Zeppelin

A Zeppelin is a type of rigid airship named after the German Count Ferdinand von Zeppelin who pioneered rigid airship development at the beginning of the 20th century. Zeppelin’s notions were first formulated in 1874 [1] and developed in detail in 1893. [2] They were patented in Germany in 1895 and in the United States in 1899. The outstanding success of the Zeppelin design, the word zeppelin came to be commonly used to refer to all rigid airships. Zeppelins were first flown commercially in 1910 by Deutsche Luftschiffahrts-AG service. By mid-1914, DELAG had carried over 10,000 fare-paying passengers. German military made extensive use of Zeppelins as bombers and scouts, killing over 500 people in bombing raids in Britain.

The defeat of Germany in 1918 temporarily slowed down the airship business. The service between Berlin, Munich, and Friedrichshafen in 1919, the airships built surrendered under the terms of the Treaty of Versailles, which also prohibited Germany from building large airships. An exception was made allowing the construction of one airship for the US Navy in 1926. The restrictions on airship construction were lifted and with the aid of donations from the public, work was started on the USS Los Angeles, a US Navy airship built in Germany by the Zeppelin Company.
the construction of **LZ 127 Graf Zeppelin**. This revived the company’s fortunes, and during the 1930s the airships **Zeppelin** and the larger **LZ 129 Hindenburg** operated regular transatlantic flights. The **Art Deco spire of the Empire State Building** was originally designed to serve as a mooring mast for Zeppelins and other airships, although it was found that high winds made this impossible and the plan was abandoned.

in 1937, along with political and economic issues, hastened the demise of the airships, although it was found that high winds made this impossible and the plan was abandoned.

The **USS Los Angeles**, a US Navy airship built in Germany by the Zeppelin Company. Principal characteristics

The USS *Los Angeles*, a US Navy airship built in Germany by the Zeppelin Company.

**Principal characteristics**
The pink ovals depict hydrogen cells inside the LZ 127, the magenta elements are Blaugas internals.

The principal feature of Zeppelin's design was a fabric-covered rigid metal framework made up from transverse rings and longitudinal girders containing a number of individual gasbags. 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 pressure envelope to maintain their shape. The framework of most Zeppelins was made of duralumin (a combination of aluminum and copper as well as two or three other metals—its exact content was kept a secret for years). Early Zeppelins used rubberised cotton for the gasbags, but most later craft used goldbeater's skin, made from the intestines of cattle.

The first Zeppelins had long cylindrical hulls with tapered ends and complex surfaces, as used by almost all later airships.

They were propelled by several engines, mounted in gondolas or engine cars, providing reverse thrust for manœuvreability.
Early models had a comparatively small externally mounted gondola for passengers. This space was never heated (fire outside of the kitchen was considered too risky) so passengers during trips across the North Atlantic or Siberia were forced to bundle themselves in blankets and furs to keep warm and were often miserable with the cold.

By the time of the Hindenburg, several important changes had taken place: the passenger space had been relocated to the interior of the overall vessel, passenger rooms were insulated from the exterior by the dining area, and forced-warm air could be circulated from the water that cooled the forward engines, all of which made traveling much more comfortable though it deprived passengers of views from the windows of their berths which had been a major attraction on the Graf Zeppelin: on both the older and newer vessels, the external viewing windows were often opened during flight. The flight ceiling was so low that no pressurization of the cabins was necessary, though the Hindenburg did maintain a pressurized air-locked smoking room (no flame allowed, however—one electric lighter was maintained permanently inside the room).

Access to the Zeppelin was achieved in a number of ways. The Graf Zeppelin's gondola was accessed while the vessel was on the ground, via gangways. The Hindenburg also had passenger gangways that could then be withdrawn entirely as well as ground access to the gondola via its electrical room which was intended for crew use only.

History

Early designs
Ferdinand von Zeppelin

Count Ferdinand von Zeppelin's serious interest in airship development began in 1874, when he took inspiration from a lecture given by Heinrich von Stephan on the subject of "World Postal Services and Aircraft" in a diary entry dated 25 March 1874. This describes a large rigidly framed aircraft with gasbags. He had previously encountered Union Army balloons in 1863 when he visited the United States as a military observer during the American Civil War.

Count Zeppelin 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 aviation, he started working on various designs in 1891, and had completed detailed designs by 1893. An official committee reviewed his plans in 1894, and he received a patent, granted on 31 August 1895, with Theodor Kober producing the technical drawings.
Zeppelin's patent described a *Lenkbares Luftfahrzeug mit mehreren hintereinander angeordneten Tragkörpern*, airship-train with several carrier structures arranged one behind another,[3] - an airship consisting of flexibly articulated rigid sections. The front section, containing the crew and engines, was 117.35 m (385 ft) long with a gas capacity of 9514 cu m (336,000 cu ft): the middle section was 16 m (52 ft 6 in) long with an intended useful load of 599 kg (1320 lb) and the rear section 39.93 m (131 ft) long with an intended load of 1996 kg (4,400 lb).[13]

Count Zeppelin's attempts to secure government funding for his project proved unsuccessful, but a lecture given to the Union of German Engineers gained their support. Zeppelin also sought support from the industrialist David Schwarz, whose construction work on the second airship design of David Schwarz. Berg was under contract not to supply aluminium to any other airship manufacturer, and subsequently made a payment to Schwartz's widow as compensation for breaking this agreement.[14] Schwarz's design differed fundamentally from Zeppelin's, crucially lacking the use of separate gasbags inside a rigid envelope.[15]
In 1898 Count Zeppelin founded the Gesellschaft zur Förderung der Luftschifffahrt (Gesellschaft zur Förderung der Luftschiff), contributing more than half of its 800,000 mark share-capital himself. Responsibility for the detail design was given to Kober, whose place was later taken by Ludwig Dürr, and construction of the hall or hangar in the Bay of Manzell near Friedrichshafen on Lake Constance (the hall was to facilitate the difficult task of bringing the airship out of the hall, as it could easily be aligned with the wind. The 1 (LZ for Luftschiff Zeppelin, or "Zeppelin Airship") was 128 metres (420 ft) long with a hydrogen capacity of 11,000 m$^3$ (400,000 cu ft), was driven by two 15 horsepower (11 kW) Daimler engines each driving a pair of propellers mounted either side of the envelope via bevel gears and a driveshaft, and was controlled in pitch by moving a weight between its two nacelles.[17]

The first flight took place on 2 July 1900 over Lake Constance.[18] Damaged during landing, it was repaired and modified and proved its potential in two subsequent flights made on 17 and 24 October 1900,velocity attained by the French airship La France. Despite this performance, 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.[18][19]
Zeppelin LZ 4 with its multiple stabilizers, 1908

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 to begin on 17 January 1906.[20] After both engines failed it made a forced landing in the North Sea, damaging the anchored ship beyond repair.

Incorporating all the usable parts of LZ 2, its successor LZ 3 became the first Zeppelin to gain the interest of the German military, but a condition of purchase of an airship was that it had to exceed the capabilities of LZ 3, leading Zeppelin to construct his fourth design, the LZ 4. Flown over Switzerland to Zürich and then back to Lake Constance, covering 386 km (240 mi) and reaching an altitude of 795 m (2,600 ft). An attempt to complete the 24-hour trial flight ended when LZ 4 made an emergency landing at...
Stuttgart because of mechanical problems. During the stop, a storm tore the airship away from its moorings on the afternoon of 5 August 1908. It crashed into a tree, caught fire, and quickly burnt out. No one was seriously injured.

Wreckage of LZ 4

This accident would have finished Zeppelin's experiments, but his flights had generated huge public interest and a sense of national pride regarding his work, and spontaneous donations from the public eventually totalling over six million marks.[22] This enabled the Count to found the *Luftschiffbau Zeppelin*, as well as the *Zeppelin Foundation*.

**Before World War I**
Before World War I (1914–1918) the Zeppelin company manufactured 21 more airships. LZ 3 and LZ 5 (a sister-ship to LZ 4 which was completed in May 1909) and designated Z 1 and Z II respectively.

was wrecked in a gale in April 1910,[24] while Z I flew until 1913, when it was decommissioned and replaced by LZ 15, designated ersatz Z I.[24] First flown on 16 January 1913, it was wrecked on 19 March of the same year. In April 1913 its newly built sister-ship LZ 15 (Z IV) accidentally intruded into French airspace owing to a navigational error caused by high winds and poor visibility. The commander judged it proper to land the airship to demonstrate that the incursion was accidental, and brought the ship down on the military parade-ground at Lunéville. The airship remained on the ground until the following day, permitting a detailed examination by French airship experts.[25]

In 1909 Count Zeppelin founded the world’s first airline, the Deutsche Luftgastgesellschaft (German Airship Airline).
In 1909 Count Zeppelin founded the world's first airline, the Deutsche Luftschiffahrts-Aktiengesellschaft (German Airship Travel Corporation), generally known as DELAG\textsuperscript{[26]} to promote his airships, initially using LZ 6, which he had hoped to sell to the German Army. The airships did not provide a scheduled service between cities, but generally operated pleasure cruises, carrying twenty passengers. The airships were given names in addition to their production numbers. LZ 6 first flew on 25 August 1909 and was accidentally destroyed in Baden-Oos on 14 September 2010 by a fire in its hangar. A monument near Bad Iburg commemorating the 1910 LZ 7 crash.

The second DELAG airship, LZ 7 \textit{Deutschland}, made its maiden voyage on 19 June 1910. On 28 June it set off on a voyage to publicise Zeppelins, carrying 19 journalists as passengers. A combination of adverse weather and engine failure brought it down at Mount Limberg near Bad Iburg in Lower Saxony, its hull getting stuck in trees. All passengers and crew were unhurt, except for one crew member who broke his leg when he jumped from the craft, which also had a short career, first flying on 30 March 1911 and becoming damaged beyond repair when caught by a strong cross-wind when being walked out of its shed on 16 May.\textsuperscript{[29]} The company's first passenger airship, \textit{Schwaben}, which first flew on 26 June 1911\textsuperscript{[30]} and carried 1,553 passengers.
Schwaben, which first flew on 26 June 1911 and carried 1,553 passengers in 218 flights before catching fire after a gust tore it from its mooring near Düsseldorf. Other DELAG ships included LZ 17 and LZ 17 Sachsen (1913). By the outbreak of World War I in August 1914, 1588 flights had carried 10,197 fare-paying passengers.

LZ 18 (L 2)

On 24 April 1912 the Imperial German Navy ordered its first Zeppelin - an enlarged version of the airships operated by DELAG - which received the naval designation Z 1 and entered Navy service in October. Admiral von Tirpitz, Secretary of State of the German Imperial Naval Office, obtained the agreement of
von Tirpitz, Secretary of State of the German Imperial Naval Office, obtained the agreement of a three-year program of expansion of German naval-airship strength, involving the building of two airship bases and constructing a fleet of ten airships. The first airship of the program, L 2, was ordered on 30 January. L 1 was lost in Heligoland when caught in a storm while taking part in an exercise with the German fleet. 14 crew members drowned, the first fatalities in a Zeppelin accident.[33] Less than six weeks later, on 17 October, L 1 was destroyed in trials, killing the entire crew.[33] These accidents deprived the Navy of most of its experienced personnel: the head of the Admiralty Air Department was killed in the L 1 and his successor died in the L 2. The Navy was left with three partially trained crews. The next Navy zeppelin, the M class L 3 did not enter service until May 1914, as DELAG had been turned into a training ship.

By the outbreak of war in August 1914 Zeppelin had started constructing the M class L 3, which was 158 m (518 ft) long, with a volume of 22,500 cubic metres (794,500 cu ft) and a useful load of 9,100 kilograms (20,100 lb). Its three Maybach C-X engines produced a 470 kilowatts (630 hp) each, and the airships could reach speeds of up to 84 kilometres per hour (52 mph).[34]

During World War I

The German airships were operated by the Army and Navy as two entirely separate organizations.
When World War I broke out, the Army took over the three remaining DELAG ships. By this time, it had already decommissioned three older Zeppelins, including Z I. During the war the Navy used them for reconnaissance missions. Bombing missions, especially those targeting London, captured the German public's imagination, but had little significant material success, although the Zeppelin raids, together with the later bombing raids carried out by aeroplanes, did cause the diversion of men and equipment from the Western Front and fear of raids had some effect on industrial production.

Early offensive operations by Army airships revealed that they were extremely vulnerable to ground fire unless flown at high altitude, and several were lost. No bombs had been developed, and the early raids dropped artillery shells instead. On 5 August 1914 Z VI bombed Liège. Flying at a relatively low altitude because of cloud cover, the airship was damaged by small-arms fire and was destroyed in a forced landing near Bonn. On 21 August Z II while supporting German army operations in Alsace, and Z VIII was lost. On 20 August Z VII while bombing Antwerp, dropping bombs near the royal palace and killing five people. A second, less effective, raid was made on the night of 1–2 September and a third on 7 October, but on 8 October Z IX was destroyed in its hangar at Marix, RNAS. The RNAS had also bombed the Zeppelin bases in Cologne on 22 September 1914.

Z V was brought down by ground fire on 28 August during the Battle of Tannenberg, and Z VI bombed Warsaw on 24 September and was also used to support German army operations in East Prussia. By 1914 the Army's airship strength was reduced to four.
1914 the Army’s airship strength was reduced to four.[37]

On 20 March 1915, temporarily forbidden from bombing London by the Kaiser, Z X (LZ 29), LZ 35 and the Schütte-Lanz airship SL 2 set off to bomb Paris: SL 2 was damaged by artillery fire while crossing the front and turned back but the two Zeppelins reached Paris and dropped 1,800 kg (4,000 lb) of bombs, killing only one and wounding eight. On the return journey Z X was damaged by anti-aircraft fire and was damaged beyond repair in the resulting forced landing. Three weeks later LZ 35 suffered a similar fate after bombing Poperinghe.[40] Two further missions were flown against Paris in January: LZ 79 killed 23 and injured another 30 but was so severely damaged by anti-aircraft fire that it crashed during the return journey. A second mission by LZ 77 the following night bombed the suburbs of Asnières and Versailles, with little effect.[41][42]

Airship operations in the Balkans started in the autumn of 1915, and an airship base was constructed at Sofia in November 1915. LZ 81 was used to fly diplomats to Sofia for negotiations with Germany, and LZ 70 was used by LZ 85 to conduct two raids on Salonika in early 1916: a third raid on 4 May ended with it being brought down by antiaircraft fire. The crew survived but were taken prisoner.[42] When Romania transferred to Yambol and bombed Bucharest on 28 August, 4 September and 25 September, LZ 86, transferred to Szentandras and made a single attack on the Ploiești oil fields on 4 September, but was wrecked on attempting to land after the mission. Its replacement, LZ 86, was damaged by antiaircraft fire during its second attack on Bucharest on 26 September and was damaged beyond repair in the resulting forced landing, and was replaced by LZ 97.
Wreckage of Zeppelin L31 or L32 shot down over England 23 Sept 1916.

At the instigation of the Kaiser a plan was made to bomb Saint Petersburg in December 1916. Two Navy zeppelins were transferred to Wainoden on the Courland Peninsula. A preliminary attempt to bomb caused by operating problems due to the extreme cold, and one of the airships was destroyed in a forced landing at Serappen. The plan was subsequently abandoned.[44]

In 1917 the German High Command made an attempt to use a Zeppelin to deliver supplies to German East Africa. L 57, a specially lengthened craft was to have flown the completion. A Zeppelin then under construction, L 59, was then modified for November 1917 and nearly reached its destination, but was ordered to return (4,000 mi) and lasted 95 hours. It was then used for reconnaissance and bom flew one bombing mission against Naples on 10–11 March 1918. A planned at 7 April 1918 it was on a mission to bomb the British naval base at Malta with the loss of all its crew.

On 5 January 1918, a fire at Ahlhorn destroyed four of the specialised double Schütte-Lanz. In July 1918, the Tondern Raid conducted by the RAF and Roy 1914–18 naval patrols
The main use of the airship was in reconnaissance over the North Sea and they manufactured were used by the Navy. Patrolling had priority over any other airship activity. Missions were flown over the North Sea alone, compared to about 50 strategic bombing raids. The German Navy had some 15 Zeppelins in commission by the end of 1915 and was able to have two or more patrolling continuously at any one time. However, their operations were limited by weather conditions. On 16 February L 3 and L 4 were lost owing to a combination of engine failure and high winds, L 3 crashing on the Danish island of Fanø without loss of life and L 4 coming down at Huk; eleven crew escaped from the forward gondola, after which the lightened airship with four crew members remaining in the aft engine car was blown out to sea and lost.

At this stage in the war there was no clear doctrine for the use of Naval airships. A single Zeppelin, L 5, played an unimportant part in the Battle of the Dogger Bank on 24 January 1915. L 5 was carrying out a routine patrol when it picked up Hipper's radio signal announcing that he was engaged with the British battle fleet's position, the Zeppelin was forced to climb above the cloud cover by fire from the British fleet: its commander then decided that it was his duty to cover the retreating German fleet rather than observe British movements. In 1915 patrols were only carried out on 124 days, and in other years the total was considerably less. 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 mines' locations.

In 1917 the British Navy began to take effective countermeasures against airships. Curtiss H.12 "Large America" long-range flying boats were delivered to RNAS HMS Furious entered service, and launching platforms for aeroplanes were fitted to the forward turrets of some light cruisers. On 14 May L 22 was shot down near Terschelling Bank by an H.12 flown by Lt. Galpin and Sub-Lt. Leckie which had
been alerted following interception of its radio traffic.\[49\] Two further unsuccessful interceptions were made by Galpin and Leckie on 24 May and 5 June, and on 14 June L 43 was brought down by an H.12 flown by Sub Lts. Hobbs and Dickie. On the same day Galpin and Leckie intercepted and attacked L 46. The Germans had believed that the previous unsuccessful attacks had been made by an aircraft operating from one of the British Navy's seaplane carriers: now realising that there was a new threat, Strasser ordered airships patrolling in the Terschelling area to maintain an altitude of at least 4,000 m (13,000 ft), considerably reducing their effectiveness.\[50\] On 21 August L 23, patrolling off the Danish coast, was spotted by the British 3rd Light Cruiser squadron which was in the area. HMS *Yarmouth* launched its in shooting the Zeppelin down in flames. The cause of the airship's loss was Zeppelin had been brought down by antiaircraft fire from surface ships.\[51\]

**Bombing campaign against Britain**
IT IS FAR BETTER TO FACE THE REALITY THAN TO BE KILLED AT HOME BY A GAS."
At the beginning of the conflict the German command had high hopes for the airships, which were considerably more capable than contemporary light fixed-wing machines: they were almost as fast, could carry multiple machine guns, and had enormously greater bomb-load range and endurance. Contrary to expectation, it was not easy to ignite the hydrogen using standard bullets and shrapnel. The Allies only started to exploit the Zeppelin’s vulnerability to fire when a combination of explosive and incendiary ammunition was introduced during 1916. The British had been concerned over the threat posed by Zeppelins since 1909, and attacked the Zeppelin bases early in the war. LZ 25 was destroyed in its hangar at Düsseldorf on 8 October 1914 by bombs dropped by Flt Lt Reginald Marix, RNAS, and the sheds at Cologne as well as the Zeppelin works in Friedrichshafen were also attacked. These raids were followed by the Cuxhaven operations carried out by ship-launched aeroplanes.

Airship raids on Great Britain were approved by the Kaiser on 7 January 1915, although he excluded London as a target and further demanded that no attacks be made on historic buildings. The raids were intended to target only military sites on the east coast and around the Thames estuary, but bombing accuracy was poor owing to the height at which the airships flew and navigation was problematic. The airships relied largely on dead reckoning system of limited accuracy. After blackouts became widespread, many bombs fell at random on uninhabited countryside.

The first raid on England took place on the night of 19–20 January 1915. Two Zeppelins, L 3 and L 4, intended to attack Humberside but, diverted by strong winds, eventually dropped their bombs on the surrounding villages, killing four and injuring 16. Material damage was estimated at £7,740.

The Kaiser authorised the bombing of the London docks on 12 February 1915. Two Navy raids failed due to bad weather on 14 and 15 April, and it was decided to delay further attempts until the more capable P class Zeppelins were in service. The Army received the first of these, LZ 38, and Erich Linnarz commanded it on a raid over Ipswich on 29–30 April and another, attacking Southend on 9–10 May. LZ 38 also attacked 16–17 May, before returning to bomb Southend on 26–27 May. These four raids killed six people and injured six, causing...
16–17 May, before returning to bomb Southend on 26–27 May. These four raids killed six people and injured six, causing property damage estimated at £16,898. Twice Royal Naval Air Service (RNAS) aircraft tried to intercept LZ 38 but on both occasions it was either able to outclimb the aircraft or was already at too great an altitude for the aircraft to intercept.

On 31 May Linnarz commanded LZ 38 on the first raid against London. In total some 120 bombs were dropped on a line stretching from Stoke Newington south to Stepney and then north toward Leytonstone in injured. 41 fires were started, burning out seven buildings and the total damage was assessed at £18,596. Aware of the problems that the Germans were experiencing in navigation, this raid caused the government to issue a cease restraint on the press from reporting anything about raids that was not mentioned in official statements. Only one of the 15 defensive sorties managed to make visual contact with the enemy, and one of the pilots, Flt Lieut D. M. Barnes, was killed on attempting to land.

The first naval attempt on London took place on 4 June: strong winds caused the commander of L 9 to misjudge his position, and the bombs were dropped on Gravesend. L 9 was also diverted by the weather on 6–7 June, attacking London and causing considerable damage. On the same night an Army raid of three Zeppelins also failed because of the weather, and as the airships returned to Evére they ran into a counter-raid by RNAS aircraft flying from was destroyed on the ground and LZ 37 was intercepted in the air by R. A. J. Warneford airship, setting it on fire. All but one of the crew died. Warneford was awarded the consequence of the RNAS raid both the Army and Navy withdrew from their bases in Belgium.

After an ineffective attack by L 10 on Tyneside on 15–16 June the short summer nights discouraged further raids for some months, and the remaining Army Zeppelins were reassigned to the Eastern and Balkan fronts. The Navy resumed raids on Britain in August, when three largely ineffective raids were carried out. On 10 August the antiaircraft guns had their first success, causing L 12 to come down into the sea off Zeebrugge, and on 17–18 August L 10 became the first Navy airship to reach London. Mistaking the reservoirs of the Lea Valley for the Thames, it dropped its bombs on Leytonstone. L 10 was destroyed a little over two weeks later: it was struck by lightning and caught fire off the entire crew was killed. Three Army airships set off to bomb London or dropped bombs between Southwark and Woolwich: LZ 74 scattered 39 bombs and dropping a single bomb on Fenchurch Street station.
The Navy attempted to follow up the Army's success the following night. One Zeppelin targeted the benzol plant at Skinningrove and three set off to bomb London: two were forced to turn back but L 13, commanded by Heinrich Mathy reached London. The bomb-load included a 300 kilograms (660 lb) bomb, the largest yet carried. This exploded near Smithfield Market, destroying several houses and killing two men. More bombs fell on the textile warehouses north of...
near Smithfield Market, destroying several houses and killing two men. More bombs fell on Paul's Cathedral, causing a fire which despite the attendance of 22 fire engines still did not stop burning. Mathy then turned east, dropping his remaining bombs on Liverpool Street station. Despite concentrated antiaircraft fire, but no hits were scored and the falling shrapnel caused both damage and alarm on the ground. The raid killed 22 people and injured 87. The monetary damage was over one sixth of the total damage inflicted by bombing raids during the war.

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 at around 18:30, the Zeppelins encountered new ground defences installed since the September raid; these had no success, although the airship commanders commented on the improved defences of the city. L 15 began bombing over Charing Cross, the first bombs striking the Wellington Streets, killing 17 and injuring 20. None of the other Zeppelins reached central London: bombs fell on Guildford, Tonbridge, Croydon, Hertford and an army camp near Folkestone. A total of 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.

Although these raids had no significant military impact, the psychological effect was considerable. The writer described one raid in a letter to Lady Ottoline Morrell:

Then we saw the Zeppelin above us, just ahead, amid a gleaming of clouds: high there was flashes near the ground — and the shaking noise. It was like Milton — that the moon is not Queen of the sky by night, and the stars the lesser lights, golden like a moon, having taken control of the sky; and the bursting shells are t

The raids continued in 1916. In December 1915 additional P class Zeppelins were delivered. The Q class was an enlargement of the P class with improved ceiling and bomb-load. The Army took full control of ground defences in February 1916, and a variety of sub 4-inch (less than 102 mm) were converted to anti-aircraft use. Searchlights were introduced, initially manned by police. By mid-1916, there were 271
were converted to anti-aircraft use. Searchlights were introduced, initially in anti-aircraft guns and 258 searchlights across England. Aerial defences again and the Royal Flying Corps (RFC), with the Navy engaging enemy airships appearing responsibility once the enemy had crossed the coastline. Initially the War Office of inert gas to protect themselves from incendiary bullets, and favoured the. However, by mid-1916 an effective mixture of explosive, tracer and incendiary airship raids in 1916, in which 125 tons of bombs were dropped, killing 293 p
Zeppelin flagstone, Edinburgh
HIGH EXPLOSIVE
BOMB
DROPPED BY
ZEPPELIN
ON NIGHT OF
APRIL 2ND 1916
Zeppelin bomb, on display at the National Museum of Flight
Section of girder from Zeppelin shot down in England in 1916. Now at NPL

The first raid of 1916 was carried out by the German Navy. Nine Zeppelins were sent to Liverpool on the night of 31 January–1 February. A combination of poor weather and mechanical problems scattered them across the were bombed. A total of 61 people were reported killed and 101 injured by the raid. A British trawler came down in the North Sea because of engine failure and damage from Dutch ground–fire. Although the wreck stayed afloat for a while and was sighted by a British trawler, the boat’s crew refused to rescue the Zeppelin crew because they were outnumbered, and all 16 crew died.[70]

Further raids were delayed by an extended period of poor weather and also by the withdrawal of the majority of Naval Zeppelins in an attempt to resolve the recurrent engine failures.[71] Three Zeppelins set off to bomb were forced by high winds to divert to Hull, killing 18, injuring 52 and causing £25,050 damage. Ten airships set off on 31 March: most turned back and L 15, damaged by anti-aircraft fire and an aircraft attacking using Ranken darts, came down in the sea near Margate. Most of the 48 killed in the raid were victims of a single bomb which fell on an Army billet in Cleethorpes. On the night of 3/4 April, ten airships were attempted on five successive nights. Ten airships set off on 31 March: most turned back and L 15, damaged by anti-aircraft fire and an aircraft attacking using Ranken darts, came down in the sea near Margate. Most of the 48 killed in the raid were victims of a single bomb which fell on an Army billet in Cleethorpes. The raid were victims of a single bomb which fell on an Army billet in Cleethorpes. The raid targeted the naval base at Rosyth, the Forth Bridge and London. None of the airships succeeded in reaching their targets; 13 were killed, 24 injured and much of the £77,113 damage was caused by the destruction of a warehouse in whisky.[74][75][76] Raids on 4/5 April and 5/6 April had little effect,[77] as did a fi
single Army Zeppelin the following night. On 2/3 July a nine-Zeppelin raid against Manchester and Rosyth was largely ineffective due to weather conditions, and one was forced to land in neutral Denmark, its crew being interned.

On 28–29 July the first raid to include one of the new and much larger R-class Zeppelins achieved very little; four turned back early and the rest wandered over a fog-covered landscape before giving up. Adverse weather dispersed raids on 30–31 July and 2–3 August, and on 8–9 August effect.[80] On 24–25 August 12 Navy Zeppelins were launched: eight turned back without attacking and only Heinrich Mathy's L 31 reached London; flying above low clouds, 36 bombs were dropped in 10 minutes on south east London, killing 9, injuring 40 and causing £130,203 of damage.[81]

Zeppelins were very difficult to attack successfully at high altitude, although Aeroplanes struggled to reach a typical altitude of 10,000 feet (3,000 m), and firing the solid bullets usually used by aircraft Lewis guns was ineffectual: they made small holes causing inconsequential gas leaks. Britain developed new bullets, the Brock containing inflammable potassium chlorate, and the Buckingham filled with phosphorus, to ignite the potassium chlorate and hence the Zeppelin's hydrogen. These had become available by September 1916.

The biggest raid to date was launched on 2–3 September, when twelve German Navy and four Army airships set out to bomb London. A combination of rain and snowstorms scattered the airships while they were still over the North Sea. Only one of the naval airships came within seven miles of central London, and both damage and casualties were slight. The newly commissioned Schütte-Lanz SL 11 dropped a few bombs on Hertfordshire while approaching London: it was picked up by searchlights as it bombed Ponders End and at around 02:15 it was intercepted by a who fired three 40-round drums of Brocks and Buckingham ammunition into the airship. The third drum started a fire and the airship was quickly enveloped in flames. It fell to the ground near Cuffley, witnessed by the crews of several of the other Zeppelins and many on the ground; there were no survivors. The victory earned Leefe Robinson a of SL 11 were gathered up and sold as souvenirs by the Red Cross to raise money for wounded soldiers.
The loss of SL 11 to the new ammunition ended the German Army's enthusiasm,[84] and another 12-Zeppelin raid was launched on 23–24 September. Eight older airships bombed targets in the Midlands and northeast, while four R-class Zeppelins attacked London. L 30 did not even cross the coast, dropping its bombs at sea. L 31 approached London from the south, dropping a few bombs on Sevenoaks and Swanley before crossing Purfleet at Purfleet. L 32 also approached from the south: it dropped a few bombs on Sevenoaks and Swanley before crossing Purfleet at about 01:00. Shortly afterwards it was found by a BE2c piloted by 2nd Lieutenant Frederick Sowrey and set alight, coming down near Leyton, killing eight people and injuring 30.
killed. L 33 dropped a few incendiaries over Upminster and Bromley-by-Bow, being at an altitude of 13,000 feet (4,000 m). As it headed towards Chelmsford it passed over to Little Wigborough. The airship was set alight by its crew, but inspection of the wreckage provided the British with much information about the construction of Zeppelins, which was used in the design of the British airship type.

The next raid came on 1 October 1916. Eleven Zeppelins were launched at targets in the Midlands and at London. Only L 31, commanded by the experienced Heinrich Mathy making his 15th raid, reached London. As the airship neared about 23:20 it was picked up by searchlights and attacked by three aircraft from Tempest. One of these, L 32, was shot down by the Tempest and came down near Potters Bar. All 19 crew died, many jumping from the burning airship.

For the next raid, on 27–28 November, the Zeppelins avoided London for targets in the Midlands. Again the defending aircraft were successful: 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 was destroyed at Ahlhorn by strong winds after sustaining damage in a poor shed while landing: the resulting fire destroyed both L 24 and the adjacent L 17.
To counter the increasingly effective defences new Zeppelins were introduced with an increased operating altitude of 16,500 feet (5,000 m) and a ceiling of 21,000 feet (6,400 m). The first of these S-class Zeppelins, LZ 91 (L 42) entered service in February 1917.[89] They were basically a modification of the R-class, sacrificing strength and power for improved altitude. The surviving R-class Zeppelins were adapted by removing one of the engines.

The extra strain on the airship crews caused by altitude sickness and exposure to extreme cold and operating difficulties caused by cold and unpredictable high winds encountered at altitude.

The first raid of 1917 did not occur until 16–17 March: the five high flying Zeppelins encountered very strong winds and none reached their targets.[91] This experience was repeated on 23–24 May. Two daylight raid on London. They were frustrated by heavy cloud but the effort I London were to stop; under pressure he later relented to allow the Zeppelin

On 16–17 June, another raid was attempted. Six Zeppelins were to take part and another two were forced to return by engine failure. L 42 bombed Ramsgate. L 48, the first U class Zeppelin, was forced to drop to 13,000 feet (4,000 m) destroyed, crashing near Theberton, Suffolk.[92]

After ineffective raids on the Midlands and other targets in the north of England last major Zeppelin raid of the war was launched on 19–20 October, with 13 Liverpool. All were hindered by an unexpected strong headwind at altitude. L 44 was brought down by ground fire over France; L 49 and L 50 were also lost to engine failure and the weather over France. L 55 was badly damaged on landing and later scrapped.[93]
There were no more raids in 1917, although the airships were not abandoned but refitted with new, more powerful engines.

There were only four raids in 1918, all against targets in the Midlands and no bomb the Midlands on 12–3 March to little effect. The following night three of the weather: the third bombed Hartlepool, killing eight and injuring 29.\[94\] A largely ineffective, with thick clouds making accurate navigation impossible. two, one of which reached the east coast and bombed Wigan, believing it was Hartlepool, killing eight and injuring 29.\[94\] The final raid on 5 August 1918 involved four death of its entire crew under the command of Fregattenkapitän Peter Strasser Service and the Führer der Luftschiiffe. Crossing the North Sea during daylight Force DH.4 biplane piloted by Major Egbert Cadbury, and shot down in flames.

Technological progress

Zeppelin technology improved considerably as a result of the increasing demands of warfare. The company came under government control, and new personnel were recruited to the company to cope with the increased demand including the aerodynamicist Paul Jaray and the stress engineer Karl Arnstein. Many of the Zeppelin's only serious competitor, the Mannheim-based Schütte-Lanz company's designs were more successful, Professor Schütte's more scientific approach to airship design led to important innovations including the streamlined hull shape, the simpler cruciform fins (replacing the more complicated box-like arrangements of older Zeppelins), individual direct-drive engine cars anti-aircraft machine-gun positions,\[97\] and gas ventilation shafts which transferred vented hydrogen to the top of the airship. New production facilities were set up, assembling Zeppelins from components fabricated in Friedrichshafen.\[98\]

The pre-war M-class designs were quickly enlarged, to produce the 163 metres (536 ft) long increased gas capacity from 22,500 m\(^3\) (794,500 cu ft) to 31,900 m\(^3\) (1,126, and an extra engine. These modifications added 610 m (2,000 ft) to the max speed, and greatly increased crew comfort and hence endurance. Twenty-two P-class airships were built; the first, LZ 38, was delivered to the Army on 3 April 1915.\[99\] The P class was followed by a lengthened version, the Q class.
In July 1916 Luftschiffbau Zeppelin introduced the R-class, 199.49 m (644 ft 8 in) long, with a volume of 55,210 m³ (1,949,600 cu ft). These could carry loads of three to four tons of bombs and reached speeds of up to 103 km/h (64 mph), powered by six 240 hp (180 kW) Maybach engines.[100]

In 1917, following losses to air defences over Britain, new designs were produced capable of flying at much higher altitudes, typically operating at around 6,100 m (20,000 ft). This was achieved by reducing the weight of the structure, halving the bomb load, deleting the defensive armament, and reducing the number of engines to five.[101] However, these were not successful as bombers: the greater height at which they operated greatly hindered navigation, and their reduced power made them vulnerable to unfavorable weather conditions.
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 dirigibles. This was equipped with a wicker chair, chart table, electric lamp and compass, with telephone line and lightning conductor part of the suspension cable. The car's observer would relay navigation and bomb dropping orders to the Zeppelin flying within or above the clouds, so remaining invisible from the ground. Used by Army airships, they were not used by the Navy, since Strasser considered that their weight meant an unacceptable reduction in bomb load.

End of the war

The German defeat also marked the end of German military dirigibles, as the Treaty demanded a complete abolition of German air forces and surrender of the remaining airships as reparations. Specifically, the following articles dealing explicitly with dirigibles:

Article 198

"The armed forces of Germany must not include any military or naval air forces and dirigibles.

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 war 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 Zeppelin crews destroyed their airships in their halls in order to prevent delivery, following the example of the German fleet which had been scuttled. 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 made on England alone,[N 1] in which 5,806 bombs were dropped, killing 557 people and injuring 1,358 while causing damage 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 is that due to the 1915–16 raids "one sixth of the total normal output of munitions was entirely lost."[106]

**After World War I**

Renaissance
Count von Zeppelin had died in 1917, before the end of the war. Dr. Hugo Eckener, vessels of peace rather than of war, took command of the Zeppelin business: Despite considerable difficulties, they completed two small passenger airships, 1919 and in the following months transported passengers between Friedrichshafen and Berlin, and a sister-ship Nordstern, which was intended for use on a regular route to Stockholm.\[107\]

However, in 1921 the Allied Powers demanded that these should be handed over as war reparations as compensation for the dirigibles destroyed by their crews in 1919. Germany was not allowed to construct military aircraft and only airships of less than 28,000 m$^3$ (1,000,000 cu ft) were permitted. This brought a halt to Zeppelin's plans for airship development, and the company temporarily had to resort to manufacturing aluminium cooking utensils.

Eckener and his co-workers refused to give up and kept looking for investors. 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, and buying the R38 (based on the Zeppelin L 70) when the British airship programme was cancelled. However, this broke apart and caught fire during a test flight above the crewmen.\[109\]
Under these circumstances, Eckener managed to obtain an order for the next airship itself, as the cost was set against the war reparation accounts, but for LZ 126 made its first flight on 27 August 1924.\[110\]

On 12 October at 07:30 local time the Zeppelin took off for the US under the command of Hugo Eckener. The ship completed its 8,050 kilometres (5,000 mi) voyage without any difficulties in 80 hours 45 minutes. Most of the US media celebrated the arrival, and President Calvin Coolidge invited Eckener and his crew to Washington, D.C. He said that the Zeppelin was an "angel of peace".

Given the designation ZR-3 USS Los Angeles and refilled with helium (partly sourced from the crossing, the airship became the most successful American airship. It operated reliably for eight years until it was retired in 1932 for economic reasons. It was dismantled in August 1940.
Graf Zeppelin under construction
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. In 1926 restrictions on airship construction were relaxed but 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 the next dirigible.

Another two years passed before 18 September 1928, when the new dirigible, christened Count, flew for the first time. With a total length of 236.6 metres (776 ft) and a volume of 105,000 m³, it was the largest dirigible to have been built at the time. Eckener's initial purpose was to use Count for transport purposes to prepare the way for regular airship traveling, carrying passengers and mail to cover the costs. In October 1928 its first long-range voyage brought it to Lakehurst, the voyage taking 112 hours and setting a new endurance record for airships. Eckener and his crew, which included his son Hans, were once more welcomed enthusiastically, with confetti parades in New York and another invitation to the White House. Graf Zeppelin returned to Spain. A second trip to the United States was aborted in France due to engine failure in May 1929.
In August 1929 *Graf Zeppelin* departed for another daring enterprise: a circumnavigation of the "giant of the air" made it easy for Eckener to find sponsors. One of these was the American press tycoon Randolph Hearst, who requested that the tour officially start in Lakehurst.[11] Hearst had placed a reporter, Grace Marguerite Hay Drummond-Hay, on board to circumnavigate the globe by air. From there, *Graf Zeppelin* flew to Friedrichshafen, Tokyo, Los Angeles, and back to Lakehurst, in 21 days 5 hours and 31 minutes. Including the initial and final trips from Friedrichshafen and back, the dirigible had travelled 49,618 kilometres (30,831 mi).
In the following year, *Graf Zeppelin* undertook trips around Europe, and following a successful tour to 1930, it was decided to open the first regular transatlantic airship line. This line was later extended to *Rio de Janeiro*, with a stop in Recife. Despite the beginning of competition from fixed-wing aircraft, *LZ 127* transported an increasing volume of passengers and mail across the ocean every year until 1936. The ship made another spectacular voyage in July 1931 when it made a seven-day research trip to the *Arctic*.\[115]\[N 2\] This had already been a dream of Count von Zeppelin twenty years earlier, which could not be realized at the time due to the outbreak of war.

Eckener intended to follow the successful airship with another larger Zeppelin, designated *LZ 128*. This was to be powered by eight engines, 232 m (761 ft) in length, with a capacity of 199,980 m$^3$ (7,062,100 cu ft). However, the loss 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*. This was intended to be filled with \[Hindenburg, end of an era\]
The Hindenburg: note swastikas on tail fins.

The coming to power of the Nazi Party in 1933 had important consequences for Zeppelin Luftschiffbau. Zeppelins became a propaganda tool for the new regime: they would now display the Nazi swastika, play march music and propaganda speeches to the people. In 1934 Joseph Goebbels contributed two million reichsmarks towards the construction of LZ 129 and directed by Ernst Lehmann, the Deutsche Zeppelin Reederei, as a subsidiary of Hugo Eckener was an outspoken anti-Nazi: complaints about the use of Zeppelins for propaganda purposes in 1936 led Goebbels to declare "Dr. Eckener has placed himself outside the pale of society. Henceforth his name is not to be mentioned in the newspapers and his photograph is not to be published".[118]

On 4 March 1936 LZ 129 Hindenburg (named after former President of Germany in the 19th century) crashed to the ground when it attempted to land in Lakehurst, New Jersey.
On 4 March 1936, LZ 129 Hindenburg (named after former President of Germany) was the largest airship ever built. It had been designed to use helium for the gas, but the gas were controlled by the United States, who refused to allow its export. Instead, the Hindenburg was filled with flammable hydrogen. Apart from the propaganda missions, it operated transatlantic service alongside Graf Zeppelin.
On 6 May 1937, while landing in Lakehurst after a transatlantic flight, the tail of the \textit{Hindenburg} burst into flames, killing 35 of the 97 people on board and one member of the ground crew. The cause of the fire has not been definitively determined. The investigation into the accident concluded that hydrogen which had leaked from the gasbags, although there were allegations of including Ernst Lehmann, were killed.\textsuperscript{[120]}

Despite the apparent danger, 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.

\textit{Graf Zeppelin} was retired one month after the \textit{Hindenburg} wreck and turned Zeppelin was completed in 1938 and, inflated with hydrogen, made some test carried passengers.\textsuperscript{[122]} Another project, \textit{LZ 131}, designed to be even larger than \textit{Graf Zeppelin II} was assigned to the \textit{Luftwaffe} and made about 30 test flights, those flights were carried out near the \textit{Polish} border, first in the \textit{Sudeten} region. During one such flight \textit{LZ 130} crossed the Polish border near the \textit{Hel} Lublin R-XIII aircraft from \textit{Puck} naval airbase and forced to leave Polish airsp; electronic scouting missions, and was equipped with various measuring equi... coastline of Great Britain in an attempt to determine whether the 100 metre were used for aircraft radio location.\textsuperscript{[123]} Photography, radio wave interception, unable to detect operational British Chain Home radar due to searching in the searched were too high, an assumption based on the Germans' own radar sy; towers were not connected with radar operations, but were for naval radio c...
Zeppelin hangar in Frankfurt, where the skeleton of LZ 131 was also located. In March 1940 Göring ordered the scrapping of the remaining airships, and on 6 May the Frankfurt hangars were demolished.

Cultural influences

Zeppelins have been an inspiration to music, cinematography and literature. In 1934, the calypsonian "Graf Zeppelin", commemorating the airship's visit to Trinidad.[125][126]

Zeppelins are often featured in alternate history fiction. In the American science fiction series, a notable historical idiosyncrasy that helps differentiate the series' two parallel episodes "The Rise of the Cybermen" and "The Age of Steel" when the TARDIS lands in a 'people's republic' and Pete Tyler, Rose Tyler's father, is alive and is a wealthy inventor. 

alternate reality 1939 plot line in the film Sky Captain and the World of Tomorrow, steampunk subcultural movement in broader terms. In 1989, Japanese animator Miyazaki released which features a Zeppelin as a plot element.

In 1968, English rock band Led Zeppelin chose their name after Keith Moon, that his idea to create a band would "go down like a lead balloon." Page's manager suggested the group use a picture of the Hindenburg crashing in New Jersey to avoid mispronunciation. "Balloon" was replaced with "Zeppelin" as a 'people's republic' and Pete Tyler, Rose Tyler's father, is alive and is a wealthy inventor.

Modern era
Zeppelin NT

Since the 1990s Zeppelin Luftschifftechnik, a daughter enterprise of the Zeppelin conglomerate that built the original German Zeppelins, has been developing Zeppelin "New Technology" (NT) airships. These vessels are semi-rigids based partly on internal pressure, partly on a frame.

The Airship Ventures company operated zeppelin passenger travel to California from October 2008 to November 2012 with one of these Zeppelin NT airships.[129]

In May 2011, Goodyear announced that they will be replacing their fleet of blimps with Zeppelin NTs, a partnership that ended over 70 years ago. They will also be building the airships in the United States.

Modern zeppelins are held aloft by the inert gas helium, eliminating the danger of combustion illustrated by the Hindenburg disaster. It has been proposed that modern zeppelins could be powered by hydrogen fuel cells.

Sightseeing trips, for example D-LZZF (c/n 03) was used for Edelweiss's birthday celebration performing flights over Austria, and it is now used, weather permitting, on flights over Munich.

See also
• Airship hangar
• Buoyancy compensator (aviation)
• Lane hydrogen producer
• List of airships of the United States Navy
• List of Schütte-Lanz airships
• List of Zeppelins
• Zeppelin Museum Friedrichshafen

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Notes

1. ^ The figures given total 54. While A. Whitehouse in The Zeppelin Fighters 2006, pp. 155–157, 528 people killed, 1,156 wounded in 208 individual sorties.
2. ^ Koestler was the only journalist on board. He describes the preparations and the voyage itself in detail in his autobiography.\[116\]

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External links

- How did London civilians respond to the German airship raids of 1915?
- Zeppelin NT in the World and Technical Data
- Airships.net – Illustrated history of passenger Zeppelins
- eZEP.de – The webportal for Zeppelin mail and airship memorabilia
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