Aviation in World War I

World War I was the first war in which aircraft were deployed on a large scale. Tethered observation balloons had already been employed in several wars, and would be used extensively for artillery spotting. Germany employed Zeppelins for reconnaissance over the North Sea and strategic bombing raids over England.

Aeroplanes were just coming into military use at the outset of the war. Initially, they were used mostly for reconnaissance. Pilots and engineers learned from experience, leading to the development of many specialized types, including fighters, bombers, and ground-attack aeroplanes.

Ace fighter pilots were portrayed as modern knights, and many became popular heroes. The war also saw the appointment of high-ranking officers to direct the belligerent nations' air war effort. While the impact of aircraft on the course of war was mainly tactical rather than strategic, most important being direct cooperation with ground forces

(especially ranging and correcting artillery fire) the first steps in the strategic roles of aircraft in future wars was also foreshadowed.

Prewar developments

About 10 years after the Wright brothers made the first powered flight, aircraft remained very primitive by later standards. Because of limitations of the engine power of the time, the effective payload of aircraft was extremely limited. The basic structural and materials technology of period airframes mostly consisted of hardwood materials or steel tubing (braced with steel wires) and linen fabric doped with a flammable liquid, when cured, provided the stiffness required to form the aerodynamic surfaces of the wing(s) and other streamlined surfaces. Aside from these primitive materials, the rudimentary aviation engineering of the time meant most aircraft were structurally fragile by later standards, and not infrequently broke up in flight especially when performing violent combat maneuvers such as pulling up from steep dives.

As early as 1909, these evolving flying machines were however recognized to be not just toys, but weapons:

The sky is about to become another battlefield no less important than the battlefields on land and sea....In order to conquer the air, it is necessary to deprive the enemy of all means of flying, by striking at him in the air, at his bases of operation, or at his production centers. We had better get accustomed to this idea, and prepare ourselves.

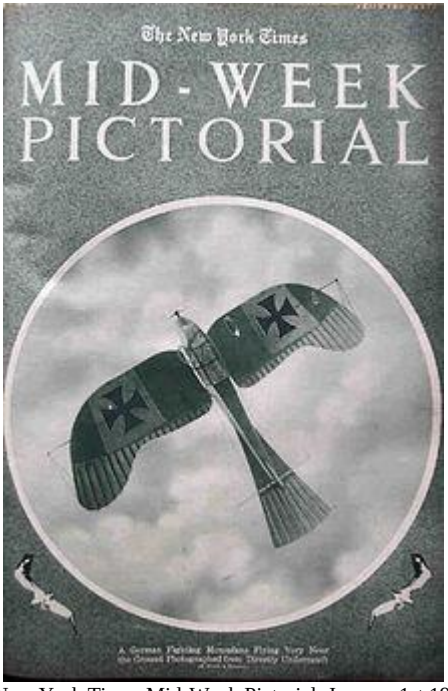
— Giulio Douhet (Italian staff officer), 1909

In 1911, Captain Bertram Dickson, the first British military officer to fly and the first British military officer to perform an aerial reconnaissance mission in a fixed-wing aircraft during army maneuvers in 1910, predicted, in a submission to the UK Technical Sub-Committee for Imperial Defense, the military use of aircraft and the ensuing development and escalation of aerial combat.

The first operational use of fixed-wing aircraft in war took place on 23 October 1911 in the Italo-Turkish War, when Captain Carlo Piazza made history's first wartime reconnaissance flight near Benghazi in a Blériot XI. The first aerial bombardment followed shortly thereafter, on 1 November, when Second Lieutenant Giulio Gavotti dropped four

bombs on two oases held by the Turks. The first aerial photography flight took place later in March 1912, also flown by Captain Piazza.

The early years of war



Front page of the New York Times Mid-Week Pictorial, January 1st 1917. Caption reads: "A German Fighting Monoplane Flying Very Near the Ground Photographed from Directly Underneath." The aircraft is of the Taube type, either a Rumpler Taube or a copy from one of the other manufacturers involved in Taube production.

From the very start, there was some debate over the uses (or usefulness) of aircraft in warfare. Many senior officers, in particular, remained skeptical.

In Germany the great successes of the early Zeppelin airships had largely overshadowed the importance of heavier-than-air aircraft. Out of a paper strength of about 230 aircraft belonging to the army in August 1914 only 180 or so were of any use. The French military aviation exercises of 1911, 1912, and 1913 had pioneered cooperation

with the cavalry (reconnaissance) and artillery (spotting), but the momentum was if anything slacking.
Great Britain had "started late" and initially relied largely on the French aircraft industry, especially for aircraft engines. The initial British contribution to the total allied air war effort in August 1914 (of about 184 aircraft) was three squadrons with about 30 serviceable machines. The American army and navy air services were hopelessly behind; even in 1917, when the United States entered the war, they were to be almost totally dependent on the French and British aircraft industries for combat aircraft.

The initial campaigns of 1914 proved that cavalry could no longer provide the reconnaissance expected by their generals, in the face of the greatly increased firepower of Twentieth century armies. It was quickly realized, on the other hand, that aircraft could at least locate the enemy, even if early air reconnaissance was hampered by the newness of the techniques involved. Early skepticism and low expectations quickly turned to unrealistic demands beyond the capabilities of the primitive aircraft available.

Even so, air reconnaissance played a critical role in the "war of movement" of 1914, especially in helping the Allies halt the German invasion of France. On 22 August 1914, British Captain L.E.O. Charlton and Lieutenant V.H.N. Wadham reported German General Alexander von Kluck's army was preparing to surround the BEF, contradicting all other intelligence. The British High Command listened to the report and started a withdrawal toward Mons, saving the lives of 100,000 soldiers. Later, during the First Battle of Marne, observation planes discovered weak points and exposed flanks in the German lines, allowing the allies to take advantage of them. The Germans' great air "coup" of 1914 (at least according to contemporary propaganda) was at the Battle of Tannenberg in East Prussia where an unexpected Russian attack was reported by Lieutenant's Canter and Mertens, resulting in the Russians' being forced to withdraw.

Early Western Front reconnaissance duties

Late in 1914 the lines between the Germans invading France and the Allies stretched from the North Sea to the Alps. The initial "war of movement" largely ceased, and the front became static. Three main

functions of short range reconnaissance squadrons had emerged by March 1915.
The first was photographic reconnaissance – building up a complete mosaic map of the enemy trench system. The first air cameras used glass plates (Kodak cellulose film had been invented, but did not at this stage have sufficient resolution).

Artillery "spotting" enabled the ranging of artillery on targets invisible to the gunners. Radio telephony was not yet practical from an airplane, so communication was a problem. By March 1915, a two seater on "artillery observation" duties was typically equipped with a primitive radio transmitter transmitting the dots and dashes of a Morse key, but had no receiver. The artillery battery signaled to the aircraft by laying strips of white cloth on the ground in prearranged patterns. These duties were shared with the tethered observation balloons. Balloonists could communicate directly with their batteries by field telephone, but were obviously far less flexible in locating targets and reporting the fall of shot.

"Contact patrol" work attempted to follow the course of a battle by communicating with advancing infantry while flying over the battlefield. The technology of the period did not permit radio contact, while methods of signaling were necessarily crude, including dropping messages from the aircraft. Soldiers were initially reluctant to reveal their positions to aircraft, as they (the soldiers) found distinguishing between friend and foe problematic.

Reconnaissance flying, like all kinds, was a hazardous business. In April 1917, the worst month for the entire war for the RFC, the average life expectancy of a British pilot on the Western Front was 93 flying hours.

Early bombing efforts

Typical 1914 aircraft could carry only very small bomb loads – the bombs themselves, and their stowage, were still very elementary and effective bomb sights were still to be developed. Nonetheless the beginnings of strategic and tactical bombing date from the earliest days of the war. Notable are the raids by the RNAS on the German airship sheds at Düsseldorf, Cologne and Friedrichhafen in September, October and November 1914, as well as the formation of the

Brieftauben Abteilung Ostende (or "Ostend carrier pigeon detachment", cover name for the first German strategic bombing unit), which mounted the first token raid over the English Channel in December.

The dawn of air combat

As Dickson had predicted, initially air combat was extremely rare, and definitely subordinate to reconnaissance. There are even stories of the crew of rival reconnaissance aircraft exchanging nothing more belligerent than smiles and waves. This soon progressed to throwing grenades, and other objects - even grappling hooks. The first aircraft brought down by another was an Austrian reconnaissance rammed on 8 September 1914 by Russian pilot Pyotr Nesterov in Galicia in the Eastern Front. Both planes crashed as the result of the attack killing all occupants. Eventually pilots began firing handheld firearms at enemy aircraft, however pistols were too inaccurate and the single shot rifles too unlikely to score a hit. On October 5, 1914, French pilot Louis Quenault opened fire on a German aircraft with a machine gun and the era of air combat was underway as more and more aircraft were fitted with machine guns.

Problems mounting machine guns

The pusher solution

As early as 1912, designers at the British firm Vickers were experimenting with machine gun carrying aircraft. The first concrete result was the Vickers Experimental Fighting Biplane 1, which featured at the 1913 aero show and appeared in developed form as the FB.5 in February 1915. This pioneering fighter, like the Royal Aircraft Factory F.E.2b and the Airco DH.1, was a pusher type. The pusher design had the engine and propeller behind the pilot, facing backward, rather than in front, as in a tractor type. This provided an optimal machine gun position, from which the gun could be fired directly forward without an obstructing propeller, and reloaded and cleared in flight. An important drawback was that pusher designs – because of the struts and rigging necessary to hold their tail units, and the extra drag this entailed – tended at best to have an inferior performance to tractor types with the same engine power. Although the F.E.2d, a more powerful version of the F.E.2b, remained a formidable opponent well into 1917, pusher

fighters were already obsolete. They were simply too slow to catch their quarry.

Machine gun synchronization

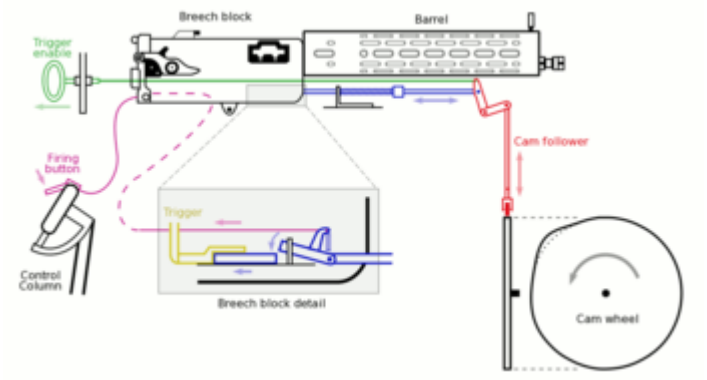


Diagram of Fokker's "Stangensteuerung" synchronization mechanism. Pulling the green handle drops the red cam follower onto the propeller shaft cam wheel. Twice during each rotation of the propeller the cam lifts the follower which depresses the blue rod against the spring, connecting the yellow trigger plate to the purple firing button allowing a round to be fired.

The forward firing gun of a pusher "gun carrier" provided some offensive capability – the mounting of a machine gun firing to the rear from a two seater tractor aircraft gave defensive capability. There was an obvious need for some means to fire a machine gun forward from a tractor aircraft, especially from one of the small, light, "scout" aircraft, adapted from pre-war racers that were to perform most air combat duties for the rest of the war. It would seem most natural to place the gun between the pilot and the propeller, firing in the direct line of flight, so that the gun could be aimed by "aiming the aircraft". It was also important the breech of the weapon be readily accessible to the pilot, so that he could clear the inevitable jams and stoppages to which early machine guns were prone. However, this presents an obvious problem, a percentage of bullets fired "free" through a revolving propeller will strike the blades, with predictable results.

Early experiments with synchronized machine guns were carried out before the war in several countries. Franz Schneider, the former Nieuport designer now working for the L.V.G. concern in Germany, patented a synchronization gear on 15 July 1913. An early Russian gear

was designed by a Lieutenant Poplavko, and the Edwards Brothers in England designed the first British example. Finally, the Morane-Saulnier company was working on the problem in 1914. All these early gears failed to attract official attention, partly due to official inertia and partly due to the terrifying results of failures of these early synchronizing gears, which included dangerously ricocheting bullets as well as disintegrating propellers.

The Lewis Gun, used on many early Allied aircraft, proved next to impossible to successfully synchronize due to its open bolt firing cycle. In an open bolt firing cycle, it is impossible to predict the exact time any given round will fire, and for obvious reasons this is an unattractive characteristic in a weapon one is attempting to fire between the spinning blades of a propeller. Photographs of apparently synchronized Lewis gun mountings on RNAS aircraft were probably in fact free firing – hardly a satisfactory solution.

The Maxim guns used by both the Allies (as the Vickers) and Germany (as the LMG 14 Parabellum and LMG 08 Spandau) had a closed bolt firing cycle that started with a bullet already in the breech and the breech closed, so the firing of the bullet was the next step in the cycle. This meant that the exact instant the round would be fired could be predicted, making these weapons considerably easier to synchronize. The standard French light machine gun, the Hotchkiss, was also most unamenable to synchronization due to rounds "hanging fire" – the Morane-Saulnier company designed a "safety backup" in the form of "deflector blades" (metal wedges) fitted to the propeller at the point where they would be struck by a bullet. Roland Garros trialed this system in a Morane-Saulnier L in April 1915. He managed to score several kills, although it proved to be an inadequate and dangerous solution. Garros eventually was forced by engine failure (possibly caused by the repeated strain on his aircraft's crankshaft of the "deflected" bullets striking his propeller) to land behind enemy lines, and he, and his aircraft, were captured by the Germans.

Famously, the German High Command passed Garros' Morane to the Fokker Company – who already produced Morane type monoplanes for the German Air Service – with orders to copy the latest design. The deflector system was totally unsuitable for the steel jacketed German ammunition so that the Fokker engineers were forced to revisit the synchronization idea (perhaps infringing Schneider's patent) resulting

in the Eindecker fighter series. Crude as these little monoplanes were, they produced a period of German air superiority, known as the "Fokker Scourge" by the Allies. The psychological effect exceeded the material – the Allies had up to now been more or less unchallenged in the air, and the vulnerability of their older reconnaissance aircraft, especially the British B.E.2 and French Farman pushers, came as a very nasty shock.

Other methods

The actual Scout C, RFC serial no. 1611, flown by Lanoe Hawker on 25 July 1915 in his Victoria Cross-earning engagement.

Another method used at this time to fire a machine gun forward from a tractor design was to mount the gun to fire above the propeller arc. This required the gun to be mounted on the top wing of biplanes and be propped up and secured by complicated, drag inducing mounting in monoplanes. Reaching the gun so that drums or belts could be changed, or jams cleared, presented problems even when the gun could be mounted relatively close to the pilot. Eventually the excellent Foster mounting became more or less the standard way of mounting a Lewis gun in this position in the R.F.C. – this allowed the gun to slide backward for drum changing, and also to be fired at an upward angle, a very effective way of attacking an enemy from the "blind spot" under his tail. This type of mounting was still only possible for a biplane with a top wing positioned near the apex of the propeller's arc – it put considerable strain on the fragile wing structures of the period, and it was less rigid than a gun mounting on the fuselage, producing a greater "scatter" of bullets, especially at anything but very short range.
The earliest versions of the Bristol Scout to see aerial combat duty in 1915, the Scout C, had Lewis gun mounts in RNAS service that sometimes were elevated above the propeller arc, and sometimes (in an

apparently reckless manner) firing directly through the propeller arc without synchronization. Captain Lanoe Hawker of the Royal Flying Corps, however, had mounted his Lewis gun just forward of the cockpit to fire forwards and outwards, on the left side of his aircraft's fuselage at about a 30° angle, on his Scout C, with serial number 1611, and with this aircraft on 25 July 1915, managed to defeat three German two seat observation aircraft to earn the first Victoria Cross awarded to a British aviator.

1915: The Fokker Scourge

The actual aircraft that started the "Fokker Scourge", *Leutnant* Kurt Wintgens' Fokker M.5K/MG with IdFlieg military serial number "E.5/15", as it appeared at the time of Wintgens' pioneering engagement on 1 July 1915.

Max Immelmann of *Feldflieger Abteilung 62* in the cockpit of his Fokker E.I. s/n *E.13/15*.

The first purpose-designed fighter aircraft included the British Vickers F.B.5 – machine gun armament was also fitted to several French types, such as the Morane-Saulnier L and N. Initially the German Air Service

lagged behind the Allies in this respect, but this was soon to change dramatically.

In July 1915 the Fokker E.I became operational – this was the first type of aircraft to enter service with a "synchronization gear" which enabled a machine gun to fire through the arc of the propeller without striking its blades. This constituted an important advantage over other contemporary fighter aircraft. This aircraft and its immediate successors – also commonly known as the *Eindecker* (German for "Monoplane") – for the first time supplied an effective equivalent to Allied fighters. Two German military aviators, Otto Parschau and Kurt Wintgens, worked for the Fokker firm during the spring of 1915, demonstrating the revolutionary feature of the forward-firing synchronized machine gun that the Eindecker was armed with, to the embryonic force of *Fliegertruppe* pilots of the German Empire.
The very first successful engagement involving a synchronized-gun-armed aircraft occurred on July 1, 1915, just to the east of Lunéville, France when *Leutnant* Kurt Wintgens, one of the pilots selected by Fokker to demonstrate the small series of five Eindecker prototype aircraft, forced down a French Morane-Saulnier Type L "Parasol" two seat observation monoplane behind Allied lines with his Fokker M.5K/MG Eindecker production prototype aircraft, carrying the IdFlieg military serial number "E.5/15". Some 200 shots from Wintgens' aircraft had hit the Gnôme Lambda rotary engine of the Morane Parasol, forcing it to land safely in Allied territory.

By late 1915 the Germans had achieved air superiority, making Allied access to vital intelligence derived from continual aerial reconnaissance more dangerous to acquire. In particular the essential defenselessness of Allied reconnaissance types was exposed. The first German "ace" pilots – notably Max Immelmann – had begun their careers.
The number of actual Allied casualties involved was for various reasons very small compared with the intensive air fighting of 1917–18.

The deployment of the Eindeckers was less than overwhelming – the new type was issued in ones and twos to existing reconnaissance squadrons – and it was to be nearly a year before the Germans were to follow the British in establishing specialist fighter squadrons. The Eindecker was also, in spite of its advanced armament, by no means an outstanding aircraft, being closely based on a pre-war French racer, but with an all-steel tubing fuselage structure (a characteristic of all Fokker

wartime aircraft designs) instead of the wooden fuselage components of the French aircraft.

Nonetheless, the morale impact of the fact that the Germans were fighting back in the air, and effectively too, created a major scandal in the British parliament and press. The ascendency of the Eindecker also contributed to the surprise the Germans were able to achieve at the start of the Battle of Verdun – the French reconnaissance aircraft failed to provide their usual cover of the German positions.

Fortunately for the Allies, two new British fighters were already in production that were a match for the Fokker—the F.E.2b and the D.H.2. These were both "pushers" and could fire forwards without gun synchronization. The F.E.2b reached the front in September 1915, and the D.H.2 in the following February. On the French front, the tiny Nieuport 11, a tractor biplane with a forward firing gun mounted outside the arc of the propeller (on the top wing) also proved more than a match for the German fighter when it entered service in January 1916. With these new types the Allies re-established air superiority in time for the Battle of the Somme, and the "Fokker Scourge" was over.

In secret, the Junkers J 1 undergoes engine running in December 1915 before its pioneering flight tests, as the world's first practical all-metal aircraft.

The Fokker E.III, Airco DH-2, and Nieuport 11 would be the very first in a long line of single seat fighter aircraft used by both sides during the war. Very quickly it became clear the primary role of fighters would be attacking enemy two-seaters, which were becoming increasingly important as sources of reconnaissance and artillery observation, while also escorting and defending friendly two-seaters from enemy fighters. Fighters were also used to attack enemy observation balloons, strafe enemy ground targets, and defend friendly airspace from enemy bombers.

Almost all the fighters in service with both sides - with the exception of the Fokkers' steel-tube fuselage airframes - had continued to stick to the

use of wood and fabric as basic structural materials, and exposed wood struts with steel wire bracing in their airframes. However, in secret, the emerging technology of practical all-metal aircraft as pioneered by the work of Hugo Junkers, also incorporating cantilever structures within their metal envelopes had resulted in the first flight tests of the initial flight demonstrator of such technology, the Junkers J 1 monoplane at the end of 1915, heralding the wave of the future in aircraft structural technology for the postwar period and beyond.

1916: Verdun and the Somme

When the battle of Verdun began on the 21 February 1916 German air superiority initially enabled the Germans to establish a blockade on the French air squadrons called *luftsperre*. However the French were already arming their specialist fighter squadrons, the *Escadrilles de chasse*, with the Nieuport 11 and with a new offensive strategy they quickly overcame the *luftsperre*, establishing air superiority over the battle by April.

In the meantime, in the aftermath of the Fokker Scourge, the need for a larger, better equipped RFC became obvious, and the process of raising many new British squadrons was started. In the short term creating new units was easier than producing aircraft to equip them, and training pilots to man them. When the Battle of the Somme started in July 1916 most ordinary RFC squadrons were still equipped with the BE.2c – the same aircraft that had proved such an easy target for the Fokker Eindecker. New types such as the Sopwith 1½ Strutter had to be transferred from production intended for the RNAS. Even more seriously, replacement pilots were being sent to France with pitifully few flying hours.

Nonetheless, air superiority and an "offensive" strategy facilitated the greatly increased involvement of the RFC in the battle itself, in what was known at the time as "trench strafing" – in modern terms close support. For the rest of the war this became a regular routine, with both the attacking and defending infantry in a land battle being constantly liable to attack by machine guns and light bombs from the air. At this time, counter fire from the ground was far less effective than it became later, when the necessary techniques of deflection shooting had been mastered.

Allied air superiority was maintained during the both battles, and the increased effectiveness of Allied air activity proved disturbing to the German High Command. A complete reorganization of the *Fliegertruppen des deutschen Kaiserreiches* into what became officially known as the *Luftstreitkräfte* followed and had generally been completed by October 1916. This reorganization eventually produced the German strategic bombing squadrons that were to produce such consternation in England in 1917 and 1918, and the specialist close support squadrons (*Schlachtstaffeln*) that gave the British infantry such trouble at Cambrai and during the German Spring offensive of 1918. Its most famous and dramatic effect, however, involved the raising of specialist fighter squadrons or *Jagdstaffeln* - a full year after similar units had become part of the RFC and the French *Aéronautique Militaire*. Initially these units were equipped with the Halberstadt D.II, the Fokker D.I, D.II and D.III, each armed with one synchronized lMG 08 machine gun, but by the end of 1916 increasing numbers of the new Albatros fighters were well on the way to establishing the German air superiority that was to mark the first half of 1917.

1917: Bloody April

Color Autochrome Lumière of a Nieuport Fighter in Aisne, France 1917

The first half of 1917 was a successful period for the *Jagdstaffeln* and the much larger RFC suffered significantly higher casualties than their opponents. While new Allied fighters such as the Sopwith Pup, Sopwith Triplane, and SPAD S.VII were coming into service, at this stage their numbers were small, and they suffered from inferior

firepower, as all three were armed with a single synchronized Vickers machine gun. On the other hand, the *jagdstaffeln* were in the process of replacing their early motley equipment with the Robert Thelen-designed Albatros D-series fighters, armed with twin synchronized "Spandau" machine guns. The D.I and D.II of late 1916 were succeeded by the new Albatros D.III, which was, in spite of structural difficulties, "the best fighting scout on the Western Front" at the time. Meanwhile, most RFC two-seater squadrons still flew the BE.2e, a very minor improvement on the BE.2c, and still fundamentally unsuited to air-to-air combat.

This culminated in the rout of April 1917, known as "Bloody April". The RFC suffered particularly severe losses, although Trenchard's policy of "offensive patrol", which placed most combat flying on the German side of the lines, was maintained.
During the last half of 1917, the British Sopwith Camel and S.E.5a and the French SPAD S.XIII, all fitted with two forward firing machine guns, became available in numbers. The ordinary two seater squadrons in the RFC received the R.E.8 or the F.K.8, not outstanding warplanes, but far less vulnerable than the BE.2e they replaced. The F.E.2d at last received a worthy replacement in the Bristol F.2b. On the other hand the latest Albatros, the D.V proved to be a disappointment, as was the Pfalz D.III. The exotic Fokker Dr.I was plagued, like the Albatros, with structural problems. By the end of the year the air superiority pendulum had swung once more in the Allies' favor.

1918: The Spring Offensive

The surrender of the Russians and the Treaty of Brest-Litovsk in March 1918, and the resulting release of troops from the Eastern Front gave the Germans a "last chance" of winning the war before the Americans could become effectively involved. This resulted in the last great German offensive of the war, the "Spring Offensive", which opened on 21 March. The main attack fell on the British front on the assumption that defeat of the British army would result in the surrender of the mutiny weakened French.

In the air, the battle was marked by the carefully coordinated use of the *Schlachtstaffeln* or "battle flights", equipped with the light *CL* class two seaters built by the Halberstadt and Hannover firms, which had proved so effective in the German counter-attack at the Battle of Cambrai. The

new German fighter aircraft, notably the Fokker D.VII, that might have revived German air superiority in time for this battle had not however reached the *Jagdstaffeln*. As with several offensives on both sides, thorough planning and preparation led to initial success, and in fact to deeper penetration than had been achieved by either side since 1914. Many British airfields had to be abandoned to the advancing Germans in a new war of movement. Losses of aircraft and their crew were very high on both sides – especially to light anti-aircraft fire. However by the time of the death of Manfred von Richthofen, the famed Red Baron, on 21 April, the great offensive had largely stalled. The new German fighters had still not arrived, and the British still held general air superiority.

The month of April 1918 began with the consolidation of the separate British RFC and RNAS air services into the Royal Air Force, the first independent air arm not subordinate to its national army or navy. By the end of April the new Fokker, Pfalz and Roland fighters had finally begun to replace the obsolescent equipment of the *Jagdstaffeln*, but this did not proceed with as much dispatch as it might have, due to increasing shortages of supplies on the side of the Central Powers, and many of the *Jastas* still flew Albatros D types at the time of the armistice. The rotary engine Fokker D.VIII and Siemens-Schuckert D.IV, as well as surviving Fokker Triplanes, suffered from poor reliability and shortened engine life due to the Voltol-based oil that was used to replace scarce castor oil – captured and salvaged Allied aircraft (especially Sopwith Camels) were scrounged, not only for engines and equipment, but even for their lubricants. Nonetheless, by September casualties in the RFC had reached the highest level since "Bloody April" – and the Allies were maintaining air superiority by weight of numbers rather than technical superiority.

1918, especially the second half of the year, also saw the United States increasingly involved. While American volunteers had been flying in Allied squadrons since the early years of the war, not until 1918 did all-American squadrons begin active operations. Technically America had fallen well behind the European powers in aviation, and no American designed types saw action, with the exception of the Curtiss flying boats. At first, the Americans were largely supplied with second-rate and obsolete aircraft, such as the Nieuport 28, Sopwith 1½ Strutter, and Dorand AR.2 types, and inexperienced American airmen stood little

chance against their seasoned opponents. As numbers grew and equipment improved the Americans came to hold their own in the air.

Impact

> “ The day has passed when armies on the ground or navies on the sea can be the arbiter of a nation's destiny in war. The main power of defense and the power of initiative against an enemy has passed to the air. ”
>
> —Brigadier General Billy Mitchell, November 1918

By the war's end, the impact of air missions on the ground war was in retrospect mainly tactical – strategic bombing, in particular, was still very rudimentary indeed. This was partly due to its restricted funding and use, as it was, after all, a new technology. On the other hand the effect of artillery, which had perhaps the greatest effect of any military arm in this war, was very much affected by the availability of aerial photography and aerial "spotting". By 1917 weather bad enough to restrict flying was considered as "putting the gunner's eyes out".
Some, such as then-Brigadier General Billy Mitchell, commander of all American air combat units in France, claimed "the only damage that has come to [Germany] has been through the air". Mitchell was famously controversial in his view that the future of war was not on the ground or at sea, but in the air:

Anti-aircraft weaponry

A German Hannover CL III shot down on 4 October 1918 by American machine gunners in the Argonne.

Though aircraft still functioned as vehicles of observation, increasingly they were used as a weapon in themselves. Dog fights erupted in the skies over the front lines – aircraft went down in flames and heroes were born. From this air-to-air combat, the need grew for better aircraft and gun armament. Aside from machineguns, air-to-air rockets were also used, such as the Le Prieur rocket against balloons and airships. Recoilless rifles and auto cannons were also attempted but they pushed early fighters to unsafe limits while bringing negligible returns. Another innovation was air-to-air bombing if a fighter had been fortunate enough to climb higher than an airship. The Ranken dart was designed just for this opportunity.

This need for improvement was not limited to air-to-air combat. On the ground, methods developed before the war were being used to deter enemy aircraft from observation and bombing. Anti-aircraft artillery rounds were fired into the air and exploded into clouds of smoke and fragmentation, called Archie by the British.

Anti-aircraft artillery defenses were increasingly used around observation balloons, which became frequent targets of enemy fighters equipped with special incendiary bullets. Because balloons were so flammable, due to the hydrogen used to inflate them, observers were given parachutes, enabling them to jump to safety. Ironically, only a few aircrews had this option, due in part to a mistaken belief they inhibited aggressiveness, and in part to their significant weight.

Bombing and reconnaissance

Gotha G.V German bomber, 1917

As the stalemate developed on the ground, with both sides unable to advance even a few hundred yards without a major battle and thousands

of casualties, aircraft became greatly valued for their role gathering intelligence on enemy positions and bombing the enemy's supplies behind the trench lines. Large aircraft with a pilot and an observer were used to scout enemy positions and bomb their supply bases. Because they were large and slow, these aircraft made easy targets for enemy fighter aircraft. As a result, both sides used fighter aircraft to both attack the enemy's two-seat aircraft and protect their own while carrying out their missions.

While the two-seat bombers and reconnaissance aircraft were slow and vulnerable, they were not defenseless. Two-seaters had the advantage of both forward- and rearward-firing guns. Typically, the pilot controlled fixed guns behind the propeller, similar to guns in a fighter aircraft, while the observer controlled one with which he could cover the arc behind the aircraft. A tactic used by enemy fighter aircraft to avoid fire from the rear gunner was to attack from slightly below the rear of two-seaters, as the tail gunner was unable to fire below the aircraft. However, two-seaters could counter this tactic by going into a dive at high speeds. Pursuing a diving two-seater was hazardous for a fighter pilot, as it would place the fighter directly in the rear gunner's line of fire; several high scoring aces of the war were shot down by "lowly" two-seaters, including Raoul Lufbery, Erwin Böhme, and Robert Little.

Strategic bombing

Plaque commemorating an 8 September 1915 Zeppelin raid on 61 Farringdon Road, London.

British recruiting poster capitalizing on the scare created by the bombing raids on London

The first ever aerial bombardment of civilians was during World War I. On 19 January 1915, two German Zeppelins dropped 24 50-kilogram (110 lb.) high-explosive bombs and ineffective three-kilogram incendiaries on Great Yarmouth, Sheringham, King's Lynn, and the surrounding villages. In all, four people were killed, sixteen injured, and monetary damage was estimated at £7,500.

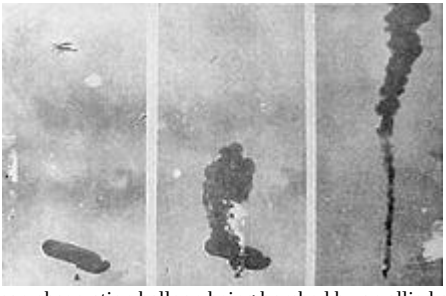
There were a further nineteen raids in 1915, in which 37 tons of bombs were dropped, killing 181 people and injuring 455. Raids continued in 1916. London was accidentally bombed in May, and, in July, the Kaiser allowed directed raids against urban centers. There were 23 airship raids in 1916 in which 125 tons of ordnance were dropped, killing 293 people and injuring 691. Gradually British air defenses improved. In 1917 and 1918 there were only eleven Zeppelin raids against England and the final raid occurred on 5 August 1918, which resulted in the death of KK Peter Strasser, commander of the German Naval Airship Department. By the end of the war, 51 raids had been undertaken, in which 5,806 bombs were dropped, killing 557 people and injuring 1,358.

The Zeppelin raids were complemented by the Gotha G bombers from 1917, which were the first heavier than air bombers to be used for strategic bombing, and by a small force of five Zeppelin-Staaken R.VI "giant" four engine bombers from late September 1917 through to mid-May 1918. Twenty-eight Gotha twin-engine bombers were lost on the raids over England, with no losses for the Zeppelin-Staaken giants. It

has been argued that the raids were effective far beyond material damage in diverting and hampering wartime production, and diverting twelve squadrons and over 10,000 men to air defenses. Calculations performed on the number of dead to the weight of bombs dropped had a profound effect on attitudes of the British government and population in the interwar years, who believed that "The bomber will always get through".

Observation balloons

Manned observation balloons floating high above the trenches were used as stationary reconnaissance points on the front lines, reporting enemy troop positions and directing artillery fire. Balloons commonly had a crew of two equipped with parachutes: upon an enemy air attack on the flammable balloon, the crew would parachute to safety. Recognized for their value as observer platforms, observation balloons were important targets of enemy aircraft. To defend against air attack, they were heavily protected by large concentrations of antiaircraft guns and patrolled by friendly aircraft. Blimps and balloons helped contribute to the stalemate of the trench warfare of World War I, and contributed to air to air combat for air superiority because of their significant reconnaissance value.



A German observation balloon being bombed by an allied aircraft.

To encourage pilots to attack enemy balloons, both sides counted downing an enemy balloon as an "air-to-air" kill, with the same value as shooting down an enemy aircraft. Some pilots, known as balloon busters, became particularly distinguished by their prowess at shooting down enemy balloons. Perhaps the best known of these was American ace Frank Luke: 14 of his 18 kills were enemy balloons.