Guide – A Short History of Balloon and Airship Manufacture in the UK

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The French balloon pioneers, 1782-83

Airships are often called dirigibles, which is the French word for 'steerable' and in the context of lighter-than-air flight simply means a 'steerable balloon'. Indeed, balloon and airship manufacture originated in France with the activities of Joseph-Michel and Jacques-Etienne Montgolfier in the early 1780s. Intrigued by paper bags that rose into the air when filled with smoke from open fires, the brothers set about making ever-larger bags which were painted to make them waterproof. By 1782 unmanned *balons* made from huge sheets of paper were being launched to amuse large crowds of onlookers. Summoned to Paris by Louis XVI in 1783, the brothers continued to build ever bigger balloons ultimately creating gigantic structures from the strongest, lightest-weight materials then available. Sheets of painted paper were glued to canvas panels and attached with coat buttons to frameworks of bamboo poles lashed together with hemp rope. The first manned, untethered flight took place on 21 November 1783 and vast crowds watched François Pilâtre de Rozier and Marquis d'Arlandes float over Paris for 25 minutes. The supply of smoke in flight was sustained by sheaves of straw thrown onto an open fire in a metal brazier hanging on chains inside the balloon. More flights followed, but the enormous, fragile structures invariably broke on landing and within five years 'Montgolfières' had been superseded by a different type of balloon.

Spurred on by the public acclaim generated by the unscientific Montgolfière experiments, Professor Jacques Charles, a chemist at The Parisian Academy of Sciences, designed the world's first gas balloon. The engineers Anne-Jean and Nicolas-Louis Robert manufactured it for him by coating sheets of silk with rubber and sewing them to form a small, airtight sphere. Charles filled it with a recently discovered lightweight gas (now known as hydrogen) and launched his unmanned Globe in August 1783. Charles's team then embarked on construction of a rubberised silk sphere encapsulated by a large-mesh net. A wooden ring encircled the base of the net and suspended from it was a wickerwork boat-shaped gondola with seats for two aeronauts. To ascend sand ballast was thrown overboard and to descend a cord opened a wooden valve letting hydrogen out of the top of the balloon. On 1 December 1783, just ten days after the first manned Montgolfière flight, Jacques Charles and Nicolas Robert, watched by 400,000 spectators, flew the first manned 'Charlière' for more than two hours. Not only could gas balloons fly for longer than smoke-filled ones, but they were also more controllable in flight and robust enough to withstand multiple landings. Montgolfières disappeared within five years of the first flight whereas Charlières proliferated and gas balloons with nets, wooden valves, sandbags and wickerwork baskets were still being flown two hundred years later.

Hot-air and gas balloon experiments in the UK, 1783-85

The first person to build an unmanned experimental gas balloon in the UK was Michael Biaggini, a London-based maker of artificial silk flowers. He took instruction from fellow Italian Count Francesco Zambeccari who had witnessed the early trials in Paris. The pair's first attempt, in November 1783, was a hydrogen-

filled sphere of oiled-silk, launched without publicity from Cheapside, City of London. Three weeks later their second balloon, double the size and painted gold, was launched in front of paying spectators from the Honourable Artillery Company Grounds at Moorfields. Thereafter the craze spread rapidly and home-built, unmanned hot air and gas balloons were soon being launched from provincial cities throughout Britain.

In February 1784 James Sadler is reported to have flown a home-built hot air balloon in Oxford and in March James Tytler released a small hydrogen balloon in Edinburgh. Other successful demonstrations soon followed, including those of Philip Astley and James Dinwiddie in London, but which types of balloons these were and how and they were built and filled is unknown. Inflating Montgolfières required large stacks of fuel for big bonfires, while Charlières needed a considerable quantity of iron filings to be constantly stirred with sulphuric acid in wooden barrels to produce a corrosive gas that was fed along large lead pipes. Both procedures involved hours of labour and a substantial financial investment.

That so many unskilled, inexperienced people in the UK were evidently able to overcome these obstacles is remarkable and the difficulties of successfully inflating these early balloons is revealed by the fact that in the ensuing race to achieve the first UK manned flight, only one in ten of the many public displays advertised managed to launch successfully. Notable spectacular disasters in the summer of 1784 included Count de Moret in Belgravia, John Sheldon's balloon (built by Allen Keegan in London) and James Tytler's home-built Montgolfière in Edinburgh. All three failures resulted in major riots with mobs of disappointed spectators causing serious damage and the British public became sceptical about balloons in general. Undaunted, Tytler repaired his barrel-shaped Montgolfière and in late August 1784, made a short hop that qualified as both the first manned flight in Britain and the first ascent by a Briton. On 15 September 1784, in London, another Italian, Vincenzo Lunardi made the first manned ascent in England in a hydrogen balloon of unknown origin. Shortly thereafter, in Oxford, James Sadler made two flights in home-built balloons, one in a hot air balloon in October and a second in a hydrogen balloon from the Oxford Physic Garden in November. Later, in June 1785, Letitia Ann Sage became the first British woman to ascend in the UK in Lunardi's second gas balloon, and Stuart Amos Arnold flew his own gas balloon in August. It is not known who built these balloons but by winter 1785 the novelty was wearing off and ballooning fell out of fashion in the UK until 1821 when the arrival of piped coal gas for domestic use simplified gas balloon inflation and led to a renaissance.

UK airship pioneers, 1785-1850

Meanwhile, back in France, only two days after the first gas balloon ascent in Paris, a distinguished engineer, Lieutenant Jean Baptiste Meusnier, had proposed creating a dirigible balloon. His idea was realised on 15 July 1784 when an elongated, hydrogen-filled balloon took off from St Cloud. Designed by Charles and built by the Robert brothers, the world's first airship was 52 feet long with a 30,000 cubic feet capacity. Although the balloon flew for 45 minutes and reached an estimated altitude of 15,000 feet it proved unsteerable and airships capable of controlled return to their place of take-off had to await the invention of the air-screw and robust, lightweight engines.

Nevertheless, many attempts were made along the way, including in the UK, where, in April 1815, Swiss citizens Jean Samuel Pauly and Durs Egg were granted a licence by George III to build an aerostatic machine to carry passengers between London and Paris. Construction of The Dolphin began in the world's first purpose-built aircraft hangar near Hyde Park in London. The outer shell of the fish-shaped, hydrogen-filled airship consisted of sewn fabric panels made gas-tight with seven layers of 'goldbeater's' skin from the dried intestines of 70,000 cattle. A second small, spherical, air-filled *ballonet* inside the fish served to maintain gas pressure. Steering was provided by two rudders and a 33-feet-high tailfin made of silk and whalebone. Propulsion was intended to come from the lightest possible steam engine but the maiden flight, planned for 1817, never took place and the project was abandoned after the partners quarrelled. A second, later proposal to connect London and Paris with regular, direct passenger flights also failed. There is uncertainty as to where Compte de Lennox built The Eagle airship, but it was exhibited at the Aeronautical Society in Kensington, London, in 1834.

Although detailed structural drawings survive of the Pneumadrome, invented in 1847 by J M Partridge, there is little documentary evidence to support the claim that several successful flights were made in 1848. The rigid, lightweight, fabric-covered, cylindrical hull framework, tapered at each end with the passenger

car suspended from a net covering the rubber-coated internal gas cell. A single ballonet regulated gas pressure but the steering apparatus, resembling sails, proved ineffective in flight. A mystery surrounds the propulsion system, said to consist of three propellers attached to the car, allegedly driven by compressed air.

While Partridge was a forerunner of the rigid airship type, the two flights in 1850 of the Patented Locomotive Balloon, made and piloted by Hugh Bell in London, proved the viability of what would become the more successful non-rigid type. Having made a series of small experimental models demonstrating that scaled-up propellers for boats could provide propulsion in air, Bell built a full-size people-carrier. His canoe-shaped car or gondola, designed to be driven by twin, hand-cranked air-screws, was suspended by bands of silk from a cylindrical gas bag made of white silk fabric which was filled with coal gas. Bell made one flight in May 1850 from the Phoenix Gas Works at Kennington and a second in July from Vauxhall Pleasure Gardens. Observers, however, saw no evidence to support Bell's claims of dirigibility during either flight.

Laying the foundations for UK airship manufacture, 1850-65

Little is known as to who actually built any of the early experimental UK balloons and airships but the construction of the component parts of all lighter-than-air flying machines depended on experts with a range of specialist skills in diverse handicrafts. Thus, would-be balloonists or inventors wishing to realise their creations who needed a gas bag or hot-air chamber were most likely to have contracted fabric engineers such as sail or tent-makers who were expert in sewing, sticking and painting coatings on to large fabric shapes. If a net was needed, along with ropes and rigging, then help could be sought from the fishing and sailing industries who had expertise in knotting and splicing cords and cables. A gondola or control car for the passengers to ride in might best be ordered from carriage builders or the makers of horse-drawn vehicles who were expert in woodwork, basket-weaving, panelling and upholstery. Airship-builders would have needed additional help from woodworkers to make their fins, rudders and propellers and, as time moved on, increasing numbers of metal workers and engineers to make and maintain their engines. Finally, the cooperation of gas manufacturers and/or fuel suppliers was also required.

Moreover, the assembly of these different components, several of which were necessarily large and fragile, had to be done with great care and supervised by someone who knew how the parts interacted. But in all cases, the final assembly must have taken place at a site where the hazardous and labour-intensive methods of producing large quantities of smoke or hydrogen could be arranged. This all changed for gas balloons with the invention of the coking process in the early 1800s, by which hydrogen-rich, coal gas could be cheaply and easily made on an industrial scale as a by-product of heating coal to produce coke. This so-called 'town gas', which was distributed for public use in UK towns via a network of gas mains in the 1820s, was a godsend to gas balloonists. It allowed quick and easy inflations to take place at any site to which a temporary gas pipe could be laid.

The first use of coal gas to inflate a balloon in Britain was in London at the coronation of George IV on 19 July 1821. The pilot of The Royal Coronation, specially built for the occasion, was Charles George Green, a showman whose spectacular stunts advanced the technology of UK balloon construction by funding a succession of increasingly large balloons. In November 1836, he made the world's first international flight from London's Vauxhall Pleasure Gardens to Nassau in Germany, a 480-mile, 18-hour flight. His balloon, The Royal Vauxhall, was made of crimson and white silk from Spitalfields. There is reason to believe that this and other UK balloons of this time were built by Edward Spencer who made 27 ascents with Charles Green and fathered a dynasty of active balloonists.

In 1852 a degree of aerial dirigibility was demonstrated in Paris, when Henri Giffard steered an elongated Charlière, propelled by a steam-engine, to a safe landing 17 miles away. This milestone in airship evolution went unremarked in the UK where attention remained focussed on public entertainment and serious scientific studies. Leading the way in atmospheric exploration was Henry Coxwell who, in September 1862, ascended to 30,000 feet while his passenger, James Glaisher, the Astronomer Royal, collected air samples. This pioneering high altitude flight started from Wolverhampton, but the pair had previously made a test flight from the Crystal Palace at Sydenham, suggesting that their giant balloon, Mammoth, may have been built there. A year later, in 1863, Gaspard-Félix Tournachon, another Frenchman, exhibited the world's

largest gas balloon fully inflated in the central transept of the Crystal Palace as a public spectacle. The French-built Le Géant was nearly 200 feet tall and had required more than 300 seamstresses to assemble the 22,000 yards of silk.

Both Tournachon's giant gas balloon and Giffard's dirigible airship were manufactured by Eugène Godard, himself a prominent French balloonist who, in July 1864, brought an even larger hot air balloon to London to amaze the public. Godard made two ascents in London in *L'Aigle* (The Eagle), a vast Montgolfière' that was lifted by hot air supplied from a straw-burning stove. Hot air ballooning, however, did not catch on, but in the late 1800s the French were clearly maintaining their lead with regard to balloon construction and innovation. At the Paris Exhibition in 1867 Henri Giffard demonstrated a giant captive balloon made of linen coated with India rubber that was restrained by a 2,000-feet-long steel cable allowing it to be winched up and down giving rides to 30 passengers seated in a circular car. In 1868 Giffard was persuaded to bring it to London where it proved hugely popular offering members of the public spectacular views of the city from Ashburnham Park in Chelsea.

UK balloon factories, 1865-1901

The potential that captive balloons had as adjustable, elevated vantage points for military use was recognised by Henry Coxwell who had previously conducted balloon experiments with the British army. He had flown with Royal Engineer officers in 1863, but it was not until 1878 that the War Office tasked Captain James Lethbridge Brooke Templer, an army reservist and experienced balloonist, with the manufacture of mobile, captive, observation balloons for use in their African campaigns. Having been appointed instructor in ballooning to the Royal Engineers at the Royal Arsenal, Woolwich, initially Templer used his own balloon, Crusader, until the unit developed a 10,000 cubic feet balloon named Pioneer. By 1879 the unit possessed five balloons and in 1882 it moved to the School of Military Engineering at Chatham, where it became known as the School of Ballooning.

Viewed with hindsight it is clear that the evolution of lighter-than-air flying machines was directly linked to the development of increasingly lighter-weight materials coupled with technological advances facilitating fabrication, inflation and operation. Templer made major contributions to these. In the 1880s most balloons in the UK were made of varnished cambric and inflated with coal gas. From his understanding of aerostatic theory Templer knew that pure hydrogen generated more lift per cubic foot and would allow smaller balloons that would be cheaper to build, easier to transport and quicker to inflate in the field. However, he had to solve several problems before he could use hydrogen.

The first problem was the balloon envelope. Varnished cambric had a high leakage rate, but the army needed observation balloons to make multiple ascents throughout campaigns lasting several days. Templer rediscovered the goldbeater's skin used by Pauly and Egg for their hydrogen balloon in 1815 and persuaded Aloys Frederick Weinling, head of an East London family skilled in using it for toy balloons, to experiment with the manufacture of a large balloon. Goldbeater's skin came from the intestines of cattle, the ceacum of each animal providing about 1.5 square feet of skin. The method of joining the skins was jealously guarded by the Weinlings and the creation of a large balloon with seven layers of skin was a difficult and slow process. In 1882 Templer set up a workshop for the Weinlings in the Royal Engineers' camp at Chatham and they produced their first military balloon envelope in 1883, the Heron. Meanwhile, Templer and Lieutenant J E Capper made a smaller balloon of silk treated with linseed oil named the Sapper. It was better at holding hydrogen than varnished cambric, but the goldbeater's skin proved superior in all respects and was adopted as the standard. Initially two sizes of balloon were made of 10,000 and 7,000 cubic feet capacity; the latter being intended to lift one light man in favourable conditions.

Templer's second problem involved the provision of hydrogen but he was able to benefit from experiments compressing hydrogen into easily transportable steel cylinders in 1882 and these were introduced into military service in 1884. Using these, Templer's observation balloons were first tested in combat in 1885. However, filling the cylinders added a gas compression plant to the hydrogen-making installation at Chatham and in 1890 the project moved to Stanhope Lines, Aldershot, joining a Royal Engineers training and test centre for British army balloon and airship experiments. The School of Ballooning was formally renamed The Balloon Factory in 1897.

At this time, three civilian balloon-builders were also competing for business in London. The oldest and best known was C G Spencer & Sons which for many years had enjoyed a virtual monopoly, manufacturing sport and advertising balloons for fêtes at workshops in Highbury, and later in Islington. The firm's founder, Charles Green Spencer, had seven children and, in 1890, was succeeded as factory manager by his eldest son, Percival, who was internationally renowned as a balloon pilot. Meanwhile, another son, Henry became partner in a rival balloon-making business at Alexandra Palace, with Auguste Eugene Gaudron, a Frenchman who had served an apprenticeship with Spencer & Sons and married Percival's daughter.

Significant competition to both the Spencer dynasty and the military Balloon Factory arrived in 1898 when Eustace and Oswald Short established a small workshop in London's Tottenham Court Road. The Short brothers built their first balloon in 1901 and were contracted in October 1903 to make two military observation balloons for the Indian government. A repeat order followed in November 1904, and, prompted by an order for a racing balloon from Charles Rolls, in June 1906 the brothers moved the business from Tottenham Court Road to the railway arches at Battersea where the Nine Elms gasworks provided coal gas for inflations. Here, the brothers built 30 balloons, mostly for members of the Aero Club.

UK civilian prototypes, 1901–05

By the turn of the century would-be airship-builders had a range of light-weight construction materials available, the only missing component being a reliable means of propulsion. In the late 1890s, as heavy steam engines gave way to lighter, more robust petrol and diesel motors, two fundamentally different solutions to the problem were demonstrated in Europe. In France, Alberto Santos Dumont joined two cylinders from his road-race tricycle so that they shared one vertically-operating piston and mounted it inside a wooden-framed keel suspended from an elongated, pressurised, hydrogen-filled balloon. He first flew the N-1, his single-seat prototype of what would become known as the 'non-rigid-type' or 'blimp', in Paris in September 1898. Meanwhile, in Germany in June 1898 Count Ferdinand von Zeppelin had started construction at Friedrichshafen of his prototype 'rigid' airship. For this, the Count encased 17, unpressurised, spherical, rubberized-cotton gas balloons in a large aluminium framework clad with a fabric cover. The combined lift of the hydrogen-filled balloons was sufficient to carry two aluminium gondolas suspended below the ship each housing a four-cylinder petrol engine driving two propellers. The first 'Zeppelin', Luftschiff-Zeppelin 1 (LZ-1), made its maiden flight in July 1900.

In London, Stanley Spencer (another of Charles Green's sons) designed his own small blimp with the intention of flying it around St Paul's Cathedral. The hydrogen-filled blimp's bamboo-framed keel held a water-cooled Simms petrol engine driving a wooden tractor propeller designed by Hiram Maxim. The Spencer family factory built the envelope, but the airship was assembled in a purpose-built balloon shed at Crystal Palace. After some local trials, Spencer set off from Crystal Palace in September 1902 but missed his target and flew over west London on a 30-mile, three-hour flight. His sponsors, Mellin's Foods, sued him, but Spencer was undeterred and built a larger more powerful airship in 1903 and later several small blimps for aerial advertising.

Two further civilian blimps were built by Gaudron at Alexandra Palace. Captain William Beedle commissioned a two-seater blimp powered by a Blake automobile engine with a patented swivelling propeller steering system. Tested at Alexandra Palace in November 1903 the experiment does not appear to have been a success. Meanwhile in 1901 the president of the Aeronautical Institute, Dr Francis Barton, convinced the War Office to award him a contract for a blimp with wings. His prototype envelope consisted of a single cylindrical gas cell filled with hydrogen that had a full-length bamboo framework 'keel' attached to the underside. This housed the crew and supported the fabric-covered 'aeroplanes' and also held two Buchet diesel engines driving unique propellers with three separate pairs of blades. Construction began in 1903 in a purpose-built shed at Alexandra Palace and the blimp eventually made a single flight from there in July 1905, however, it proved impossible to steer and was wrecked after landing. Meanwhile, Beedle, unable to find funding in London, took parts of his ship to Cardiff and joined forces with Ernest Thompson Willows. Together, they refined the swivelling propeller concept and incorporated it into a small semi-rigid – The Willows No.1 – which was the first in a series of five successful airships built by Willows and Beedle. It made the first of its six flights near Cardiff in August 1905.

Pre-war military airships, 1905–14

The early UK civilian attempts were noticed by the British military authorities and in 1902 Colonel Templer obtained permission for his Balloon Factory in Aldershot to make two experimental airship envelopes of goldbeater's skin which were put into storage. At the end of 1905, the factory relocated from Balloon Square, Aldershot, to a site three miles away on the edge of Farnborough Common. Here, wooden sheds for brine tanks, workshops with large floor areas for assembling the skins, a hydrogen generation station, a single balloon shed and a 72-feet high airship shed were built on Laffens Plain.

In 1906 Colonel John Capper replaced Templer as superintendent of the Balloon Factory and used one of Templer's experimental envelopes for the first UK military airship. Completed in 1907, Nulli Secundus (British Army Dirigible No.1) had a cylindrical envelope with spherical ends. The goldbeater's skin was strong enough to withstand high gas pressure and ballonets were considered unnecessary, although relief valves were fitted. The difficulty of attaching load-bearing patches to animal skin was solved by covering the envelope with a net and four broad silk bands that spread the load of a suspended, triangular, steel framework or keel with a rudder and elevators at the back and movable horizontal planes at the front. From this in turn was hung a small car containing an Antoinette engine powering two belt-driven, metal-bladed propellers. The Balloon Factory may have built the car in-house at Farnborough, although it is known that from 1906 until 1908 Beedle and Willows built gondolas for the British army. Nulli Secundus made several flights but was storm-damaged on the ground at Crystal Palace in October 1907. Rebuilt with modifications, Nulli Secundus II was flown again in July 1908, but the longer envelope and silk fabric covering which replaced the net proved of little benefit. A large bow elevator also made the ship unstable and after a few flights it was dismantled.

The army's Baby was built at the Farnborough Balloon Factory during spring 1909. The small, fish-shaped, goldbeater's skin envelope contained a single ballonet and had two Berliet engines mounted in a long car driving a single propeller. During the autumn permission was obtained to enlarge the envelope and fit a more powerful engine; modifications so drastic and visibly different that the resultant ship was given a new name – Beta. Around this time the Balloon Factory was separated from the Balloon School. Colonel Capper continued as commander of the army's school while Mervyn O'Gorman, a consultant engineer, was appointed civilian superintendent of the Royal Aircraft Factory.

The next army blimp, Gamma, first flew at Farnborough in February 1910. Its rubber-coated cotton envelope was designed in the UK, but built by Astra in Paris. This enabled Gamma to leap-frog ahead of Farnborough's improved and enlarged Baby/Beta, which did not fly until May 1910. Gamma was also later reconfigured and this continuing process of modification demonstrates the challenges the UK military authorities faced at this time in keeping up with new materials and lessons learned from flight trials. They were also keeping an eye on what other countries were doing and, although Count Zeppelin's early prototypes had not been hugely successful, his basic concept of multiple individual gas cells contained inside a long, rigid, fabric-covered, metal framework, was sound, and the rapid development of rigid airships in Germany began to create a concern in official circles. The main worry was that large airships with long flight endurance might prove invaluable at sea and, in the event of war, the British navy would be badly handicapped if the German fleet were escorted by Zeppelins operating as aerial scouts.

The Committee of Imperial Defence for the Admiralty, therefore, decided early in 1909 to place an order for a naval rigid airship with Vickers who, in 1901, had built the Royal Navy's first submarine at Barrow-in-Furness. In 1911 the newly renamed Vickers Ltd (Aviation Department) completed His Majesty's Airship No.1 (HMA No.1r, also known as Mayfly and Hermione), but in September the ship was wrecked while leaving the shed before it had flown. As a result, in February, 1912, UK rigid airship construction was discontinued, and in March the Naval Airship Section was disbanded. However, intense military experimentation continued with the army's final two blimps – Delta (1912) and Eta (1913) – which along with Gamma II and Beta II saw useful service at army manoeuvres.

In the first of several financially motivated U-turns, the Naval Airship Section was reconstituted, stationed at Farnborough and tasked by the Admiralty, in September 1912, with procuring airships and training pilots for them. In recognition of the fact that UK airship construction was seriously lagging behind continental builders, it was determined to purchase blimps from foreign makers until British firms had gained sufficient experience to enable them to compete. This decision permitted Britain's Committee of Imperial Defence to order Astra-Torres blimps from France and Parsevals from Germany. In that same year, 1912,

Willows moved to Birmingham and built his fourth airship, which he sold to the Admiralty for pilot training. It was renamed as His Majesty's Naval Airship No.2 (HMA No.2) while the Astra-Torres became HMA No.3 and the Parseval HMA No.4. Both the foreign bought airships proved successful in trials and several more were ordered along with three semi-rigid ships from Italy, although many were never delivered due to the outbreak of war in 1914.

Airships of the First World War, 1914–18

On 1 January 1914 the Royal Engineers Air Battalion Airship Section was disbanded and their small fleet of non-rigid and semi-rigid airships, together with a number of officers and men, passed to the Admiralty's Air Department. In July 1914 the Royal Naval Air Service (RNAS) was formed and took possession of two airship stations, one at Farnborough and one at Kingsnorth on the Kent coast. The RNAS also owned seven airships – Nos. 2, 3 and 4, plus the four Farnborough-built, ex-army ships: Beta II, Gamma II, Delta and Eta.

Soon after the start of war German U-boats began sinking supply ships in the hope of starving Britain into surrender. In response, the UK authorities planned to encircle the coast with RNAS base stations from which airships could patrol the main shipping routes, escorting convoys and searching for submarines and mines. Airships capable of carrying out these tasks became an urgent requirement and in February 1915 approval was given for the construction of a prototype non-rigid Sea Scout (SS) airship. The deflated envelope of HMA No.2 was rushed from Farnborough to Kingsnorth where it was inflated and the fuselage of a BE2C aeroplane, complete with engine but minus wings, was suspended from it. The SS1 trial flight was so successful that a large number of SS-type ships were ordered immediately.

The envelopes of SS airships were made of rubber-proofed, two-ply cotton, 'Macintosh' fabric with five coats of aluminium dope applied externally for weather protection. Later versions of the SS-type flew with control cars made by Maurice Farman and Armstrong Whitworth. They were among dozens of businesses throughout Britain that were enlisted to help manufacture parts for the blimps which were rapidly assembled by the RNAS in specially-constructed wooden sheds and dispersed to the new coastal stations. Manufacture commenced in mid-1915 prompting the RNAS to abandon the station at Farnborough and transfer all airship activity to Kingsnorth. Bigger, faster airships with greater endurance were soon found necessary and the RNAS pursued a policy of vigorous experimentation and innovation as the war progressed. The result was the rapid developement of a whole range of increasingly sophisticated blimps with a variety of capabilities. These were built or assembled initially at Kingsnorth and Wormwood Scrubs in London, but later also at many of the RNAS coastal stations as experience was gained and personnel trained.

The first of the SS-class entered service in March 1915 and a total of 60 of this type were built during the war. They were followed in March 1916 by the Coastal (C-class), a UK rebuild of the Franco-Spanish Astra-Torres, of which 35 were built. An improved version of the SS, the Sea Scout Zero (SSZ) followed entering service from September 1916 of which 77 were built. Six of the Sea Scout Pusher (SSP) class came next starting in January 1917, to be followed one year later by the C-Star class with the first of ten entering service in February 1918. The largest of the RNAS blimps, the North Sea (NS-class), began operations in March 1918 with 14 built in all and finally there were 13 Sea Scout Twins (SST) which entered service in June 1918. Added to these, during the war, were three additional Parsevals (HMA Nos. 5, 6 and 7) which were built under licence by Vickers to complete the pre-war order after

the patent rights of the Parseval had been obtained. These brought the total number of First World War RNAS blimps to 215.

In January 1915, German Zeppelins carried out their first bombing raid on the British mainland. The cancellation of a 1913 order for a second rigid airship from Vickers was hurriedly reversed and

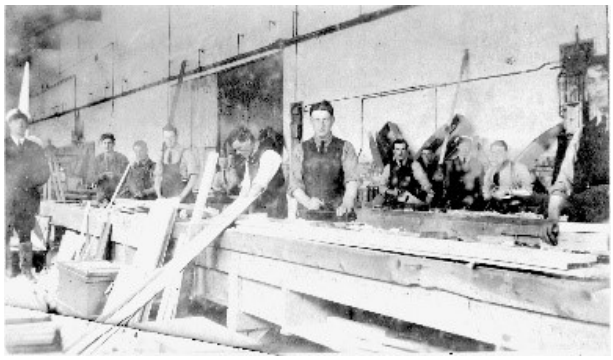
HMA No.9r made its first flight at Barrow in November 1916. In service it proved slow and unwieldy, but in 1915 the Admiralty ordered an improved version from Vickers (No.23r) based on information derived from the wreckage of downed Zeppelins. Two further airships of the same design were ordered from Beardmores at Inchinnan, Glasgow (No.24r) and Armstrong Whitworth at Barlow, Yorkshire (No.25r). However, after

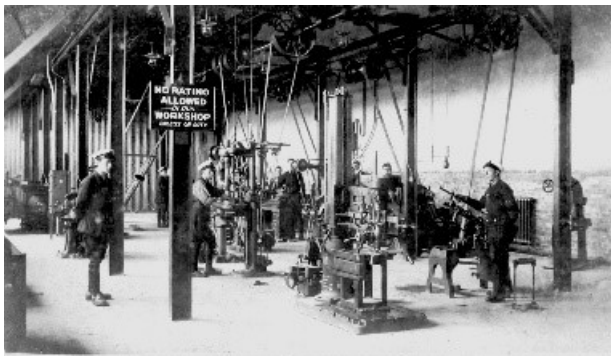
the first four of the Admiralty's planned fleet of ten 23-class airships proved unable to carry the proposed payload, the designs were amended and another two enlarged airships were built, R27 (Beardmore) and R29 (Armstrong Whitworth). All six airships were flown extensively but none matched the performance of the German Zeppelins.

The last of the navy's rigids, R31 had its origins in a 1916 Admiralty contract awarded to Short Brothers for two large rigid ships to be built in their newly-built construction facilities at Cardington, Bedfordshire. R31 differed from the rest of the aluminium-framed wartime British fleet, in that its wooden frame was based on technology invented by Schutte-Lanz in Germany. It first flew in July 1918, but arrived too late and performed too poorly to support the war effort. All of the UK's rigid ships and most of the blimps were scrapped in 1919. Two privately-funded, rigid-framed, war-time 'Zeppelin killers' are worthy of mention, although neither of them flew: the McMechan built by Marshall Fox at Bow, London, which proved unairworthy and the uncompleted framework which Earle's shipyard built for Alfred Liversedge in Hull.

The golden age of rigid airships, 1918–30

When the RNAS merged with the Army's Royal Flying Corps in April 1918, to form the Royal Air Force, several rigid airships were unfinished and these did not fly until after the war ended. The first of them, R33 built by Armstrong Whitworth was a close copy of the Zeppelin L-33. It first flew in March 1919 and went on to become the UK's most successful airship amassing more than 700 flying hours. It was the subject of much testing by the National Physical Laboratory (NPL) before it was scrapped in March 1928. Its twin, R34, was built by Beardmore and made its first flight at Inchinnan in March 1919 to be followed, in July, by its historic double-Atlantic crossing. It was finally scrapped after storm damage in January 1921.



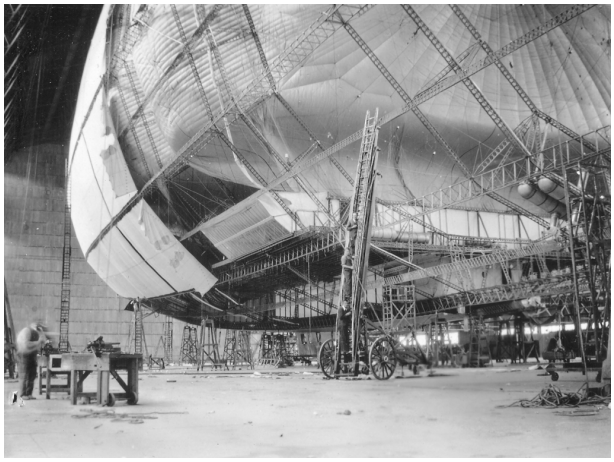


Left: The carpenters' workshop at the Royal Naval Air Service experimental airship station, Pulham, c.1919. Right: The engineers' workshop at the Royal Naval Air Service experimental airship station, Pulham, c.1919. Both © Airship Heritage Trust

HMA R32, the second of the pre-war, wooden-framed R31-class, was completed by the Short Brothers at Cardington in 1919, and first flew in September. After a short but successful flying career it was scientifically tested to destruction by the NPL in 1920 by which time the Short Brothers' establishment at Cardington had been taken over by the Air Ministry and renamed the Royal Airship Works. In that same year, at Barrow, Vickers was also working to complete another war-time contract. Designed by Barnes Wallis, R80 marked a step-change in design being the first properly aerodynamic shape. Up to this point the frames of all British rigid airships had been so-called 'pencils' consisting of long, thin, flat-sided cylinders with nose and tail cones stuck on the ends. The fully streamlined R80 first flew in July 1920 and after many crew-training flights it was also tested to destruction in 1923. Meanwhile in Glasgow, Beardmores had been tasked with production of Britain's first purpose-built, civilian registered, passenger carrier R36 (G-FAAF). It performed well in a short career after its first flight in April 1921, but had to be dismantled in June after an accident caused irreparable damage.

The next airship to leave a construction shed was the ill-fated R38. Originating from a pre-war contract with Short Brothers this copy of a German light-weight 'height-climber' was built by the Royal Airship Works at Cardington and made its first flight in June 1921. Planned by the British government as a commercial venture the ship was sold to the US navy which renamed it ZR-2. However, during an excessively vigorous manoeuvre on its fourth test flight the fragile hull broke in half and fell into the Humber estuary resulting in the loss of 44 lives. It was against the background of this major disaster that

the rules governing construction for the UK's final two large rigid ships were drawn up. As a consequence both the passenger-carring Imperial Airship Scheme airships, R100, built at Howden by the Airship Guarantee Co, a subsidiary of Vickers, and R101, built at the Royal Airship Works, Cardington, were structurally over-weight. At the time of their respective first flights in 1929 – October (R101) and December (R100) – neither was capable of carrying a commercially viable payload. Although R100 did make a double-Atlantic crossing in 1930 it completed only ten flights before being broken up in November 1931 following the crash of R101 on its twelfth flight in October 1930. This second disaster, which resulted in the loss of 47 lives, ended serious UK government and commercial interest in airships.



Left: His Majesty's Airship R101 on the mooring mast at the Royal Airship Works, Cardington, 1930. Right: The R101 undergoing reconstruction to lengthen the airship at the Royal Airship Works, Cardington, 1930.
Both images © Airship Heritage Trust

Post-war blimps, 1930-2002

In 1920 Vickers built a further two non-rigid Parseval blimps under licence which were sold to the Japanese navy, but no further blimps flew in the UK until September 1929 when the AD1 made its first flight at Cramlington Aerodrome, near Newcastle. Registered and built in 1927 by the Airship Development Co of Guildford, Surrey, the non-rigid blimp was designed by Captain Weir-MacCall to carry aerial advertising. It made several advertising flights in the UK and was then flown to Belgium where it was wrecked by a storm in October 1930. No further airships were built in the UK until 1951 when the Bournemouth was assembled at Cardington by The Airship Club under the leadership of Lord Ventry. It was a semi-private project partly funded by the town of Bournemouth where the gondola and fins were built. The non-rigid envelope was modified from a standard Second World War barrage balloon design and manufactured by Airborne Industries of Southend-on-sea, Essex. The engine was a French-built Salmson radial. Several local flights were made before falling debris in the shed damaged the ship beyond repair in 1952.

Fifteen years later a small semi-rigid was assembled at Cardington for the film *Chitty Chitty Bang Bang*. Designed by M A Brighton & Co, of Farnham, Surrey (founded in 1966 by Malcolm Anthony Brighton), it was the first British airship to be inflated with helium. The single-cell, neoprene-proofed cotton envelope was one of two manufactured by Airborne Industries and the tubular duralumin keels for them were welded by C F Taylor of Wokingham. One boat-shaped wooden gondola, fitted with two belt-driven propellers powered by an air-cooled Volkswagen car engine, was built at Blackbushe Airport in Surrey by Robinson Aviation. It first flew in August 1967 and achieved 11 flying hours.

Airborne Industries also built the envelope of a small contemporary blimp, the Gloster for a team of enthusiasts but it never flew and, in 1972, the Goodyear GZ-20 Europa (N2A) was assembled at Cardington at the start of a European flying career based near Rome that lasted several years. Another private venture in 1973 featured in a television documentary entitled *Mr Smith's Airship*, when the Santos Dumont blimp, owned and financed by author and broadcaster Anthony Smith, was filmed at Cardington. The wooden gondola and tail fins were constructed in an artist's studio in London and its single-cell, neoprene and cotton envelope, manufactured by Airborne Industries, was inflated with helium. Powered by two Wankel

rotary engines driving ducted propellers, the blimp made several flights during 1973-5 and gained an experimental CAA certificate of airworthiness having logged a total of 31 flying hours.

In 1979 Cardington became the centre of a renaissance in UK airship construction when Roger Munk's Aerospace Developments Ltd used new materials and technologies to assemble the first modern airship there. Component manufacturing was outsourced to glider-building specialists, Slingsby Aviation of Kirkbymoorside, North Yorkshire, for the gondola and tail fins, and to French-based Aerazur, for the single-ply, polyester envelope coated with a polyurethane/titanium dioxide dope. The Kevlar-reinforced-plastic gondola was suspended internally from the top of the envelope by Kevlar cables and it housed two, inboard-mounted Porsche engines that drove vectored, reversible-pitch, ducted-propellers via helicopter tail-rotor gearboxes. The prototype AD 500 G-BECE first flew at Cardington in February 1979.

In 1980 Airship Developments was acquired by the Isle of Man-based Thermo-Skyships Ltd and after the merger the two parts of the new company pursued different goals with Roger Munk working on small blimps for passenger operations in London and at Cardington while Malcolm Wren in the Isle of Man focused on large freight-carrying rigid airships. However, in 1982 the two parts of the company separated again and Wren Skyships Ltd erected a temporary, fabric-clad hangar at Jurby airfield on the Isle of Man and also began work on a large non-rigid design. Construction of the prototype Advanced Non-Rigid commenced but envelope problems delayed completion and it never flew. Wren Skyships changed its name again to become the Advanced Airship Corporation in 1988. However, Airship Industries continued to develop the small non-rigid type and produced 500-02 G-BIHN which became the first production model Skyship 500, the first airship series to gain world-wide certification for commercial passenger carrying. Following assembly and first flight at Cardington in September 1981, BIHN remained active until 1987. Later variants included the 500-HL (Heavy Lift) designed to carry envelope-mounted, electronic nightsigns and the Skyship 600 series, which had an uprated propulsion system and increased the passenger seating from 9 to 13. Two of the ten 600s were built at Cardington, the others were assembled in the US and Japan. Skyship 600-04 made a major contribution to advances in aeronautical technology in October 1988 when it became the first aircraft to be fitted with 'Fly-By-Light' fibre-optic flight controls now commonly used in commercial and military aircraft.

Meanwhile, starting in the 1970s, there had been a renaissance in hot air balloon construction in which the UK had taken a leading role and by the early 1980s, hundreds of hot air balloons had been built for sport and advertising purposes by two companies – Cameron Balloons Ltd in Bristol and Thunder & Colt Ltd at Oswestry in Shropshire. In response to requests from clients both produced small helium-filled blimps that were suitable for sport, advertising and pilot-training. Cameron's DG14 and larger DG19 had small, centrally placed gondolas holding propane-fuelled motors driving large, single, vectoring, ducted-propellers. With an unconventionally short ratio of length to diameter and distinctive, air-inflated fins and rudders they were small enough to be housed in conventional aircraft hangars.

In the late 1980s and early 1990s Airborne Industries also built envelopes for the GA-42 series of non-rigid blimps. The first was flown and flight tested at Rednal airfield in Shropshire, by the designer and test pilot Mats Backlin, who was then working for Thunder & Colt Ltd (which later became Lindstrand Balloons and a sister company to Airborne Industries). Advertised as the 'world's smallest blimp' with a volume of 42,000 cubic feet, the GA42 was capable of carrying two people and was the first airship to use electrical 'Fly-by-wire' flight control with no mechanical connections between the side-stick controller and the fin actuators. Thunder & Colt/Lindstrand built nine GA42 airships, several of which were used as aerial camera-platforms displaying advertisements for clients at major sporting events. Competition came in 1987 in the form of the Lightship A-50 after the founding in the USA of the American Blimp Corporation whose UK subsidiary, The Lightship Group, had offices in Telford, Shropshire. During the early 1990s the company leased more than 15 small blimps from the USA for advertising and filmingthat were assembled from American-made parts at Halfpenny Green, near Wolverhampton. The translucent fabric envelopes held internal lights to illuminate advertisers' logos during night-time operations. In 1995 The Lightship Group formed a partnership with Sir Richard Branson's Virgin Group and later larger Lightships, such as the A-60 and A-60+, were assembled at Cardington.

The small airships were, however, less successful than the Skyships which undertook numerous passenger, advertising, security and military roles around the world for more than 35 years. The last UK Skyship, 600

G-SKSC, was active from 1984 until 1990 when Airship Industries' assets and intellectual property were split up and sold. Slingsby Aviation ran the UK business after the closure from 1990 until 1993 when it was taken-over by Westinghouse in the USA. After the demise of Airship Industries in 1990, Roger Munk's team continued to work on airship designs while the company underwent a number of name changes under international ownership. It finally re-emerged in the UK in 1997 as Airship Technologies Group which produced one small pilot-training and advertising blimp, the AT10. Its envelope had an 'X' tailfin configuration and a single ballonet for hull pressure control. The gondola's flight deck had seats for two pilots operating sidestick/fly-by-wire controls and behind them a compartment had seating for four passengers. Power came from two, horizontally opposed, direct-injection, two-stroke diesel engines and the first flight was at Cardington in March 2002. The AT10 did not achieve certification and the prototype was deflated when the company failed financially in 2006.

Thermal airships and hybrids, 1965-2020

The idea of using hot air balloon technology to create a cheap and quickly inflated, mobile, aerial camera-platform as an alternative to a helium-filled airship was conceived by British journalist and gas-balloonist, Anthony Smith. In 1965 he employed a young engineer, Malcolm Brighton, to design the WASP for his planned Warm AirShip Project. Brighton had no aeronautical experience but based his design on the the newly-invented American sporting balloons which used lightweight, polyurethane-coated fabrics for their envelopes and propane-gas burners to supply the heat. Taking inspiration from the WASP name Brighton created an elongated, black-and-yellow striped balloon which was sewn by Vacuum-Reflex of Ipswich, Suffolk. He simplified the American propane burner and ordered his own design of a single-coil, stainless-steel burner with unique spherical fuel tanks to be made by C F Taylor of Wokingham. The completed ship, powered by a VW Ardem car-engine, was assembled at Cardington but moved to a sandpit near Farnham in Surrey for burner tests. The project was abandoned after the ship proved to be unstable while moored and it was never flown.

In 1967 Malcolm Brighton designed and built Bristol Belle, the first UK modern hot air sport balloon for a syndicate of glider pilots using his WASP technology. Vacuum-Reflex built the envelope, C F Taylor made the burner and the basket was woven by Workshops for the Blind in Peckham, London. In early 1968 some of the Hot Air Group syndicate founded the UK's second balloon manufacturer, Omega Aerostatics, with production centred at GQ Parachute Co Ltd, Woking, Surrey. In early 1970 the company split into two, Western Balloons and Cameron Balloons, and in 1972, Cameron, based in Bristol, began work on the first of what became a series of commercially succesful hot air airships. In 1973, the first D-96, registration G-BAMK, was demonstrated at the Icicle Balloon Meet at Newbury, Berkshire. Since then several hundred thermal airships have been built for customers world-wide by a succession of UK manufacturers that have been subject to a series of name-changes, amalgamations and take-overs. These have included Thunder Balloons (founded in 1972); Colting Balloons (moved from Eire in 1978); Colt Balloons (1978); ThunderColt (1980); Lindstrand Balloons (1991) and Lindstrand Technologies Ltd (1991). The largest hot air airship built to date was the Thunder & Colt AS-261, designed to drop an observation platform into the canopy of tropical rainforests. In 1993 it was fitted with a larger replacement envelope manufactured by Lindstrand Balloons and renamed the AS-300.

After AT10 the Airship Technologies Group in Bedford turned to designing non-cylindrical, helium-filled, 'lifting-body' airships known as 'hybrids', although these are not strictly classed as lighter-than-air flying machines as the weight of their structure exceeds the lift of the contained gas. In 2007 a new company, Hybrid Air Vehicles Ltd, was formed and the first full-size (300 feet long) prototype using the Airship Technologies Group design, the Long Endurance Multi-intelligence Vehicle, was built for the US army by Northrop Grumman and flown successfully in the USA in 2012. When the US army cancelled the project in 2013, the ship was sold back to Hybrid Air Vehicles and brought to Cardington where it was reassembled, with many improvements and UK components. Renamed the Airlander 10 prototype, it flew a test programme from 2016 until late 2017 when it was badly damaged in a mooring incident. In early 2020 Hybrid Air Vehicles announced plans to redesign Airlander 10 with a new gondola, nose and tail sections, aiming to fly by 2024.

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