship program.

List of other semi-rigid airships

Pre-War and WWI

- "*Bartholomeu de Gusmão*" from Augusto Severo de Albuquerque Maranhão in Brazil in 1894, destroyed in March 1894 by a gust of wind
- "*Pax*" from Augusto Severo de Albuquerque Maranhão in France in 1902, caught fire at its first ascent, killing the pilot
- *Le Jaune* - Built by Lebaudy Frères in France, first flight: 1902-11-13. Lebaudy built many other semi-rigid airships, among them the *Patrie* and the *République*.
- Forlanini F.1 *Leonardo da Vinci*, Italy, 3265 m³, 40 PS, first ascent: 1909; 1910-02-01 damaged beyond repair
- The Groß-Basenach-type airship (5 built for the Prussian army)
- The *Luftschiff von Veeh*, (also *Veeh I* or *Stahlluftschiff*) built by Albert Paul Veeh from Apolda in Düsseldorf in the 1910s
- Siemens-Schuckert I (1911)

- M.1, Italian, first flight 1912, 83 metre long, 17 metre diameter, 2x 250 PS Fiat SA.76-4 engines each with one airscrew, payload: 3800 kg, first with the Army then the Navy, 164 flights, decommissioned 1924
- M.2, *Città di Ferrara*, Italian, first flight 1913, hull identical to the M.1, 83 metre long, 17 metre diameter, 4×125 PS driving two airscrews, payload 3000 kg, speed: 85 km/h, a Navy airship, stationed in Jesi, on 1915-06-08 shot down by an Austrian flying boat
- Forlanini F.2 *Città di Milano*, Italy, 11,500 m³, 2×85 PS, first flight: 1913-04-09, destroyed 1914-04-09 at Como
- SR.1 (M-class) built by Italy for England 1918, 12,500 m³, 83 m long, 17 m Diameter, 9 man crew, internal keel of triangular steel components

1920's and 1930s

- among the Parseval airships designed by August von Parseval in the 1900s-1930s:
 - PL 26 and PL 27
 - Parseval-Naatz designs
- Zodiac V10 was built 1930 for the French Navy
- O-1 (airship) built by SCDA, Italy, and the only true semi-rigid airship to serve with United States Navy.
- RS-1 was the only semi-rigid American military airship (used by the United States Army) built in the USA. Manufacturer: Goodyear, maiden flight: 1926.
- Raab-Katzenstein 27 - maiden flight: 1929-05-04

Nobile's company designed or built the following airships:

- T 34 *Roma*, 33,810 m³, sold to the US, successfully crossed Atlantic and later destroyed after collision with high tension wires
- N 1 *Norge*, 19,000 m³, reached the North Pole in 1926
- N 2 a 7000 m³-airship built in hangars at Augusta (Italy)
- N 3 Sold to Japan as naval Airship No. 6, first flight on 1927-04-06. It was lost in 1927 after encountering a typhoon in the Pacific.
- N 4 *Italia* Flew to Svalbard for Arctic expedition 1928, crashed after third polar flight on return from North Pole
- N 5 was a project for a 55,000 cubic metre keel airship, many times interrupted, eventually abandoned 1928
- Nobile-designed airships of the Russian airship program, such as the Soviet SSSR-V6 OSOAVIAKhIM (1934–1938)

Current developments

As of 2008 the only flying manned semi-rigid airship is the Zeppelin NT. It comprises a single gas cell kept at a slight over-pressure, ballonets to maintain constant volume, and a triangular keel structure internal to the cell.

CL160 "Cargolifter" was an unrealised design of the now liquidated German Cargolifter AG (1996–2003). **Cargolifter Joey** was a small semi-rigid experimental airship produced to test the design

Chapter- 5

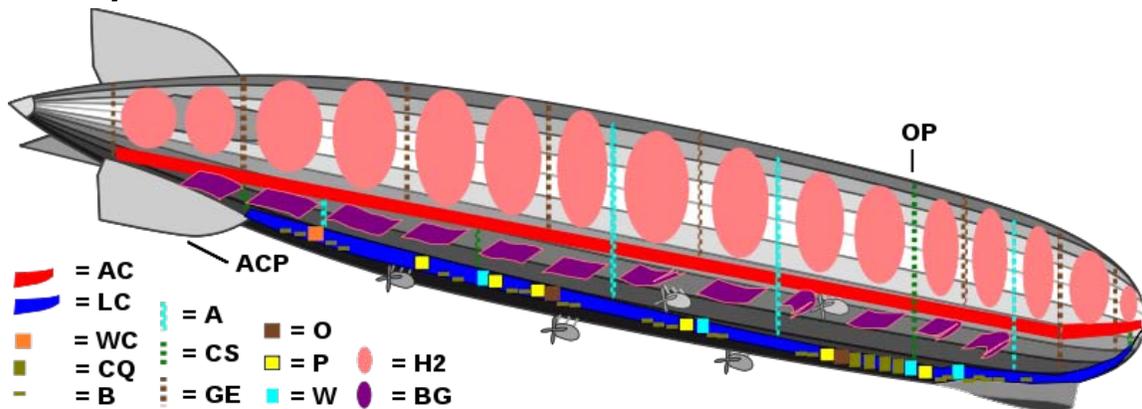
Zeppelin

A **Zeppelin** is a type of rigid airship pioneered by the German Count Ferdinand von Zeppelin in the early 20th century. It was based on designs he had outlined in 1874 and detailed in 1893. His plans were reviewed by committee in 1894 and patented in the United States on 14 March 1899. Given the outstanding success of the Zeppelin design, the term *zeppelin* in casual use came to refer to all rigid airships.

Zeppelins were operated by the Deutsche Luftschiffahrts-AG (DELAG). DELAG, the first commercial airline, served scheduled flights before World War I. After the outbreak of war, the German military made extensive use of Zeppelins as bombers and scouts.

The World War I defeat of Germany in 1918 halted the airship business temporarily. But under the guidance of Hugo Eckener, the deceased Count's successor, civilian zeppelins became popular in the 1920s. Their heyday was during the 1930s when the airships LZ 127 *Graf Zeppelin* and LZ 129 *Hindenburg* operated regular transatlantic flights from Germany to North America and Brazil. The Art Deco spire of the Empire State Building was originally if impractically designed to serve as a dirigible terminal for Zeppelins and other airships to dock. The Hindenburg disaster in 1937, along with political and economic issues, hastened the demise of the Zeppelin.

Principal characteristics



The LZ 127 Graf Zeppelin's main elements labelled. Each of the five engines was housed in its own gondola, the passenger and command gondola was at the front, lower

right. :ACP = Auxiliary control post in the lower vertical stabiliser :red = AC = axial corridor running to the front mooring hub :blue = LC = lower corridor leading to a ladder at the front joining the axial corridor :orange = WC = crew's toilet :beige = CQ = crew's quarters with tables, chairs and berths :beige = B = berths or cargo space :blue stripes = A = air ventilation shaft :green stripes = CS = climbing shaft :brown stripes GE = exhaust gas shaft :brown box = O = oil tanks :yellow box = P = petrol tanks :light blue box = W = water tank :pink cell = H2 = hydrogen lifting gas cell :magenta cell = BG = propulsion Blaugas cell :OP = Observation post on top of hull

The most important feature of Zeppelin's design was a rigid metal alloy skeleton, made of rings and longitudinal girders. The advantage of this design was that the aircraft could be much larger than non-rigid airships (which relied on a slight overpressure within the single gasbag to maintain their shape). This enabled Zeppelins to lift heavier loads and be fitted with more and more powerful engines.

The basic form of the first Zeppelins was a long cylinder with tapered ends and complex multi-plane fins. During World War I, as a result of improvements by the rival firm Schütte-Lanz Luftschiffbau, the design was changed to the more familiar streamlined shape and cruciform fins used by almost all airships ever since. Within this outer envelope, several separate balloons, also known as "cells" or "gasbags", contained the lighter-than-air gas hydrogen or helium. For most rigid airships the gasbags were made of many sheets of goldbeater's skin from the intestines of cows. About 200,000 were needed for a typical World War I Zeppelin. The sheets were joined together and folded into impermeable layers. Non-rigid airships do not have multiple gas cells.

Forward thrust was provided by several internal combustion engines, mounted in nacelles (cowlings) connected to the skeleton. The R101 airship used diesel engines, which were then an untried technology for powering aircraft; they were unsuccessful. The Graf Zeppelin used spark-ignition engines, but fuelled with a natural gas called Blaugas, which was stored uncompressed. It was similar to propane and was named after its inventor rather than its colour (*Blau* is German for "blue"). The advantage of Blaugas for airships was that it weighed more or less the same as air and so as the fuel was used up, it did not affect the trim of the airship.

A Zeppelin was steered by adjusting and selectively reversing engine thrust and by using rudder and elevator fins. The word for these combined control surfaces is empennage.

A comparatively small compartment for passengers and crew was built into the bottom of the frame, but in large Zeppelins this was not the entire habitable space; they often carried crew or cargo internally for aerodynamic reasons.

History

The first generations

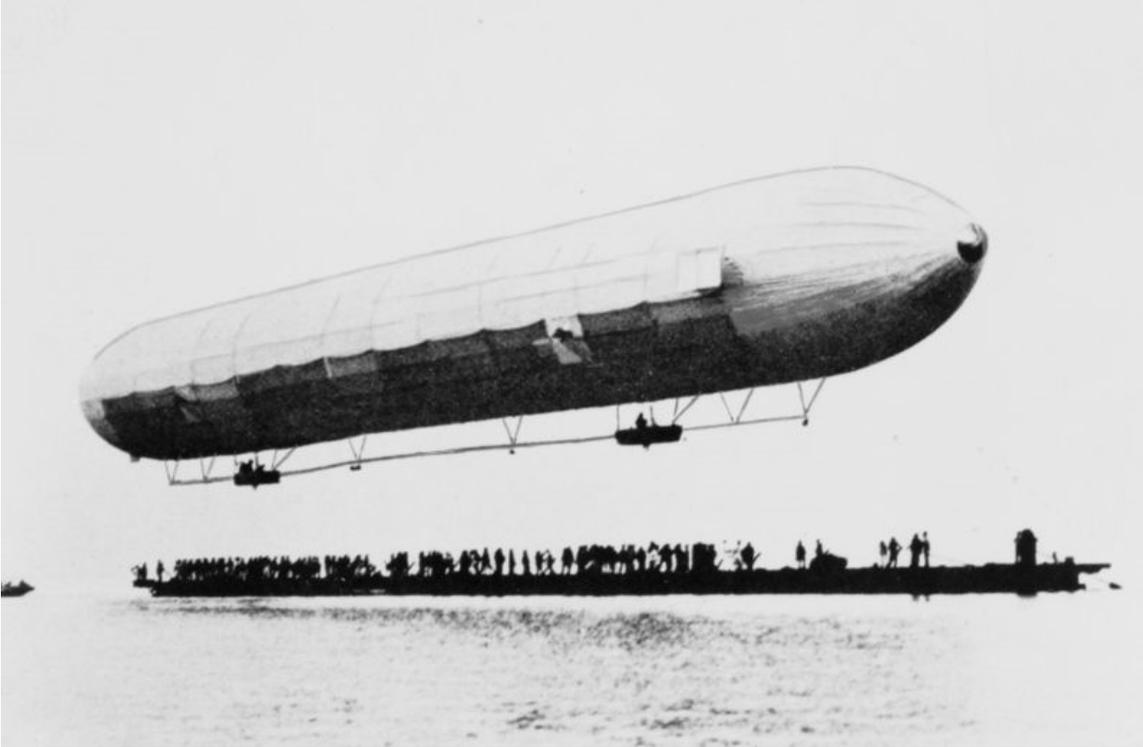
Count Ferdinand von Zeppelin became interested in constructing a "Zeppelin balloon" after the Franco-Prussian War of 1870–1871, where he witnessed the French use balloons to transport mail during the early part of the war. He had also encountered Union Army balloons in 1863, during the American Civil War, where he was a military observer. He first wrote of his dirigible interest in 1874 and began to seriously pursue his project after his early retirement from the military in 1890 at the age of 52.

Convinced of the potential importance of aircraft designs, he started working on various designs shortly after leaving the military in 1891. He had already outlined an overall system in 1874, and detailed designs in 1893 that were reviewed by committee in 1894, and that he patented on 31 August 1895, with Theodor Kober producing the technical plans. After hearing about the rigid airship constructed by David Schwarz and witnessing its trial flight at the Tempelhof Airfield near Berlin on November 3, 1897, he proceeded to buy the patent rights from the widow of the prematurely deceased Schwarz, in order to allow Carl Berg to supply aluminium. However, Schwarz's design was "radically different from Zeppelin's" and in December 1897 Zeppelin admitted the Schwarz design could not be developed. Sean Dooley speculates on the indirect benefits Zeppelin gained from Carl Berg and Schwarz's work. In 1899, Zeppelin started constructing his first airship from his own designs.

One unusual idea, which never saw service, was the ability to connect several independent airship elements like train wagons; indeed, the patent title called the design *Lenkbarer Luftfahrzeug* (steerable air train).

An expert committee to whom he had presented his plans in 1894 showed little interest, so the count was on his own in realizing his idea. In 1898 he founded the *Gesellschaft zur Förderung der Luftschiffahrt* (Society for the promotion of airship flight), contributing more than half of its 800,000 Mark share capital himself. He assigned the technical implementation to the engineer Theodor Kober and later to Ludwig Dürr.

Construction of the first Zeppelin began in 1899 in a floating assembly hall on Lake Constance in the Bay of Manzell, Friedrichshafen. This location was intended to facilitate the difficult launching procedure, as the hall could easily be aligned with the wind. The prototype airship LZ 1 (LZ for *Luftschiff Zeppelin*, or "Airship Zeppelin") had a length of 128 metres (420 ft), was driven by two 14.2 horsepower (10.6 kW) Daimler engines and was controlled in pitch by moving a weight between its two nacelles.



The first ascent of LZ1 over Lake Constance (the Bodensee) in 1900

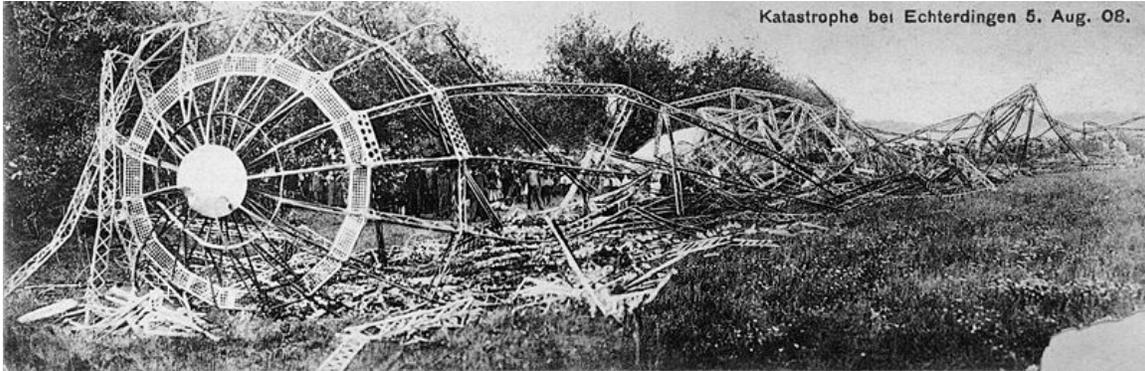
The first Zeppelin flight occurred on 2 July 1900 over Lake Constance (the Bodensee). It lasted only 18 minutes before *LZ 1* was forced to land on the lake after the winding mechanism for the balancing weight failed. After it was placed back in the hangar an apparatus used to suspend it broke. Upon repair, rigid airship technology proved its potential in subsequent flights (the second and third flights were on 17 October 1900 and 24 October 1900) beating the 6 m/s velocity record of the French airship *La France* by 3 m/s. Despite this performance, the shareholders declined to invest more money, and so the company was liquidated, with Count von Zeppelin purchasing the ship and equipment. The Count wished to continue experimenting, but he eventually dismantled the ship in 1901.

It was largely due to support by aviation enthusiasts that von Zeppelin's idea got a second (and third) chance and would be developed into a reasonably reliable technology. Only then could the airships be profitably used for civilian aviation and sold to the military.

Donations, the profits of a special lottery, some public funding, a mortgage of Count von Zeppelin's wife's estate and a 100,000 Mark contribution by Count von Zeppelin himself allowed the construction of *LZ 2*, which took off for the only time on 17 January 1906. After both engines failed, it made a forced landing in the Allgäu mountains, where the anchored ship was subsequently damaged beyond repair by a storm.

Incorporating all usable parts of *LZ 2*, the successor *LZ 3* became the first truly successful Zeppelin, which by 1908 had travelled a total of 4,398 kilometres (2,733 mi)

in the course of 45 flights. The technology then interested the German military, who bought *LZ 3* and redesignated it *Z 1*. She served as a school ship until 1913, when she was decommissioned as obsolescent.



Wreckage of LZ 4. It was destroyed when a storm broke the zeppelin from its mooring, causing it to crash into a tree and catch fire.

The army was also willing to buy *LZ 4*, but requested a demonstration of her ability to make a 24-hour trip. While attempting to fulfill this requirement, the crew of *LZ 4* had to make an intermediate landing in Echterdingen near Stuttgart. During the stop, a storm tore the airship away from its anchorage in the afternoon of 5 August 1908. She crashed into a tree, caught fire, and quickly burnt out. No one was seriously injured, although two technicians repairing the engines escaped only by making a hazardous jump. This accident would have certainly knocked out the Zeppelin project economically had not one of the spectators in the crowd spontaneously initiated a collection of donations, yielding an impressive total of 6,096,555 Mark. This enabled the Count to found the *Luftschiffbau Zeppelin GmbH* (Airship Construction Zeppelin Ltd.) and a Zeppelin Foundation.

Before World War I



A monument near Bad Iburg commemorating the 1910 LZ 7 crash

Before World War I, a total of 21 Zeppelin airships (*LZ 5* to *LZ 25*) were manufactured. In 1909 *LZ 6* became the first Zeppelin used for commercial passenger transport. The world's first airline, the newly founded *DELAG*, bought seven Zeppelins by 1914. The airships were given names in addition to their production numbers, four of which were *LZ 8 Deutschland II* (1911), *LZ 11 Viktoria Luise* (1912), *LZ 13 Hansa* (1912) and *LZ 17 Sachsen* (1913). Seven of the twenty-seven were destroyed in accidents, mostly while being moved into their halls. There were no casualties. One of them was *LZ 7 Deutschland* which made its maiden voyage on 19 June 1910. On 28 June it began a pleasure trip to make Zeppelins more popular. Among those aboard were 19 journalists, two of whom were reporters of well known British newspapers. *LZ 7* crashed in bad weather at Mount Limberg near Bad Iburg in Lower Saxony, its hull getting stuck in trees. The crew then let down a ladder to allow all the passengers to leave the ship. One crew member was slightly injured on leaving the craft.

All together, the several airships traveled approximately 200,000 kilometres (120,000 mi) and transported about 40,000 passengers.

The German Army and Navy purchased 14 Zeppelins, who labeled their aircraft Z 1/2/... and L 1/2/..., respectively. During the war, the Army changed their scheme twice: following *Z XII*, they switched to using LZ numbers, later adding 30 to obscure the total

production. When World War I broke out, the military also took over the three remaining DELAG ships. By this time, it had already decommissioned three other Zeppelins (*LZ 3* "Z 1" included). Five more had been lost in accidents, in which two people had died; a storm forced Navy Zeppelin *LZ 14* or "L 1" down into the North Sea, drowning 14; *LZ 18* or "L 2" burst into flames following an engine explosion, killing the entire crew.

By 1914, state-of-the-art Zeppelins had lengths of 150 to 160 metres (490 to 520 ft) and volumes of 22,000–25,000 m³, enabling them to carry loads of around 9,000 kilograms (20,000 lb). They were typically powered by three Maybach engines of around 400 to 550 horsepower (300 to 410 kW) each, reaching speeds of up to 80 kilometres per hour (50 mph).

During World War I

Bombers and scouts

Zeppelins were used as bombers during World War I. At the beginning of the conflict the German command had high hopes for the craft, as they appeared to have compelling advantages over contemporary aircraft – they were almost as fast, carried many more guns, and had a greater bomb-load and enormously greater range and endurance. However, their great weakness was their vulnerability to incendiary ammunition.

The German airships were operated by both the Army and Navy as two entirely separate divisions. At the beginning of the war the German Army had nine machines (including three DELAG craft requisitioned from civilian ownership), the Navy had four. All the craft were identified with the pre-war prefix *LZ* and a number, to avoid confusion between craft with the same number it is customary to use the prefix *LZ* for Naval craft and just *L* for Army craft (the Schütte-Lanz and Parseval types are sometimes identified with the respective prefixes *SL* and *PL*). Before the war the Army had lost three zeppelins to accidents and the Navy two, both Naval losses occurred in 1913 and accounted for the majority of experienced personnel. There were major differences in doctrine. The Army emphasised bombing from a low level and close support to ground forces, while the Navy had trained for reconnaissance.



The observation car preserved at the Imperial War Museum

At the beginning of the war, Captain Ernst A. Lehmann and Baron Gemmingen, Count Zeppelin's nephew, developed an observation car for use by Zeppelin dirigibles. The car was equipped with a wicker chair, chart table, electric lamp, compass, telephone, and a lightning conductor. With the Zeppelin sometimes within, sometimes above the clouds and unable to see the ground, the observer in the hanging basket would relay orders on navigation and when and which bombs to drop. Defenders could hear the engines but their searchlights and artillery fire could not reach the airship. The LZ26's basket was lowered from the airship on a specially constructed tether 1000 metres long; other airships may have used one approximately 750 metres long. The tether was high-grade steel with a brass core insulated with rubber to act as the telephone cable.

Patrols

The main use of the craft was in reconnaissance over the North Sea and the Baltic, where the endurance of the craft led German warships to a number of Allied vessels. Zeppelin patrolling had priority over any other airship activity. During the war around 1,200 scouting flights were made. The German Navy had some 15 Zeppelins in commission in 1915 and was able to have two or more patrolling continuously at any one time, almost regardless of weather. They prevented British ships from approaching Germany, spotted when and where the British were laying mines and later aided in the destruction of those

mines. Zeppelins would sometimes land on the sea next to a minesweeper, bring aboard an officer and show him the lay of the mines. Before the widespread availability of incendiary ammunition made commerce raiding too risky, they would also land or hover close to a merchant ship suspected of carrying contraband, order all ship's hands to leave in boats, then inspect the ship, and either destroy it or take it back to Germany as a prize.

1915 raids



1917 watercolour by Felix Schwormstädt - translated title: "In the rear engine gondola of a Zeppelin airship during the flight through enemy airspace after a successful attack on England"

The Naval and Army Air Services also directed a number of strategic raids against Britain, leading the way in bombing techniques and also forcing the British to bolster their anti-aircraft defences. The possibility of airship raids was approved by the Kaiser on 19 January 1915, although he excluded London as a target and further demanded that no attacks be made on historic or government buildings or museums. The nighttime raids were intended to target only military sites on the east coast and around the Thames estuary, but after blackouts became widespread, many bombs fell at random on East Anglia.

The first attack was planned for 13 January 1915. Four Zeppelins were launched but bad weather forced all the craft to abandon the raid. The first successful raid was on the night of January 19–20, 1915, in which two Zeppelins, *L.3* and *L.4*, were directed towards the Humber but, diverted by strong winds, dropped twenty-four 50 kg high explosive bombs and ineffective 3 kg incendiaries on Great Yarmouth, Sheringham, King's Lynn and the surrounding villages. In all 4 people were killed and 16 were injured. Monetary damage was estimated at £7,740.

The Kaiser allowed the bombing of London docks from February 1915, but no raids took place on London until May. The first two London raids failed owing to poor weather – *L.8* crashed near Ghent on 26 February and a four airship raid by the Army ran into fog on 17 March and was abandoned. One Army airship was damaged on landing and three more were lost in the next few weeks. With two Navy raids failing due to bad weather on 14 April and 15, it was decided to hold off further action until the more capable P-class Zeppelins were in service. The Army received its P-class Zeppelins first and undertook the first raids. Erich Linnarz commanded *LZ.38* on a raid over Ipswich on April 29–30 and again on May 9–10, attacking Southend; it also attacked Dover and Ramsgate on May 16–17, before returning to bomb Southend on May 26–27. These four raids killed 6 people and injured 6, causing property damage estimated at £17,000. Twice Royal Naval Air Service (RNAS) aircraft tried to intercept *LZ.38* but on both occasions the zeppelin was either able to outclimb the aircraft or was already at too great an altitude for the aircraft to intercept – the BE2 took some fifty minutes to climb to 10,000 feet (3,000 m).



Crater of a Zeppelin bomb in Paris

The Kaiser extended the, so far theoretical, ambit of the London raids in May 1915, allowing attacks anywhere east of the Tower of London. On 31 May Captain Linnarz again commanded *LZ.38* on the first London raid; *LZ.37* was also to be part of the raid but suffered structural damage early on and returned to Namur. Flying from Evere *LZ.38*

crossed the English coast near Margate at 21:42 before turning west once over Southend. London police were warned of an incoming raid around 23:00; a few minutes later small incendiaries began to fall. The devices were a simple metal canister filled with a mix of thermite, tar, and benzol; the exterior was wrapped in tarred rope and a simple fuse was fitted. The first device fell on a house at 16 Alkham Road, others were scattered around residential streets as the Zeppelin flew south over Stoke Newington and then Hoxton. Two incendiaries fell on Shoreditch Empire Music Hall and as *LZ.38* turned southeast explosive bombs were dropped on Spitalfields and a whiskey distillery in Commercial Road. Turning northeast the remaining load was dropped on Stepney, Stratford and finally, around 23:30, five bombs fell on Leytonstone. *LZ.38* then headed back towards Southend, crossing the coast near Foulness. In total some 120 devices were dropped, totalling 3,000 pounds (1,400 kg), including 91 incendiaries, 28 bombs and two 'grenades'. 7 people were killed, 35 were injured; forty-one fires were started, burning out seven properties, damage was priced at £18,596. The RNAS had fifteen aircraft in the air, but only one even sighted the Zeppelin; no ground-based guns fired and no searchlights found the airship. This marked failure by the capital's defences led to the British government implementing strong press restrictions on the reporting of air-raids.

The Naval airships also tried to raid London. *L.10* attempted to reach the city on 4 June, strong winds led the commander to misjudge his position and the bombs were dropped on Gravesend. *L.9* was also diverted by the weather on June 6–7, attacking Hull instead of London and causing considerable damage. On the same night an Army raid of three Zeppelins also failed because of the weather; in an added blow, as the craft returned to Evere they coincided with a pre-planned raid by RNAS aircraft flying from Furnes, France. *LZ.38* was destroyed on the ground while *LZ.37* was intercepted in the air by R. A. J. Warneford in his Morane Parasol, he dropped six 20 pounds (9.1 kg) Hales bombs on the zeppelin which caught fire and crashed into the convent school of St. Amansdsberg. 2 nuns were killed and the entire crew of the Zeppelin also died except for one man. Flight S/L Warneford was awarded the Victoria Cross for his achievement. As a further consequence of the raid both the Army and Navy withdrew from all bases in Belgium; the vulnerability of such sites was now clear.

The short summer nights discouraged further raids for some months, after an ineffective attack by *L.10* on Tyneside on June 15–16. In the same period the remaining Army Zeppelins were re-assigned to the Russian Front. The Navy returned to raids on Britain in August. On August 9–10 four Zeppelins were directed against London; none reached their target and one, *L.12*, was damaged by ground fire while near Dover and ditched into the sea off Zeebrugge. Despite eight attacks by RNAS aircraft the craft was towed into Ostend where it was abandoned and later dismantled. The four-Zeppelin raid was repeated on August 12–13; again only one craft made landfall, *L.10* dropped its bombs on Harwich. A third four-Zeppelin raid again tried to reach London on August 17–18, two turned back with mechanical problems, one bombed Ashford, Kent on 10 August in the belief it was Woolwich, but *L.10* became the first Navy airship to reach London. *L.10* was also misnavigated, mistaking the reservoirs of the Lea Valley for the Thames, and consequently dropping the bombs on Walthamstow and Leytonstone. 10 people were killed, 48 injured, property damage was estimated at £30,750 by the London Fire

Brigade. A number of guns fired at *L.10* and a few aircraft were launched (two Caudron G.3s crashed on landing after their search), but the Zeppelin suffered no damage in the raid (*L.10* was destroyed a little over two weeks later in a thunderstorm over the North Sea; it crashed off Cuxhaven and the whole crew was killed).

Two Army Zeppelins successfully bombed London on September 7–8, *SL.2* dropped bombs on the Isle of Dogs, Deptford, Greenwich and Woolwich. *LZ.74* was forced to drop weight on its approach and scattered 39 bombs over Cheshunt, before heading on to London and dropped devices on Bermondsey, Rotherhithe and New Cross. 18 people were killed and 28 injured, property damage totalled £9,616. Fog and mist prevented any aircraft being launched but a number of anti-aircraft guns fired at *LZ.74* with no effect.

The Navy attempted to follow up the Army's success the following night. Three Zeppelins were directed against London and one against an ironworks at Skinningrove. *L.11* turned back early with engine trouble; *L.14* suffered the same problem while over Norfolk, its bombs were dropped on East Dereham and the Zeppelin returned home. *L.13* reached London, approaching over Golders Green, *Kapitänleutnant* Heinrich Mathy began bombing around 22:40. Amongst the bomb-load was a 300 kilograms (660 lb) device, the largest yet carried by a significant margin. It exploded on Bartholomew Close, did much property damage, gouged a crater eight feet deep and killed two men. The Zeppelin was repeatedly caught by searchlights and all twelve anti-aircraft emplacements in London were active – but every shell exploded too low and the falling shrapnel caused both damage and alarm on the ground. Three aircraft were in the air. None even saw the Zeppelin; one crashed on landing killing the pilot. The raid took 22 lives and injured 87. The wavering line of destruction through central London caused damage estimated at £530,787.

After three more raids were scattered by the weather a five-Zeppelin raid was launched by the Navy on 13 October, the "Theatreland Raid." Arriving over the Norfolk coast around 18:30 the Zeppelins encountered new ground defences installed since the September raid under the guidance of Sir Percy Scott. These new gun sites proved ineffectual. Indeed a 13-pounder near Broxbourne was actually put out of action by three bombs dropped from *L.15*. *L.15* continued on to London and began bombing over Charing Cross, the first bombs striking the Lyceum Theatre and the corner of Exeter and Wellington Streets, killing 17 and injuring 20. Further bombs were dropped on Holborn, as the airship neared Moorgate it was engaged by a new 75 mm gun sited at the Honourable Artillery Company. *L.15* quickly recognised this new threat and dumped ballast, dropped only three more bombs (one landing on Aldgate High Street causing much damage) before departing, having suffered some engine damage from the shells. *L.13* dropped its bombs around Guildford and later near Woolwich. *L.14* dropped bombs on Otterpool Army Camp, killing 14 soldiers and injuring 12, and later bombed Tonbridge and East Croydon, on its return path it almost collided with *L.13* over Bromley. Both the other Zeppelins, *L.16* and *L.11*, were even further off course, *L.16* dropped up to fifty bombs on Hertford and *L.11* scattered a few bombs over Norfolk before heading home. In total 71 people were killed and 128 injured. This was the last

raid of 1915, as bad weather coincided with the new moon in both November and December 1915, and continued into January 1916.

There were twenty raids in 1915, in which 37 tons of bombs were dropped, killing 181 people and injuring 455.

Italy was the only country other than Germany to use lighter-than-air craft for bombing purposes. Italian airships were "semi-rigid dirigibles," they were different to the "rigid" Zeppelins in that they had a keel only, as opposed to the entire frame favoured by the Germans. Their first bombing raid was on 26 May 1915, three days after entering the war, when they crossed the Adriatic to attack Sebenico, which was attacked by a dirigible again the following day. On 8 June 1915, the *Città di Ferrara* took off from an airfield in Pordenone to bomb the Whitehead Torpedo factory and the oil refinery at Fiume, killing one woman in Fiume and injuring several other people, but only causing slight damage. It then turned for home, but a L-48 flying boat from the Austro-Hungarian Naval Air Service shot it down over the Kvarner Gulf near the island of Lussino. This seems to have been the first airship ever shot down in a combat action.

1916 raids

British ground defences were divided between the Royal Navy and the British Army at first, before the Army took full control in February 1916, and a variety of sub 4-inch (less than 102 mm) calibre guns were converted to anti-aircraft use. Searchlights were introduced, initially manned by police, their inexperience led to a number of illuminated clouds being mistaken for attacking airships. In January 1916 a set of two defensive rings was proposed for London with 490 guns and 490 searchlights divided between them, this grand scheme was soon reduced and by mid-1916 there were *nationally* 271 anti-aircraft guns and 258 searchlights.

Aerial defences against Zeppelins were haphazard and divided between the RNAS and the Royal Flying Corps (RFC), with the Navy engaging enemy craft approaching the coast while the RFC took responsibility once the enemy had crossed the coastline. The lack of an interrupter gear in early fighters meant the basic technique of downing them was to drop bombs on them (a technique which was to resurface in World War II). Initially the War Office also believed that the Zeppelins used a layer of inert gas to protect themselves from incendiary bullets and discouraged the use of such ammunition in favour of bombs. The initial trials of incendiary bullets in mid-1915 were unimpressive. Incendiary ammunition also underwent several separate development tracks, the first bullet was designed by John Pomery, but by mid-1916 the RFC also had Brock, Buckingham and 'Sparklet' incendiary cartridges. Ten 'home defence' squadrons were organised from February 1916, with London's defences assigned to No. 19 RAS at Sutton's Farm and Hainault Farm (renamed No. 39 (Home Defence) Squadron in April 1916 who were also allocated North Weald Bassett airfield in August 1916). The actual number of aircraft varied, in February there were only eight squadrons and less than half the number of aircraft expected, by June the number of squadrons were cut to six and

only No. 39 Squadron was at full strength and equipped with newer aircraft – BE12s with interrupter gear and Lewis guns firing a mix of explosive, incendiary and tracer rounds.



A plaque, (located on 61 Farringdon Road, London), commemorating a World War I Zeppelin raid on London.

Raids continued in 1916. In December 1915 new Q-class airships were delivered to both the German Army and Navy as well as additional P-class Zeppelins. The Q-class simply added two more gas cells to the P-class, lengthening the craft to 585 feet (178 m), adding 100,000 cubic feet (2,800 m³) of gas, and improving both ceiling and bomb-load.

The first raid of 1916 was organised by the Navy. Nine Zeppelins were sent to Liverpool over the night of 31 January – 1 February. A combination of poor weather, difficult navigation and mechanical problems scattered the aircraft across the English Midlands and several towns were bombed. A total of 61 people were reported killed and 101 injured by the raid. Despite ground-fog, twenty-two aircraft were launched to find the Zeppelins but none succeeded. In attempting to land in the poor conditions, sixteen aircraft suffered various degrees of damage and two pilots were killed. One airship, the L.19, crashed in the North Sea because of engine failure and damage from Dutch ground-fire; all 16 crew were lost. Further raids were curtailed by an extended period of poor weather and also by the withdrawal of the majority of Naval Zeppelins in an attempt to identify and remove the recurrent mechanical failures. Three P-class Zeppelins did attack Hull on March 5–6, causing significant property damage.

On July 28–29 the first 'Super Zeppelin', the 650 ft M-class *L.31*, appeared in English skies. Powered by six engines and capable of operating at 13,000 ft (4,000 m), (with another 5,000 ft (1,500 m) to its maximum ceiling), while carrying up to four tonnes of bombs. Part of a ten-Zeppelin raid that achieved very little, four returned home early and the rest wandered over a fog-shrouded landscape before giving up. Adverse weather dispersed the next raid on July 30–31 and again on August 2–3. On August 8–9 two M-class Zeppelins were part of a nine craft raid that did much damage to Hull. The sixth successful London raid was on August 24–25, thirteen Navy Zeppelins were launched and Heinrich Mathy's *L.31* reached London, flying above low cloud, thirty-six bombs were dropped in ten minutes on West Ferry Road, Deptford Dry Dock, the station at Norway Street and homes in Greenwich, Eltham and Plumstead. 9 people were killed, 40 injured and £130,000 of damage was caused. *L.31* suffered no damage in the attack but several weeks of repair-work was needed following a rough landing.

The biggest raid so far was launched on September 2–3, twelve Navy craft and four Zeppelins from the Army took part. A combination of rain and snowstorms scattered the craft while they were still over the North Sea. None of the Naval craft reached London. Only the Army's *LZ.98* and the newly commissioned *SL.11* achieved their objective. *SL.11* came in over Foulness with the intention of looping around and attacking the capital from the north-west. The craft dropped a few bombs over London Colney and South Mimms. At about 01:50 it was picked up by a searchlight over Hornsey and subjected to an intense but ineffective barrage. *SL.11* was lost in cloud over Wood Green but rediscovered by the searchlights at Waltham Abbey as it bombed Ponders End. At around 02:15 one of the three aircraft in the sky that night finally came into range – a BE2c piloted by Lt. William Leefe Robinson flying from Suttons Farm. Robinson fired three drums of ammunition from his Lewis gun, one on each of three passes. After emptying the third drum the airship began burning from the stern and was quickly enveloped in flames, it fell to the ground near Cuffley. There were no survivors. Four Naval Zeppelins which had regrouped over Hertfordshire saw the fate of *SL.11* and quietly slipped away. For the first Zeppelin downed on British soil and the first 'night fighter' victory Leefe Robinson received the Victoria Cross. The pieces of *SL.11* were gathered up and sold by the Red Cross to raise money for wounded soldiers.

The loss of *SL.11* ended the Army's interest in raids on Britain. The Navy remained aggressive and a twelve Zeppelin raid was launched on September 23–24, eight older craft bombing targets in the Midlands and four M-class Zeppelins (*L.30*, *L.31*, *L.32*, and *L.33*) attacking London. *L.30* did not even cross the coast, dropping its bombs at sea.

L.31 approached London from the south, dropped a few bombs on Kenley and Mitcham and was picked up by a number of searchlights. Forty-one devices were then dropped in rapid succession over Streatham, killing 7 and wounding 27. More bombs were dropped on Brixton before crossing the river and dropping ten bombs on Leyton, killing another 8 people and injuring 30. *L.31* then headed home. Also coming in from the south was *L.32*, running late due to engine problems, it dropped a few bombs on Sevenoaks and Swanley before crossing Purfleet at about 01:00. The Zeppelin then came under anti-aircraft fire as it dropped bombs on Aveley and South Ockendon. Shortly thereafter, at 01:10, a BE2c

piloted by 2nd Lieutenant Frederick Sowrey engaged *L.32*. He fired three drums of incendiaries and succeeded in starting a blaze which quickly covered the entire craft. The Zeppelin crashed to earth at Snail's Hall Farm, Great Burstead, the entire crew was killed although some, including the commander *Oberleutenant-zur-See* Werner Peterson, chose to jump rather than burn.

L.33 dropped a few incendiaries over Upminster before losing its way and making a number of turns, heading over London and dropping bombs on Bromley at around midnight. As the bombs began to explode, the Zeppelin was hit by an anti-aircraft shell fired from the guns at either Beckton, Wanstead, or Victoria Park despite being at 13,000 feet (4,000 m). Dropping bombs now to shed weight, a large number fell on homes in Botolph Road and Bow Road. As the craft headed towards Chelmsford it continued to lose height, coming under fire at Kelvedon Hatch and briefly exchanging fire with a BE2c. Despite the efforts of the crew, *L.33* was forced to the ground at around 01:15 in a field close to New Hall Cottages, Little Wigborough. The Zeppelin was set alight and the crew headed south before being arrested at Peldon by the police. A close inspection of the wreckage enabled the British to understand where their own rigid airship designs had been deficient. Furthermore, one 250 hp (190 kW) engine recovered from the wreck subsequently substituted for two (of four) 180 hp (130 kW) engines on a Vickers-built machine, the hitherto underpowered *R.9*.

The next raid came on 1 October 1916. Eleven Zeppelins were launched at targets in the Midlands and at London. As usual weather played a major role and only *L.31* under the experienced Heinrich Mathy, on his fifteenth raid, reached London. Approaching from Suffolk, *L.31* was picked up by the searchlights at Kelvedon Hatch around 21:45; turning away, the craft detoured over Harlow, Stevenage and Hatfield before cutting its engines and drifting with the wind over Hertford. As the airship neared Cheshunt at about 23:20 the engines were restarted and the craft was quickly picked up by six searchlights. Three aircraft of No. 39 Squadron were in the air and closed on *L.31*. Mathy ordered the dumping of bombs, (fifty fell on Cheshunt), in order to gain altitude. A BE2c piloted by 2nd lieutenant Wulstan Tempest engaged the Zeppelin around 23:50; three bursts were sufficient to set *L.31* ablaze and it crashed near Potters Bar with all nineteen crew dying – although again many decided to jump rather than burn (including Mathy, whose body was found near the wreckage, embedded some four inches in the softened earth). Tempest had had to dive out of the way of the stricken craft and, over-wrought, had crashed on landing, suffering minor injuries.

With the next raid on November 27–28, the Zeppelins avoided London for targets in the Midlands. But again the aircraft and the incendiary bullet proved lethal – *L.34* was shot down over the mouth of the Tees and *L.21* was attacked by two aircraft and crashed into the sea off Lowestoft. There were no further raids in 1916 although the Navy lost three more craft, all on 28 December – *SL.12* was destroyed at Ahlhorn by strong winds after sustaining damage on a poor landing, and at Tondern *L.24* crashed into the shed while landing and the resulting fire destroyed both *L.24* and the adjacent *L.17*.

There were 23 airship raids in 1916 in which 125 tons of ordnance were dropped, killing 293 people and injuring 691.

1917 raids

Anti-aircraft defences were becoming tougher and new Zeppelins were introduced with an increased operating altitude of 16,500 feet (5,000 m) and a maximum ceiling of 21,000 feet (6,400 m). The first S-class Zeppelins entered service in February 1917. They were largely a modification of the M-class, sacrificing weight for improved altitude. The surviving M-class Zeppelins were converted to S-class, notably by reducing the number of engines from six to five. To avoid searchlights, they flew above the clouds whenever possible, lowering an observer through them in a *Spähkorb* (observation gondola) to direct the bombing. The improved safety was counteracted by the extra strain on the airship crews who became more prone to altitude sickness and exposure to extreme cold and high altitude winds.

The first raid of 1917 did not occur until March 16–17 and the five high flying Zeppelins encountered very strong winds and none reached their targets. This experience was repeated on May 23–24. Two days later twenty-one Gotha bombers attempted a daylight raid on London. They were halted by heavy cloud but the effort led the Kaiser to announce that airship raids on London were past; under pressure he later relented to allow Zeppelin attacks to continue under "favourable circumstances".

On June 16–17 another Zeppelin raid was attempted, only two out of six Zeppelins reached England in the face of strong winds. *L.42* bombed Ramsgate, hitting a munitions store. The month-old *L.48*, commanded by *Korvettenkapitän* Franz Eichler, but with *Korvettenkapitän* Viktor Schutze also on board, suffered from both engine problems and compass malfunction. It was forced to drop to 13,000 feet (4,000 m) where it was caught by four aircraft and destroyed, crashing near Theberton, Suffolk. This was the last Zeppelin raid to explicitly target London.

After ineffectual raids on the Midlands and other targets in the north of England on August 21–22 and September 24–25 the last major Zeppelin raid was launched on October 19–20 with thirteen airships headed for Sheffield, Manchester and Liverpool. Two Zeppelins did not launch and the remainder quickly found themselves badly affected by powerful headwinds which made navigation extremely difficult. *L.45* was trying to reach Sheffield, instead it dropped bombs on Northampton and London. Undetected and with no warning its bombs did great damage – the first few fell on Hendon Aerodrome but the rest, dropped at random from 16,000 feet (4,900 m), struck in Piccadilly, Camberwell and Hither Green. *L.45* then reduced altitude to try and escape the winds but was forced back into the higher air currents by a BE2e. The craft then had mechanical failure in three engines and was pushed by the wind out over France, eventually coming down near Sisteron; it was set ablaze and the crew surrendered. *L.44*, *L.49*, and *L.50* were also lost to anti-aircraft fire or the weather over France. *L.55* was badly damaged on landing and later scrapped.

There were no more raids in 1917, although the airships were not abandoned but refitted with new, more powerful engines.

1918 raids

There were only four raids in 1918, all against targets in the Midlands and northern England. The final raid on 5 August 1918 resulted in the loss of *L.70* and the death of its entire crew under the command of *Frigattenkapitän* Peter Strasser, head of the Imperial German Naval Airship Service and the *Führer der Luftschiffe*. Crossing the North Sea during daylight, the airship was intercepted by a Royal Air Force DH.4 biplane piloted by Major Egbert Cadbury, and shot down in flames.

On 5 January 1918 a fire at Ahlhorn destroyed four of the specialised double sheds along with four Zeppelins and one Schütte-Lanz. The British had begun bombing the Zeppelin production lines and their sheds in Cologne and Düsseldorf as early as September/October 1914. This was followed by the Cuxhaven Raid, which included Zeppelins as its targets, on Christmas Day 1914. In July 1918, the Tondern Raid conducted by the RNAS, destroyed two Zeppelins in their sheds.

Supply

In 1917, the German High Command made an attempt to deliver much needed supplies using a dirigible to Lettow-Vorbeck's East African Campaign in German East Africa. *L.59* Zeppelin travelled over 6,400 km (4,000 miles) in 95 hours, but in the end failed to deliver the supplies. The craft had been purpose-built and was intended to be broken up and used on arrival. It never attempted the mission again, and was converted into a bomber.

Technological progress

Strategic issues aside, Zeppelin technology improved considerably as a result of the increasing demands of warfare.

The pre-war M-class designs were quickly enlarged, first to the 530 feet (160 m) long duralumin P-class, which increased gas capacity from 880,000 cubic feet (25,000 m³) to 1,130,000 cubic feet (32,000 m³), introduced a fully enclosed gondola, and extra engines. these modifications added 2,000 feet (610 m) to the maximum ceiling, over 10 mph to the top speed, and greatly increased crew comfort and hence endurance. Twenty-two P-class craft were ordered and the first, *LZ.38*, was delivered to the Army on 3 April 1915.

In 1916 the Zeppelin Company, having spawned several dependencies around Germany with shipyards closer to the fronts than Friedrichshafen, delivered airships of around 200 m (660 ft) in length (some even more) and with volumes of 56,000–69,000 m³. These M-class dirigibles could carry loads of 3–4 tons of bombs and reach speeds of up to 100 to 130 kilometres per hour (62 to 81 mph) using six Maybach engines of 260 hp (190 kW) each.

To avoid enemy defences such as British aircraft, guns and searchlights, Zeppelins became capable of much higher altitudes (up to 7,600 metres (24,900 ft)) and they also proved capable of long-range flights. For example, *LZ.104 L.59*, based in Yambol, Bulgaria, was sent to reinforce troops in German East Africa (today Tanzania) in November 1917. The ship did not arrive in time and had to return following reports of a German defeat by British troops, but it had traveled 6,757 kilometres (4,199 mi) in 95 hours and thus had broken a long-distance flight record.

A considerable, frequently overlooked, contribution to these technological advancements originated from Zeppelin's only serious competitor, the Mannheim-based Schütte-Lanz airship construction company. While their dirigibles never became comparably successful, Professor Schütte's more scientific approach to airship design led to a number of important innovations copied, over time, by the Zeppelin company. These included the streamlined hull shape, the simple yet functional cruciform fins (replacing the more complicated box-like arrangements of older Zeppelins), individual direct-drive engine cars, anti-aircraft machine-gun positions, and gas ventilation shafts which removed excess hydrogen.

End of the war

The German defeat in the war also marked the end of German military dirigibles, as the victorious Allies demanded a complete disarmament of German air forces and delivery of the remaining airships as reparations. Specifically, the Treaty of Versailles contained the following articles dealing explicitly with dirigibles:

Article 198

The armed forces of Germany must not include any military or naval air forces. [...] No dirigible shall be kept.

Article 202

On the coming into force of the present Treaty, all military and naval aeronautical material [...] must be delivered to the Governments of the Principal Allied and Associated Powers. [...] In particular, this material will include all items under the following heads which are or have been in use or were designed for warlike purposes:

[...]

- *Dirigibles able to take to the air, being manufactured, repaired or assembled.*
- *Plant for the manufacture of hydrogen.*
- *Dirigible sheds and shelters of every kind for aircraft.*

Pending their delivery, dirigibles will, at the expense of Germany, be maintained inflated with hydrogen; the plant for the manufacture of hydrogen, as well as the sheds for dirigibles may at the discretion of the said Powers, be left to Germany until the time when the dirigibles are handed over. [...]

On 23 June 1919, a week before the treaty was signed, many war Zeppelin crews destroyed their airships in their halls in order to avoid delivery. In doing so, they followed the example of the German fleet which had been scuttled two days before in Scapa Flow. The remaining dirigibles were transferred to France, Italy, Britain, and Belgium in 1920.

A total of 84 Zeppelins were built during the war. Over 60 were lost, roughly evenly divided between accident and enemy action. 51 raids had been undertaken, in which 5,806 bombs were dropped, killing 557 people and injuring 1,358 while causing damaged estimated at £1.5 million. It has been argued the raids were effective far beyond material damage in diverting and hampering wartime production, one estimate was that the due to the 1915-16 raids "one sixth of the total normal output of munitions was entirely lost," and diverting 12 fighter squadrons and over 10,000 personnel to air defences.

After World War I

Renaissance

Count von Zeppelin had died in 1917, before the end of the war. Dr. Hugo Eckener, a man who had long envisioned dirigibles as vessels of peace rather than of war, took command of the Zeppelin business. With the Treaty of Versailles having knocked out their competitor Schütte-Lanz, the Zeppelin company and DELAG hoped to resume civilian flights quickly. In fact, despite considerable difficulties, they completed two small Zeppelins: *LZ 120 Bodensee*, which first flew in August 1919 and in the following two years actually transported some 4,000 passengers; and *LZ 121 Nordstern*, which was envisaged being used on a regular route to Stockholm.

However, in 1921, the Allied Powers demanded these two Zeppelins be delivered as war reparations, as compensation for the dirigibles destroyed by their crews in 1919. Further Zeppelin projects could not be realized, partly because of Allied interdiction. This temporarily halted German Zeppelin aviation.

Eckener and his co-workers refused to give up and kept looking for investors and a way to circumvent Allied restrictions. Their opportunity came in 1924. The United States had started to experiment with rigid airships, constructing one of their own, the ZR-1 USS *Shenandoah* (see below), and ordering another from the UK when the British *R38 (ZR-2)* was cancelled. However, the *R38* (based on the Zeppelin L70, ordered as *ZR-2*) broke apart and exploded during a test flight above the Humber on 23 August 1921, killing 44 crewmen.

Under these circumstances, Eckener managed to acquire an order for the next American dirigible. Of course, Germany had to pay the costs for this airship itself, as they were calculated against the war reparation accounts, but for the Zeppelin company, this was secondary. So engineer Dr. Dürr designed *LZ 126*, and using all the expertise accumulated over the years, the company finally achieved its best Zeppelin so far, which took off for a first test flight on 27 August 1924.



ZR-3 USS *Los Angeles* over southern Manhattan



The USS *Los Angeles*, a US Navy zeppelin built by the Zeppelin Company



Zeppelin docking tower in Recife, Brazil – the only one preserved in its original form

No insurance company was willing to issue a policy for the delivery to Lakehurst, which, of course, involved a transatlantic flight. Eckener, however, was so confident of the new ship that he was ready to risk the entire business capital, and on 12 October 07:30 local time, the Zeppelin took off for the US under his command. His faith was not disappointed, and the ship completed her 8,050 kilometres (5,000 mi) voyage without any difficulties in 81 hours and two minutes. American crowds enthusiastically celebrated the arrival, and President Calvin Coolidge invited Dr. Eckener and his crew to the White House, calling the new Zeppelin an "angel of peace".

Under its new designation the ZR-3 USS *Los Angeles* (the former *LZ 126*), became the most successful American airship. She operated reliably for eight years until she was retired in 1932 for economic reasons. She was dismantled in August 1940.

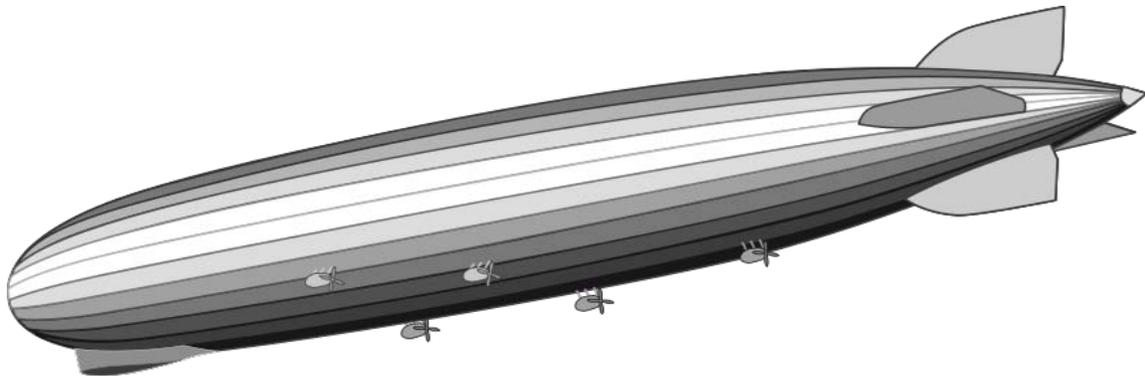
Golden age

With the delivery of *LZ 126*, the Zeppelin company had reasserted its lead in rigid airship construction, but it was not yet quite back in business. Acquiring the necessary funds for the next project proved a problem in the difficult economic situation of post-World-War-I Germany, and it took Eckener two years of lobbying and publicity work to secure the realization of *LZ 127*.

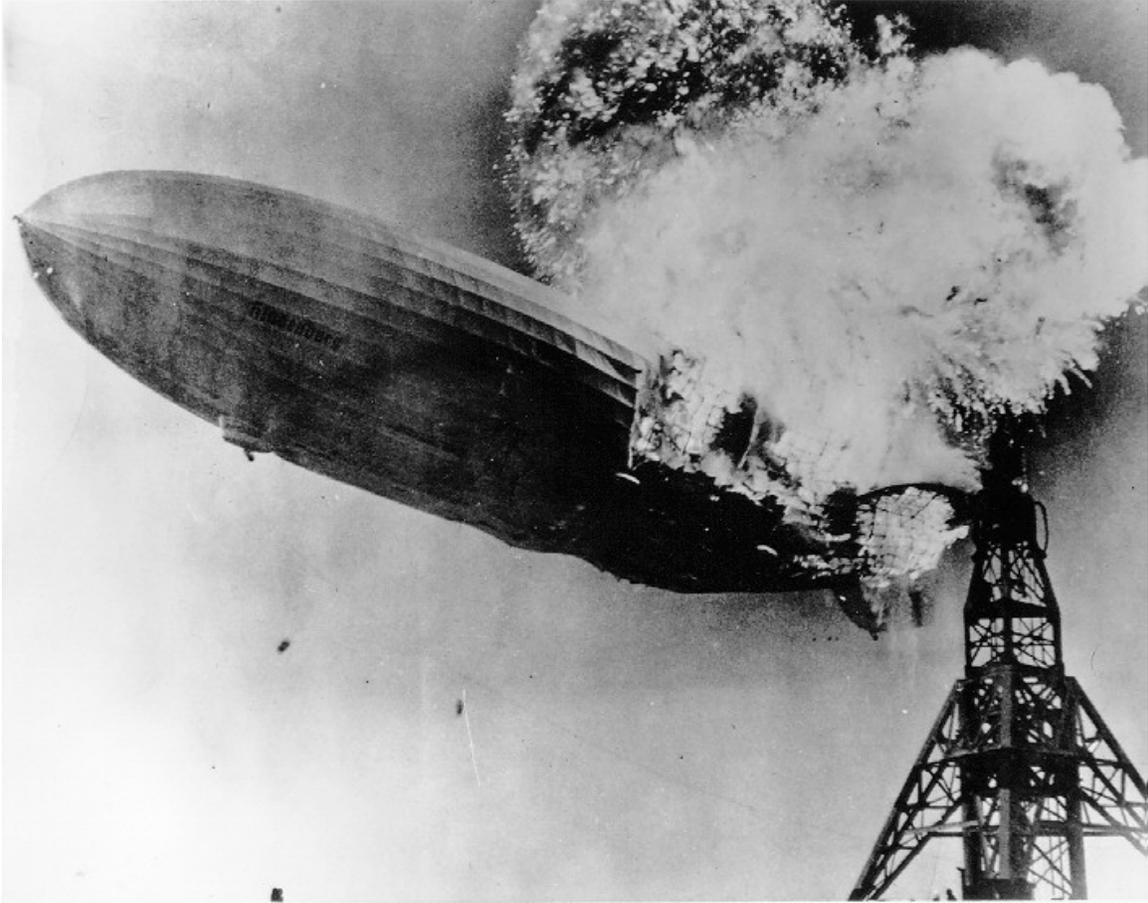
Another two years passed before 18 September 1928, when the new dirigible, christened *Graf Zeppelin* in honor of the Count, flew for the first time. With a total length of 236.6 metres (776 ft) and a volume of 105,000 m³, she was the largest dirigible yet.

Eckener's initial concept was to use *Graf Zeppelin* for experimental and demonstration purposes to prepare the way for regular airship traveling, by carrying passengers and mail to cover the costs. In October 1928 the first long-range voyage brought her to Lakehurst, where Eckener and his crew were once more welcomed enthusiastically with confetti parades in New York and another invitation to the White House. *Graf Zeppelin* toured Germany and visited Italy, Palestine, and Spain. A second trip to the United States was aborted in France due to engine failure in May 1929.

In August 1929 *LZ 127* departed for another daring enterprise: a circumnavigation of the globe. The growing popularity of the "giant of the air" made it easy for Eckener to find sponsors. One of these was the American press tycoon William Randolph Hearst, who requested the tour officially start in Lakehurst. As with the October 1928 flight to New York, Hearst had placed a reporter, Grace Marguerite Hay Drummond-Hay, on board who therefore became the first woman to circumnavigate the globe by air. From there, *Graf Zeppelin* flew to Friedrichshafen, then Tokyo, Los Angeles, and back to Lakehurst, in 21 days 5 hours and 31 minutes. Including the initial and final trips Friedrichshafen–Lakehurst and back, the dirigible traveled 49,618 kilometres (30,831 mi).



Airship LZ 127 "Graf Zeppelin"



The Hindenburg on fire in 1937

In the following year, *Graf Zeppelin* undertook a number of trips around Europe, and following a successful tour to Recife, Brazil in May 1930, it was decided to open the first regular transatlantic airship line. This line operated between Frankfurt and Recife in 68 hours, and later, between Frankfurt and Rio de Janeiro, with a stop in Recife. Despite the beginning of the Great Depression and growing competition from fixed-wing aircraft, *LZ 127* would transport an increasing volume of passengers and mail across the ocean every year until 1936. The ship pursued another spectacular venue in July 1931 with a research trip to the Arctic. This had already been a dream of Count von Zeppelin twenty years earlier, which could, however, not be realized at the time due to the outbreak of war.

Eckener intended to supplement the successful craft by another, similar Zeppelin, projected as *LZ 128*. However the disastrous accident of the British passenger airship *R101* on 5 October 1930 led the Zeppelin company to reconsider the safety of hydrogen-filled vessels, and the design was abandoned in favour of a new project. *LZ 129* would advance Zeppelin technology considerably, and was intended to be filled with inert helium.

Hindenburg, end of an era

Following 1933, the establishment of the Third Reich in Germany began to overshadow the Zeppelin business. The Nazis were not interested in Eckener's ideals of peacefully connecting people; they also knew very well dirigibles would be useless in combat and thus chose to focus on heavier-than-air technology.

On the other hand, they were eager to exploit the popularity of the airships for propaganda. As Eckener refused to cooperate, Hermann Göring, the German Air minister, formed a new airline in 1935, the *Deutsche Zeppelin-Reederei* (DZR), which took over operation of airship flights. Zeppelins would now display the Nazi swastika on their fins and occasionally tour Germany to play march music and propaganda speeches for the people from the air.

On 4 March 1936, LZ 129 *Hindenburg* (named after former President of Germany Paul von Hindenburg by Eckener) made her first flight. The *Hindenburg* was the largest airship ever built. However, in the new political situation, Eckener had not obtained the helium to inflate it due to a military embargo; only the United States possessed the rare gas in usable quantities. So, in what ultimately proved a fatal decision, the *Hindenburg* was filled with flammable hydrogen. Apart from the propaganda missions, LZ 129 began to serve the transatlantic lines together with *Graf Zeppelin*.

On 6 May 1937, while landing in Lakehurst after a transatlantic flight, in front of thousands of spectators, the tail of the ship caught fire, and within seconds, the *Hindenburg* burst into flames, killing 35 of the 97 people on board and one member of the ground crew. The actual cause of the fire has not been definitively determined; it is likely that a combination of leaking hydrogen from a torn gas bag, the vibrations caused by a swift rotation for a quicker landing to have started static electricity in the duralumin alloy skeleton and a flammable outer coating similar to rocket fuel accounted for the fact that the fire spread from its starting point in the tail to engulf the entire airship so rapidly (34 seconds).

Whatever caused the disaster, the end of the dirigible era was due to politics and the upcoming war, not the wreck itself, though it surely led to some public misgivings. Despite everything, there remained a list of 400 people who still wanted to fly as Zeppelin passengers and had paid for the trip. Their money was refunded in 1940.

Graf Zeppelin completed more flights, though not for overseas commercial flights to the U.S., and was retired one month after the *Hindenburg* wreck and turned into a museum. Dr. Eckener kept trying to obtain helium gas for *Hindenburg*'s sister ship, *Graf Zeppelin II*, but due to political bias against the airship's commercial use by the Nazi leadership, coupled with the inability to obtain helium gas in sufficient quantities due to an embargo by the United States, his efforts were in vain. The intended new flagship Zeppelin was completed in 1938 and, inflated with hydrogen, made some test flights (the first on 14 September), but never carried passengers. Another project, LZ 131, designed to be even

larger than *Hindenburg* and *Graf Zeppelin II*, never progressed beyond the production of some single skeleton rings.

The career of *Graf Zeppelin II* was not over. She was assigned to the *Luftwaffe* and performed about 30 test flights prior to the beginning of World War II. Most of those test flights were carried out near the Polish border, first in the Sudeten mountains region of Silesia, then in the Baltic Sea region. During one such flight *LZ 130* crossed the Polish border near the Hel Peninsula, where she was intercepted by a Polish Lublin R-XIII aircraft from Puck naval airbase and forced to leave Polish airspace. During this time, *LZ 130* was used as an electronic scouting airframe and was equipped with various telemetric equipment. From May to August 1939, she performed flights near the coastline of Great Britain in an attempt to determine whether the 100-metre towers erected from Portsmouth to Scapa Flow were used for aircraft radio localization. Photography, radio wave interception, magnetic and radio frequency analysis were unable to detect operational British Chain Home radar due to searching in the wrong frequency range. The frequencies searched were too high, an assumption based on the Germans' own radar systems. The mistaken conclusion was the British towers were not connected with radar operations, but formed a network of naval radio communications and rescue.

After the German invasion of Poland started the Second World War on 1 September, the *Luftwaffe* ordered *LZ 127* and *LZ 130* moved to a large Zeppelin hangar in Frankfurt, where the skeleton of *LZ 131* was also located. In March 1940 Göring ordered the destruction of the remaining airships and the Duralumin fed into the Nazi war industry. In May a fire broke out in the Zeppelin facility, which destroyed most of the remaining parts. The rest of the parts and materials were soon scrapped, with almost no trace of the German "giants of the air" remaining by the end of the year.

Non-German Zeppelin-type airships



U.S. Navy Zeppelin ZRS-5 "*USS Macon*" over Moffett Field in 1933

Airships using the Zeppelin construction method are sometimes referred to as zeppelins even if they had no connection with the Zeppelin business. Several airships of this kind were built in the USA and Britain in the 1920s and 1930s, mostly imitating original Zeppelin designs derived from crashed or captured German World War I airships.

The British *R33* and *R34*, for example, were near identical copies of the German *L-33*, which crashed virtually intact in Essex on 24 September 1916. Despite being almost three years out of date by the time they were launched in 1919, these sister ships were two of the most successful in British service. On 2 July 1919, *R34* began the first return crossing of the Atlantic by aircraft. She landed at Mineola, Long Island on 6 July 1919 after 108 hours in the air. The return crossing commenced on 8 July because of concerns about mooring the ship in the open, and took 75 hours. Their success led to proposals for a fleet of airships to link far-flung British colonies, but unfortunately post-war economic conditions resulted in most airships being scrapped and trained personnel dispersed, until design and construction of the *R-100* and *R-101* commenced in 1925.

Another example was the first American-built rigid dirigible *ZR-1 USS Shenandoah*, launched in September, 1923, while the *USS Los Angeles (ZR-3)* was still under construction. The ship was christened on 20 August in Lakehurst, New Jersey and was the first to be inflated with helium, which was still so rare at the time that *Shenandoah* contained most of the world's reserves. When *Los Angeles* was delivered, she was at first

filled with helium borrowed from ZR-1. Other airships were the USS Akron (ZRS-4) and the USS Macon (ZRS-5).

Chapter- 6

USS Shenandoah (ZR-1)



USS Shenandoah

Career (United States)	
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Name:	<i>USS Shenandoah</i>
Laid down:	24 June 1922
Launched:	20 August 1923
Christened:	10 October 1923
Maiden voyage:	4 September 1923
Fate:	Torn apart and crashed in a storm on 3 September 1925.

General characteristics

Type:	Airship
Tonnage:	77,500 pounds (35,153 kg)
Length:	680 ft (207.26 m)
Beam:	78 ft 9 in (24 m) (maximum diameter)
Height:	93 ft 2 in (28.40 m)
Propulsion:	300 horsepower six-cylinder gasoline engines manufactured by the Packard Motor Car Company
Speed:	60 kt (120km/h or 117m/ph)
Range:	5,000 miles (8000km)

- Capacity:
- **Useful lift**
53,600 pounds (24,312 kg)
 - **Nominal gas volume:**
2,100,000 cu.ft (59,465 m³)
(at 95% inflation)

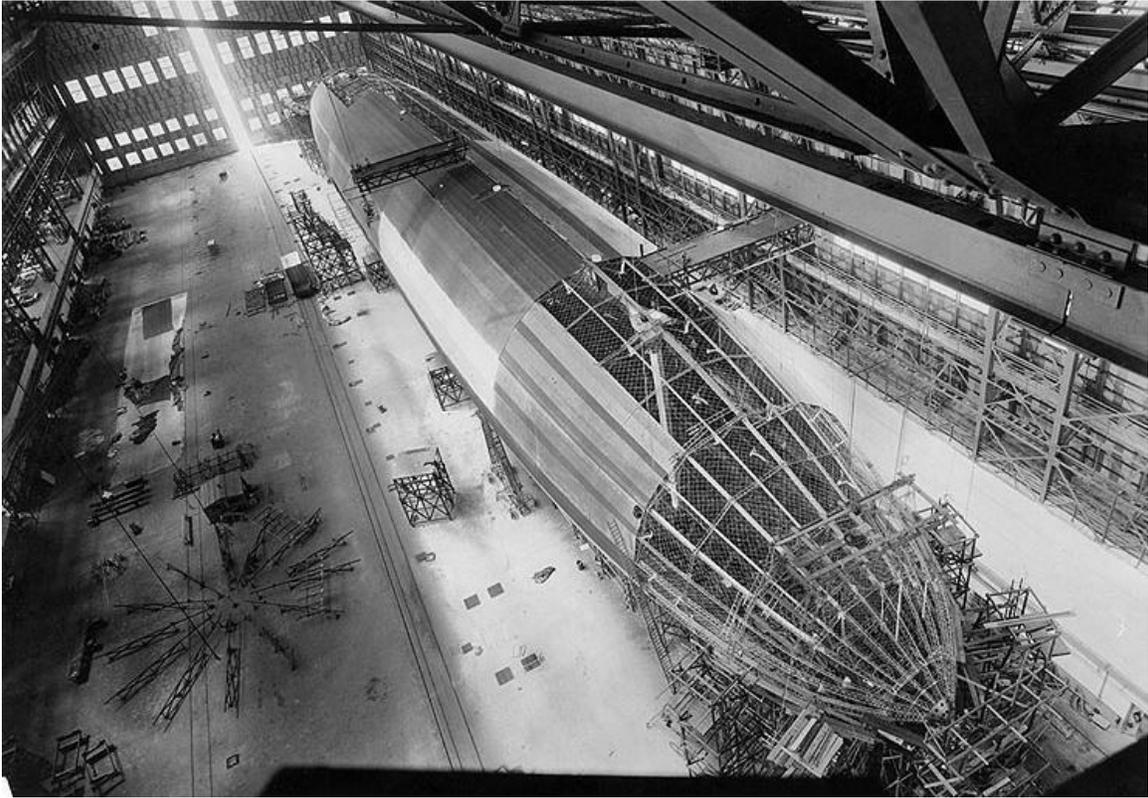
Complement: 25

- Armament:
- 6 x .30 cal. (7.62 mm)
Lewis machine guns
 - 8 x 500-pound (227 kg)
bombs total 3000lb
(1361kg)

USS *Shenandoah* was the first of four United States Navy rigid airships. It was built in 1922-23 at Lakehurst Naval Air Station, and first flew in September 1923. It developed the Navy's experience with rigid airships, even making the first crossing of North America by airship. On the 57th flight, *Shenandoah* was torn apart in a squall line over Ohio in 1925.

Design and construction

The *Shenandoah* was originally designated FA-1, for 'Fleet Airship Number One' but this was changed to ZR-1. The airship was 680 feet (210 m) long and weighed 36 tons. It had a range of 5,000 miles (8,000 km), and could reach speeds of 70 miles per hour (110 km/h). The *Shenandoah* was assembled at Lakehurst Naval Air Station in 1922-23, in Hangar No. 1, the only one large enough to accommodate the ship. (Her parts were fabricated at the Naval Aircraft Factory in Philadelphia.) Lakehurst had served as a base for Navy blimps for some time, but the *Shenandoah* was the first rigid airship to join the fleet.



Construction of USS *Shenandoah* in 1923, showing the framework of a rigid airship

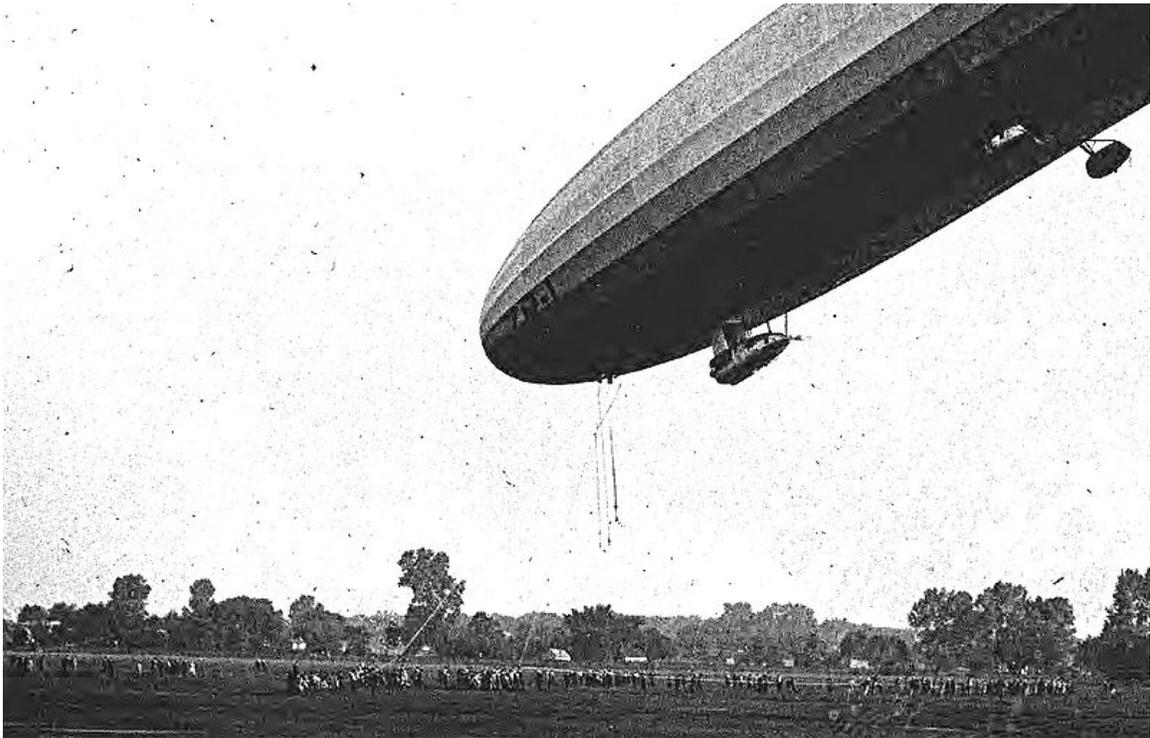
The design was based on Zeppelin bomber *L-49* (LZ-96). *L-49* was a lightened "height climber", designed for altitude at the expense of other qualities. The design was found insufficient and a number of the features of newer Zeppelins were used, as well as some structural improvements. The structure was built from a new alloy of aluminum and copper known as duralumin. Girders were fabricated at the Naval Aircraft Factory. Whether the changes introduced into the original design of *L-49* played a part in *Shenandoah* later breaking up is a matter of debate. An outer cover of high-quality cotton cloth was sewn, laced or taped to the duralumin frame and painted with aluminum dope.

The gas cells were made of goldbeater's skins, one of the most gas-impervious materials known at the time. Named for their use in beating and separating gold leaf, goldbeater's skins were made from the outer membrane of the large intestines of cattle. The membranes were washed and scraped to remove fat and dirt, and then kept in a solution of water and glycerine in preparation for application to the rubberized cotton fabric providing the strength of the gas cells. The membranes were wrung out by hand to remove the water-glycerine storage solution and then rubber-cemented to the cotton fabric and finally given a light coat of varnish. The twenty gas cells within the airframe were filled to about 85 percent of capacity at normal barometric pressure. Each gas cell had a spring loaded relief valve and manual valves operated from the control car.

Shenandoah had a significant edge in safety over previous airships, being the first rigid to use helium rather than hydrogen. Helium was relatively scarce at the time, and the

Shenandoahs used much of the world's reserves just to fill its 2.1 million-cubic-foot volume. USS *Los Angeles* (ZR-3), the next rigid airship to enter Navy service, was at first filled with the helium from *Shenandoah* until more could be procured.

Shenandoah was powered by 300 horsepower (220 kW), 8-cylinder Packard gasoline engines. The first frame of *Shenandoah* was erected by 24 June 1922; on 20 August 1923, the completed airship was floated free of the ground. Helium cost \$55 per thousand cubic feet at the time, and was considered too expensive to simply vent to the atmosphere to compensate for the weight of fuel consumed by the gasoline engines. Neutral buoyancy was preserved by installing condensers to capture the water vapor in the engine exhaust.



Flight test run, steep angle docking at St. Louis on October 2, 1923



After docking at St. Louis, Cmdr McCrary stepped out to meet Adm Moffet and Mayor Kiel; shown still inside the Control Car are Anton Heinen (German test pilot and consultant in the construction of the ZR1) and Cmdr Ralph D. Weyerbacher (design/build).

It was christened on 10 October 1923; sponsored by Mrs. Edwin Denby, wife of the Secretary of the Navy; and commissioned on the same day, Commander Frank R. McCrary in command.

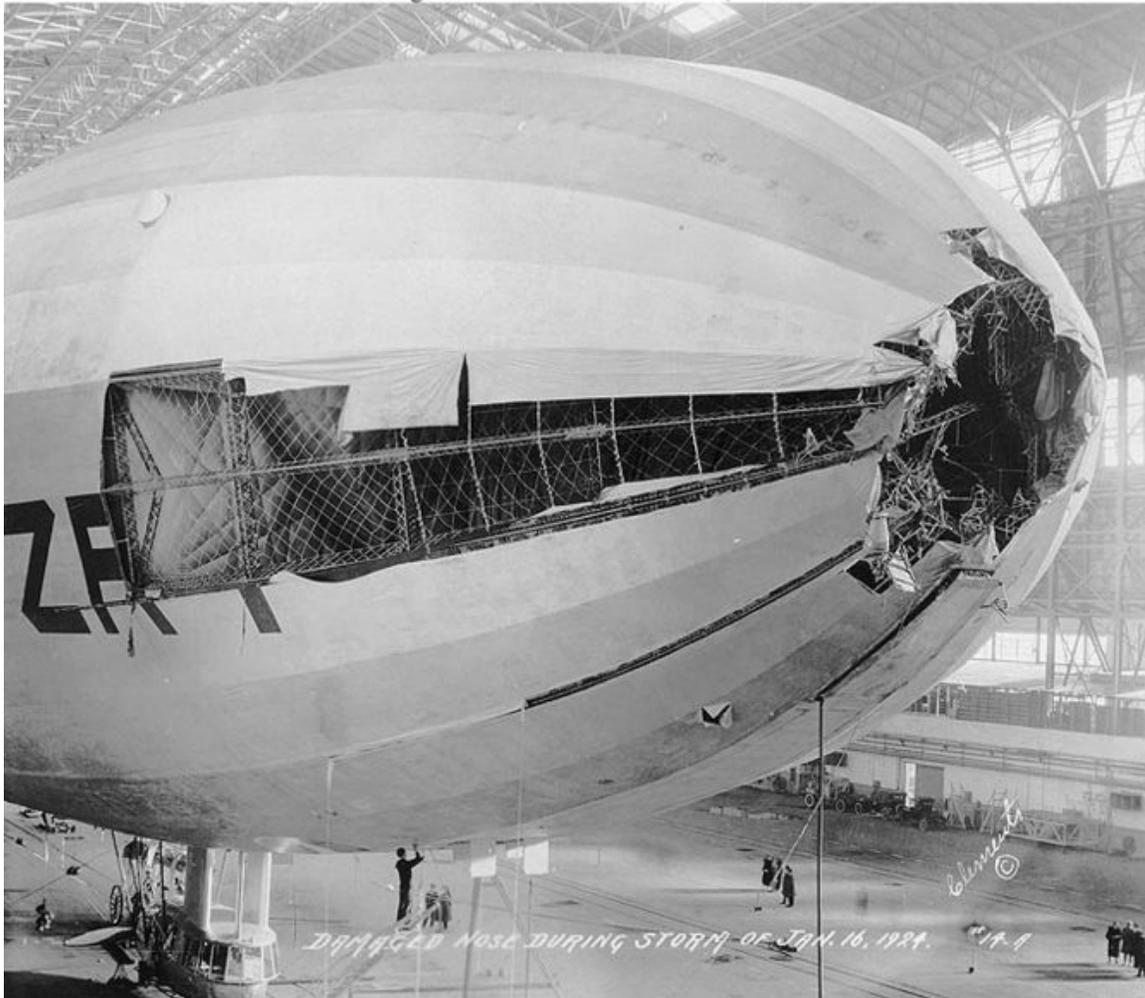
Early Naval service

USS *Shenandoah* took to the sky for the first time on 4 September 1923.

Shenandoah was designed for fleet reconnaissance work of the type carried out by German naval airships in World War I. Her precommissioning trials included long range flights during September and early October 1923, to test her airworthiness in rain, fog and poor visibility. On 27 October, *Shenandoah* celebrated Navy Day with a flight down

the Shenandoah Valley and returned to Lakehurst that night by way of Washington and Baltimore, where crowds gathered to see the new airship in the beams of searchlights.

Photo # NH 92612 Damage to USS Shenandoah's nose, from storm of 16 Jan. 1924



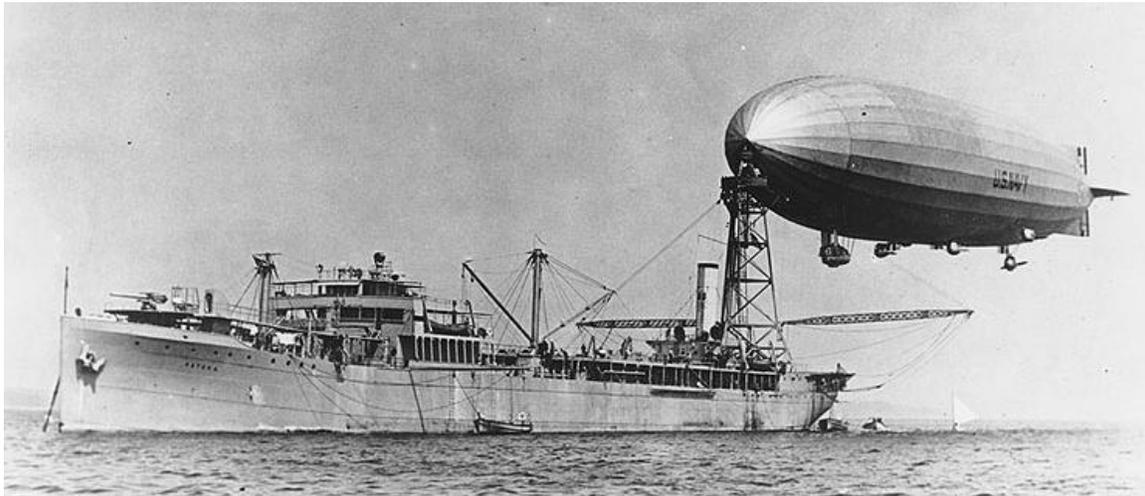
ZR-1's bow following the January storm

At this time, Rear Admiral William Moffett, Chief of the Bureau of Aeronautics and staunch advocate of the airship, was discussing the possibility of using *Shenandoah* to explore the Arctic. Such a program, he felt, would produce valuable weather data as well as experience in cold-weather operations. With her endurance and ability to fly at low speeds, the airship was thought to be well-suited to such work. President Calvin Coolidge approved Moffett's proposal, but on 16 January 1924, *Shenandoah* was torn from her Lakehurst mooring mast by a gale and her nose was damaged. It rode out the storm and landed safely, but a period of repair was needed, and the Arctic expedition was dropped.

Shenandoah's repairs were completed in May, and the summer of 1924 was devoted to work with her powerplant and radio equipment to prepare for her duty with the fleet. On 1 August, it reported for duty with the Scouting Fleet and took part in tactical exercises.

Shenandoah succeeded in discovering the “enemy” force as planned but lost contact with it in foul weather. Technical difficulties and lack of support facilities in the fleet forced her to depart the operating area ahead of time to return to Lakehurst. Although this marred the exercises as far as airship reconnaissance went, it emphasized the need for advanced bases and maintenance ships if lighter-than-air craft were to take any part in operations of this kind.

Flight across North America



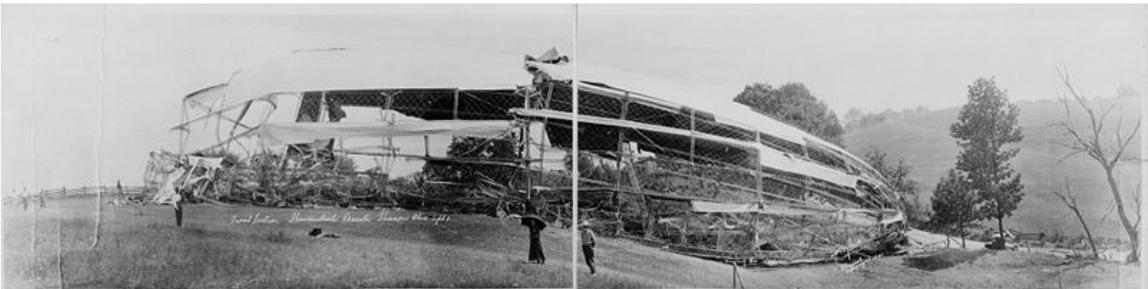
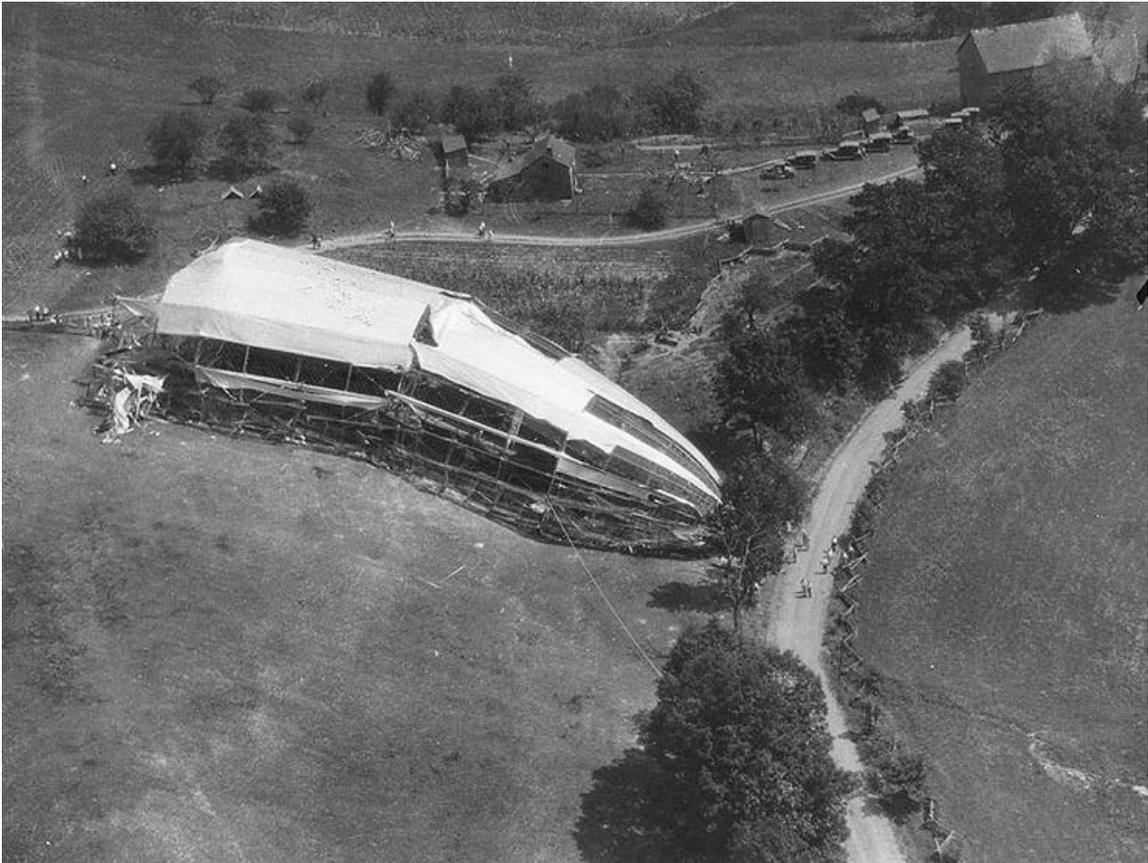
The USS Shenandoah moored to the USS Patoka

In July 1924 the oiler *Patoka* (AO-9) put in to Norfolk Navy Yard for extensive modifications to become the Navy's first Airship Tender. An experimental mooring mast some 125 feet (38 m) above the water was constructed; additional accommodations both for the crew of *Shenandoah* and for the men who would handle and supply the airship were added; facilities for the helium, gasoline, and other supplies necessary for *Shenandoah* were built; as well as handling and stowage facilities for three seaplanes. *Shenandoah* engaged in a short series of mooring experiments with *Patoka* to determine the practicality of mobile fleet support of scouting airships. The first successful mooring was made 8 August 1924. During October 1924, *Shenandoah* flew from Lakehurst to California and on to Washington to test newly erected mooring masts. This was the first flight of a rigid airship across North America.

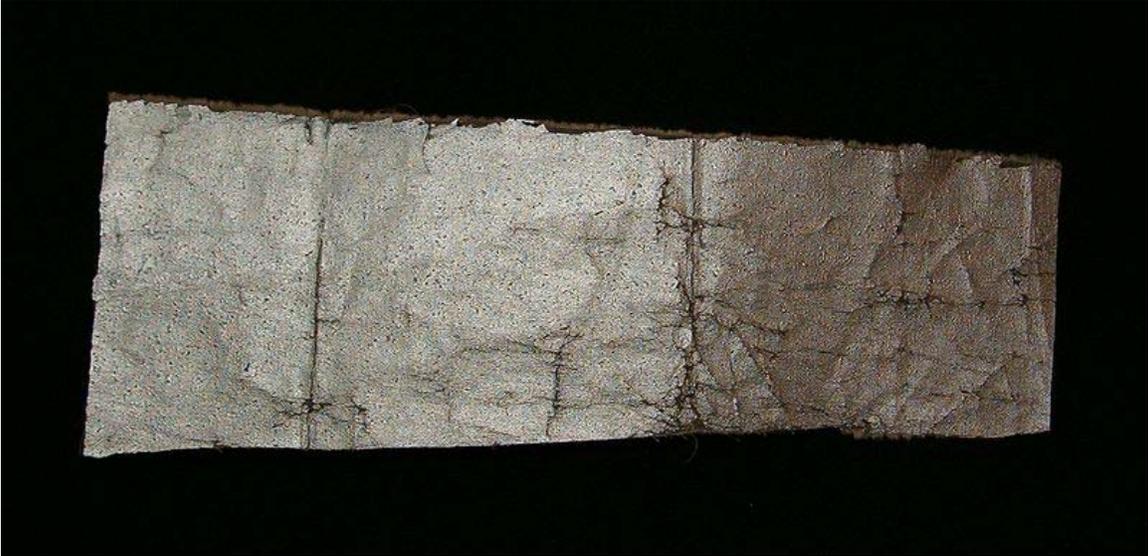
Later Naval career

The year 1925 began with nearly six months of maintenance and ground test work. *Shenandoah* did not take to the air until 26 June, when it began preparations for summer operations with the fleet. During July and August, it again operated with the Scouting Fleet, successfully performing scouting problems and being towed by *Patoka* while moored to that ship's mast.

Wreck of the Shenandoah



The front section of the wreck



Fabric from the airship USS Shenandoah, recovered from the crash site

On 2 September 1925, *Shenandoah* departed Lakehurst on a promotional flight to the Midwest which would include flyovers of 40 cities and visits to state fairs. Testing of a new mooring mast at Dearborn, Michigan was included in the schedule. While passing through an area of thunderstorms and turbulence over Ohio early in the morning of September 3, during its 57th flight, the airship was caught in a violent updraft that carried it beyond the pressure limits of its helium gas bags. It was torn apart in the turbulence and crashed in several pieces near Caldwell, Ohio. *Shenandoah's* commanding officer, Commander Zachary Lansdowne, and 13 other officers and men were killed. This included the entire crew of the control cabin (except for Lieutenant Anderson, who barely escaped before it detached from the ship), two men who went through holes in the hull, and several mechanics who fell with the engines. Those killed were:

- LCDR Zachary Lansdowne, Commanding Officer, Greenville, Ohio
- LCDR Lewis Hancock, Jr., Executive Officer, Austin, Texas,
- LT. Arthur Reginald Houghton, Watch Officer, Alston, Mass.
- LT. JG Edgar William Sheppard, Engineering Officer, Washington D. C.
- LT. John (Jack) Bullard Lawrence, Watch Officer, St. Paul, Minn.
- CPO George Conrad Schnitzer, Radio Officer, Tuckertown, N. J
- AMM1C James Albert Moore, Radio Generator, Savannah, Ga
- AR1C Ralph Thomas Joffray, Rigger, St. Louis, Mo.
- AMM1C Bartholomew (Bart) B. O'Sullivan, Lowell, Mass
- CPO James William Cullinan, Binghamton, N. Y
- CPO Everett Price Allen, Chief Rigger, St. Louis, Mo.
- AMM Charles Harrison Broom, Tom's River, N. J.
- AMM Celestino P. Mazzuco, Murray Hill NJ
- AMM William Howard Spratley, Venice, Ill.

Twenty-nine survivors succeeded in riding three sections of the airship to earth. The largest group was eighteen men who made it out of the stern after it rolled into a valley. Four others survived a crash landing of the central section. The remaining seven were in the bow section which Commander (later Admiral) Rosendahl navigated as a free balloon. In this group was Anderson who, until he was roped in by the others, straddled the catwalk over a hole. The survivors were:



ZR-1 at the mooring mast

- Louis E. Allely
- LT. Joseph B. "Andy" Anderson
- G. W. Armour
- LT. Charles E. Bauch

- Henry Ballard {died on USS Akron}
- CBM Henry L. Boswell {died on USS Akron}
- CBM Arthur E. Carlson {died on USS Akron}
- Warrant Officer Chief Gunner CWO Raymond Cole
- Lester Coleman
- James E. "Red" Collier
- Mark Donovan
- John J. Hahn
- Col. Chalmers G. Hall
- Chief Machinist CWO, Shine S. Halliburton
- Thomas Hendley
- Benjamin O. Hereth
- Walter Johnson
- Aviation Machinist's Mate Ralph Jones
- MM2C Julius E. Malak
- CPO Franklin E. Masters
- ACR, Chief Rigger John F. McCarthy
- LT. Roland Mayer
- ACR Frank L. Peckham
- ACMM August C. Quernheim {died on USS Akron}
- LT. Walter T. Richardson (Naval Reserve, traveling as a civilian observer)
- LCMDR Charles Emery Rosendahl
- ACMM William A. Russell {died on USS Akron}
- AMM1c Joseph Shevlowitz {died on USS Akron}
- Charles Solar
- CBM Frederick J. "Bull" Tobin

Aftermath

Thousands of people flocked to the wreckage which was then heavily looted, with the logbooks and most of the ship's fabric stolen. Official inquiry into the fatal flight brought to public attention the fact that it had been made under protest by Commander Lansdowne (a native of Greenville, Ohio), who warned of the violent weather conditions which were prevalent in the area and common to Ohio in late summer. His pleas for a cancellation of the flight only led to a postponement. His superiors were keen to publicize airship technology, and justify the huge cost of the airship to the taxpayers. So, as Lansdowne's widow consistently maintained at the inquiry, publicity rather than prudence won the day. This event was the trigger for Army Colonel Billy Mitchell to heavily criticize the leadership of both the Army and the Navy, leading directly to his court-martial for insubordination and the end of his military career.

Ultimately a positive result of the disaster was that future airships were better built. Hulls were strengthened, control cabins were built into the keels rather than suspended from cables, and engine power was increased. More attention was also paid to weather forecasting. When the United States used blimps in World War II and the Cold War, these improvements may have prevented other crashes.

Memorials

Several memorials exist near the crash site, as well as a small private museum, are located in Ava, Ohio.

The Noble Local School District, which services the area where the Shenandoah crashed, has named its elementary, junior high and high schools after the Shenandoah. Their sports teams are named "The Zeps." Additionally, a truck stop located about 15 miles (24 km) away in Old Washington was named Shenandoah Plaza after the airship. The truck stop has since closed and is in the process of being torn down.

Chapter- 7

USS Macon (ZRS-5)



USS *Macon* over Moffett Field

Career (United States)



Name:	USS <i>Macon</i> ZRS-5
Launched:	21 April 1933
Commissioned:	23 June 1933
Struck:	26 February 1935
Fate:	Crashed following structural failure on 12 February 1935.

General characteristics

Class and type:	Airship
Tonnage:	108 tonnes (106 LT; 119 ST)
Length:	239 m (784 ft)
Beam:	40.5 m (133 ft) (diameter)
Height:	44.6 m (146 ft)
Propulsion:	8 internal combustion engines, 420 kW (560 hp) each
Speed:	140 kilometres per hour (76 kn;

	87 mph) maximum
Capacity:	<ul style="list-style-type: none"> • Useful load 72 tonnes (71 LT; 79 ST) • Volume 184,000 m³ (6,500,000 cu ft)
Complement:	91
Aircraft carried:	five F9C biplanes

USS *Macon* (ZRS-5) was a rigid airship built and operated by the United States Navy for scouting. She served as a flying aircraft carrier, launching Sparrowhawk biplanes. In service for less than two years, in 1935 *Macon* was damaged in a storm and lost off California's Big Sur coast, though most of her crew were saved. The wreckage is listed as **USS *Macon* Airship Remains** on the U.S. National Register of Historic Places.

Less than 20 ft (6.1 m) shorter than *Hindenburg*, she and her sister, *Akron*, were among the largest flying objects in the world in terms of length and volume. Although the hydrogen-filled *Hindenburg* was longer, the two sisters still hold the world record for helium-filled airships.

Construction and commissioning

The *USS Macon* was built at the Goodyear Airdock in Springfield Township, Ohio by the Goodyear-Zeppelin Corporation. For this was by far the biggest airship ever to be build in America, a team of experienced German airship engineers, led by Chief Designer Karl Arnstein, instructed and supported design and construction of both US Navy airships USS Akron and USS Macon.

The airship was named after the city of Macon, Georgia, which was the largest city in the Congressional district of Representative Carl Vinson, the then chairman of the House of Representative's Committee on Naval Affairs.

The *Macon* was christened on March 11, 1933 by Jeanette Whitton Moffett, wife of Rear Admiral William A. Moffett, Chief of the US Navy's Bureau of Aeronautics. The airship first flew one month later, shortly after the tragic loss of her sister ship, *Akron* (ZRS-4). *Macon* was commissioned on June 23, 1933 with Commander Alger H. Dresel in command.

The *Macon* had a structured duraluminum hull with three interior keels. The airship was kept aloft by 12 helium-filled gas cells made from gelatin-latex fabric. Inside the hull, the ship had eight German-made Maybach, 12 cylinder, 560-horsepower gasoline-powered engines that drove outside propellers. The propellers could be rotated down or backwards, providing an early form of thrust vectoring, to control the ship during take-off and landings. Designed to carry five F9C Sparrowhawk biplanes, *Macon* received her first aircraft on board July 6, 1933 during trial flights out of Lakehurst, New Jersey. The

planes were stored in bays inside the hull and were launched and retrieved using a trapeze.

Early service history

Departing the East Coast October 12, 1933, *Macon's* homefield became Naval Air Station (NAS) Sunnyvale (now Moffett Federal Airfield) in Santa Clara County, California. *Macon* had a far more productive career than her sister ship, *Akron*. *Macon's* commanders developed the doctrine and techniques of using her aircraft to do scouting while the airship remained out of sight of the opposing forces in exercises. *Macon* participated in several fleet exercises, though the men who framed and conducted the exercises lacked an understanding of the ZRS's capabilities and weaknesses. It became standard practice to remove the F9C-2 fighter's landing gear aboard the airship and replace it with a fuel tank, giving the aircraft 30% more range.

Later in 1934, Lt. Commander Herbert Wiley surprised President Franklin D. Roosevelt (and the Navy) when *Macon* searched for - and located - the heavy cruiser USS *Houston*, which was then carrying the President back from a trip to Hawaii. Newspapers were dropped to the President on the ship, and the following communications were sent back to the airship: "from *Houston*: 1519 The President compliments you and your planes on your fine performance and excellent navigation 1210 and 1519 Well Done and thank you for the papers the President 1245."

The commander of the Fleet, Admiral Joseph M. Reeves, was upset about the matter—however, Commander of the Bureau of Aviation, Admiral Ernest J. King, was not. Wiley, one of only three survivors of the *Akron* crash, was soon promoted to Commander, and in time became a Rear Admiral.

Leading up to the crash

During a crossing of the continent, *Macon* was forced to fly up to 6,000 ft (1,800 m) to clear mountains in Arizona. As the ship's pressure height—the height at which the gas cells would start to leak and eventually rupture due to pressure difference—was less than 3,000 ft (910 m), a large amount of helium was vented to reach this altitude without rupturing the gas cells. To compensate for the loss of lift, 9,000 lb (4,100 kg) of ballast and 7,000 lb (3,200 kg) of fuel had to be dumped. *Macon* was being flown 15,000 pounds (6,800 kg) 'heavy' and was operating at full power not only in order to have sufficient dynamic lift, but to have enough control to fly in the severe turbulence through a mountain pass near Van Horn, Texas. Following a severe drop, a diagonal girder in ring 17.5, which supported the forward fin attachment points, failed. Rapid damage control by Chief Boatswain's Mate Robert Davis repaired the girders before further failures could occur. *Macon* completed the journey safely but the buckled ring and all four tailfins were deemed in need of strengthening. The appropriate girders adjacent to the horizontal and lower fins were repaired, but the repair to the girders on either side of the top fin were delayed until the next scheduled overhaul when the adjacent gas cells could be deflated.

Disaster

On February 12, 1935 the repair process was still incomplete when, returning to Sunnyvale from fleet maneuvers, *Macon* ran into a storm off Point Sur, California. During the storm, she was caught in a wind shear which caused structural failure of the unstrengthened ring (17.5) to which the upper tailfin was attached. The fin failed to the side and was carried away. Pieces of structure punctured the rear gas cells and caused gas leakage. Acting rapidly and on fragmentary information an immediate and massive discharge of ballast was ordered. Control was lost and, tail heavy and with engines running full speed ahead, the *Macon* rose past the pressure height and kept going until enough helium was vented to cancel the lift. It took her 20 minutes to descend from 4,850 ft (1,480 m) and, settling gently into the sea, *Macon* sank off Monterey Bay. Only two crewmembers died from her complement of 76, thanks to the warm conditions and the introduction of life jackets and inflatable rafts after the *Akron* tragedy. The two that perished did so needlessly: Radioman 1 class Ernest Edwin Dailey jumped ship after she had lost most of her altitude but was still high above the ocean surface; Mess Attendant 1 class Florentino Edquiba drowned while swimming back into the wreckage to try to retrieve personal belongings. An officer was rescued when Commander Wiley swam to his aid, an action for which he was later decorated.

The cause of the loss was operator error following the structural failure and loss of the fin. Had the ship not been driven over pressure height (where the cells were expanded fully and lifting gas released) *Macon* could have made it back to Moffett Field. Four F9C-2 scoutplanes carried aboard were lost with the airship.

Macon, having completed 50 flights from her commissioning date, was stricken from the Navy list on February 26, 1935. Subsequent airships for Navy use were of a nonrigid design.

Wreck site exploration



USS Macon flies over New York City

The Monterey Bay Aquarium Research Institute (MBARI) succeeded in locating and surveying the debris field of the *Macon* in February 1991, and was able to recover artifacts from her. The exploration included sonar, video and still camera data, as well as some artifact recovery.

In May 2005, MBARI returned to the site as part of a year-long research project to identify archeological resources in the bay. Side-scan sonar was used to survey the site.

2006 expedition

A more complete return, including exploration with remotely operated vehicles and involving researchers from MBARI and the National Oceanic and Atmospheric Administration's Office of National Marine Sanctuaries, took place in September 2006. Video clips of the expedition were made available to the public through the OceansLive Web Portal, a service of NOAA.

The 2006 expedition was a success, and revealed a number of new surprises and changes since the last visit, ~15 years ago. High-definition video and more than 10,000 new images were captured, which will be assembled into a photomosaic of the wreck.

Protection

U.S.S. *Macon* Airship Remains

U.S. National Register of Historic Places



The *Macon's* fifth F9C-2 biplane is preserved at the Steven F. Udvar-Hazy Center, while four biplanes lie in the wreckage.

Location:	Monterey Bay National Marine Sanctuary, Big Sur, California
Area:	5654.7 square meters
Governing body:	Private
Added to NRHP:	January 29, 2010
NRHP Reference#:	09001274

The wreckage of the *Macon* was listed in the National Register of Historic Places on January 29, 2010. The wreck site remains secret, and is within a marine sanctuary, the Monterey Bay National Marine Sanctuary, and is not accessible to divers due to depth (1,500 ft, 460 m). It is also a U.S. Navy gravesite.

According to the U.S. National Park Service:

When the USS *Macon* was christened on March 11, 1933, she was the most sophisticated of the Navy's lighter-than-air (LTA) fleet. The *Macon* exhibited the highest expression of naval LTA technology during her short career. At 785 feet in length, the airship's size captured American fascination during flyovers of U.S. communities as chronicled in numerous advertisements, articles, and newsreels. The dramatic loss of the *Macon* and her sister ship, the *Akron*, within two years of each other contributed to the cancellation of the Navy's rigid airship program. The archeological remains of the USS *Macon* lie off California's Big Sur coast in NOAA's Monterey Bay National Marine Sanctuary. The site also contains the remains of four of the airship's squadron of small Curtiss F9C Sparrowhawk scout aircraft which the *Macon* carried in an internal hangar bay.

The site was listed on the U.S. National Register of Historic Places on January 29, 2010. The listing was announced as the featured listing in the National Park Service's weekly list of February 12, 2010.