SOUTH AUSTRALIAN AVIATION MUSEUM

SIGNIFICANT AVIATOR & AVIATION EVENTS PROFILES

AERIAL PHOTOGRAPHY
PART 3 – DEVELOPMENTS DURING WORLD WAR II

In September 1910, when Captain Bertram Dickson used his Bristol Boxkite to demonstrate, to high-ranking British military officers and the then Home Secretary Winston Churchill, the potential for aeroplanes to perform a military reconnaissance role from the air and report back, far quicker than cavalry forces of the day, it must have been hard to imagine that in less than a decade, further developments would bring superior aircraft, partly automated cameras capable of capturing fine detail, the ability to produce up-to-date photomaps in the form of mosaics, and the ability to view the lay of the land stereoscopically.

Early in WWI, observation balloons were still in use, but within six days of arriving in France, Royal Flying Corps (RFC) aviators flew their first aerial reconnaissance mission. Within six weeks of British aircraft arriving in France and after the armies fighting on both fronts moved into defensive positions in trenches, as well as locating and reporting on enemy movements, Allied aviators also took on an artillery observation role. Initially, reconnaissance aircraft were unarmed and generally remained on their side of the lines. Both sides quickly realized the great advantages to be gained by mobile aerial reconnaissance, the value of seeing what was going on behind enemy lines, and obviously, the need to suppress the enemy from doing likewise. Aircrews began carrying revolvers and rifles, and a practice soon began of taking potshots at enemy aircraft, to scare them away from their role of observing respective enemy positions. As reconnaissance aircraft ranged further behind enemy lines, machine guns were carried and there are written accounts of observers standing up in aircraft, using hand-held Lewis guns. Defensive machine guns began to appear, mounted for use by observers. Subsequently, offensive machine guns were mounted on aircraft and devices were invented to synchronize the firing of bullets with the rotation of propellers. Incendiary rounds were carried to deal with hydrogen filled enemy observation balloons.

The practice of dropping projectiles on the enemy trenches saw a progression from sharpened steel darts/flechettes, each weighing around 0.5 kg, often dropped in their hundreds, through grenades, to initially limited but heavier bomb loads, as aircraft became more powerful and capable of carrying additional weight. Single and two-seater aircraft continued to be used for aerial reconnaissance and photography. Two-seater aircraft were often protected by single-seater fighters, and the Allied forces and the enemy developed bigger and bigger bombers, to seek out targets to disrupt troop movements, communications etc.

Both sides discovered the advantages of “strategic bombing,” and by May 1917, the Germans began using heavy Gotha G.IV bombers against England. In June 1918, the British engaged in long-range bombing of industrial targets deep in German territory. Missions, undertaken with de Havilland DH9s and Handley Page 0/400s, saw 660 tons of bombs dropped on Germany, more than twice what Germany had managed to drop on England. The first raid against Berlin, scheduled for November 1918, was cancelled due to the armistice.

Twenty years later, in 1938, the German Army Chief, Werner Freiherr von Fritsch, noted that “in the next war, whoever had the best air reconnaissance would win.” This did not appear to be on the minds of the Allied forces from WWI, who had focused on a growing doctrine of “strategic bombing” as the decisive weapon of war. However, it was not long into WWII, it was discovered that bombing

was generally ineffective unless accompanied by intensive aerial reconnaissance. Consequently, apart from some minor developments and improvements in aerial cameras and some areas of photogrammetric research that had not really been taken up, "the various parties went into the new war with mostly the same cameras and procedures they had used when exiting the last one, and initial doctrines, on both sides, were focused on battlefield observation, which had assumed a relatively static front, as it had been in the previous war."

The Interwar Years:

Amrom Harry Katz (1915-1997) was an American physicist who specialized in aerial reconnaissance and later in satellite technology. He developed methods for aerial reconnaissance, supported by space satellites. In 2000, he was acknowledged as one of the 10 founders of the US National Reconnaissance Office NRO), considered to be one of the "big five" US intelligence agencies.

Believing it was a job not yet done by anyone else, and in an effort to begin writing a history of aerial reconnaissance, tracing it from photography in the 1850s, through to the end of the Korean War in 1953, Katz wrote a series of notes in the 1960s. The notes were started for a speech he gave at the Open Space and Peace Symposium, held at Stanford University in September 1963. After giving the speech, he planned to start documenting the subject in its entirety, but Vietnam and other problems caused him to temporarily put aside the task. Unfortunately, he did not continue the history and we only have Part One of his notes, which he circulated in 1966.

Katz's notes record, that late in World War II, he discovered a book called *"Airplane Photography,"* written in 1919 by Herbert Eugene Ives (1882-1953). Katz described Ives' book as "an obscure work, yet a remarkable book that had been largely disregarded by workers between WWI and WWII, because of its age, and hence its apparent obsolescence." Katz was surprised to find that many of the things he and other members of his group had rediscovered during WWII had been anticipated by Ives, and the book was therefore a "genuine mine of information." For those interested, a copy of the e-book version is available at Project Gutenberg at the following link:
https://www.gutenberg.org/ebooks/53508

In his book, Ives prophesized where aerial photography was likely to be heading:

- Novelty "bird's eye" views and obliques to show entire form and location of buildings and other large objects, including stereoscopic oblique images. He could see a market for recording previously unseen perspectives for tourist attractions, e.g. cathedrals, castles and ruins, for guidebook images.
- Mapping / planning applications with ability to capture large amounts of detail difficult to obtain with conventional surveying techniques.
- Advertising for planned country estates, real estate developments, and to promote existing resorts and large-scale attractions.
- Preliminary surveys for planning large projects. Recording periodic progress for large structures, bridges, ships etc.
- He wrote, "News events will soon call for an aerial photographic service. Already we are seeing newspapers and magazines featuring aerial photographs of the entry into conquered cities and the parades of returning fleets. Accidents, fires, floods and wrecks, of either local or national interest, can best be represented by this newest form of photography."
- Scientific uses for aerial views, including geology, how pictures from the air of things like extinct volcanoes, canyons and river courses would give information as to their configuration that would otherwise require months of painstaking survey to obtain, and how aerial photographs of successive active volcano eruptions could provide a record that would be

unobtainable by any other means.

Perhaps most importantly, from a reconnaissance perspective, Ives wrote about how he believed aerial photography could be used to quickly record minute ground detail that could be transferred to existing maps and how aerial photographs, in strip or mosaic form, could be used for navigating aircraft. Contrasting with these types of pictorial maps, he discussed how the application of aerial photography, may in the future, prove practical to precision mapping, while at the same time raising the need to address lens distortion, and for the implementation of auxiliary devices to record compass direction, altitude and inclination. He even discussed gyroscopic mounting of cameras.

Ives wrote about how remote and uncharted regions could possibly be mapped through "triangulation," using a number of natural or artificial points appearing in constituent pictures. He wrote about a theoretical possibility whereby contours from stereo-aerial pictures could perhaps be plotted. He was talking here about photogrammetric techniques where ground control points, previously fixed through traditional surveying triangulation techniques, are transferred to corrected stereo pairs of aerial photographs and details from the photographs are then plotted, using a stereo-plotting instrument, allowing the transfer of image data, including contours, into map form.

As an aside, at the time of writing his 1919 book, Dr Herbert Ives was the Head of Aerial Research in the US Army Signal Corps, a position he had held since 1918. In 1919, he joined AT & T's research division and his first major responsibility was to develop commercial telephotography (very similar to today's fax machines), transmitting still photographs via telephone lines. In January 1925, he proposed speeding up the AT & T facsimile system "to the point where the product would be television." By December 1925, he had devised an electromechanical system capable of transmitting images from one laboratory bench to the next. In March 1926, he demonstrated a low definition video telephone, with only 50 lines of resolution at 16 frames per second. However, the image of a human face was recognizable on the 2" x 2.5" window. On 27 April 1927, Ives and at least 200 engineers, scientists, and technicians he coordinated, contributed to the first demonstration of long-distance television, conducted between Washington DC and New York City, a distance of over 200 miles. During WWII, Ives worked on night vision devices, for which the US awarded him the Medal of Merit, the highest civilian honour.

Advances in photogrammetry and cartography occurred during the 1930s but did not appear to be taken up and translated into an operation reconnaissance capability by the British and US military. Photogrammetry is discussed further in a later Part.

Colour aerial photography was introduced in the US in 1935 but did not find widespread application. Experiments with flash bomb photography at night were carried out pre-war but did not lead to any operational capability until later in WWII.

Interwar Aerial Camera Development:

Sherman Mills Fairchild:

American businessman Sherman Fairchild founded over 70 companies, including Fairchild Aviation Corporation, Fairchild Industries and Fairchild Camera and Instrument Corporation. Rejected from military service in 1917, due to poor health, Fairchild wanted to find a way to support the war effort. He and his father won a US Government contract to develop an improved aerial camera, to rectify significant image distortion in existing aerial cameras, caused by slow shutter speeds that could not keep up with the movement of the aircraft during the period of exposure. Given a budget of $7000, the project ended up costing $40,000. Fairchild's father paid the balance.

Figure 1 *– Fairchild F-1 Aerial Camera. Image from Smithsonian National Air and Space Museum.*

Although the US military did not accept his camera until after the end of WWI, two cameras were purchased for training. Fairchild then focused his attention on developing a more advanced camera, and in February 1920, established the Fairchild Aerial Camera Corporation, the predecessor of Fairchild Camera and Instrument Corporation. During 1920, the US Army ordered 20 additional Fairchild F-1 aerial cameras and selected it as their standard for aerial cameras.

Wanting to expand the use of his cameras for mapmaking and aerial surveying, Fairchild formed Fairchild Aerial Surveys in 1921 and purchased a surplus WWI Fokker D.VII biplane to take aerial photographs. Soon after starting the business, Fairchild received a contract to make a photomap of Newark, New Jersey. This was the first aerial mapping of a major city.

In 1923, Childs formed Fairchild Aerial Surveys of Canada Ltd and in the same year, made an aerial map of Manhattan Island. Other US cities began using aerial mapping, as they found it was faster and less expensive than ground surveys.

Right - Figure 2 *– Fairchild F-1 Aerial Camera. Image from Wikipedia Sherman Fairchild.*

Fairchild K-3 Aerial Cameras:

The US involvement in WWI had seen the development of Fairchild K-1 and K-2 aerial cameras. In 1918, the Fairchild K-3 was produced with a between the lens shutter and intervalometer. In basic terms, the intervalometer is a mechanism to control the timing of exposures, i.e. correct exposure interval necessary to give complete coverage, and for photogrammetric applications, sufficient overlap (60%) to allow sensitivity of measurement.

Without going into formulas, the “Pulse Repetition Rate,” i.e. when the shutter should be triggered, is calculated using the aircraft ground speed, altitude above terrain, camera focal length, format length in direction of flight (i.e. physical size of negative e.g. 9” x 9”) and the required overlap.

For the more modern aerial cameras, e.g. Wild RC10 which began production in the late 1960s and was used extensively for mapping in Australia, by looking through a separate navigation sight, capable of viewing vertically or forward, a moving line could be viewed. Having set the required overlap, the operator would adjust the speed of the moving line onto an object passing through the sight. The camera itself would then calculate when to make the exposures. Early intervalometers, although some were equipped with a propeller mechanism to measure the speed the aircraft was travelling, were basically just timers that had to be set according to calculations.

In 1925, the US Army requested modifications to the Fairchild K-3, to include a device that would automatically record data, which would otherwise have to rely on human memory and written notes, both likely to be unreliable in the stress of combat. Accordingly, Fairchild designed the K-3A, in which each negative was marked at the time of exposure, with the date, hour, serial number, name of operator, altitude of the aircraft and level condition of the camera.

Figure 3 *- Fairchild K-3A Camera*

The K-3A, shown left, is fitted with an 8.2-inch lens cone, it also came with 12-inch, 20-inch and 24-inch lens cones.

The period between 1927 and 1930 saw the appearance of several Fairchild cameras, designed for various specific purposes, some of which were used in mapping photography. The K-4 was equipped with a larger between the lens shutter. The US Army K-6 was a focal plane shutter camera, designed for long-distance, high altitude photography and was used only for obliques. The F-4 was a low priced, all-purpose instrument, designed around the K-6. These cameras were used by new aviation units that had been started in the National Guard who were financially unable to purchase the K-3. The K-7 was another high-altitude reconnaissance camera. Its 9" x 18" negative size and long focal length lens resulted with pictures of large-scale, wide coverage and great clarity.

Folmer Graflex K-10:

Figure 4 *- Folmer Graflex K-10 camera.*

In 1929, the US Army expressed the need for a camera of the same type as the US Navy Fairchild F-1. Folmer-Graflex designed and built the K-10, which was later smoothed in line, reduced in bulk and weight in the developing of the Fairchild F-8. The Folmer-Graflex K-10 was used mostly for oblique images. Records indicate only 50 K-10s were made in 1930.

Fairchild F-8 Camera:

Designed in 1929 and released in 1930, the Fairchild F-8 camera was used by both military and civilian aerial photographers. The 1930s saw a surge of civilian applications including photographing Alaskan glaciers and landforms and towns in South America and Africa. In 1934-35, Margaret Bourke-White shot aerial images for several US airlines.

Left - Figure 5 *- Fairchild F-8 Aerial Camera being used by Margaret Bourke-White. Image Alfred Eisenstaedt – The LIFE Picture Collection/Getty Images.*

Designed for taking oblique aerial images, the F-8 had a focal plane shutter and was fitted with a Schneider Xenar 240mm/f8 lens. The F-8 camera comprised of a rectangular camera body, with a large lens cone that completely encased the lens. Lens settings were altered by accessing the front of the lens inside the cone and the focal distance was altered by adjusting a ring at the rim of the cone. Aperture stops were available between f4.5 and f45 and shutter speeds of 1/125, 1/175, 1/225, 1/300 and 1/400th of a second. The camera could either use a 5" x 7" sheet film magazine, or a magazine that could be loaded with 7" roll film, taking 40 exposures. The fold out Newton viewfinder was fitted with a pointing device as well as cross hairs, designed to reflect what the camera would be capturing on the film.

Williamson F24 Camera:

Figure 6 *- F24 Aerial Camera. RAF airmen carrying a hand-held version of the F24 camera. The weight of the typical hand-held version was about 20lb. Image Wikipedia – F24*

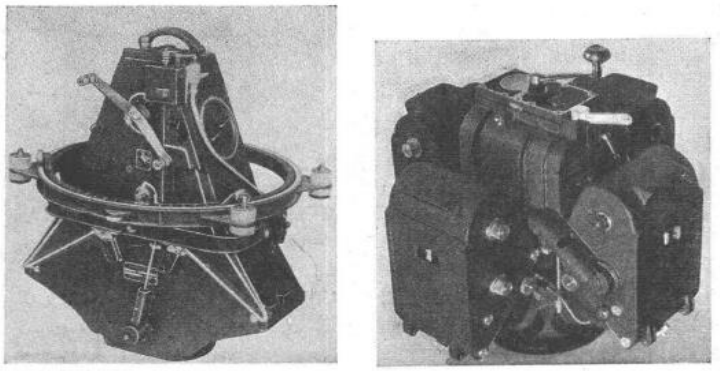
Introduced in 1925, the outline design for the F24 camera was done by the Royal Aircraft Establishment at Farnborough. Detailed design and most of the production were carried out by Williamson Manufacturing Company Ltd. The F24 was designed to be lighter and smaller than the Fairchild F-8 and the F-8 continued to be used in less demanding installations.

The main component units of the F24 comprised of the body, fitted with a roller blind focal plane shutter, gearbox, film magazine and lens cone. The image format was 5" x 5" on 5" roll film, allowing up to 250 exposures. The shutter speed was preset between 1/100 second and 1/1000 second. Longer focal length lenses and larger image formats offered more detail in images from extremely high altitudes. Prior to 1937, available lenses included focal lengths of 3.25-inch (f/5.6), up to a 14-inch lens. In late 1940, a 20-inch (f/5.6) lens became available, and in 1942, a 36-inch lens was added.

Multiple Lens Cameras:

The basic principles of the multi-lens camera were contained in an eight-lens camera built by Captain Theodore Scheimspflug of the Austrian Army in 1904. In 1918, Major James W. Bagley's tri-lens T-1 camera, discussed in Part 2, showed sufficient promise that a number of them were constructed by the US Army and these were used in connection with various post-war government operations.

In 1927, the addition of a fourth lens in the Fairchild T-2A camera solved a military requirement that necessitated extension of the air base (the length of line joining two exposure stations). The five lens Fairchild T-3A, designed primarily for military use, was developed around 1933. To allow greater coverage for each exposure, a mount was developed to allow two T-3As to be mounted in tandem.



Above Figure 7 *- Fairchild T-2A and T-3A multi-lens cameras.*

In 1935, the US Coast and Geodetic Survey requested the building of a nine-lens camera to meet problems covering large areas of coastline and surrounding waters, where there was difficulty in securing control points. This camera, designed by Commander O.S. Reading and built by Fairchild, was the only one made. To save on space, the lenses were placed in a compact group, all pointed vertically. The ground image was brought into the eight oblique facing side lenses, at the required angle by using a stainless-steel mount, equipped with eight stainless steel mirrors. The mount and mirrors were machined from the same ingot to prevent any warping or distortion caused by differences in coefficient of expansion.

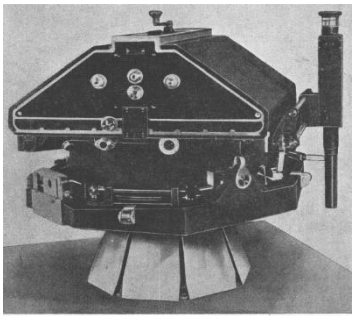


Figure 8 *- The Fairchild nine-lens camera.*

Australian Aviation and Photography Pioneer - Frederick Sidney Cotton:

Figure 9 *- Frederick Sidney Cotton. Image from alchetron.com*

Queensland born Frederick Sidney Cotton OBE (1894 – 1969), or as he preferred to be called "Sid Cotton", was an inventor, and aviation and photography pioneer, considered to be largely responsible for the development of British aerial photographic reconnaissance before and during WWII. Numbering amongst his close friends were Winston Churchill and Ian Fleming. His clandestine activities leading up to and during WWII (described below), the reason why he flew the last civilian flight out of Berlin, his love of gadgets and things like a post-war conviction for gun running, led many to believe he may have provided inspiration for Fleming's James Bond character.

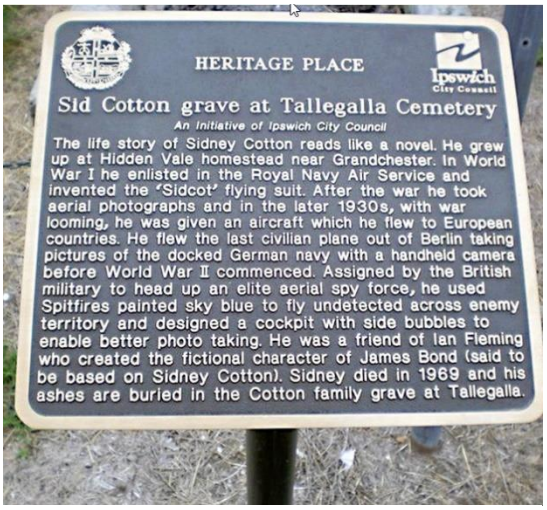


Figure 10 *- Plaque erected by Ipswich City Council at Sidney Cotton's Tallegalla Cemetery gravesite.*

Cotton was 20 years old when WWI broke out in Europe. He saw this as an opportunity to learn how to fly and left Australia to join the Royal Flying Corps (RFC). En route, he became interested in the navigation techniques used by the ship's officers and decided he would join the British Navy instead.

Cotton joined the Royal Naval Air Service in November 1915. Within weeks of arriving in England, and following a demonstration of a circuit and landing with an instructor, who wrongly gained the impression Cotton had some previous flying experience, the instructor sent Cotton off on a solo flight in a Maurice Farman Longhorn. Cotton later described this as a frightening experience. Hardly daring to move the controls, he managed to take off. When he did experiment with a turn, he overdid the banking and struggled for a few minutes to regain level flight. His subsequent erratic diving and climbing, twisting, and turning attracted the attention of other students and instructors.

A first headlong landing attempt failed, and he zoomed skywards again. On his second attempt, he fluked a perfect landing inside the marked circle on the ground. Believing he had been executing advanced techniques and manoeuvres, the onlookers rushed to congratulate Cotton. Three days later, Cotton was posted to Andover, to learn how to fly the B.E. 2c. After instruction in navigation and Morse Code, and with only five hours of solo flying, he qualified as a pilot and was posted to Dover, where after learning to fly French designed Breugets, he was posted to France, where he was based at an airfield near Dunkirk. Initially flying Channel patrols, he went on to participate in night bombing sorties over France and Germany with No.3 and No. 5 Wings.

In the winter of 1916, after scrambling hurriedly to get airborne without time to change out of oily overalls, Cotton was not troubled by the cold, whereas several members of his squadron returned practically frozen. He concluded that the oil on his overalls sealed the fabric and trapped a layer of warm air next to his body. He had Robinson & Cleaver Department Store make up a one-piece suit which had three layers, comprising of a thin layer of fur, another of airproof silk and an outside layer of light Burberry material. The suit also had a fur collar and cuffs. Within four weeks, Robinson and Cleaver were making 1000 a month of what was to become known as "The 'SIDCOT' Flying Suit." It became such a highly prized item that it was the first item to be confiscated from British pilots when taken prisoner. German ace, Baron von Richthofen, was wearing one when he was shot down.

Figure 11 *- Advertisement for the "Sidcot" Flying Suit that was not retired until cabin heating became standard. Image from aerosociety.com*

Towards the end of 1917, the Air Board concluded the Sidcot Flying Suit was regarded by pilots as the most suitable for operational use in cold temperatures. This flying suit, with various modifications, was widely used by the RAF until the 1950s.

After the war, Cotton returned to Australia with his new wife and settled in Tasmania, from where he wrote to the newly formed Australian Flying Corps, offering his services. The AFC contacted the Admiralty in London and were told, "He is of a difficult temperament and is unsuitable for employment in a uniformed service." The AFC did not take up his offer.

Cotton ran his father's apple drying business for a while and then tried to set up a farm rental company. Other ventures failed, he fell out with his father and he and his wife went back to England. Using previous contacts, Cotton got a job with the engine manufacturing company Napiers, hoping that his involvement with them could lead to attempting a flight from England to Australia. At the time, Aircraft Engine Manufacturing Company (Airco) were preparing the last of three de Havilland DH.14 Okapi two-seater bombers that had been designed as an Airco DH.4 and DH.9 replacement. With the war drawing to a close, the RAF were reluctant to accept the three that were built.

The two military variants were completed in 1921 and used for trials. One of them crashed at Burnham Beeches on 10 February 1922 and no production aircraft were ever ordered. The third aircraft, registered G-EAPY, was the first to fly. In 1919, it was completed by Airco as a private venture design, designated DH.14A and was to compete in the Daily Mail Transatlantic Flight Competition. It had a Napier Lion engine and increased fuel capacity of 586 gallons. With the winning of the prize by Allcock and Brown, the Project was abandoned. Cotton was then to use the aircraft, intending to try and win the Australian Government's £10,000 prize for a flight between England and Australia. However, before Cotton was ready, Keith and Ross Smith won the prize.

This left a record for a flight from England to South Africa as an option. Cotton persuaded Sefton Brancker, who ran Airco, to let him attempt the England to South Africa record and for Brancker to give him the DH.14A if he succeeded. Cotton and Townsend, an engineer loaned by Napier, left Hendon in January 1920. Within minutes, the oil pressure valve blew out and the oil-soaked pair landed at Handley Page's aerodrome at Cricklewood. After a quick valve change and change of clothes, they were on their way again. More engine trouble forced them down again in Paris. After repairs, they reached Rome. Pre-flight checks the following day revealed the bearing behind the propellor had been starved of oil and had broken down. It took a day and a half to get replacement parts fitted. Believing he would be able to reach Catania in Sicily by nightfall, Cotton departed Rome. A headwind proved too strong, and with no hope of reaching Sicily, Cotton attempted a landing on a beach near Naples. A tyre burst and the aircraft flipped over onto its back.

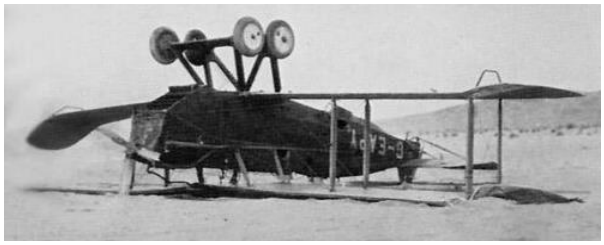


Figure 12 *- Cotton's DH.14A upside down on a beach near Naples. Image reproduced from Aircraft Enthusiasts' Group*

The DH.14A was shipped back to England. Cotton bought the wreck for £500 and then repaired it for nothing. Before repairs were completed, Cotton entered the aircraft into the Aerial Derby, requiring two 100-mile circuits of Greater London. He arranged for the repairers to streamline any projections and the fabric was given a hard and shiny dope finish. He was confident this would increase his cruising speed.

In the competition, while nearing the end of the first lap, the engine on the DH.14A burst into flames. At only 800 feet, he needed to find somewhere to land quickly. After turning tightly and finding himself too low to clear a looming line of trees, Cotton flew between two trees that tore off the wings, and the fuselage ended upside down in a barley field. The aircraft was a complete write-off. Cotton had taken out insurance before the race and was now £5000 richer.

Between then and the outbreak of WWII, Cotton took part in various business activities, including an airborne seal spotting service, search and rescue operations for lost explorers in Newfoundland and Greenland, he established the first airmail service in Newfoundland and carried airmail between Newfoundland and Nova Scotia. He travelled in the US, trying out any venture that would make him money, the most promising of which appeared while he was pursuing his interests in aerial photography. In the 1930s, 80% of colour film usage was in the US. Cotton held 52% of the shares in 1933 registered company called Dufaycolour, which competed with Kodachrome. Sales of Dufaycolour increased dramatically after the National Geographic Magazine specified it as their preferred colour film. Other film companies wanted to become involved and Cotton signed agreements in several countries. In one year alone, Cotton made 20 trans-Atlantic business flights.

Spy Missions:

In September 1938, Cotton was recruited by Fred Winterbotham, the Chief of Air Intelligence at MI6, to take clandestine aerial photographs of the German military buildup. At the time, Cotton was negotiating with Agfa in Germany who wanted a licence to put Dufaycolour, a product for which the patent was owned by Cotton, on their film base. Winterbotham offered Cotton the use of an aircraft to fly to and from Germany, secretly taking photographs on the way. In return, Cotton was to be paid a generous allowance to cover all his expenses. Within weeks, Cotton was flying a Lockheed 12A business aircraft, Registered to Imperial Airways. Canadian Bob Niven, who was appointed by Winterbotham, flew as co-pilot and Cotton took his secretary, Pat Martin, as part of his cover story.

Figure 13 - Sidney Cotton's Lockheed 12A

The first trip was to French Somalia at the southern end of the Red Sea. While Cotton had a number of cover stories, the real purpose of the flight was to test the long-range tanks and three F24 cameras fitted into the floor of the cabin.

Their first refueling stop was in Malta. The following day a "sight-seeing flight" over Sicily happened to pass over a number of Italian military sites. They then travelled on to Egypt, via the Dodecanese islands of Leros and Rhodes, both fortified by the Italians. The RAF were forbidden to fly over Italian occupied Eritrea and Abyssinia, but this ban was ignored by Cotton in the high-flying Lockheed. The route home, following the coast of Libya to Benghazi, was just as productive in photographic targets. Overall, the flight was considered a great success in terms of the photographs produced.

A second Lockheed 12A (G-AFTL) arrived in May 1939. This aircraft was modified with two extra fuel tanks, each of 70 gallons capacity, fitted in the cabin. This modification increased the range from 700 to 1600 miles.

In preparation for flights over Germany, three of the latest Leica reporter cameras were purchased. These were fitted into the belly of the aircraft, with one pointing vertically downwards and the others angled outwards for oblique photography. The cameras were concealed by a sliding portion of the fuselage skin which was opened by a windscreen wiper motor. This modification inadvertently solved a condensation problem because when the panel was opened, warm air was sucked out of the cabin and passed the lenses, which then stayed clear and were not affected by condensation which would otherwise cloud the lenses above 8000 feet.

To give the pilot a better view downwards, Cotton had a Perspex teardrop window made. He later took out a patent on this design, which was licensed to Triplex, and over 10,000 were subsequently produced. Using the teardrop window, in tests, Cotton was able to position the Lockheed directly over targets and this worked perfectly up to around 20,000 feet.

Figure 14 *- Cotton at the controls of a Lockheed 12A, showing the teardrop window. Image reproduced from Aircraft Enthusiasts' Group website.*

Two of the latest RAF cameras were borrowed. Winterbotham himself helped to file off all of the serial numbers which could identify them as RAF cameras. These cameras were concealed by having the additional fuel tanks built around them.

Cotton then travelled several times to visit Agfa's representative, Herr Schöne, at first with no cameras fitted. He was sure the aircraft had been thoroughly searched more than once but the cameras were never located. The Germans subsequently became familiar with the pale blue Lockheed.

Although flight plans were dictated by the German government, Cotton consistently managed to get away with flying off track and over military installations. He had a very persuasive manner and exploited any advantage he could. As an example, the Commandant of Templehof Airport, Rudolph Bottger, invited Cotton to fly to an air rally to be held at Frankfurt. Cotton took an Australian reporter and the editor of *"The Aeroplane."* On that occasion, two Leica cameras were fitted to the aircraft. At the rally, Bottger said he would love a flight in the Lockheed. Cotton mentioned his favourite aunt had always said the Rhine at Mannheim was particularly nice and asked, "Could we fly there?" Bottger went off to get official clearance and on the subsequent flight he sat beside Cotton, enjoying the view from 2000 feet. Bottger did not notice Cotton pushing a button under his seat which was triggering the Leica cameras as they flew over several military installations. The next day, there were so many aircraft leaving the rally that Cotton's "weaving flight" above the Siegfried line appeared to go unnoticed.

Agfa's representative, Herr Schöne, appeared proud of his friendship with Goering. He had shown Goering some of the Dufay photographs and Goering had said he would like to meet this Australian. Cotton was invited to Goering's country estate, together with a Dufay film crew, to take a series of photographs of Göring's Karinhall house. Cotton departed on 17 August 1939 and took a slightly roundabout route so he could photograph some airfields north of Berlin. On his arrival, Cotton was met by Herr Schöne who advised him, "Security wants to know why you were flying so far north."

Cotton answered, “Oh, I always fly a great circle course.” Schöne smiled and said, “Ah yes. Like Lindbergh.”

While at Göring’s estate, Cotton formed the belief that if he could get Göring to come to Britain, for direct talks, then the threatened war might be avoided. On his return, Cotton contacted British Foreign Secretary and fervent peacemaker, Lord Halifax, who agreed with the plan. Cotton, through Schöne, offered to fly Göring himself in the Lockheed aircraft and the offer was accepted. Cotton’s plan was to pick up Göring from a small airfield near Munich and fly him to White Waltham. Cotton proposed to then use his own car to deliver Göring to Chequers.

Cotton took his Canadian co-pilot, Bob Niven, believing that as Australian and Canadian Nationals, there was a thin detachment from Anglo-German relations which might possibly be useful if things went wrong. The Lockheed’s fixed cameras were removed but they kept a couple of Leica cameras in their hiding place in the cabin. Cotton and Niven waited in a Berlin hotel, expecting to make the flight with Göring on 24 August 1939.

On the evening of 23 August, Cotton received a coded telegram from Winterbotham, saying “his mother was very ill and asking for him.” Also, he was visited by an official from the German Foreign Office, telling him he had to leave Germany. Cotton was not told the reason, but it was believed it was because Hitler had signed a non-aggression pact with Russia, clearing the way for the German invasion of Poland. Later that evening, Cotton learned “his mother was sinking fast and urgently needed to see her son.”

At dawn the next morning, the Lockheed taxied towards the runway ready to take off. A steady red light from the control tower halted them and they stopped with the engines idling. A car arrived, containing a very agitated airfield commandant, who said, “All flying is banned. We are trying to get special permission for you to go.” After a long wait, and a phone call to Göring, clearance was given. The clearance was given with a detailed route across North Germany to the Dutch border and Cotton was told, “If you deviate from this, you will be shot down.”

They stuck to the route, constantly looking for possible subjects to photograph. Flying at precisely 300 metres, there was little of interest to be seen in the 250 miles to the Dutch border. Once over the border and on flying clear of cloud, Niven looked over his shoulder and saw in the distance a line of warships in the Schillig Roads near Wilhelmshaven. The quality lens of the Leica captured the images perfectly. Jeffrey Watson’s book *“Sidney Cotton: The Last Plane Out of Berlin”* gives an account of Cotton’s exploits.

Two days later, Cotton, Niven and Pat Martin flew to Copenhagen “on business.” They flew as close as they could to the German East Frisian Islands. Niven operated the F24 cameras and Martin used the hand-held Leica from the co-pilot’s seat. Useful pictures were taken as they flew directly over the German airfield on the island of Sylt.

By this time, because Cotton’s Göring plan had infuriated MI6 and the Foreign Office, both wanted to get rid of him, but his photographs had made a considerable impact in high places and his work was in demand, particularly by the Royal Navy. Unknown to Cotton, the Navy was planning to take over his organisation from MI6, because he was supplying excellent photographs while the RAF Photographic Unit seemed unable to get any.

Cotton was asked to go and talk with Air Vice Marshal Richard Peck. In the meeting that followed, Peck was surprised to learn that Cotton had no special equipment and yet was achieving such good results. Peck admitted that the RAF had been asked by the Navy for up-to-date photographs of the Dutch ports of Flushing and Ijmuiden, but they had lost some Blenheims and failed to get anything useful. Peck asked Cotton to return the following day and meet with RAF pilots and technicians.

On returning to his office, Cotton looked out at the weather and it was a perfect day. He rang the airfield at Heston and told Niven to get the Lockheed ready. They flew over the targets at 11,000 feet and landed at Farnborough, where processing technicians had been warned to do a "rush job." The images were printed as 12" x 12" enlargements and mounted in a special album.

The planned meeting the following day was crowded. Unexpectedly the Vice Chief of Air Staff, Air Marshal's Richard Peirse, attended. After allowing the discussion to ramble on for a while, Cotton produced his album and asked, "Is this the sort of thing you want?" AVM Peck assumed the pictures had been taken in peacetime. He said, "You would not expect this superb quality in wartime. When were they taken?" Cotton said, "3:15 yesterday afternoon." The meeting erupted with comments such as, "You can't do this……. flouting authority…. should be arrested." It went on and on until Cotton could stand it no longer, and he left, slamming the door behind him.

RAF No. 1 Photographic Reconnaissance Unit (1 PRU):

The day following the meeting at which Sidney Cotton produced his album of enlargements, he was called to the office of the Chief of Air Staff, Air Chief Marshal Sir Cyril Newall. It was suggested that Cotton should take over the RAF's Photographic Unit, but Cotton refused. Realizing that he could not work restrained by service red tape, Cotton offered to run a special unit in his own way and based at a civil airfield. Newall agreed, and on 24 September 1939, Cotton was appointed as a Squadron Leader and Honorary Wing Commander and appointed to head up the Heston Flight at Heston aerodrome, reporting directly to AVM Peck. The unit, comprising of five officers and 17 other ranks, set themselves up in an Airwork hangar and the clubhouse of the pre-war flying club at Heston.

On 1 November 1939, Heston flight was renamed No. 2 Camouflage Unit. On 17 January 1940, No.2 Camouflage Unit was renamed the Photographic Development Unit (PDU). On 18 June 1940, the Photographic Development Unit was renamed the Photographic Reconnaissance Unit and on 14 November 1940, it became known as No.1 Photographic Unit (1 PRU) The unit was equipped with a variety of aircraft that were modified for the photographic reconnaissance role. These included Bristol Blenheims, Lockheed Hudsons, Supermarine Spitfires and de Havilland Mosquitos. On 18 October 1942, I PRU was disbanded and the individual Flights of the Unit were redesignated as five separate Squadrons; Nos. 540, 541, 542, 543 and 544 Squadrons.

Soon after his appointment to The Photographic Development Unit, Cotton was introduced to the RAF's Director of Research and Development, Air Commodore Tedder. Cotton wanted two Spitfires but all of them were earmarked to build up Fighter Command's squadrons. The RAF's Photo Reconnaissance aircraft at the time were Blenheims. Tedder advised Cotton he could start with two of those and that he was to liaise closely with Farnborough if he intended to make any modifications. All of the unnecessary equipment, including the guns, were removed and all of the paint was stripped off. Any holes were filled with plaster of Paris and any projections were smoothed and streamlined. Spinners were fitted to the propellers and a blister window was fitted for the pilot. The aircraft were painted in semi-gloss Camotint (duck egg blue). The modifications caused a speed increase of 18 mph.

Fighter Command were fitting out some Blenheims as long-range fighters. ACM Sir Hugh Dowding had heard about the increased speed obtained by Cotton and he called in to Heston, where he had

one of his pilots fly the modified PR Blenheim. When Dowding tried to get the fighter Blenheims that were being made "Cottonized," he was told that it could not be done. Cotton's engineers were not too busy at the time and Cotton suggested that they could do the work. Eight Blenheims were modified within a week and Dowding was apparently delighted. Dowding said to Cotton, "If there is anything I can do for you, let me know." Cotton quickly came back with, "Could you lend me a couple of Spitfires?" The next morning, two Spitfires landed at Heston.

The Spitfires were "Cottonized" and went up from 360 to 396 mph. A 29-gallon tank was fitted under the pilot seat and small tanks were squeezed into the leading edges. The range of the new PR Spitfire was now 1250 miles. Fitting the camera in the fuselage behind the pilot was difficult, but a solution was found. The prototype Spitfire had a fixed pitch wooden two blade propeller, weighing 88 lbs. The metal three blade variable pitch propeller, which replaced it in later production Spitfires weighed 375 lbs. To balance that, a total of 32 lbs. of lead weights were packed in the fuselage behind the tail. These were removed and the weight of the camera restored the balance. A heating duct was fitted, channeling warm air to the camera housing, thereby preventing condensation.

By October 1939, the RAF 1 Photographic Unit was still not fully equipped for operations. Cotton was asked to liaise with Air Marshall Arthur Barratt, the Commander-In-Chief of the RAF contingent in France. Barratt only had Blenheims and Battles for PR work, which were usually flown at altitudes between 5000 and 10,000 feet. These aircraft were frequently intercepted and had therefore been suffering heavy losses.

Figure 15 *- Shows Wing Commander Cotton, at the right of the image, adjusting Flying Officer Longbottom's parachute harness immediately before the first operational sortie in a PR Spitfire. Image believed to have come from the book "Above all Unseen: The RAF Photographic Reconnaissance Units 1939 to 1945" by Edward Leaf.*

Cotton was confident one of his Spitfires was unlikely to be detected at 30,000 feet and this proved to be the case when the first high level PR sortie was flown, along the length of the Siegfried line, by Shorty Longbottom on 22 November 1939.

The film was rushed back to Heston for processing but there was no RAF unit capable of producing large quantities of prints. Cotton approached the person who had run Cotton's aerial survey business in Newfoundland 20 years earlier. He now had his own company that was using up-to-date equipment and trained interpreters, operating the most modern Swiss Wild stereoscopic machines. AVM Peck was adamant that no civilian organisation could be employed to do the work and Cotton would have to wait until a proper RAF unit was set up and personnel trained. Cotton ignored this ruling, swore the civilians to secrecy, and got them to produce and interpret his prints. At the same time, he borrowed a much longer focal length lens from the company, which gave a better scale to photographs taken from 30,000 feet.

The British forces in France needed up-to-date information about the situation in Belgium. They were convinced that any German attack would avoid the Maginot Line and come through Belgium. The Belgians wanted no incident, however minor, which might infringe their neutrality and they had banned RAF overflights of their territory. Cotton's reaction was typical: the high-flying Spitfire's cameras covered a wide swathe of territory and "the Belgians would never see it anyway."

Since the outbreak of war, the RAF had photographed only 2500 square miles of enemy territory, for the loss of 40 aircraft, mostly Blenheims, and the French had photographed 6000 square miles, for the loss of 60 aircraft. Although Cotton's PDU was working in France with just a couple of caravans and only one Spitfire, by the end of January 1940, the Spitfire had photographed 5000 square miles in just three flights.

In early 1940, came an unusual request for flights over Azerbaijan via Iraq, as part of 'Operation Pike', a joint Anglo-French strategic bombing plan to destroy the Soviet oil industry, to cause the collapse of the Soviet economy and deprive Nazi Germany of Soviet oil imports. A Hudson was painted with Camotint and given a civilian registration. One mission was flown on 30 March 1940. After leaving RAF Habbaniya in Iraq, Cotton flew over the mountainous region of South Eastern Kurdistan, across the coast of the Caspian Sea and then north towards Baku. After a four-hour flight, the aircraft entered Soviet airspace, where it remained for one hour, making six photographic runs with a 14-inch focal length F24 aerial camera.

A second reconnaissance sortie was flown on 5 April 1940, again from RAF Habbaniya, this time crossing Turkish airspace to reach Batumi. This flight encountered Soviet anti-aircraft fire and a Soviet fighter attempted an interception.

Analysis of the photography obtained by the PDU revealed that the oil infrastructure in Baku and Batum were particularly vulnerable to air attack, as both could be approached from the sea. On 1 April 1940, four squadrons, comprising 48 Bristol Blenheim Mk IV bombers, were transferred to the Middle East command, supplemented with a number of single-engined Wellesley bombers. A French force of 65 Martin Maryland bombers and supplementary force of 24 Farman F.222 heavy bombers were allocated and the French were preparing new airfields in Syria, which were expected to be ready by 15 May 1940.

The German Blitzkrieg and the swift fall of France on 10 May 1940, derailed the plans after the Germans captured a train containing boxes of secret documents evacuated from Paris. Amongst these were documents dealing with Operation Pike. On 4 July 1940, in a propaganda campaign to justify the invasion of France, the German News Bureau (DNB) released excerpts of the captured documents, asserting that "Germany must be credited with saving these other States [including the Soviet union] from being drawn into this chaos by Allied schemings….because they took timely countermeasures and also crushed France quickly." The strategic Anglo-French bombing campaign against Soviet targets was postponed and eventually abandoned. Ironically, when the Germans occupied France, the photographs taken by the PDU were seized and used during the German attack on Russia.

Due to his propensity to flout regulations, under Cotton's leadership, the PDU acquired nicknames of "Cotton's Club" and "Cotton's Crooks." Cotton reveled in being seen as unorthodox, and even had a special badge struck bearing the initials "CC-11" signifying the 11th commandment; "Thou shalt not be found out." By mid-1940, Cotton had clashed with senior officials in the Air Ministry over his participation in the evacuation of British agents from France, under a cover name of "Special Survey Flights." Following one of his returns from France, couriering Marcel Boussac, the head of the Christian Dior garment and perfume empire, for a fee, Cotton was removed from his post and banned from any involvement with air operations. After several efforts to be reinstated, even involving Churchill himself, Cotton resigned his Commission and acted as an unofficial consultant to the Admiralty for the remainder of the war.

Cotton's aerial photographs were far ahead of their time. Under his leadership, 1 PDU pioneered techniques for high-altitude, high-speed stereoscopic photography that were instrumental in revealing locations of many crucial military and intelligence targets. Some of these photographs were

used to establish the size and the characteristic launching mechanisms for both the V1 flying bomb and the V2 rocket. Cotton also worked on ideas such as a prototype specialist reconnaissance aircraft and further refinements of photographic equipment.

Germany's Pre-WWII and early WWII Efforts:

Figure 16 *- Oberstleutenant Theodore Rowehl.*

Fortunately for Germany, the Luftwaffe had their own Cotton. After the end of WWI, experienced reconnaissance pilot, Theodore Rowehl, who was concerned about the strategic influence of the alliance between Poland and France and rumours of Polish construction of border fortifications, began flying clandestine photographic reconnaissance missions, in his free time, using a hired private plane. The aircraft used was a Junkers W 34 that had set a world record altitude of 12,739 metres on 26 May 1929. He flew at 13,000 feet to evade detection. He showed the images to the Abwehr, Germany's military intelligence Department, and in 1930, was placed on their payroll. Sometimes he flew along the border with Poland and sometimes he entered Polish airspace.

By 1934, Rowehl's operation had expanded to five aircraft and a small group of handpicked pilots, based at Kiel. After the 1936 signing of the German-Polish Non-Aggression Pact, the unit went underground and moved to Berlin as the "Experimental Post for High-Altitude Flights." Purportedly investigating weather conditions and operating from the Staaken airfield, they expanded operations to include aerial reconnaissance of the Soviet Union, France and Czechoslovakia, making Germany's first use of stereo photography.

In 1936, at Göring's invitation, Rowehl's unit was transferred to the Luftwaffe, where it became the "Squadron for Special Purposes," under the General Staff of the Fifth Branch (Intelligence). Greater resources afforded by the Luftwaffe, allowed Rowehl to recruit more pilots. He sought out pilots who had experience with aerial photography companies, international airlines and aircraft manufacturers. Rowehl also advised on the development of specialised aircraft for reconnaissance purposes. The unit used converted bombers, beginning with Heinkel He 111s and later Dornier Do 215s, Junkers Ju 86s, Junkers Ju 87s, Dornier Do 217s, Henschel Hs 130 and Messerschmitt Me 410s. These were equipped with auxiliary fuel tanks and an oxygen-nitrogen fuel mix that would supercharge the engine for 20 to 25 minutes to facilitate escape. Some had pressurised cabins. They were disguised as civilian planes or had minimal markings. The unit, often called "The Rowehl Group," provided strategic reconnaissance for both the Army and the Luftwaffe. Rowehl was, for a while, head of the Luftwaffe's Main Photo Centre.

The Heinkel He III bombers used were painted in Deutsche Luft Hansa colours, to add credence to a cover story that they were investigating possible new routes for the airline to develop, giving them free access to the skies over most of Europe. During 1938 and 1939, these aircraft photographed much of eastern and southern Britain, the entire continental coast of the English Channel and the North Sea, and even penetrated as far up the Baltic coast as Leningrad.

By 1939, the Germans had formed 23 long-range reconnaissance squadrons, each with its own photographic laboratory, from which films could be developed, the resulting prints analysed, and then distributed. Master prints were forwarded to the Luftwaffe intelligence library at Zossen, which was established in January 1938. Commanded by Major Josef "Beppo" Schmid, this unit was tasked with monitoring developments in foreign air forces and preparing detailed military and economic target information for use by the Luftwaffe in time of war.

Schmid, who had transferred from the Army in 1935, had no apparent interest in aircraft or air

warfare. He was later shown to be incompetent. Luftwaffe rising star, Adolf Galand, later described Schmid as "a complete washout as an intelligence officer, the most important job of all." Göring's own deputy, Erhard Milch, also recognised that Schmid "trimmed his sails to the wind" for fear of upsetting his bosses. It was believed that due to Schmid's incompetence, Luftwaffe intelligence never made the best use of the huge quantity of photographs its pilots had captured and produced.

***Figure 17**- A captured Zeiss Rb 50/30 aerial camera.*

The aircraft used by Rowehl and his crews carried the latest Zeiss mapping cameras with 19.8-inch focal length lenses. Mounted in pairs, as split verticals, they produced 12-inch x 12'inch negatives. While the results were surprisingly detailed, the physical size of the cameras made it hard to subsequently fit them into high-performance aircraft with small fuselages, e.g. the Messerschmitt Me 109. Some of these fighters were eventually fitted with cameras but they did not have the range to make a satisfactory photographic reconnaissance platform. Accordingly, the Luftwaffe stuck with bombers for high level photographic reconnaissance. Camera development stagnated and the early advantage the Germans had over the Allies was lost.

Significant Camera Development During WWII:

Fairchild Cameras:

Fairchild continued to develop and improve aerial cameras throughout WWII. Over 90% of all aerial cameras used by Allied Forces during WWII were of Fairchild design or manufacture.

The RAF continued to use **Fairchild F-8** cameras throughout the war.

***Figure 19** - Fairchild F-8 aerial camera (without film magazine) being fitted into PR Mk XI Spitfire at RAF Kuala Lumpur. Image Imperial War Museum.*

***Figure 18** - F-8 Camera, with magazine and 20 inch lens cone fitted, being carried for installation in a PR Spitfire.*

A significant camera, designed for low-altitude oblique photography, was the **Fairchild K-20**. Approximately 15,000 K-20 aerial cameras were manufactured in the US between 1941 and 1945, under licence by Folmer Graflex. One of these was used to photograph the nuclear mushroom cloud

over Hiroshima from the Enola Gay's tail gunner position. The K-20 used 5.25-inch wide roll film that came in rolls of 20 feet to 200 feet, with an image size of 4 x 5 inches. The 6.375-inch, f/4.5 aperture lenses were not interchangeable. This camera featured the use of a vacuum to keep the film flat.

Williamson Cameras:

The Williamson F24, introduced in 1925, took 5-inch square negatives on roll film. By 1940, most configurations of the F24 included a Dallmeyer Pentac lens, with a focal length of 8 inches and f/2.9 aperture. 14 and 20-inch focal length lenses became available later. The camera came with either a Type 21 hand adapter with two side handles, as shown earlier in ***Figure 6*** of this Profile, or a Type 25 fixed mounting and Type 35 control box and motor drive.

Figure 21 **below** shows a Type F24 aerial camera Mk I, used for night photography. Attached to the lens cone, on the left-hand side, is a photo-electric cell, valve amplifier and relay mechanism. On the left, connected to the camera body, is the camera driving motor. To the right of the camera is a Type 35 No. 5 camera control unit, and, at far right, a distribution box containing the batteries and an accumulator. The illumination for night photography was provided by a 4.5 Aircraft Photographic Flash, fused for the height at which the aircraft was flying.

During WWII the F24 was installed in aircraft types, including; Avenger, Blenheim, Catalina, Corsair, Halifax, Hellcat, Hudson, Hurricane, Lancaster, Liberator, Lysander, Maryland, Mitchell, Mosquito, Mustang, Spitfire, Stinson, Stirling, Sunderland and Wellington.

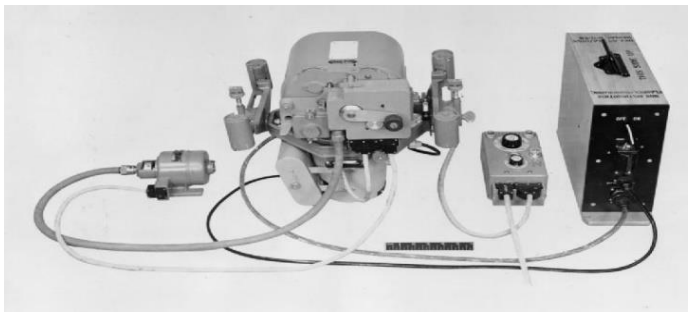


Figure 20 *- F24 Mk.1, motorized camera for night photography, showing a Type 35 camera control unit. Image from the Imperial War Museum.*

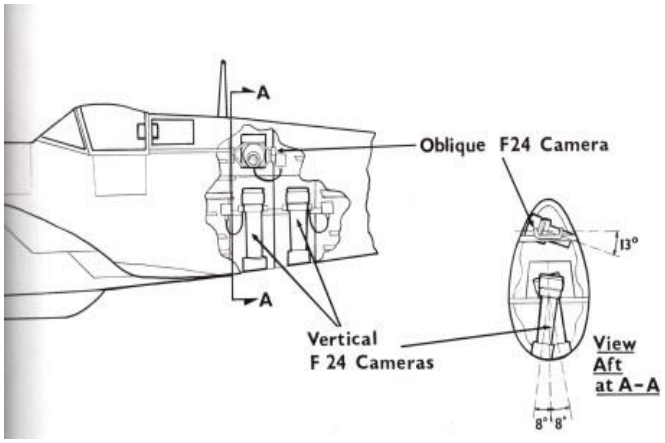


Figure 21 *- Drawing showing vertical and oblique F24 configurations in a PRU Spitfire. Figures 22-24 are from 'Spitfire - A Complete Fighting History' by Alfred Price.*

The F24 mounting configurations in specific types of PR Mk Spitfires is discussed later. Below is a drawing of one of the configurations, together with images of the access hatch for vertically mounted cameras in a PR Mk VI Spitfire and an underwing mounting for an oblique camera. There were basically two types of configurations; vertical for high-altitude and oblique for low-altitude photography. The drawing shows both types of mountings, although, so far as is known, no Spitfire in service ever carried two vertical cameras and an oblique camera at the same time. This is believed to be the case because access to the lower cameras would have been very awkward. Two F24 cameras fitted, as shown, was known as the 'X' fitting. If two smaller F-8 cameras were used, this was known as the 'W' fitting. The majority of PR Spitfires, that were used for medium to high-altitude reconnaissance, had one of these two fitments.

Figure 23 *- Close-up of fuselage of a PR Type F. showing the access hatch for the vertically mounted cameras. Note the bulge in the side of the canopy, to enable the pilot to see directly underneath the aircraft for vertical photography.*

Figure 22 *- Underwing mount for oblique camera.*

F24 cameras continued to be used for aerial reconnaissance by British and Allied Armed Forces into the mid-1950s.

The **Williamson F52,** high-altitude, day reconnaissance camera was introduced after January 1942. It could be fitted with 5-inch, 8-inch, 14-inch, 20-inch, 36-inch and 40-inch focal length lenses, producing 500 exposures, each of 8.5 x 7 inches. Weighing 78 pounds, its long focal length was particularly suitable for high-altitude reconnaissance, and it became the standard British camera for most of the war. **Figure 25 below** shows a physical size comparison between the F24 and F52.

Figure 24 *- Photographers at RAF Benson testing cameras before installing them in a PR Mosquito: (left to right) two F24 14-inch lens vertical cameras, one F24 14-inch lens oblique camera, two F52 vertical cameras with 20-inch lenses.*

Eastman Kodak Co Aircraft Camera Type K-24 Camera:

In 1942, a modified version of the Williamson F24, weighing 10 lbs less than the F24, was designed and manufactured, for use by the US forces, by Eastman Kodak. This camera was the K-24. More than 9000 K-24 cameras were made, for use in tactical reconnaissance aircraft, including the Supermarine Spitfire. The North American F-6 (modified P-51), and the Canadian built De Havilland F-8 (modified Mosquito). The K-24 camera was used for night aerial reconnaissance and orientation and verifying a bomber's position over a target at the time of bomb release.

Left: Figure 25 *- K-24 mounted in B-17 "camera pit." Image from The National Museum of the United States Air Force.*

Figure 26 *- K-24 mounted behind the pilot's seat in a P-51 Mustang. Image from The National Museum of the United States Air Force.*

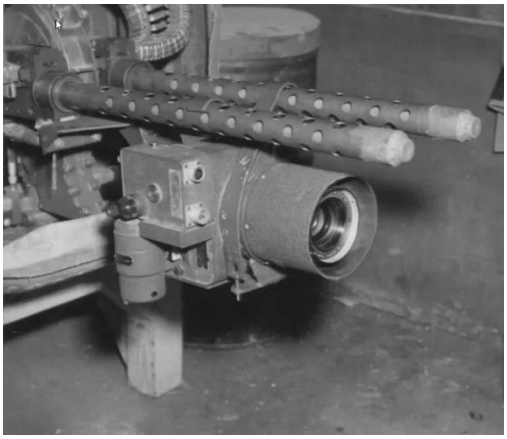


Figure 27 *- K-24 being used as a gun camera on a B-26 Marauder. Image from The National Museum of the United States Air Force.*

RAF Reconnaissance Aircraft:

Figure 28 *-Westland Lysander aircraft used for early reconnaissance role.*

Prior to Sidney Cotton's appointment to the Photographic Development Unit, short range photo reconnaissance for the British Army was in the hands of Army Cooperation Command Westland Lysanders and long range strategic reconnaissance was being undertaken by Blenheim IV bombers of No. 2 Group.

The first operational sortie of the war was undertaken by a PR Blenheim from 139 Squadron at RAF Wyton. However, flying at 24,000 feet froze the camera and the aircraft's radio, and the aircraft returned to base.

Figure 30 *- - Photographic Development Unit Bristol Blenheim. Image reproduced from Aircraft Enthusiasts' Group website*

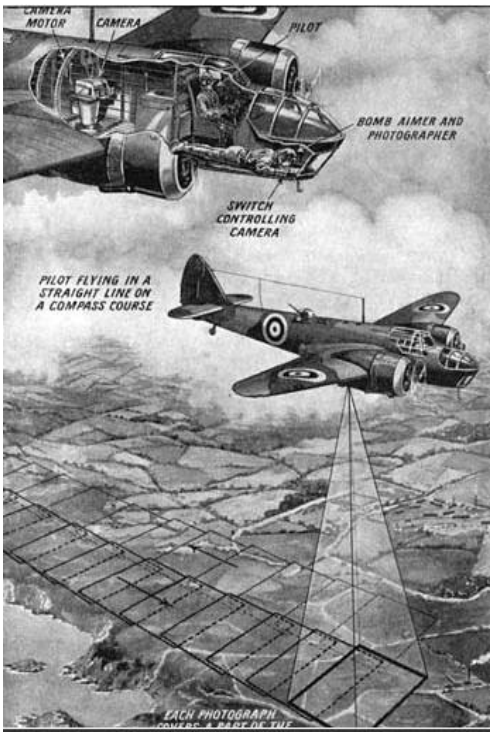


Figure 29 *- Basic drawing showing a Blenheim flying in a reconnaissance role.*

By 1941, it was clear the RAF needed more and better equipment to be able to photograph occupied Europe and Germany. They also needed specialists to interpret the images obtained, to build up a visual picture of everything that was happening in enemy occupied territory. After Sidney Cotton's removal from the Photographic Development Unit, steps were taken to set up a new Central Interpretation Unit and to obtain improved cameras and aircraft.

Following the introduction of the first two photographic reconnaissance (PR) Spitfires in 1939, the use of Spitfires, continued. By the end of the war, around 1000 Spitfires were either converted, or built from scratch, for the reconnaissance role. In its various reconnaissance versions, the Spitfire became the main aircraft of choice for PR Squadrons. Unarmed, except for only two low-flying variants, which retained either four or eight machine guns, the PR Spitfires relied on speed and altitude to ensure their survival. The Spitfire PR Mk XI, of which 471 were produced, was the most used Spitfire for photo reconnaissance. It could fly at 422 mph, had a service ceiling of 44,000 feet and had a maximum range in excess of 2000 miles.

The PR Spitfires were originally identified by letters. This system was used until the autumn of 1941, by which point there were six different types – A to F. This system had the potential to cause confusion, because the same letters were also used to describe different types of Spitfire wings. Accordingly, from the autumn of 1941 onwards, each PR type was given a designation using Roman numerals. The first six (I to VI) were allocated to the existing types, although the types A and B had already gone out of service by that time. Under this system, the Mk VII and the PR Mk II were very different aircraft. From the PR Mk X, numbers were allocated to either fighter or PR aircraft.

The first two **PR Type A (PR Mk I)** Spitfires, obtained by Sidney Cotton, carried two 5-inch focal length F24 cameras that were mounted in the wings, in place of the inner guns, and pointed downwards. To save weight, all the guns were removed. The gun ports were sealed over and as many joins and gaps in the fuselage as possible were closed over to improve speed. A sliding hood was fitted, with teardrop shaped blisters on each side, to improve visibility. One of these Spitfires was actually the first Spitfire to operate overseas, when it joined the British Expeditionary Forces in France in November 1939.

***Figure 31** – A RAF Spitfire from No. 1 Photographic Reconnaissance Unit in flight. Experiments were carried out to find the most effective camouflage paint, including light blue, light green, and even light pink was tried before the RAF settled on pure white.*

Both original PR Mk 1 Spitfires were later converted to the PR Type C or Mk III standard.

The **PR Type B (Mk II)** was an upgrade to the PR Mk I. To improve on image detail, the F24 cameras were fitted with newer 8-inch focal length lenses. An extra 29-gallon fuel tank was installed behind the pilot. This version was first used on 10 February 1940 when it took photographs of the German naval bases at Wilhelmshaven and Emden.

The **PR Type C (PR Mk III)** entered service in March 1940 and was the first PR Mark to be produced in significant numbers. In all, a total of 40 were produced by converting existing aircraft. To increase the range, a 30-gallon fuel tank was added under the port wing. This also helped balance the two F24 cameras, each fitted with 8-inch focal length lenses, that were placed in another blister under the starboard wing. This variant could also have an F24 mounted vertically in the rear fuselage behind the pilot.

***Figure 33** - PR Mk III Spitfire in flight showing the underwing fuel tank and blister containing the F24 cameras. Image from WW2 RAF Reconnaissance Aircraft Part One website.*

***Figure 32** - Two F24 cameras fitted under the wing of a PR Mk III Spitfire. Image from WW2 RAF Reconnaissance Aircraft Part One website.*

The **PR Type D (PR Mk IV)** was produced as a super long-range version. A total of 229 were produced. Both wing leading edges were fitted with 60-gallon fuel tanks. Nicknamed "The Bowser", it had a range of 2000 miles. The PR Mk IV entered service in October 1940 (after the Mk VI). In one of its first missions, a PR Mk IV reached Stettin, in the Baltic.

The PR Mk IV was capable of being fitted with a range of cameras and each setup was coded:

- **Code S:** 2 x F24 cameras with 14-inch focal length lenses.
- **Code W**: A fan of 2 x F.8 cameras with 20-inch focal length lenses, set at inclinations of 10° to the vertical and 20° to each other.
- **Code X**: A fan of 2 x F24 cameras with 14-inch focal length lenses, each set at 8 ½° to the vertical. Also fitted was an F24 oblique camera with either an 8 inch or 14-inch focal length lens.
- **Code Y**: One F52 Camera, mounted vertically and fitted with a 36-inch focal length lens. The Code Y installation was only fitted to a limited number of PR Mk IVs and was known as the "bomb damage assessment installation."

Only one **PR Type E (PR Mk V)** was produced for low-level photography reconnaissance. It represented a significant development, in that it was the first PR Spitfire to be equipped with oblique cameras. It had one F24 camera installed under each wing, in bulged fairings, with the lenses at right angles to the direction of flight and looking slightly below the level of the horizon.

***Figure 34** - PR Mk VI Spitfire, showing additional fuel tanks mounted under the wings. Image from WW2 RAF Reconnaissance Aircraft Part One website.*

The **PR Type F (PR Mk VI)** The first of a total of 15 PR Mk VIs appeared in March 1940. It was an interim design, produced to fill a gap before the appearance of the PR Mk IV. It had two additional 30-gallon fuel tanks below the wings, as well as an additional fuselage tank, giving it an endurance of 4.5 hours and putting Berlin within range. The first flight to the German capital was made on 14 March 1941. This version carried 2 x F24 cameras with 8-inch focal length lenses, which were later replaced by 2 x F.8 cameras with 20-inch focal length lenses. Finally, some PR Mk VIs were fitted with an F24 camera, with a 14-inch focal length lens, in an oblique mounting.

An obvious danger of using the low-level oblique camera, was that it put the PR Spitfire back in the range of German fighters and also anti-aircraft guns. One response to the fighter danger was to produce an armed PR Spitfire. The **PR Mk VII** was designed to undertake very low-level oblique images. The PR Mk VIIs were armed with the same 8 x standard machine guns as fitted to the Mk Ia Spitfire. The PR Mk VIIs were fitted with the "G" camera installation, i.e. 2 x vertical F24 cameras, with the front camera having a 5 or 8-inch focal length lens fitted and the rear camera an 8-inch or 14-inch focal length lens. The PR Mk VII was also fitted with an oblique F24, with either an 8-inch or 14-inch focal length lens, which could face either to the left or the right. Forty-five PR Mk VII Spitfires were produced by converting standard Mk V Spitfires. With this wide range of cameras, the PR Mk VII was able to undertake a wide range of tasks. However, with only a fuel tank fitted behind the pilot, it had a very limited range.

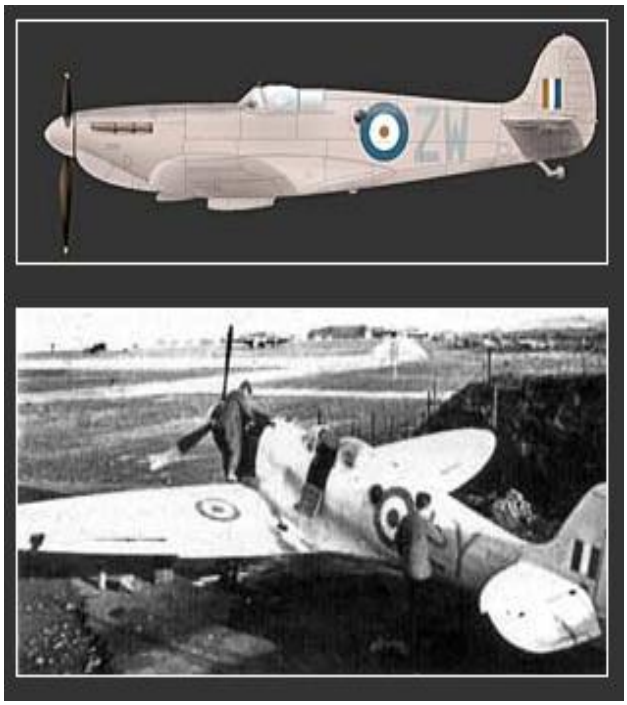


***Figure 35** - PR Mk VII Spitfires. Image from WW2 RAF Reconnaissance Aircraft Part One website.*

Only a small number of standard **Mk IX** Spitfires were adapted to perform a reconnaissance role. This was done by removing all of the guns and replacing them with two vertically mounted cameras.

The most heavily armed reconnaissance Spitfires were a small number of Fighter Reconnaissance **FR Mk IX** Spitfires, used for low to medium level reconnaissance. These carried the standard guns of the Mk IX fighter and had one obliquely mounted F24 camera.

The **PR Mk X** appeared in spring 1944 (long after the PR Mk XI). This was the PR version of the standard Mk VII fighter, produced by matching the fuselage from a Mk VII with the wings from the PR Mk IX. The guns were replaced with 2 x 66.5-gallon fuel tanks. Only 16 were produced and they were withdrawn in September 1945.

The **PR Mk XI** was produced in greater numbers than any other PR variant, with over 470 produced. Based around the Mk IX fuselage, it had the extra fuselage tanks of the standard PR variants, as well as wing mounted tanks. The first PR Mk XI flew on 21 November 1942 and entered service in the summer of 1943. The PR Mk XI used a universal camera installation, allowing the cameras to be easily swapped and a much wider variety of cameras could be used. Common variants included 2 x F52 cameras, fitted with 36-inch focal length lenses, 2 x F.8 cameras with 20-inch focal length lenses, 1 x F52 (20-inch) and two F24 cameras fitted with 14-inch focal length lenses, combined with one F24 (14-inch or 8-inch) in an oblique position. Some also carried a 5-inch F24 just behind the wheel well, for low to medium level tactical reconnaissance.

The **PR Mk XIII** was a low-level reconnaissance fighter, converted from old Mk I, Mk V or PR Mk VII Spitfires. It carried four machine guns and no additional fuel tanks, which limited its range. It first flew in August 1942 and went into service in 1943. PR Mk XIIIs were amongst the aircraft used to take low-level images of the Normandy beaches, in preparation for the D-Day landings. It carried two vertically mounted F24 cameras and one oblique F24 camera.

The **PR Mk XIX** first flew in April 1944 and entered service in May 1944. It was the only Griffon powered reconnaissance Spitfire. It was produced by combining the Mk XIV fuselage, PR Mk XI wings and PR Mk X cabin. It could carry up to 254 gallons of fuel internally, using space in the wings that had originally held cameras. It could also carry a 170-gallon drop tank, although the largest sized used on operations was 90 gallons.

The PR Mk XIX could carry two vertically mounted F.8 cameras with 14 or 20-inch focal length lenses or 2x F.52 cameras with 20-inch focal length lenses, together with one oblique F24 camera on the port side, fitted with either an 8-inch or 14-inch focal length lens.

With a top speed of 445 mph and a service ceiling of 43,000 feet, it was almost impossible for enemy fighters to intercept the PR Mk XIX. All but the first 22 of the 225 produced had pressurised cockpits. The last of the wartime reconnaissance variants, the Spitfire PR Mk XIX, could fly over 100 mph faster, two miles higher, and more than four times farther than Cotton's pioneer PR Type A (Mk 1) Spitfire.

The last operational flight by a RAF Spitfire was made by a PR Mk XIX on 1 April 1954. Three continued to fly with the Temperature and Humidity Flight, performing meteorological research, until they were finally retired on 10 June 1957.

Figure 36 *- Spitfire XIX of the RAF Battle of Britain Memorial Flight – Although retaining her genuine serial number (PS915),it was painted to represent PR Mk XIX (PS888) which carried out the very last RAF Spitfire sortie. Image from 100th Anniversary of Dutch Military Aviation in 2013. Image by Alan Wilson.*

PR Mosquitos:

Air Vice-Marshall Frank Dodd, as a Flight Commander in No. 544 Squadron, played a major part in PR Mosquito operations, which over the last two years of the war, contributed some 50% of the total PR effort. AVM Dodd spent approximately 18 months of this time with No. 544 Squadron. Speaking at the "Photographic Reconnaissance in World War II" seminar, held at the Royal Air Force Museum on 10 June 1991, AVM Dodd referred to one of the greatest tributes to the Mosquito coming from Reichsmarschall Göring, who was quoted as saying, "I turn green with envy when I see the Mosquito. The British knock together a beautiful wooden aeroplane that every piano factory over there is building. There is nothing the British do not have."

The Mosquito was designed as a private venture by De Havilland in 1939. The then Air Council Member for Research and Development, Sir Wilfred Freeman, was able to persuade his Air Council Colleagues to back this revolutionary project for an unarmed wooden aircraft for front-line use. The first contract, for 50 aircraft, was issued on 1 March 1940.

Such was the importance being attached to longer range PR operations at the time, that 20 of the first 50 Mosquitos were switched from bomber to PR fit. The first PR Mosquito came online in July 1941, at a time Pearl Harbor and the US entry into the war was still six months away and the German armies were advancing on Leningrad, the Crimea and the Ukraine. Keeping the Atlantic supply routes from the US open and the necessity of keeping the Soviet Union in the war, by sending supply convoys to Murmansk, became very high priorities. Attaining these objectives depended heavily on intelligence derived from long-range PR monitoring of German shipping movements and apparent preparations.

Prior to the introduction of PR Mosquitos, PR coverage of Norwegian ports and anchorages north of Trondheim relied on Soviet Union cooperation and use of airfields in the Murmansk area. PR Spitfires

were able to cover the most northerly targets but coverage throughout the year was not feasible. From UK bases, the early PR Mosquitos were able to extend coverage to as far north as Narvik, a vital intermediate port being used by German Admiral Raeder's ships. The intelligence derived allowed early warning of likely enemy intentions. The range of the early Mosquitos also enabled almost complete coverage of the Baltic.

The threat to Atlantic shipping was monitored by PR Spitfires from St Eval, providing very comprehensive coverage of Brest and other French ports. PR Mosquitos were able to assist by covering the more southerly ports and airfields, e.g. Bordeaux, Marseilles and Toulon, which at the time were near the limit of a PR Spitfire's range.

The PR Mk I Mosquito first went operational on 17 September 1941. It was powered by two Merlin 21 two speed supercharged engines, giving it a top speed of 382 mph, a maximum ceiling of 35,000 feet, and a range of 2200 miles, with a fuel load of the 690 gallons. The unarmed PR Mk I evaded three Messerschmitt BF 109s at 23,000 feet.

Only 10 PR Mk I Mosquitos were produced, closely followed in April 1942 by the PR Mk IVs. These were essentially conversions of the Mk IV bomber version to the PR role. These aircraft used the same engines as the Mk Is, but the inclusion of two 50-gallon drop tanks increased the fuel load to 760 gallons, giving a range of 2400 miles. A PR Mosquito covered the Baltic, as far east as Konigsberg, on 3 March 1942 and another covered Narvik on 15 May 1942.

The PR Mk VIII followed. This was essentially a prototype for the PR Mk IX, which came off the production line in May 1943. This model raised the maximum ceiling to 38,000 feet and a top speed of 410 miles an hour at 26,000 feet. The cruising speed, at 30,000 feet, was 365 mph.

The PR Mk IX and PR Mk XVI versions, the latter essentially a pressurised version of the PR Mk IX, became the mainstay for longer-range PR operations in the European theatre, up to the German surrender. Powered by Merlin 72 two-stage, two-speed supercharged engines, including 2 x 50-gallon drop tanks, it carried a fuel load of 860 gallons. Drop tanks of 100 gallons and 200 gallons could also be fitted. These types had the advantage of being designed from the outset as PR aircraft, with purpose designed camera bays, providing a better and more extensive camera fit. They carried a split pair of F52 (36"), F24 (14") behind the pilot and an oblique F24 (8" or 14") in the bomb bay.

***Figure 37** - De Havilland Mosquito PR Mk IX of No. 1409 (Meteorological) Flight based at Wyton, Huntingdonshire, November 1944. Image from Imperial War Mueum*

A few PR Mk 32s came into service in late 1944. These were primarily high-flying aircraft with lengthened and lightened wings. Powered by the even more powerful Merlin 114 series engines, pushed their operational ceiling up another 4000 feet, to 42,000 feet.

The second to last of the PR Mosquito line was the PR Mk 34, designed primarily for the very long ranges required in the Far East theatre. A total of 181 were built. Powered by two 1690 horsepower Merlin 113 and 114 engines, the port Merlin 114 drove a Marshal cabin

supercharger. The PR Mk 34 had a belly tank of 1192 gallons + 2 x 200-gallon drop tanks, giving it a range of 3600 miles, cruising at 300 mph. The PR Mk 34's maximum speed was 335 mph at sea level, 405 mph at 17,000 ft and 425 mph at 30,000 ft. All PR Mk 34s were fitted with four split F52 vertical cameras, two forward, two aft of the fuselage tank, and one F24 oblique camera. Sometimes a K-17 camera was used for air surveys. In August 1945, the PR Mk34A was the final photo-reconnaissance variant with one Merlin 113A and 114A, each delivering 1,710 hp.

In addition to the extra range provided by PR Mosquitos, they had other advantages over the PR Spitfires:

- The bomb bay provided room for additional cameras,
- W/T could be fitted as well as VHF,
- The second engine was a great comfort, particularly over long sea crossings,
- It could carry an observer, who combined the duties of navigator with those of W/T and camera operator,
- The navigator/camera operator could keep a vital lookout over the tail when over hostile territory.

In early 1943, euphoria in the Air Ministry over the PR Mosquito was such that the Vice-Chief of the day was almost persuaded to re-equip entirely with PR Mosquitos. Fortunately, the Commander-In-Chief of Coastal Command backed the view of the PRU that retention and further development of the PR Spitfire was essential. In a subsequent paper, written by the Commander-In-Chief of Coastal Command, he made the point that the PR Spitfire enjoyed three significant advantages over the PR Mosquito:

- "Quicker rate of climb, shorter warning to enemy radar, and reduced risk of interception on the shorter range tasks.
- Greater manoeuvrability and smaller size of the Spitfire makes evasion of enemy fighters at high altitude easier and decreases vulnerability to AA at low altitude.
- The smaller size and comparative quietness of the Spitfire increases the chances of passing undetected through enemy radar networks, sound locators and visual reporting system."

Conditions Endured by PR Pilots:

An insight into the mind of the PR pilot can possibly be gleaned from the words of an old PRU rhyme:

"When you're seven miles up in the heavens
That's a hell of a lonely spot
And it's 50 degrees below zero
Which isn't exactly hot
When you're frozen blue like your Spitfire
And you're scared a green shade of pink
When you're hundreds of miles from nowhere
And there's nothing below but the drink."

In a June 1991 seminar, held at the RAF Museum and titled "Photographic Reconnaissance in World War II," Air Chief Marshal Sir Neil Wheeler, who had been a PR Flight Commander and Squadron Commander, spoke about early PRU operations. His logbook showed he had only gone over 10,000 feet 30 times in the five years prior to WWII. He noted that most of the Spitfire PR sorties were flown between 25,000 and 35,000 feet, where temperatures were around -50°C. There were early problems with the vent of the oil tank and the cameras requiring some form of heating and cockpit heating was

an obvious necessity. No one seemed to think of harnessing hot air from the corner and radiator until 1942, when at long last cockpit heating was provided.

Air Chief Wheeler does not appear to have worn a "Sidcot Flying Suit" developed by his boss, Sidney Cotton. In the seminar, ACM Wheeler said he had found the extreme cold most uncomfortable. On his feet, he wore a pair of ladies' silk stockings, a pair of football stockings, a pair of oiled Scandinavian ski socks and RAF fur-lined boots. On his hands, he wore two pairs of silk gloves and some special fur backed and lined gauntlets, which he had to purchase himself. It was essential to retain some fingertip control, particularly for the camera control box. Otherwise, he wore normal uniform (the RAF battle dress was not invented in 1940), together with a thick vest, roll neck sweater and "a thing called a Tropal lining" which was stuffed with a form of kapok. At one point, they had tried electric gloves, but ACM Wheeler noted some pilots received burns from these gloves.

Before the war, on the rare occasions pilots went to that altitude, it had been mandatory to turn on oxygen at about 10,000 feet. The oxygen supply system in early PR aircraft was primitive. PR pilots could be on oxygen for about four or more hours. They initially had a crude and very leaky cloth mask, with a form of continuous supply. Once the oxygen was turned on, whether breathing in or out, the oxygen still flowed. This was extremely wasteful and oxygen cylinders were heavy. PRU pilots, with the help of their own doctor, designed a good rubber mask, based on a captured German one. In November 1940, the "Oxygen Economiser" was introduced, which worked with a form of bellows and only gave oxygen when the pilot inhaled. Pilots nicknamed this device "Puffing Billy."

It was not until early 1944 that the Mk X, a pressurised version of the PR Spitfire, became available, but this was not a success and unpopular, due to poor visibility through a strengthened yellowish coloured canopy and reduced performance due to the extra weight. It was withdrawn from European operations towards the end of 1944.

High-altitude PR aircraft had no armament and pilots had to be conscious of producing a condensation trail over enemy territory. After a great deal of research work, aided by Oxford University, it was established that the tell-tale condensation trails were produced by the exhaust and not the propeller. Pilots endeavoured to keep just below condensation height, but on rare occasions they could pass through the layer and fly above, with the advantage that they could see enemy fighters climbing up.

Until late 1942, PR Spitfires were not equipped with radios, and for navigation, they had no aids beyond a magnetic compass, maps and a watch. Often pilots flew in poor weather conditions, without any sight of the ground for several hours, in un-checkable forecast winds, using elapsed time and dead reckoning only.

Sources:

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A Few Memorable Aerial Images from WWII:

Figure 38 *- Smoke billowing from the burning Saint Pol oil refinery during allied evacuation from Dunkirk. Image from National Collection Aerial Photography (NCAP)*

Figure 39 and 41 below *- Moehne Dam, breached during the daring 'Dambusters' low-level bombing raid by 617 Squadron, RAF. Image from National Collection Aerial Photography (NCAP).*

Figure 40 *- Moehne Dam - Taken 17 May 1943.*

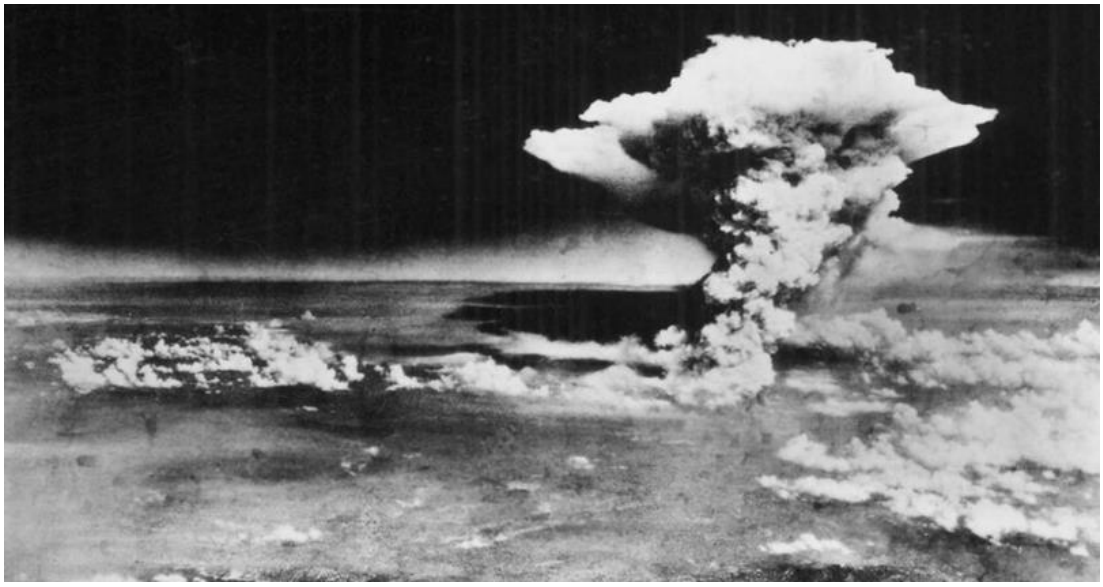

Figure 41*- Aftermath of a nuclear bomb dropped on Hiroshima on 6 August 1945. Image Public Domain.*

Figure 42 *- Craters surrounding a site at Peenmunde, taken 2 September 1944, following an allied bombing raid on the site where 'V' weapons were designed and tested. Image from NCAP, Scotland.*

Figure 43 *- Dotted around fields in Holland, the gliders clustered together formed just a small part of Operation Market Garden in September 1944 - the largest airborne operation ever carried out. Image from NCAP.*

Gary Petts
History Group Member – Oct 2020