ZEPPELIN - HANDOUT

America and the Airship.

The history of American military aviation began during the Civil War, when the Union Army operated observation balloons. A balloon was used by the US Army in Cuba during the Spanish–American War. Although the use of observation balloons continued after the end of World War I. Balloons, of course, must either be tethered, or go where they are blown by the wind, but towards the end of the nineteenth century, powered airships, capable of being directed, were developed.

Ferdinand Von Zeppelin did not come to the U.S. to observe balloon operations. He served with Federal cavalry units in Northern Virginia in the Army of the Potomac. A 25-year-old German cavalry officer, a Prussian nobleman, came to America during the Civil War as a foreign military observer of the Union Army.

Just across the street from his hotel, a balloonist named John Steiner was flying passengers in his observation balloon. Steiner had flown for the Union Army as a civilian observer. His work probably saved McClellan's Army from defeat in 1862. The German officer decided to add a balloon ride to his American adventure. So Steiner sent him up on a solo flight at the end of a 700-foot tether rope. Our young officer wrote a letter-report of the experience. Outwardly it was straightforward reporting of the military potential of observation balloons; but between the lines bubbled a barely controlled excitement.

At the end of his visit, he wanted to see some more of the country. He travelled to New York City, up the Hudson, across the state on the Erie Canal, across the Great Lakes and out into Minnesota, where he met John Steiner, one of Lowe's aeronauts, who had returned to his pre-war profession as an exhibition balloonist. Zeppelin flew with him and listened to his dreams of a navigable airship. Many years later the Count explained that the experience with Steiner had marked the beginning of his own interest in flight.

And we're left with the astounding fact that the seed for all this was sown in Western America during the Civil War. Shortly before he died, Zeppelin wrote,

> *"While I was above St. Paul, I had my first idea of aerial navigation strongly impressed on me and it was there that the first idea of my Zeppelins came to me."*

In 1908, the US Army experimented with its first powered aircraft, the SC-1, or Signal Corps number 1. It was a small non-rigid airship with a top speed under 20mph and endurance of just over 2 hours. Following tests at Fort Myer, the SC-1 was sent to Fort Omaha, Nebraska, where the Signal Corps School was located. While the SC-1 was being tested at Fort Myer, the Signal Corps built an airship hangar and a plant to produce hydrogen gas at Fort Omaha. Fort Omaha became, for a while, the first permanent military airfield in the United States. The SC-1 was scrapped in 1912, and the base at Fort Omaha closed in 1913.

A **Zeppelin** was 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 and developed in detail in 1893. They were patented in Germany in 1895 and in the United States in 1899. After 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 (DELAG), the world's first airline in revenue service. By mid-1914, DELAG had carried over 10,000 fare-paying passengers on over 1,500 flights.

Ferdinand von Zeppelin

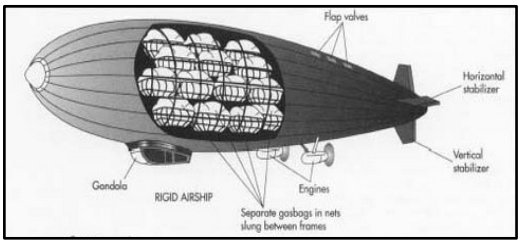
The principal feature of Zeppelin's design was a fabric-covered rigid metal framework made up from transverse rings and longitudinal girders containing a number of individual gasbags. The advantage of this design was that the aircraft could be much larger than non-rigid airships, which relied on a slight 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 multi-plane fins. During World War I, following the lead of their rivals Schütte-Lanz Luftschiffbau, the design changed to the more familiar streamlined shape with cruciform tail surfaces, as used by almost all later airships.

They were propelled by several engines, mounted in gondola's or engine cars, which were attached to the outside of the structural framework. Some of these could provide reverse thrust for manoeuvring while mooring. Early models had a comparatively small externally mounted gondola for passengers and crew which was attached to the bottom of the frame. 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 miserable with the cold.

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 Air Travel" to outline the basic principle of his later craft in a diary entry dated 25th March 1874. This describes a large rigidly framed outer envelope containing several

separate 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. 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 31st August 1895, with Theodor Kober producing the technical drawings.



Zeppelin's patent described a *Lenkbares Luftfahrzug mit mehreren hintereinanderen angeordneten Tragkörpern* [Steerable airship-train with several carrier structures arranged one behind another], 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 (1320lb) and the rear section 39.93 m (131 ft) long with an intended load of 1996 kg (4,400lb)

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 Carl Berg, then engaged in construction work on the second airship design of David Schwarz. Berg was contracted not to supply aluminium to any other manufacturer, and subsequently made payment to Schwartz's widow as compensation for breaking this agreement. Schwarz's design differed fundamentally from Zeppelin's, crucially lacking the use of separate gasbags inside a rigid envelope.

The first flight of LZ 1 over Lake Constance (the Bodensee) in 1900.

In 1898 Count Zeppelin 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. Responsibility for the detail design was given to Kober, whose place was later taken by Ludwig Dürr, and construction of the first airship began in 1899 in a floating assembly-hall or hangar in the Bay of Manzell near Friedrichshafen on Lake Constance (the *Bodensee*).

The intention behind the floating 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 LZ 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.

The first flight took place on 2 July 1900 over Lake Constance. Damaged during landing, it was repaired and modified and proved its potential in two subsequent flights made on 17th and 24th October 1900, bettering the 6 m/s (21.6 km/h, 13.4 mph) velocity attained by the French airship *La France*. 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.

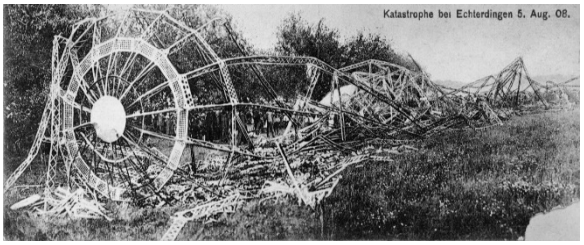
Donations, the profits of a special lottery, some public funding, a mortgage of Count von Zeppelin's wife's estate and a 100,000 mark contribution by Count von Zeppelin himself allowed the construction of LZ 2, which made only a single flight on 17 January 1906. After both engines failed it made a forced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

Incorporating all the usable parts of LZ 2, its successor LZ 3 became the first truly successful Zeppelin. This renewed the interest of the German military, but a condition of purchase of an airship was a 24-hour endurance trial. This was beyond the capabilities of LZ 3, leading Zeppelin to construct his fourth design, the LZ 4, first flown on 20 June 1908. On 1 July it was 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 had to make a landing at Echterdingen near 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.

Zeppelin LZ 4 with its multiple stabilizers, 1908.

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 began pouring in, eventually totaling over six million

marks. This enabled the Count to found the *Luftschiffbau Zeppelin GmbH* (Airship Construction Zeppelin Ltd.) and the Zeppelin Foundation

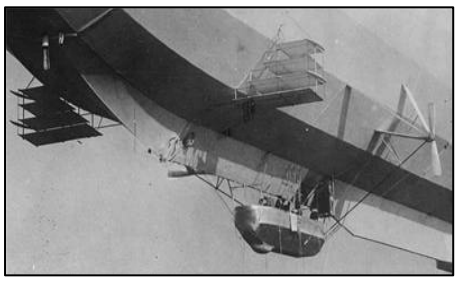


Wreckage of LZ 4.

Before World War I (1914–1918) the Zeppelin company manufactured twenty-one more airships. The Imperial German Army bought LZ 3 and LZ 5 (a sister-ship to LZ 4 which was completed in May 1909) and designated them Z 1 and Z II respectively. Z II was wrecked in a gale in April 1910, while Z I flew until 1913, when it was decommissioned and replaced by LZ 15, designated *ersatz* Z I.

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.

In 1909 Count Zeppelin founded the world's first airline, the Deutsche Luftschiffahrts-Aktiengesellschaft (German Airship Travel Corporation), generally known as DELAG 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 25th August 1909 and was accidentally destroyed in Baden-Oos on 14th September 1910 by a fire in its hangar. DELAG's goal was to commercialize zeppelin travel by providing passenger air service, and to purchase airships built by the Zeppelin Company at a time when support by the military was still uncertain.



LZ.7 *Deutschland*

The second DELAG airship, LZ 7 *Deutschland*, made its maiden voyage on 19 June 1910. On 28th June it set off on a voyage to publicize Zeppelins, carrying nineteen journalists as passengers. A combination of adverse weather and engine failure brought it down at Mount Limberg near BadIburg 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. It was replaced by LZ 8 *Deutschland II* which also had a short career, first flying on 30th March 1911 and becoming damaged beyond repair when caught by a strong cross-wind when being walked out of its shed on 16th May.

The company's fortunes changed with the next ship, LZ 10 *Schwaben*, which first flew on 26th 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 11 *Viktoria Louise* (1912), LZ.13 *Hansa* (1912) and LZ.17 *Sachsen* (1913). By the outbreak of World War I in August 1914, 1588, flights had carried 10,197 fare-paying passengers. On 24th 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 1912. On 18th January 1913 Admiral Alfred von Tirpitz, Secretary of State of the German Imperial Naval Office, obtained the agreement of Kaiser Wilhelm II to a five-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 30th January. L 1 was lost on 9th September near Heligoland when caught in a storm while taking part in an exercise with the German fleet. fourteen crew members drowned, the first fatalities in a Zeppelin accident. Less than six weeks later, on 17th October, LZ 18 (L 2) caught fire during its acceptance trials, killing the entire crew. 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: in the meantime, *Sachsen* was hired from DELAG as a training ship.

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

During World War I.

During World War I the German military made extensive use of

Zeppelins as bombers and scouts, killing over 500 people in bombing raids in Britain.

Crater of a Zeppelin bomb in Paris, 1916.

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 Zeppelins were mainly used in 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 airplanes, did cause the diversion of men and equipment from the Western Front and fear of the 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 5th 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 21st August Z VII and Z VIII were damaged by ground fire while supporting German army operations in Alsace, and Z VIII was lost. On the night of 24/25th August Z IX bombed Antwerp, dropping bombs near the royal palace and killing five people.

A second, less effective, raid was made on the night of 1–2nd September and a third on 7th October, but on 8th October Z IX was destroyed in its hangar at Düsseldorf by Flight Lt. Reginald Marix, RNAS.

Flt.Lt. Reginald George Marix RNAS

The RNAS had also bombed the Zeppelin bases in Cologne on 22nd September 1914. On the Eastern Front, Z V was brought down by ground fire on 28th August during the Battle of Tannenberg; most of the crew were captured. Z IV bombed Warsaw on 24th September and was also used to support German army operations in East Prussia. By the end of 1914, the Army's airship strength was reduced to four.

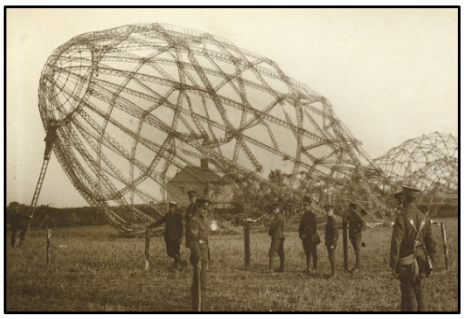
On 20 March 1915, temporarily forbidden from bombing London by the Kaiser, Z X (LZ 29), LZ 35 and the Schütte-Lanz airship SL 2 set off to bomb Paris: SL 2 was damaged by artillery fire while crossing the front and turned back but the two Zeppelins reached Paris and dropped 1,800 kg (4,000lb) of bombs, 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. Two further missions were flown against Paris in January 1916: on 29th January LZ 79 killed 23 and injured another thirty, 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.

Airship operations in the Balkans started in the autumn of 1915, and an airship base was constructed at Szentandras. In November 1915, LZ 81 was used to fly diplomats to Sofia for negotiations with the Bulgarian government. This base was also used by LZ 85 to conduct two raids on Salonika in early 1916: a third raid on 4th May ended with it being brought down by antiaircraft fire. The crew survived but were taken prisoner. When Romania entered the war in August 1916, LZ 101 was transferred to Yambol and bombed Bucharest on 28th August, 4th September and 25th September. LZ 86, transferred to Szentandras and made a single attack on the Ploiesti Oil Fields on 4th 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 26th September and was damaged beyond repair in the resulting forced landing and was replaced by LZ 97.

How inhabitants of the sleepy villages of Great Burstead near Billericay and Little Wigborough, near Colchester, were suddenly thrust into the front line of the First World War when Zeppelins crashed in their fields. Zeppelin L32 was shot down by Frederick Sowrey, RFC, aged 23, and crashed near Snails Farm, South Green, Great Burstead, Near Billericay. Its target was London, but because of an anti-aircraft barrage, it dropped its bombs near Purfleet. It began to make its way back to Germany when it was intercepted by Sowrey who was on routine night patrol. The airship was picked out in the night sky by searchlights and Sowrey launched his attack. Firing three drums of incendiary ammunition into the body of the airship, she caught alight and plummeted to the ground at sometime after 1 a.m. All 22 of the crew were killed. One witness described how in the night sky

he saw a pink glare which turned to coppery red, then a ball of flame emerged which changed its shape to a perpendicular cylindrical mass of flame. A few days later the crew were buried at Great Burstead Churchyard. The bodies were later transferred to a church in Staffordshire.

The other ill-fated Zeppelin was L33. On the raid it was damaged by anti-aircraft fire and was forced to land at New Hall Farm, Little Wigborough, only twenty yards from a nearby house. The occupants of the house, the Lewis family, ran for their lives as the airship hit the ground. The crew ran from the craft and shortly after, it exploded.



The Lewis family had a lucky escape.

Special Constable Edgar Nicholas, who lived nearby, made his way to the scene, and came across the crew walking along a road. They identified themselves as the Zeppelin crew and he arrested them. Other officers later joined them and the local constable, Pc 354 Charles Smith, arranged for the prisoners to be handed over to the military to be taken off to a prisoner-of-war camp.

At the instigation of the Kaiser a plan was made to bomb St Petersburg in December 1916. Two Navy Zeppelins were transferred to Wainoden on the Courland Peninsula. A preliminary attempt to bomb Reval on 28th December ended in failure 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.

In 1917, the German High Command made an attempt to use a Zeppelin to deliver supplies to Lettow-Vorbeck's forces in German East Africa. L 57, a specially lengthened craft was to have flown the mission but was destroyed shortly after completion. A Zeppelin then under construction, L 59, was then modified for the mission: it set off from Yambol on 21st November 1917 and nearly reached its destination, but was ordered to return by radio.

Its journey covered 6,400 km (4,000 mi) and lasted 95 hours. It was then used for reconnaissance and bombing missions in the eastern Mediterranean. It flew one bombing mission against Naples on 10–11th March 1918. A planned attack on Suez was turned back by high winds, and on 7 April 1918 it was on a mission to bomb the British naval base at Malta when it caught fire over the Straits of Otranto, with the loss of all its crew.

On 5th January 1918, a fire at Ahlhorn destroyed four of the specialised double sheds along with four Zeppelins and one Schütte-Lanz. In July 1918, the Tondern Raid conducted by the RAF and Royal Navy, destroyed two Zeppelins in their sheds.

1914 – 18 Naval patrols .

The main use of the airship was in reconnaissance over the North Sea and the Baltic, and the majority of airships manufactured were used by the Navy. Patrolling had priority over any other airship activity. During the war almost 1,000 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 16th 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 Blaavands 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 Admiral Hipper's radio signal announcing that he was engaged with the British battle cruiser squadron. Heading towards the German 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. 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 mines' locations.

In 1917 the British Navy began to take effective countermeasures against airship patrols over the North Sea. In April the first Curtiss H.12 "Large America" long-range flying boats were delivered to RNAS Felixstowe, and in July 1917 the aircraft carrier HMS *Furious* entered service, and launching platforms for airplanes were fitted to the forward turrets of some light cruisers. On 14th 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. 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 Lieutenants 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. On 21st 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 Sopwith Pup, and Sub-Lt. B. A. Smart succeeded in shooting the Zeppelin down in flames. The cause of the airship's loss was not discovered by the Germans, who believed the Zeppelin had been brought down by anti-aircraft fire from surface ships.

Bombing campaign against Britain

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 great 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 Raid on Christmas Day 1914, one of the first operations carried out by ship-launched airplanes.

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, supplemented by a radio direction-finding system of limited accuracy. After blackouts became widespread, many bombs fell at random on uninhabited countryside.

British First World War poster of a Zeppelin above London at night.

1915

The first raid on England took place on the night of 19–20th January 1915. Two Zeppelins, L 3 and L 4, intended to attack Humberside but, diverted by strong winds, eventually dropped their bombs on Great Yarmouth, Sheringham, King's Lynn and 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, but no raids on London took place until May. 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 29–30th April and another, attacking Southend on 9–10th May. LZ 38 also attacked Dover and Ramsgate on 16–17th May, before returning to bomb Southend on 26–27th 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 31st 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.

Seven people were killed and 35 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 D notice prohibiting 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 Lieutenant D. M. Barnes, was killed on attempting to land.

The first naval attempt on London took place on 4th 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 6–7th June, 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, and as the airships returned to Evére they ran into a counter-raid by RNAS aircraft flying from Furnes, Belgium. LZ 38 was destroyed on the ground and LZ 37 was intercepted in the air by R. A. J. Warneford, who dropped six bombs on the airship, setting it on fire. All but one of the crew died. Warneford was awarded the Victoria Cross for his achievement. As a consequence of the RNAS raid both the Army and Navy withdrew from their bases in Belgium.

Sub Lieutenant Reginald "Rex" Warneford

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 Walthamstow and Leytonstone.

L 10 was destroyed a little over two weeks later: it was struck by lightning and caught fire off Cuxhaven, and the entire crew was killed. Three Army airships set off to bomb London on 7–8 September, of which two succeeded: SL 2 dropped bombs between Southwark and Woolwich: LZ 74 scattered 39 bombs over Cheshunt before heading on to London and dropping a single bomb on Fenchurch Street station.

A commemorative plaque at 61 Farringdon Road, London

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 *Kapitänleutnant* Heinrich Mathy reached London. The bomb-load included a 300 kilograms (660lb) 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 St Paul's Cathedral, causing a fire which despite the attendance of 22 fire engines caused over half a million pounds of damage: Mathy then turned east, dropping his remaining bombs on Liverpool Street station. The Zeppelin was the target of 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 Lyceum Theatre and the corner of Exeter and Wellington Streets, killing 17 and injuring 20.

None of the other Zeppelins reached central London: bombs fell on Woolwich, Guildford, Tonbridge, Croydon, and 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 D. H. Lawrence 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 up, like a bright golden finger, quite small (...) Then there were flashes near the ground — and the shaking noise. It was like Milton — then there was war in heaven. (...) I cannot get over it, that the moon is not Queen of the sky by night, and the stars the lesser lights. It seems the Zeppelin is in the zenith of the night, golden like a moon, having taken control of the sky; and the bursting shells are the lesser lights."

1916

The raids continued in 1916. In December 1915 additional P class Zeppelins and the first of the new Q class airships, 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) calibre guns were converted to anti-aircraft use. Searchlights were introduced, initially manned by police. By mid-1916, there were 271 anti-aircraft guns and 258 searchlights across England. Aerial defences against Zeppelins were divided between the RNAS and the Royal Flying Corps (RFC), with the Navy engaging enemy airships approaching the coast while the RFC took responsibility once the enemy had crossed the coastline. Initially the War Office had believed that the Zeppelins used a layer of inert gas to protect themselves from incendiary bullets, and favoured the use of bombs or devices like the Ranken dart. However, by mid-1916 an effective mixture of explosive, tracer and incendiary rounds had been developed. There were 23 airship raids in 1916, in which 125 tons of bombs were dropped, killing 293 people, and injuring 691.

Zeppelin flagstone, Edinburgh

The first raid of 1916 was carried out by the German Navy. Nine Zeppelins were sent to Liverpool on the night of 31 January–1st February. A combination of poor weather and mechanical problems scattered them across the Midlands and several towns were bombed. A total of 61 people were reported killed and 101 injured by the raid. Despite ground fog, 22 aircraft took off to find the Zeppelins but none succeeded, and two pilots were killed when attempting to land. One airship, the L 19, 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. At the beginning of April, raids were attempted on five successive nights. Ten airships set off on 31 March: most turned back and L 15, damaged by antiaircraft 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 following night two Navy Zeppelins bombed targets in the north of England, killing 22 and injuring 130. On the night of 2/3rd April a six-airship raid was made, targeting the naval base at Rosyth, the Forth Bridge and London. None of the airships bombed their intended targets; 13 were killed, 24 injured and much of the £77,113 damage was caused by the destruction of a warehouse in Leith containing whisky. Raids on 4/5 April and 5/6 April had little effect, as did a five-Zeppelin raid on 25/26 April and a raid by a 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 28–29th July the first raid to include one of the new and much larger R-class Zeppelins, L 31, took place. The 10-Zeppelin raid 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 nine airships attacked Hull with little effect. 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 southeast London. Nine people were killed, 40 injured and £130,203 of damage was caused.

Heinrich Mathy

Zeppelins were very difficult to attack successfully at high altitude, although this also made accurate bombing impossible. Airplanes 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 2–3rd 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 BE2c flown by Lt. William Leefe Robinson, 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 Victoria Cross; the pieces of SL 11 were gathered up and sold as souvenirs by the Red Cross to raise money for wounded soldiers.

British propaganda postcard, entitled "The End of the 'Baby-Killer'"

The loss of SL 11 to the new ammunition ended the German Army's enthusiasm for raids on Britain. The German Navy remained aggressive, 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 the southern suburbs before crossing the Thames and bombing Leyton, killing eight people and injuring 30. 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 Great Burstead. The entire crew was killed.

L 33 dropped a few incendiaries over Upminster and Bromley-by-Bow, where it was hit by an anti-aircraft shell, despite being at an altitude of 13,000 feet (4,000 m). As it headed towards Chelmsford it began to lose height and came down close 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 R33-class airships. The next raid came on 1st 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 Cheshunt at about 23:20 it was picked up by searchlights and attacked by three aircraft from No. 39 Squadron. 2nd lieutenant Wulstan Tempest succeeded in setting fire to the airship, which came down near Potters Bar. All nineteen crew died, many jumping from the burning airship. For the next raid, on 27–28th 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 lost three more craft, all on 28 December: SL 12 was destroyed at Ahlhorn by strong winds after sustaining damage in a poor landing, and at Tondern L 24 crashed into the shed while landing: the resulting fire destroyed both L 24 and the adjacent L 17.

1917

To counter the increasingly effective defences new Zeppelins were introduced with 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. 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 improved safety was offset by 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.

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 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. This experience was repeated on 23–24 May. Two days later 21 Gotha bombers attempted a daylight raid on London. They were frustrated by heavy cloud but the effort led the Kaiser to announce that airship raids on London were to stop; under pressure he later relented to allow the Zeppelins to attack under "favourable circumstances".

On 16–17 June, another raid was attempted. Six Zeppelins were to take part, but two were kept in their shed by high winds and another two were forced to return by engine failure. L 42 bombed Ramsgate, hitting a munitions store. The month-old L 48, the first U class Zeppelin, was forced to drop to 13,000 feet (4,000 m) where it was caught by four aircraft and destroyed, crashing near Theberton, Suffolk. After ineffective raids on the Midlands and other targets in the north of England on 21–22 August and 24–25 September, the last major Zeppelin raid of the war was launched on 19–20 October, with 13 airships heading for Sheffield, Manchester and Liverpool. All were hindered by an unexpected strong headwind at altitude. L 45 was trying to reach Sheffield, but instead it dropped bombs on Northampton and London: most fell in the north-west suburbs but three 300 kg (660lb) bombs fell in Piccadilly, Camberwell and Hither Green, causing most of the casualties that night. L 45 then reduced altitude to try to escape the winds but was forced back into the higher air currents by a BE2e. The airship then had mechanical failure in three engines and was blown over France, eventually coming down near Sisteron; it was set on fire and the crew surrendered. 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. There were no more raids in 1917, although the airships were not abandoned but refitted with new, more powerful engines.

1918

There were only four raids in 1918, all against targets in the Midlands and northern England. Five Zeppelins attempted to bomb the Midlands on 12–3 March to little effect. The following night three Zeppelins set off, but two turned back because of the weather: the third bombed Hartlepool, killing eight and injuring 29. A five-Zeppelin raid on 12–13 April was also largely ineffective, with thick clouds making accurate navigation impossible. However some alarm was caused by the other two, one of which reached the east coast and bombed Wigan, believing it was Sheffield: the other bombed Coventry in the belief that it was Birmingham. The final raid on 5th August 1918 involved four airships and resulted in the loss of *L.70* and the death of its entire crew under the command of *Fregattenkapitän* 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.

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 these technological advances originated from Zeppelin's only serious competitor, the Mannheim-based Schütte-Lanz company. While their dirigibles were never as 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, 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. The pre-war M-class designs were quickly enlarged, to produce the 163 metres (536ft) long duralumin P-class, which increased gas capacity from 22,500 m^3 (794,500 cu ft) to 31,900 m^3(1,126,000 cu ft), introduced a fully enclosed gondola and an extra engine. These modifications added 610 m (2,000 ft) to the maximum ceiling, around 9 km/h (6 mph) to the top 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. 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, and with a volume of 55,210 m^3 (1,949,600 cu ft). These could carry loads of three to four tons of bombs and reach speeds of up to 103 km/h (64 mph), powered by six 240hp (180 kW) Maybach engines.

In 1917, following losses to air defences over Britain, new designs were produced which were 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 airship by reducing the weight of the structure, halving the bomb load, deleting the defensive armament and by reducing the number of engines to five. 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. 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. Although 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 victorious Allies demanded a complete abolition of German air forces and surrender 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 23rd 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 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 sixty were lost, roughly evenly divided between accident and enemy action. 51 raids had been made on England alone, 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 the due to the 1915–16 raids "one sixth of the total normal output of munitions was entirely lost."

After World War

The US Army operated French observation balloons during World War I, but did not operate another airship until after the war ended. During World War I the Joint Airship Board assigned the US Navy the role of acquiring and developing rigid airships. This did not dissuade the Army from pursuing its own course. Colonel William Hensley flew as an observer on the return voyage of the British R34 airship from Long Island, New York to the UK in the summer of 1919. Hensley was then sent on a confidential mission to contact the Zeppelin Company to attempt to purchase the remaining undelivered wartime Zeppelin, the L 72. The scheme probably originated with General "Billy" Mitchell. Hensley visited the Zeppelin plant, inspected L 72, and flew on the Bodensee, a small passenger Zeppelin. The Inter-Allied Commission of Control ordered that L 72 should be turned over to France. In November 1919 the US Army contracted with the Zeppelin corporation for construction of the LZ 125, which was to be larger than the R38 class airship which the USN had contracted to purchase from Britain as the ZR-2. This attempt to avoid the conditions set by the Joint Airship Board would have encountered legal problems as the US Senate refused to ratify the Allied Peace Treaty with Germany until October 1921. Complaints by the Secretary of the Navy resulted in the Secretary of War ordering the German contract terminated in December 1919

Count von Zeppelin had died in 1917, before the end of the war. Dr. Hugo Eckener, who had long envisioned dirigibles as vessels of peace rather than of war, took command of the Zeppelin business, hoping to quickly resume civilian flights. Despite considerable difficulties, they completed two small passenger airships; LZ 120 *Bodensee*, which first flew in August 1919 and in the following months transported passengers between Friedrichshafen and Berlin, and a sister-ship *LZ 121 Nordstern*, which was intended for use on a regular route to Stockholm.

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 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*, 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 Humber on 23 August 1921, killing 44 crewmen.

The airship U.S.S. Shenandoah was the first American built rigid airship. Although built in the United States, Shenandoah was based on the design of the German L-49, a World War I high altitude bomber which had been forced down intact in France in October, 1917 and carefully studied.
The L-49 was one of the “height climbers” designed by the Germans late in World War I, when improvements in Allied fighter aircraft and anti-aircraft artillery made it necessary for zeppelins to climb to great altitudes to avoid being shot down. For the zeppelins to rise to greater heights on a fixed volume of lifting gas, however, the weight and strength of their structures were dramatically reduced. This decrease in strength was accepted as a wartime necessity, since a structurally weaker zeppelin flying above the reach of enemy aircraft and artillery was safer than a stronger zeppelin that could be easily attacked. The copying of this design for an American airship, however, may later have had tragic consequences.

Construction of ZR-1 took place during 1922 and 1923; parts were fabricated at the Naval Aircraft Factory in Philadelphia, and the ship was assembled at the Lakehurst Naval Air Station in New Jersey. ZR-1 was 680.25 feet long, with a diameter of 79.7 feet, and could carry up to 2,115,174 cubic feet of lifting gas in 20 gas cells. As originally built the ship carried six Packard 6-

cylinder engines — five mounted in individual power cars attached to the hull, and one mounted at the rear of the control gondola — but the sixth engine was removed in 1924. Like all previous zeppelins, ZR-1 had been designed on the assumption that the ship would be operated with hydrogen, but the fiery crash of the U.S. Army airship Roma in 1922 convinced the U.S. government to operate future Airship's with helium, despite the high cost and very limited supply of the gas.

Officers of the USS Shenandoah on her first flight (left to right): Lieut. A.R. Houghton, Lieut. L.E. Mueller, Cdr. J.H. Klein, Lieut. C.E. Rosendahl, Lieut. Cdr. M.R. Pierce, Lieut. J.C. Arnold, Lieut. E.H. Kincaid, Lieut. H.V. Wiley, Lieut. R.J. Miller, Lieut. R.F. Tyler, Lieut. J.B. Andserson.

The First Flights of USS Shenandoah

ZR-1 made its first flight on September 4, 1923. It was the first ascent of a helium inflated rigid airship in history. It made a series of test and demonstration flights in September and early October 1923 — including an appearance at the National Air Races in St. Louis and flights over New York and Washington — and on October 10, 1923, the ship was christened USS Shenandoah (an American Indian term meaning "daughter of the stars") and officially accepted as a commissioned vessel of the US Navy.

Shenandoah's first flights were on-the-job training for the American Navy, which had no previous experience operating a rigid airship of its own.

The Navy also had to learn how to use helium to operate a large rigid airship, which had never previously been attempted. The need to conserve the expensive and scarce lifting gas required flight operations which differed considerably from the techniques which had been developed for operating airships inflated with easily-replaced hydrogen. For example, while the Germans typically began a zeppelin flight with gas cells inflated to 100% capacity, and then valved hydrogen (either manually or automatically) as the ship rose, the Americans — unable to afford the loss of precious helium — had to operate with lower inflation levels, and therefore less lift, and had to be more careful about valving gas to descend or to maintain aerostatic equilibrium.

The need to preserve helium had many operational implications, including the timing of flights to coordinate with changes in ambient temperature, and the development of water recovery equipment to capture water from engine exhaust to compensate for the weight of fuel burned in flight. And perhaps most significantly, the desire to conserve helium also led to a highly controversial decision to reduce the number of Shenandoah's automatic gas valves, which became the subject of much debate in light of later events.

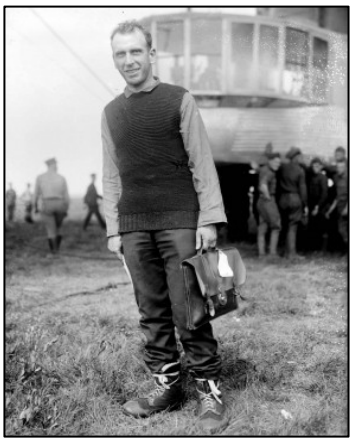
On the evening of January 16, 1924, Shenandoah was seriously damaged during a gale, when a gust of wind tore the ship from its mooring mast. The ship was grounded for repairs until May 22, 1924, when it was returned to service with reinforcements to its mooring assembly, nose, and fins. The sixth engine in its control car was also removed and replaced with radio equipment, including a long distance direction finding set.

On February 12, 1924, while it was undergoing repairs, Shenandoah received a new commanding officer, Lt. Cdr. Zachary Lansdowne.

Zachary Lansdowne in front of control car of USS Shenandoah.

Lansdown, a 1909 graduate of the United States Naval Academy, was one of the Navy's first officers trained in lighter-than-air aviation. He trained with the crew of the British airship R-34, and became the first American to cross the Atlantic nonstop by air as the American naval observer aboard R-34's 1919 transatlantic flight.

After service as a White House aide, Lansdowne was the Assistant Naval Attaché in Germany in 1922-1923, where was involved with the negotiations for the construction of the LZ-126, which became the ZR-3 USS Los Angeles.



Lansdowne's energetic personality and fierce devotion to lighter-than-air aviation would drive the operations of USS Shenandoah and determine its future. Although Shenandoah was too small to conduct extended operations at sea (since the ship's relatively small gas capacity limited its ability to carry fuel, and therefore its range), Lansdowne was determined to demonstrate the potential of the rigid airship as a naval scouting vessel, and to show that large airships could operate alongside the surface fleet. Lansdowne conducted pioneering operations in which he moored Shenandoah to a mast installed on the support ship Patoka, to show the possibility of underway replenishment and supply to extend the ship's range and allow an airship to work closely with the fleet, and Lansdowne conducted operations with surface ships such as the battleship USS Texas whenever possible.

Shenandoah made one of its most impressive demonstrations in October 1924, when the ship made a difficult 19-day journey across the United States from Lakehurst to San Diego, via Forth Worth, and then traveled up the west coast to Seattle and back to San Diego, before returning to Lakehurst via Fort Worth. Shenandoah logged 235 flight hours on its headline-making journey across the country, and captured the enthusiasm of both the American public and also leaders in the field of aviation around the world.

Upon Shenandoah's return to Lakehurst the ship was deflated so that its helium could be transferred to the newly arrived ZR-3 (soon to be commissioned USS Los Angeles) which had just been delivered to Lakehurst by Hugo Eckener and his German crew; the supply of helium was so scare in 1924 that the United States did not have enough of the gas to inflate two large airships at the same time.

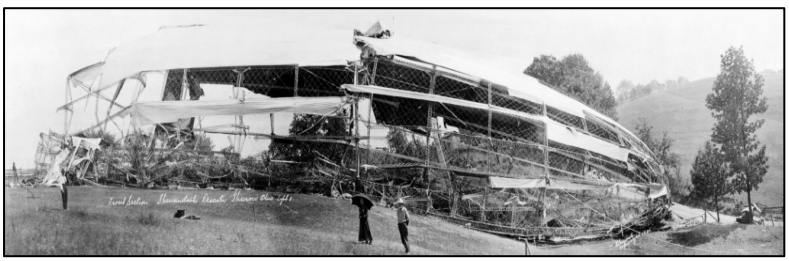
ZR-1 Shenandoah moored to USS Patoka at sea.

The Crash of the USS Shenandoah

On September 3, 1925, on its 57th flight, Shenandoah was caught in a storm over Ohio. Updrafts caused the ship to rise rapidly, at a rate eventually exceeding 1,000 feet per minute, until the ship reached an altitude over 6,000 feet. Shenandoah rose, fell, and was twisted by the storm, and the ship finally suffered catastrophic structural failure, breaking in two at frame 125, approximately 220 feet from the bow. The aft section sank rapidly, breaking up further, with two of the engine cars breaking away and falling to the ground, killing their mechanics.

The control car, attached to the bow section, also separated from the ship, and crashed to the ground, killing the six men still aboard, including the ship's captain, Lt. Cdr. Lansdowne. Without the weight of the control car, the remaining bow section, with seven men aboard, including Navigator Charles Rosendahl, ascended rapidly. Under Rosendahl's leadership, the men in the bow valved helium from the cells and free-ballooned the bow to a relatively gentle landing. In all, fourteen members of the crew were killed in the crash. Two schools of thought developed about the cause of the crash. One theory is that the gas cells over-expanded as the airship rose, due to Lansdowne's decision to remove the 10 automatic release valves, and that the expanding cells damaged the framework of the airship and led to its structural failure. But Karl Arnstein, the Stress Engineer who designed the L-49, the zeppelin on which Shenandoah was based, blamed the basic design of the ship, and the decision to operate a ship of that design in adverse weather conditions. Arnstein argued that the wartime L-49 had been designed as a "height-climber;" a zeppelin built with deliberately reduced structural strength in order to lighten the ship and enable it to climb to extremely high altitudes, above the reach of attacking British airplanes and ground fire.

The German height-climbers were never intended to operate in difficult weather conditions, Arnstein explained, or over large land masses with their potentially violent updrafts and downdrafts; World War I zeppelins were operated infrequently, when the weather was good, and in the relatively calmer atmosphere over the flat, open ocean. And the very shape of Shenandoah, known as its fineness ration (the ship's long, thin, pencil-like hull) reduced its ability to withstand bending forces; the next zeppelins designed by Arnstein, the USS Akron and USS Macon, would have a very different profile.



Wreckage of USS Shenandoah

The loss of the Shenandoah — and the loss of its officers and crew — was naturally a setback to the Navy's rigid airship program, but attention soon shifted to the zeppelin which would be the most successful airship in American history, the USS Los Angeles.

ZR-3 USS *Los Angeles* over southern Manhattan

Under these circumstances, Eckener managed to obtain an order for the next American dirigible. Germany had to pay for this airship itself, as the cost was set against the war reparation accounts, but for the Zeppelin company this was unimportant. LZ 126 made its first flight on 27 August 1924.

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. American crowds enthusiastically celebrated the arrival, and President Calvin Coolidge invited Eckener and his crew to the White House, calling the new Zeppelin an "angel of peace".

Given the designation ZR-3 USS *Los Angeles* and refilled with helium (partly sourced from the *Shenandoah*) after its Atlantic 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.

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. In 1926 restrictions on airship construction were relaxed by the Locarno treaties, but 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 to secure the realization of *LZ 127*.

***Graf Zeppelin* under construction**

Another two years passed before 18th September 1928, when the new dirigible, christened *Graf Zeppelin* in honour of the Count, flew for the first time. With a total length of 236.6 metres (776 ft) and a volume of 105,000 m^3, it was the largest dirigible to have been built at the time. Eckener's initial purpose was to use *Graf Zeppelin* for experimental and demonstration 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* 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.

The *Graf Zeppelin*

In August 1929 *Graf Zeppelin* 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 that 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: she 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 between Friedrichshafen and Lakehurst 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 Recife, Brazil in May 1930, it was decided to open the first regular transatlantic airship line. This line operated between Frankfurt and Recife, and was later extended to Rio de Janeiro, with a stop in Recife.

Despite the beginning of the Great Depression and growing 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. This had been a dream of Count von Zeppelin twenty years earlier, which could not be realized at the time due to the outbreak of war.

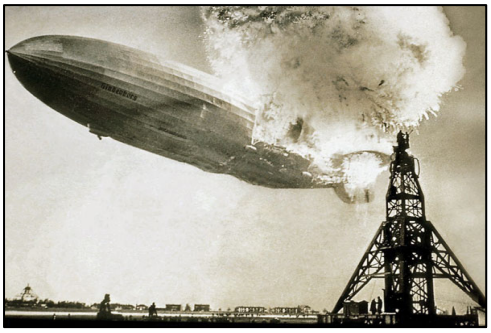
Eckener intended to follow the successful airship with another larger Zeppelin, designated LZ 128. This was to be powered by eight engines, 232 m (761ft) in length, with a capacity of 199,980 m^3 (7,062,100 cu ft). However the loss of the British passenger airship R101 on 5 October 1930 led the Zeppelin 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 inert helium.

Hindenburg, end of an era.

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 on their fins and occasionally tour Germany to play march music and propaganda speeches to the people. In 1934 Joseph Goebbels, the Minister of Propaganda, contributed two million reichsmarks towards the construction of LZ 129 and in 1935 Hermann Göring established a new airline directed by Ernst Lehmann, the *Deutsche Zeppelin Reederei*, as a subsidiary of *Lufthansa* to take over Zeppelin operations.

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".

On 4 March 1936 LZ 129 *Hindenburg* (named after former President of Germany, Paul von Hindenburg) made its first flight. The *Hindenburg* was the largest airship ever built. It had been designed to use non-flammable helium, but the only supplies of the gas were controlled by the United States, who refused to allow its export. So, in what proved to be a fatal decision, the *Hindenburg* was filled with flammable hydrogen. Apart from the propaganda missions, *LZ 129* was used on the transatlantic service alongside *Graf Zeppelin*.



The Hindenburg on fire in 1937

On 6 May 1937, while landing in Lakehurst after a transatlantic flight, 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 cause of the fire has not been definitively determined. The investigation into the accident concluded that static electricity had ignited hydrogen which had leaked from the gasbags, although there were allegations of sabotage. 13 passengers and 22 crew, including Ernst Lehmann, were killed. 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.

Graf Zeppelin was retired one month after the *Hindenburg* wreck and turned into a museum. 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 a few ring frames.

Graf Zeppelin II was assigned to the *Luftwaffe* and made about 30 test flights prior to the beginning of World War II. Most of those 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 it 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 for electronic scouting missions, and was equipped with various measuring equipment. In August 1939, it made a flight 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 location. 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 were for naval radio communications.

After the beginning of 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 scrapping of the remaining airships, and on 6 May the Frankfurt hangars were demolished.

Compiled by Norman Bambridge
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