# Origins of Aerial Photographic Interpretation, U.S. Army, 1916 to 1918

**James B. Campbell**

## Abstract

*World War I formed the incubator for aerial reconnaissance and photointerpretation. This study, based upon official histories and archival materials, including correspondence, reports, unit histories, and related documents, surveys the development of photoreconnaissance as practiced by the American Expeditionary Forces (AEF) during the period 1917 to 1919. The most visible advances were technologic improvisations, developed in the field that integrated the camera and the airplane to form, arguably, the most effective intelligence resource of the conflict. Technological innovations were accompanied by parallel developments in organizational and training infrastructures necessary to derive information for images acquired by these instruments. Interpretation techniques developed from simple annotations of oblique photographs acquired using handheld cameras to sophisticated analyses of images acquired by automatic cameras suspended in the aircraft fuselage. As the war concluded, efforts were underway to develop foundations for photogrammetric methods to derive accurate planimetry, which later formed foundations for civil applications of aerial photography.*

## Introduction

It is difficult to find an account of the history of remote sensing, or of the development of aerial photography, that does not cite World War I as a prominent landmark. Clearly, World War I forms a critical period in the history of photointerpretation; within a few years of intense innovation, the camera and the airplane were integrated to form, arguably, the most effective intelligence resource of the conflict[1]. Further, technological changes were accompanied by parallel developments in the organizational and training infrastructures required to exploit information gathered by these instruments. Together, both technological and human resources developed from these tentative beginnings evolved to establish techniques that have endured into different technological eras, and to be applied to different applications.

However, the usual accounts seldom offer more than highly generalized overviews of the development of aerial reconnaissance during this era. Because insight on activities of this era must be based upon specifics, this article provides detail to illuminate the technological and organizational innovations that established the foundations of the field of photointerpretation, and the many civil applications built upon its military origins.

This paper sketches development of military photointerpretation in the U.S. Army during World War I (from spring, 1917 through November, 1918). It is largely based upon sources held by the U.S. National Achieves, and upon the U.S. Army History of World War I, including unit histories, training schedules, training syllabi, photographs, and official correspondence that document the evolution of aerial photography and photointerpretation techniques. Here, the focus upon U.S. sources means that significant French, and British contributions to aerial reconnaissance are described in far coarser detail (and, that German and Russian activities of this era are not mentioned). Because of the rapid evolution of this field during this interval, details vary by date; a practice in use at one date may have been superseded by a later date. Usually, this account reflects those practices prevailing near the end of the conflict.

Evidence at hand clearly indicates that applications of aerial photography to military reconnaissance were conceived and applied by junior leadership in the field, usually in the face of apathy or opposition of senior officers. Its origins therefore reside in the experience and insight of pilots supporting of front line units during the early days of the war. Evidence indicates that origins of aerial reconnaissance and aerial photography reside at the front, supported by immediate field commanders but resisted, initially, by senior leadership.

[1]Although later paragraphs provide clarification, some readers may benefit now from informal definitions of several related terms:

*Aerial observation*: observation of the battlefield from the air, most often using fixed-wing aircraft. Initially, aerial observation was conducted by direct visual surveillance, reported in written summaries. Later, aerial observation was supplemented by aerial photography, which developed into its own specialized field.

*Aerial reconnaissance*: active gathering of battlefield information by means of aerial observation, most often from fixed-wing aircraft;

*Aerial photoreconnaissance*: application of aerial photography to the military reconnaissance mission.

*Photointerpretation*: identification of objects recorded by aerial photography, and assessment of their significance.

Department of Geography, Virginia Tech, Blacksburg VA 24061 (jayhawk@vt.edu).

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## Context: U.S. Military Aviation, 1916 to 1917

At the onset of hostilities in August 1914, aviation's reconnaissance potential was not recognized; the airplane was still a recent invention, and military aviation was still in its infancy. Aircraft design of the day offered poor visibility for observers, and photographic technology was not compatible with aircraft design. Nonetheless, nascent aerial reconnaissance soon proved its value, and began its rapid technological and organizational evolution to form the foundation for military aviation's other missions.

The stage can be set with reference to the origins of British aerial reconnaissance: "At this time [Spring 1915] there was no such thing as an aerial observer. Staff Officers were taken up, but they proved practically useless owing to inexperience of the air and fright." (Gorrell, Roll 34, p. 71).

"Until 1915 the work of the Air Service had practically been limited to long distance reconnaissance. There had been no combat aviation, no employment of wireless, no photographs with special cameras. However in February 1915 a noticeable advance was made by the appearance at the front of the Caudron G 3[2], and the successful completion of close reconnaissance missions. About the same time also some progress was made in the development of the transmission of wireless from planes. By May 1915 Farman and Caudron G 3 squadrons were attached to Army Corps for Artillery Reglage[3] work . . ." (Gorrell, Roll 34, p. 72).

Meanwhile, in North America, General John Pershing's Mexican campaign (1916 to 1917) provided the context for development of U.S. military aviation (Miller, 2003). The U.S. Army's First Aero Squadron, based in San Antonio, had previously been assigned to patrol the Mexican border for surveillance of smugglers and armed incursions. In 1916, it was assigned to support General Pershing's Mexican expedition in pursuit of Pancho Villa. During this campaign, aircraft were used extensively for rudimentary communication, surveillance, and reconnaissance, and for initial experiments with aerial photography.

The 1st Aero Squadron was equipped with eight Curtiss model JN-3 biplanes, said to be the first aircraft purchased specifically for military service. However, the JN-3 was found to be poorly suited for field operations; after 38 days service, of the eight aircraft, only one remained fit for service. (Its successor, the model JN-4, was robust, practical, produced in large numbers for successful military service in World War I, and in later decades, was widely used for civil aviation in a multiplicity of roles.)

In 1917, within a few weeks of the departure of the last of Pershing's troops from Mexico, the U.S. was at war with Germany. Some U.S. aviation units did not enter service until a year after hostilities were declared, and were in the field for only seven or eight months prior to November 1918. Because of their late arrival and inexperience, U.S. aviation units initially relied upon British and French aviation equipment and upon their training programs and procedures, as described in subsequent sections.

## Origins of Military Aerial Reconnaissance and Surveillance

Military aerial photography and photointerpretation grew from precursory reconnaissance and surveillance activities, now largely extinct.

### Balloon Observation

The earliest form of military aerial observation used balloons to provide the vantage point to view troop movements and spot artillery fire. The French photographer Nadar (Gaspard-Félix Tournachon) (1820 to 1910), a pioneer in balloon photography, is credited with offering his services to the French Army in 1859 in support of its operations in Italy. Although it is not known if his offer was accepted, his proposal plausibly marks the earliest recognition of the military potential of aerial photography. Later, balloon observations were employed, largely experimentally, in the U.S. Civil War (1861 to 1865) and the Franco-Prussian War (1870 to 1871). During World War I, balloon observation matured into an institutionalized observation system. Balloon companies observed enemy territory from tethered balloons, adjusted friendly artillery fire, and located enemy artillery for counter-battery fire. A team of observers, typically junior officers suspended in the observation basket, communicated with ground staff by telegraphy. Balloon operations were fraught with the danger and hardships of attacks by enemy aircraft, incendiary shells, and the ordeal of night marches along crowded roads to relocate units near the front to be in position for the dawn advance of friendly troops. Although group photographs often show balloon crews equipped with aerial cameras (Figure 1), training and operational documents do not highlight the role of balloon photography, and from accounts now at hand, it is clear that aerial photoreconnaissance developed within the realm of airplane.

### Aerial Observation

The development of military aerial photography originated from the practice of visual aerial observation by pilots, and by crews assigned observation duties. Although early aircraft offered poor visibility (due to masking of terrain by wings and struts), later designs were better suited for effective observation.

The British aviation arm, the Royal Flying Corps (RFC), was formed in 1912. Prior to hostilities, the RFC, like companion services of other nations, expressed little interest in uses of aerial photography. However, once aircraft were used operationally, pilots improvised use of conventional hand-held cameras to acquire aerial photographs. Their experiments demonstrated the effectiveness of photoreconnaissance, but also that the usual cameras would be unsatisfactory for use in open cockpits. Despite the support of their wing commander, these aviators encountered opposition and apathy when they attempted to develop their experiments into an operational capability.

Nonetheless, in February 1915, the RFC created a provisional unit to assess operational feasibility of aerial photography, and to design a camera suited for use with the airplane. The first aerial cameras were designed and constructed by Thornton-Pickard Ltd, a leading British camera manufacturer. Their design, a tapered box-like form, largely of wooden construction, was used operationally for the first time in March 1915, at Fauquissant. This camera's heavy, cumbersome structure led to evolution of improved designs, outlined below, that continued throughout the war (Rendell, 1992).

In due course, aerial reconnaissance was assigned three missions, each tailored to the circumstances of trench warfare on the Western Front (Gorrell, Observers Reconnaissance Reports, John H. Snyder, Roll 34, pp. 357–358.).

*Infantry Liaison*

In 1916, in an effort to break the tactical stalemate on the Western Front, belligerents began to use *rolling barrages* (known also as *creeping barrages*) to subdue defending forces with artillery fire progressively advancing about 50 meters in front of attacking infantry. This tactic (eventually recognized

[2]*Caudron G-3*: a French-manufactured two-seat biplane, circa 1914; *Farman*: another French biplane current during the early World War I period.

[3]*Artillery Réglage* refers to artillery adjustment.


Figure 1. Group photograph, members of 14th Photo Section, 1st Army. Note the number and variety of aerial cameras, illustrating the aggressive experimentation that characterized the development of the aerial camera during World War I. U.S. National Archives and Records Administration, Still Pictures, E-4293.

as successful only locally) required close communication between artillery units and the advancing infantry. In an era without tactical radio communications, rolling barrages presented a serious hazard to the attacking forces, as the intense artillery fire disrupted usual communications through noise, smoke, and breaks in telephone wire. Without accurate knowledge of the exact position of their own infantry, artillery fire could easily be lethal to the supported forces. As a result, aerial observers were assigned to observe the progress of the infantry advance, often by recognition of communication panels, and then to communicate with relevant artillery units by dropping of weighted messages.

*Regulation of Artillery*

Aerial observers could use their elevated perspective to direct friendly artillery fire, and to note flashes of enemy artillery to guide counter-battery fire. Hughes (n.d., pp. 4–5) reports that aerial photographs depicting shell craters in German territory convinced skeptical British artillery officers of the inaccuracy of their unobserved artillery fire, and of the merits of using aerial observers to observe artillery fire. Prior to the availability of wireless, aerial observers communicated with ground units by means of weighted messages.

*Visual Reconnaissance and Aerial Photography*

Initially, these first two activities were regarded as military aviation's primary missions. However, as the conflict continued, a third mission often assumed primary significance. Aerial observers were trained to monitor enemy territory and to report against a detailed checklist of possible enemy activities, including new weapons emplacements, presence of smoke, fresh tracks in open fields, massing of personnel, vehicle traffic, and many others (Table 1).

Initially, reconnaissance photography was regarded as an ancillary to visual reconnaissance, to document the observer's written report, which was cross-referenced to any photographs that had been acquired. Early aerial cameras were hand-held; they required manual operation to change photographic plates, one at time, in flight. As a result, early aerial photography did not provide systematic coverage, but was acquired to document specific scenes of special significance. In this context, there was no real role for photointerpretation in its modern meaning, as the photograph was intended to document features already identified by the observer.

Later, camera and aircraft designs matured. Once fuselage-mounted automatic cameras were employed photographic reconnaissance could be conducted by the pilot alone without as much reliance upon the observer. (Gorrell, Roll 34, p. 351; notes on aerial photography, R.A. Clapp). The advent of vertical photography required a new set of photointerpretation skills; the more abstract vertical image required application of more formalized interpretation skills, and opened avenues for development of analytical techniques, including mensuration and use of mosaics.

By 1918, it could be stated that ". . . the work of the observer and observation pilot is the most important and

TABLE 1. OBSERVER'S REPORT, 25 JUNE 1918, OBSERVATION FLIGHT: PONT-A-MOUSSON – METZ. (GORRELL, OBSERVERS RECONNAISSANCE REPORTS, J.H. SYNDER, P. 453)

OBSERVERS REPORT

| | | | | | | |
|---|---|---|---|---|---|---|
| 25 | June | 1918 | 3:55 | 5:25 | 5000 M. | Good |
| Day | Month | Year | Departure | Return | Altitude | Visibility |

| | | |
|---|---|---|
| Lt. Snyder | Lt. Kelty | Sal. No. 4 |
| Observer | Pilot | Machine |

| | | | |
|---|---|---|---|
| MISSION | Special Reconnaissance | PLATES EXPOSED | Nil |
| AREA COVERED | Pont-a-Mousson – Metz | | |

. . . . . .

| | |
|---|---|
| FIRES | Two (2) clouds of brownish black smoke from west side R.R. tracks 100 M.E. and 50 M.N. of Pournoy la Chetive at co-ordinates 84.7–48.2, at 4:44. There was too much smoke from factories and mist to observe anything in the R.R. yards. |
| TRAIN MOVEMENTS | Train at co-ordinates 89.0–54.0 going S.E. at 4:35.<br>Train at co-ordinates 86.0–56.1 going S.E. at 4:36.<br>Train going S.E. at Lemud 4:35.<br>Train at co-ordinates 93.6–52.2 going N.W. at 4:38.<br>Train at co-ordinates 89.0–58.9 going E at 4:40.<br>Train at co-ordinates 84.9–62.5 going N. at 4:40.<br>Train at co-ordinates 84.0–59.0 going S.W. at 4:40.<br>Train at co-ordinates 81.1–43.4 going S.W. at 4:40.<br>Narrow gauge train at co-ordinates 81.1–43.4 going S.W.? at 4:40. |
| HOSTILE ARTILLERY: | A.A. battery at co-ordinates 382.8–254.3 at 4:40. A.A.A. throughout course. High explosive shells were fired, as well as luminous incendiary shells, three luminous shell being suspended on wire. These were fired from the region of Orly and also Verny. |
| HOSTILE BALLOONS | Balloon in ascension at co-ordinates 86.7–43.7 at 4:35. |
| MISCELLANEOUS | Material on W. side of tracks at co-ordinates 87.8–47.1 at 4:30. Southern end of dump was camouflaged, while there was new material (apparently new lumber) at northern edge. Camouflaged objects on the west side of tracks at co-ordinates 84.7–48.1. apparently it was a dump about 75 M in length.<br>Two large barracks under construction at co-ordinates 89.3–46.3 at 4:37. At S.E. edge of Verny. No movement on roads |

far-reaching which an Air Service operating with an Army is called upon to perform." (Air Service History, Vol. 1, p. 104). As photographic reconnaissance increased in significance, it influenced techniques, equipment, organization, and tactics. Reconnaissance became a primary aviation mission (although aerial bombing was employed, it was still in its infancy), which formed the *raison d'être* of other missions. Aviation's pursuit (also, *chasse* refers to "hunter") mission focused upon protection of one's own reconnaissance aircraft, and denial of the enemy's ability to conduct reconnaissance over one's home territory.

## Organization

During World War I, each U.S. Army Corps was assigned an Observation Group, nominally composed of 771 personnel (141 commissioned, 631 enlisted), commanded by a Lieutenant Colonel, to provide logistical support for assigned observation squadrons. The Corps Observation Group consisted of a headquarters, two or more observation squadrons, and a photo section. The photo section, staffed by 30 enlisted personnel led by a 1st Lieutenant, provided technical support for processing of film and for printing of multiple copies for distribution.

The basic functional unit for aerial observation was the Observation Squadron, Air Service, usually assigned to support an infantry division.[4] Each Observation Squadron was staffed by 229 personnel, including 43 commissioned officers and 196 enlisted personnel. An observation squadron was commanded by a major, who was assigned flight duties as a pilot.[5] In all, 47 personnel (12 commissioned, 35 enlisted) were assigned flight status.

By September 1918, each squadron was assigned 24 aircraft organized into six air sections.[6] (Air Service History, Vol. 4, Tables, p. 516). Each squadron included an intelligence officer (1st Lieutenant,) supported by a draftsman (a sergeant), clerk, and two privates, who provided

[4]The plan approved by General Pershing in September 1917, modified previous plans to support 41 observation squadrons (7,093 personnel), to provide a total of 80 observation squadrons, intended for support of French and British units, as well as U.S. forces. (Air Services History, Vol. II., Early Concepts of Military Aviation, p. 136).

[5]The preferred age for pilots was between 19 and 24 years of age; that for observers, 23 to 30 years (Air Services History, Vol. 4, p. 9). Pilots could hold either officer or noncommissioned officer status, but the observer was always a trained tactical officer, because ". . . in reconnaissance of this nature an untrained person can not interpret the military significance of what he sees." (Air Services History, Vol. 2, p. 49).

courier service. It is noteworthy that the Observation Squadron included its own capability for examination of photographs, although it is not clear if this capability supported a genuine intelligence function.

The squadron headquarters staff was, in principal, staffed by non-fliers, preferably former pilots disqualified for flight service. A major or captain of infantry from the supported division was attached on a rotating two- or three-week schedule, intended to build an appreciation of value of aerial observation, and to nurture communication cohesion between the units. In his postwar review essay, Col. Frank P. Lahm, Chief of Air Service, Second Army, noted that: "Perhaps our weakest point has been in the lack of understanding between the Air Service (observation in particular) and the line." (Air Service History, Vol. 4, p. 19). His proposed remedy was to continue and expand the policy detailing of officers from Air Service to infantry line units, and *vice versa*, to provide each with first-hand familiarity with operations of the other's branch.

Each combat unit, including Air Service units, was assigned a Branch Intelligence Officer (BIO). Upon the entry of the U.S. into World War I, the War Department General Staff reinstated its Intelligence Division, and assigned intelligence officers to combat units as small as battalions. "This officer was responsible for the collection, compilation, and distribution of all information of the enemy pertaining, directly or indirectly, to aerial operations. He was further responsible for the collection, compilation, and transmission to all higher commands of information of the enemy gathered from Air Service sources." (Air Service History, Vol. 1 p. 173).

At the time, experienced combat arms officers were considered qualified for intelligence assignment; intelligence was considered to be a function integral to all combat units, so no special qualifications were considered to be requisite for this assignment. However, the rapid pace of technological change, especially in aviation and photography, equipped personnel in line units with skills and experience well beyond that of the experience of the BIO. This gap in experience led to inefficiencies that inhibited effective use of AEF's photoreconnaissance capabilities.

## Training

Because the skills required for aerial observation and photointerpretation had no civilian counterparts (and indeed, no military precedents), comprehensive training programs were required to prepare personnel for their duties. Curricula were based upon recently-acquired field experience, initially from British and French service, later from the AEF. In some instances, training programs designed for U.S. forces were to be implemented just as the war was concluding, so were in place for only a few months. Nonetheless, the design of these training programs reveals the procedures and techniques considered significant at the time.

In the absence of experienced AEF personnel, early training of aerial observers and pilots was conducted by French instructors at a school in Paris. Field exercises for training pilots and observers were conducted at several additional sites in France (Air Service History, Vol. 1, p. 105). By July 1918, the AEF had organized its own school for aerial observers and reconnaissance pilots (intended for Tours), but hostilities ended just as just as its first class was underway. Table 2 shows an abstract of the training program for intermediate aerial observers, and the following paragraphs describe training activities for which the availability of syllabi, lesson plans, lecture notes, and correspondence permit examination of the specifics.

### British Intelligence School, Harrow

The first cohort of U.S. Army intelligence officers was assigned to attend an eight week intelligence course, British School of Intelligence, Harrow: a course that provided a broad perspective on military intelligence, including aerial reconnaissance and aerial photography. About 30 officers attended the course (May through July 1918): six from the U.S., with the remainder from British and colonial services. The school was staffed by three British officers, with numerous guest lecturers from the War Office and the British Expeditionary Force, France. The course was dedicated to a comprehensive view of intelligence operations and analysis, primarily at the division level. The Harrow curriculum included organization of intelligence work, co-ordination of collection, and the plotting of information on maps and graphics.

"An instructional unit was specifically devoted to 'aeroplane photographs' and their roles within the intelligence sections of the Division, the Corps and the Army." (Hugh Maehay, 2nd Lt., Infantry, USR). The latter portion of the course specifically addressed intelligence applications of aerial photography in support of artillery and air squadrons,

TABLE 2. INTERMEDIATE TRAINING PROGRAM, AERIAL OBSERVERS (CONDENSED FROM GORRELL, ROLL 34, PP. 50–55)

| |
|---|
| Intermediate Training, Aerial Observers (one month) |
| 90 hours, Ground |
| Photo Interpretation: 10 hrs |
| Five lectures of one hour each, in which aerial photographs are projected upon a screen and explained by the instructor. The same picture should be projected the next day and the students called upon at random to interpret them. Five hours of individual work by each student in interpreting photographs, the transference of data from photos to maps of different scales by tracing on the map in India Ink anything of importance upon the photograph, the restitution of photographs, etc. |
| Assemblage of Photos: 5 hrs |
| Students should assemble the two most successful sets of the photographs which they themselves have taken. The assemblage should be well done and neatly lettered. |
| 35 hours, Air |
| Photo missions 10 hours |
| Every student should be practiced in three types of photo missions: (1) Consecutive overlapping photos; (2) Photos of separate objectives; (3) Oblique photos. Every student should have actual practice with each type of aerial camera in current use. Missions should be assigned graphically (i.e., by co-ordinates) and by the required scale. |
| Advanced reconnaissance 3 hrs<br>(continued first hand flight experience) |

*Source*: condensed from Gorrell, Roll 34, pp. 50–55.

[6]These totals, effective September 1918, increased the total aircraft from the 18 per squadron authorized in September 1917 (which provided 15 pilots and 3 flight commanders for observation) (Air Services History, Vol. 4, p. 50). However, the 1918 increase to 24 aircraft was not matched by an accompanying increase in authorized pilots, so the additional aircraft usually formed a much-needed maintenance reserve.

including exercises requiring students to use aerial photograph to ". . . make maps to plot into and record information on machine-gun emplacements, batteries, trench-mortars and aerodromes in the same way that Branch Intelligence Officers would be required to do in the field." (Donald N. McGibney, 1st Lt. Inf.).

#### AEF Intelligence School, Langres

The British course at Harrow formed the model for an AEF intelligence school, Langres (Haute Marne). In July 1918, LTC D.E. Nelson instructed Col. Conger to establish an AEF intelligence school, ". . . along the lines of the British school," to be led by "one of the best officers we have . . .", and staffed by ". . . reserve officers who are graduates of the British school."

A sample of the Langres instructional schedule (30 September to 09 November, six days a week, 7.75 hours a day, 0900 to 1700, and 2000 to 2100 each evening) shows content specifically pertaining to aerial photography and related topics. The percentages specify the contribution of each topic to the total hours of instruction within the course.

- map reading about 12 hours ( 4 percent)
- aerial photography, about 50 hours (18 percent) (including use of British and French materials, interpretation, restitution of aerial photographs, and study of enemy organization by aerial photography).

(Report: Training of Positive Intelligence Personnel, August 1918)

#### Photographic Intelligence Training within the U.S.

In August 1918, LTC M. Churchill, Chief, Military Intelligence Branch, General Staff, U.S. Army, submitted a report to the Chief of Staff, U.S. Army, critiquing intelligence training in U.S. Army schools in the U.S. The report specifies an intensive course of intelligence instruction: 28 hours per week for a minimum of six weeks. (p. 6). (Churchill, 1918, p. 6). ". . . the study of aerial photography could not be successfully pursued as no samples were available beyond those contained in text books on the subject which were supported by limited studies and no large scale complete maps of the terrain photographs." (Churchill, 1918, p. 3).

His report further comments upon absence of authentic training materials, including not only aerial photography, but also foreign maps, and captured enemy documents. In his concluding recommendations, LTC Churchill outlines requirements for training in applications of aerial photography: "Special training for officers and selected enlisted personnel of the regimental and division groups will be given by the G-2 of the division on interpretation of air photographs, preparation of summaries, and the recording of information by written and graphic methods, but this interaction may be undertaken after the close of the division school." (Churchill, 1918, p. 8).

Such statements offer further evidence of the perceived significance of training in applications of aerial photography, and the necessity for sound training of both officers and enlisted personnel at the division level, which would include not only divisional staff, but also personnel at regimental levels.

In addition, other training documents record specific training for pilots assigned to aerial observation missions. Specifics include: maintaining a planned flight plan in a side wind, flight strategies to acquire both vertical and oblique photography, flights to follow specific roads or rail lines, to position the route in the center of each frame, and formation flying to acquire systematic coverage. (Gorrell, Roll 34, p. 233)

Such material indicates that the AEF undertook a comprehensive training program in observation and reconnaissance; training that anticipated the basics of what, decades later, could be considered as a thorough program of study. The program emphasized the integration of photographic intelligence with other forms of intelligence. The syllabus built on experience of French and British forces in the field, and upon first-hand AEF experience. Training emphasized the significance of practical experience, and preparing students to prepare for photographic missions on short notice, including proficiency in quick calculation of fight altitudes required, to acquire required photography.

#### Aerial Reconnaissance Operations

Aerial photographic interpretation developed within the very specific operational conditions of World War I's Western Front: a single fixed, fortified front with constrained ranges of locations, environments, and observation missions. Within months after the onset of warfare, the front crystallized into a fixed trench system, leading to increasing dependence upon the artillery arm. In the context of this stable, fortified front, the commander's traditional reconnaissance resource (cavalry) could no longer fulfill its role to inform the commander of his enemy's activities. Aerial observation was well-positioned to fill this information gap. Further, the brutal effects of massed artillery barrages created large regions of impassible terrain, devoid of vegetative cover, difficult to patrol on foot, but open to observation from the air. Aerial reconnaissance was well-matched to perform well under these severe conditions.

AEF doctrine called for systematic, repeated coverage of each sector to facilitate detection of significant changes that could signal enemy activities or intentions. By 1918, aerial observation had become a key component of military operations, as is indicated by the systematic and detailed form of observation orders (Table 3).

To exploit the concealment of darkness, German logistical operations were most active during nighttime hours. Further, atmospheric conditions and effectiveness of enemy defenses during daylight hours often restricted effective aerial observation. Although night reconnaissance could be effective under favorable circumstances, only a few crews were trained for night reconnaissance, so the early morning observations were often considered optimum for reliable and timely detection of enemy activities.

Thus, the dawn patrol, celebrated in literature and cinema, was designed to observe enemy-held territory as soon as daylight could permit observation, to detect changes to trenches, wire, munitions dumps, and other evidence signaling enemy intentions. Although the phrase "dawn patrol" does not appear in the official histories used here, it is clearly stated that doctrine called for visual reconnaissance at dawn and twilight, to be supplemented with photographic missions. (Air Service History, Vol. 1, p. 191). Deep reconnaissance focused upon observation of construction in progress behind the front and enemy rail arteries, to detect unusual traffic, as indicators of enemy intentions.

Practice called for division of the front into sectors of responsibility (Figure 2), with a squadron assigned to conduct visual and photographic reconnaissance with each sector. Smaller sectors, closer to the front, were deemed to require more intensive effort, due to the diversity and intensity of activities underway near the front. The larger sectors, more distant from the front (F and G in Figure 2), required less intensive observation and so could be observed with fewer machines. However, these sectors required assignment to aircraft with the range to reach these zones, and the armament to protect themselves. This practice was intended to provide a steady, dependable flow of information

TABLE 3. EXAMPLE OBSERVATION PLAN: INITIAL PHASE OF THE MEUSE-ARGONNE OFFENSIVE

Appendix II

September 17th. 1918.

Observation Plan – Under Battle Instructions No. 2

1. The Enemy can, in addition to reacting on the front attack, do the following:
   a. On the right bank of the Meuse he can engage reserves which he always has in the area Damvillers-Mangiennes in order to attack either on the Haute de Mesue or by debouching from the Forest of Spincourt.
   b. On the left bank of the Meuse attempt an attack as a diversion or take away reserves from this part of the front and transport them to the right bank.
   c. Bring up reserves on both sides of the river from other parts of the front.
2. In consideration of the above the following observations will be carried out:
   a. On the right bank there must be constant observation of the area north of the Forest of Spincourt.
   b. In addition, reconnaissance carried out over the Montmedy – Longuyon – Spincourt – Audun-le-Roman would give notice of any arrival and unloading of reserves which might be brought from other parts of the front.
   c. On the left bank of the Meuse there must be constant observation of the area north of the Forest of Spincourt.
   d. In addition, reconnaissance must be pushed along the Mouzon—Dun-and Mouzon–St. Juvin railroads in order to determine is any unloading has taken place.
   e. Observation of the crossings over the Meuse are indispensable.
3. To carry out the foregoing plan the following instructions will govern:
   a. Observation Squadrons of the respective Corps will be responsible before operations for a depth of eight kilometers. Boundaries are indicated on map attached hereto. During operations units will not go beyond a depth of five kilometers unless they are provided with pursuit planes for protection.
   b. Enemy front lines will be photographed by Corps Machines at every opportunity. Prints of such photos will be sent to Army Dropping Ground by airplane delivery.
   c. Army Observation units will observe the area bounded on attached map by single green line, carrying out the missions indicated in paragraph #2 above.
   d. The necessary steps will be taken to secure the cooperation of the observation service of the 4th and 8th French Armies.

Approved: Willey Howell
Lt. Col. G.S.
A.C. of S, G-2

Wm Mitchell
Colonel, Air Service
Chief of Air Service

*Source:* The U.S. Air Service in World War I, Vol. II Early Concepts of Military Aviation. p. 328, Chapter ll. The Corps Observation Group.

from the front that could be integrated with other forms of intelligence: "During stable trench warfare photographic missions are a matter of daily routine to be accomplished by the Corps Air Service upon every day of favorable weather. During open warfare photographic missions are only occasional and are requested to clear up map obscurities or most other specific demands for information." (Air Service History, Vol. 2, p. 342).

For tactical control in flight, a squadron's aircraft were organized into *flights* of six aircraft, each commanded by a senior pilot, who reported to the Squadron Commander (Air Service History, Vol. 2, p. 342). Operational policy called for reconnaissance aircraft to be protected by at least two *chasse* aircraft (Air Service History, Vol. 1, p. 264). Sometimes, observation duties were split between several aircraft, to allow one to focus upon photographing railways, another on entrenchments, etc. (Air Service History, Vol. 1, p. 227). Deep reconnaissance often employed several planes, each equipped with a camera; planes could then alternate in assuming the photographer's role, acquiring images, then rotating to the protective screen, while another plane assumed responsibility for the photography (Air Service History, Vol. 1, p 264).

American Expeditionary Forces (AEF) doctrine called for aerial reconnaissance area extending into enemy-held territory equal to the depth of allied artillery range: "The pursuit elements of the enemy lines which is allotted to the Corps and Divisional Observation squadrons clear of enemy machines. In other words the aerial front line must be maintained, at minimum, as much in advance of the line of battle on the ground as the range of the Corps Artillery. Pursuit machines, therefore, specialize on the fighting, and of necessity have to adopt certain tactics, varying with the type of machine used, with the activity of the sector and with the altitude at which they are working, but certain principles are universal (Air Service, Vol.2, pp. 355).

Thus, pursuit aircraft were assigned the mission of maintaining air superiority over a zone extending into enemy territory at least as deep as the range of corps artillery. Allied artillery of the day was rated at a maximum range of about 6,675 meters (7,300 yards), so this policy specified a patrolling depth of about 6.7 kilometers (4.2 miles). Thus, even allowing for departures from normal procedure, the reconnaissance mission of this era was focused over a narrow, fixed, zone with known operational and geographic contexts.

## Equipment

Military aerial photography originated as an extension of visual aerial observation. The aerial camera formed a means of supplementing, or documenting, the observer's report with selected images, usually oblique views. Initially, aerial cameras were rudimentary hand-held instruments, usually with a simple sighting device. The observer, usually in the rear cockpit of a biplane, aimed the camera laterally seeking the best field of view possible through the obstructions formed by wings, struts, and supporting cables. Observers were subjected to propeller blast, which could inhibit accurate aim and contribute to camera motion. Oil spray thrown from the engine and carried by the propeller blast, could fog the lens.

### Camera Design

Aerial cameras experienced rapid evolution during the war. The following discussion follows Ives' (1920) categorization of cameras as (a) hand-held, non-automatic, (b) semi-automatic, or (c) automatic, even though these designations are not really distinct.

*Hand-held, Non-automatic Aerial Cameras*

Aerial camera design is discussed in detail by Gamble (1919) and Ives (1920). Although the very earliest experiments used off-the-shelf commercial cameras, there was rapid development of instrument specifically designed for use in the open cockpit of military aircraft, characterized by strong, rigid, construction, with brass hardware, pistol-grip handles, and a sighting reticule. The British-designed Thornton-Pickard aerial camera was constructed from seasoned mahogany or similar woods selected for their resistance to temperature changes associated with altitude. Controls were oversized to permit effective operation by photographers, who often wore heavy gloves in flight. Gamble (1919)

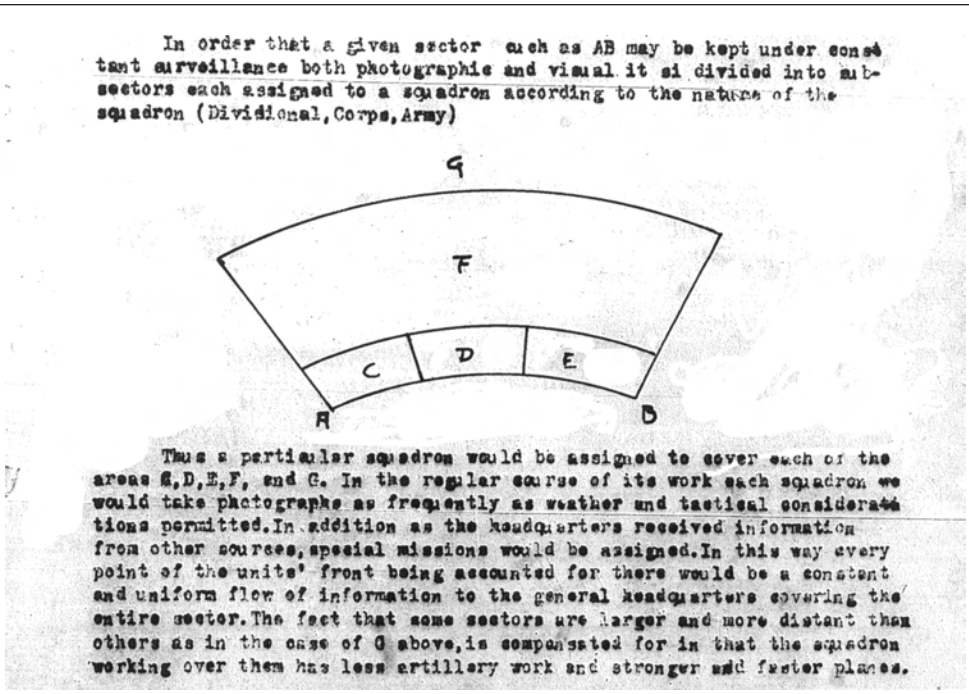



Figure 2. Sketch illustrating the assignment of squadrons to sectors at the front. Thomas E. Hibben, 1st Lt., 49th Inf., att AS: The Importance of Aerial Photographics in Intelligence (Gorrell, Roll 34, p. 267).

describes in detail the efforts that British designers and manufactures took to protect cameras from thermal expansion and contraction, including tests in thermal chambers. British and French designers eventually turned to aluminum frames to provide dimensional stability, and reduce weight. Such cameras could weigh 16 kg (35 lbs) or more.

Goddard (1969, pp. 10–11) provides a vivid description of the use of a hand-held, pistol-grip camera 3.6 to 5.5 kg (8 to 12 lbs) in weight: "The photographer stood in the rear cockpit belted in by a leather strap hooked to the inside cowl. In taking pictures, he looked through a viewfinder with cross-hairs and fired away at the prescribed area. Optimum altitude ranged from 12,000 to 15,000 feet and of course there was no such thing as an oxygen mask should it be necessary to go higher. When the picture had been taken and the aircraft was back on the ground, the men in the laboratory field units raced against time to get the pictures developed. Ten minutes was considered fast work."

Observers were instructed to keep the camera clear of the fuselage (to avoid effects of vibration), and to avoid an instinctive inclination to aim the camera too high, thereby recording the desired target at the lower edge of the plate, rather than near the center (Maurer, 1979, Vol. 1, p. 355) (Figure 3).

Cameras of the day used plates to record each image. For vertical photography, photographers were instructed to orient the camera such that the width of the plate was parallel to the line of flight, and to acquire one-third to one-half overlap, to allow for effects of variations in speed or altitude upon coverage. Although instruction explicitly covered stereo photography, the principal motivation for this amount of overlap seemed to focus upon acquisition of continuous coverage for compilation of mosaics. (Russell Clapp; Gorrell, Roll 34, pp. 353–355).

*Side-mounted Cameras*

Initially, it was necessary to manually change each plate as a new exposure was required. The approved technique for rapid change of plates in flight was explicitly addressed in training programs. Later, hand-held cameras were replaced by side-mounted cameras, initially with magazines of 12 or so plates each (Figures 4 and 5). Nonetheless, even with use of side-mounted camera, observers were required to lean over the side of the open cockpit to change magazines.

Although hand-held aerial cameras were superseded by more advanced designs, they remained in use throughout the war, due to their flexibility and ability to aim at targets of opportunity. In their more advanced forms, hand-held cameras were extensively used through World War II and later. The difficulty of changing plates during flight was one of the principal incentives driving the evolution of aerial cameras. The operator of a s*emi-automatic* aerial camera triggered the shutter as needed, but plates were changed by a mechanical device, powered by any of several alternative mechanical devices, including timers, electrical mechanism, and air-driven propellers.

Finally, *fully automatic* aerial cameras could acquire exposures at set intervals, established by the camera operator. Ives (1920, p. 125) reports that the fully automatic designs of the day were often undependable, and that observers favored the availability of a semi-automatic override to permit the operator to respond to unanticipated tactical situations, and to address mechanical failures.

An important U.S. contribution to the progress of aerial photoreconnaissance was the deployment of the de Ram aerial camera (Figure 6), described by Ives (1920) as the "only completely automatic plate-changing camera produced commercially before the end of the war," (Ives, 1920, p.129). This camera was designed by Lt. G. de Ram, French Air Service, who had previously offered the design to the


Figure 3. Hand-held Aeroplane Graflex Camera, circa 1917 to 1918. This photograph depicts many of the conditions mentioned in the text, including the rudimentary sighting device, exposed position of the observer, the difficulty of communication between the observer and the pilot, and the obstacles presented by struts and wires. U.S. National Archives and Records Administration, Still Pictures, ARC 530712.

French government. Although his camera was declined by the French, the U.S. Air Service, AEF, adopted it in 1917. The de Ram was produced in many versions and used extensively both during and after the war; the French model was designed as fully automatic, while a U.S. model was designed for semi-automatic operation.

The de Ram carried a magazine of 50 plates, 18 cm × 24 cm (7 in × 9.5 in). Some models powered shutter operation and the plate changing by a constant-speed propeller positioned in the slip stream; later models were powered electrically. Mechanical power was transmitted to the camera through a Bowden wire (a specific design for a flexible sleeved cable), which also permitted the operator to set intervals between exposures. The de Ram design was first used by U.S. forces in the Argonne offensive, early 1918 (U.S. Army History, 1919, Vol. 15, p. 286).

#### Camera Supports

When the de Ram was loaded with a magazine of 50 plates, it weighed about 100 lbs., large and heavy, even by contemporary standards. Its size and weight accelerated efforts to design mounts suitable for positioning aerial cameras within the fuselage. Earlier experiments with mounting semi-automatic cameras on the exterior of the fuselage (chiefly a British practice) were not practical due to excessive vibration and the requirement for the operator to lean into the slipstream to change plates and address malfunctions. Alternatively, installation of the camera directly in the fuselage subjected the camera to excessive vibration.

The AEF devoted considerable attention to devising systems for deploying cameras within the fuselage (Figures 7 and 8). In June and July 1918, AEF undertook an intensive effort to design suspensions suitable for mounting aerial cameras within the fuselage. Ives (1920) and archival photographs document the many efforts to design mounts to install the de Ram in the fuselage. Although theory offered several design options, practical considerations led to use of springs and rubber cushions to dampen vibrations, or to use of pendular supports (Figure 6). One reason this issue received such serious attention was the recognition that proper stabilization and orientation of the camera formed a prerequisite for use of aerial photography for accurate mapping and measurement. In other words, practitioners of the day were looking beyond immediate applications to set the stage for more rigorous applications of aerial photography. Thus, U.S. military experimentation with camera mounts during this era appears to have set the stage for postwar designs for both military and civil applications of aerial cameras. (U.S. Army, 1919, Vol. 13, G-2).

In 1918, Major James W. Bagley (a USGS employee prior to U.S. entry into the war) was assigned to the European theatre to conduct field tests with an experimental three-lens

Figure 4. Curtiss JN-4, with external mount for aerial camera. The camera appears to be a (British) Thornton-Pickard "Type C" (or variant thereof) first manufactured in 1915. U.S. National Archives and Records Administration, Still Pictures, E-6401.

aerial camera (Air Service History, Vol. 13, p. 58.) Bagley's earlier USGS work applied photogrammetric principals to topographic mapping using terrestrial photography, and outlined applications of his techniques to aerial photography (Bagley, 1917). Although Bagley's team arrived in Europe too late to complete the planned trials under wartime conditions, the camera was evaluated after the Armistice to photograph sectors of the St-Mihel and Meuse-Argonne battlefields to assess its effectiveness for military reconnaissance. Bagley's design was judged to be effective, although opinion favored the use of a longer focal length camera for military use (Air Service History, Vol. 13, p. 65). After the war, the Bagley design became a key component of civil aerial survey.

#### Photographic Plates

Although roll film had been available for decades prior to the war, and aerial film cameras had been developed during the war, Allied military services relied upon use of glass plates. Although plates and their sheaths were heavy, and difficult to handle, they were considered superior to films available at the time. Ives (1920, pp. 237–238) stated that ". . . emulsions on film have not yet proved the equal of those on glass." Ives also discusses the unproven dimensional stability of film bases of the day, and problems encountered with static discharge on images. Likewise, the discussion in Air Service History (Vol. 13, p. 65), refers specifically to the "disadvantage of all film cameras in requiring more favorable weather conditions that plate cameras," and to the comparative suitability of film cameras for commercial applications, in which weather conditions are not as severe. Presumably, references to the relationship between roll film and weather are based upon the requirement for military missions to photograph under marginal atmospheric conditions, and a perceived or genuine superiority of the photographic plate of the day for this purpose.

## Photointerpretation

Information at hand documents use of a broad range of photointerpretation techniques, encompassing a surprisingly large proportion of the current repertoire of techniques. Initially, aerial photographs were regarded as an ancillary to the observer's report.

Observers using hand-held cameras, common during the early era of aerial photography, specifically selected targets, and acquired photographs that formed individualized illustrations of features noted in the observer's report. Many, if not most, were oblique images that required less rather than more interpretation talent. Tactical annotations of photographs marked weapons positions, trenches, barbed wire, and concertina (a frequent comment concerns the difficulty of observing the placement of barbed wire emplacements on aerial photographs). Aerial photographs,


Figure 5. De Haviland DH-4, with port for oblique photography. The photographer wears a chest-mounted microphone for communication with the pilot, and holds a supply of plates for the camera. U.S. National Archives and Records Administration, Still Pictures, E-4156.

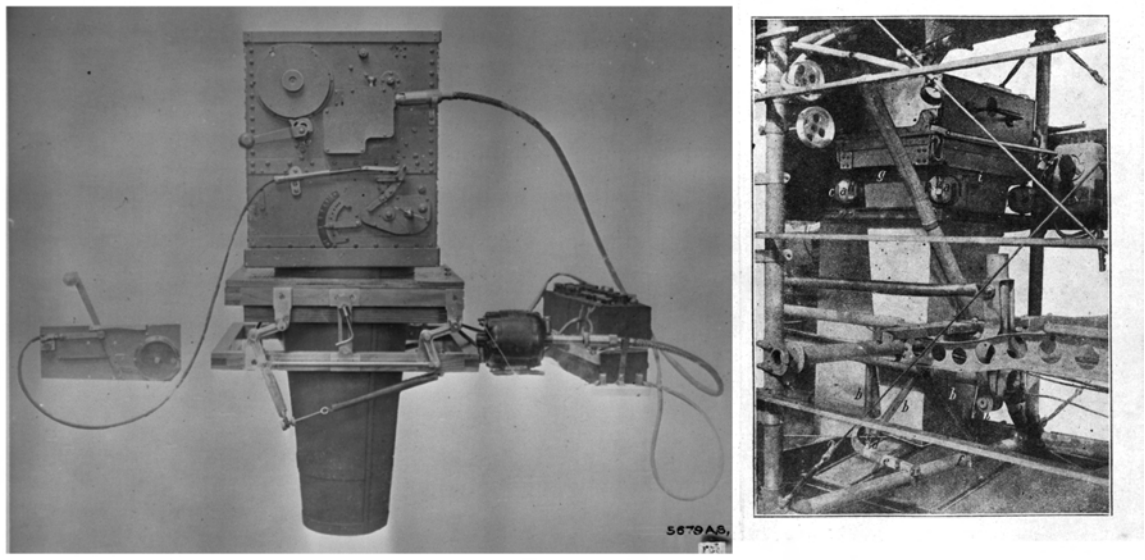
usually obliques, were annotated to show attacking infantry the positions of critical routes and landmarks: "One of the contributing factors of the success of the drive at St. Mihiel was the splendid photography of the enemie's (sic) works as done by the Observation Squadrons. For days before the attack they coursed up and own the lines taking pictures of the front line works of enemy, his batteries, and his contemplated battery positions. His machine-gun nests were shown up, his barbed-wire entanglements, and his communication trenches. Before the infantry went over the top each platoon commander knew from the photographs in his possession the exact nature of the terrain over which his men had to advance." (Gorrell, Roll 34, p.359; To pilots of observation squadrons, Ralph E. deCastro, 1st Lt., A.S., First Aero Squadron).

Later, as automated cameras were more widely used, and the use of the vertical aerial photograph increased, it would seem likely that the link between the observer/photographer and the image weakened, and extraction of information would require a more abstract and formalized approach: ". . . a Reconnaissance mission has ceased to be merely an expedition to see and record things and has become a mission during which areas are photographed and then, when the prints are interpreted, the information extracted is pooled with that recorded by the observer. (Russell A. Clapp, 1st Lt., F.A., Notes on Aerial Photography, 3rd A.I.C.; Gorrell, Roll 34, p. 351.)

In this context, interpretation procedures evolved to apply higher order analyses, requiring a broad range of information and analytical skills: "Take the plate of a recent photograph and project it upon a screen, drawing the outline of the elements of the system. Later another recent plate of the same area is put upon the screen. Orient it by having the same points coincide and any new elements can be readily seen and drawn in." (Russell A. Clapp, 1st Lt. F.A., Notes on Aerial Photography, 3rd A.I.C.; Gorrell, Roll 34, p. 351).

"An excellent map can be map by taking a photograph and tracing in India Ink everything of military importance on the photograph. The print is then put in an acid solution and everything but the inked lines disappear. An Infantry Commander preparing an attack over unfamiliar grounds is given the nearest thing possible to an aeroplane ride over the terrain – he receives a photograph of it (an oblique view is preferable for this use)." (Notes on Aerial Photography Russell A Clapp; Gorrell, Roll 34, p. 351).

Photointerpretation practices of the era clearly defined the basics of flight planning, scale calculations, change detection, preparation of reports and overlays. Training syllabi and lecture notes indicate an appreciation of the geometric errors introduced by tilt and relief displacement. Intelligence applications, however, did not address positional errors in a systematic manner, no doubt in part because relevant interpretation tasks did not depend upon




(a) (b)

Figure 6. The de Ram aerial camera and illustration of camera suspension: (a) lateral view of the U.S. version of the de Ram camera, showing operator's controls, battery, motorized drive, and electrical connections, and (b) lateral view one of many systems for suspending aerial cameras within the aircraft fuselage. This example appears to show the 50-centimeter de Maria camera positioned on a tennis-ball-type mounting (one of many alternative systems intended to maintain orientation and protect the camera from vibration). U.S. National Archives and Records Administration Still Pictures, NARA 342-FH-3B:11929-5679-AC and 18-E-5928.

linear or areal measurements, and in part because practical procedures to address the issue were not then at hand. Nonetheless, interpreters did apply *ad hoc* methods to extract positional information. For example, Collier (2002) discusses the use of aerial photography during World War I to update maps through the use of proportional dividers to transfer detail from photographs to the maps. MacLeod (1919) reports the use of optical projection to produce planimetric representations of oblique aerial photographs, a practice apparently favored by British photointerpreters.

#### Cataloging and Indexing

During the U.S. experience in World War I, we can discern the beginnings of systematic indexing of photography. *The U.S. Air Service in World War I* describes procedures used to organize and index photographic coverage. The photographic laboratory prepared three copies of each photograph. One copy of each photograph was to be maintained in the Intelligence Office as a file copy, and the other two copies in placed in the Operations Room for ready reference by observers. The Intelligence Officer maintained a card index for each photograph, indicating camera used, co-ordinates of the photographic center, identification of each frame, altitude, date, and an assessment of photographic quality.

A map marked with a one-kilometer grid designated those cards describing photographic coverage within each cell. The photographs themselves were stored in a grid of *pigeon holes* replicating the geographic grid. Further, another map plotted each mission, summarized weekly and monthly, and a book indexed each frame to the observer who acquired each photograph. Accounts mention the value of posting a panoramic photograph of each unit's sector, as well as photographic mosaics, for the benefit of the intelligence and operations staff. These practices anticipate later acceptance of such procedures as the basis for routine operations in photointerpretation and remote sensing.

#### Stereoscopic Analysis

At the time of World War I, stereoscopic images were commonplace as educational aids, and as a novelty within the home. Application of stereoscopy to aerial imagery was well understood (apparently, stereoscopic aerial photography was first employed in the military arena by the French (see Collier, 2002; Air Service History, Vol. 1, p. 65). A.E.F. training syllabi and lecture notes clearly document that the value of stereoscopic analysis was recognized by instructors and practitioners of photo reconnaissance. Yet, comments such as the following indicate that the stereoscope was not then employed as an effective tool: "Stereoscopic prints were only occasionally called for." . . . "Initiative in these direction[s] on the part of Photographic Sections was discouraged and there was a general atmosphere concerning these things which suggested it was none of our affair and did not conform to Army Intelligence Regulations. It was not until towards the end of hostilities and after the Photographic Sections had thoroughly demonstrated their efficiency by promptly meeting every proposition placed before them, that a larger leeway was given and a few more months would have seen the present relationship considerably changed in our favor." (Air Service History, Vol. 4, p. 296).

"A number of specialists, stereoscopic printers, had been trained at the Photo School, 2nd A.I.C., with a view to assigning them to the various Photo Sections at the front. All photo missions could then have been sent out in stereo-prints as well as the usual single prints. This would have materially increased the work of the Photo Section in the


Figure 7. 2nd A.I.C. Aerial Photography School, Tours. Demonstration of aerial photographer's technique for oblique photography, using a cut-away segment of the De Havilland DH-4 fuselage. It appears that the photographer is wearing a chest-mounted microphone for communication with the pilot. U.S. National Archives and Records Administration, Still Pictures, E-6402.

field. The experiment was successful, and in a short time this would have become a general practice, and the value of the photographs to those studying them would have been very materially increased adoption of our Richard stereoscope to the Intelligence Section. This was done and the instruments were secured by their Supply Service, but, to the best of our information they were never issued to the Branch Intelligence Officers and the Photographic Sections were consequently never called upon to make the stereopositives required for use in these instruments." (Air Service History, Vol. 4, p. 296).

These statements are confirmed by examination of the many photographs taken to document activities underway at AEF schools, units, and headquarters offices (Figure 9). Clearly, many, if not most, of these photographs are posed, to document practices in use at the time, and to show units in their most favorable light. Use of the stereoscope is rarely, if ever, recorded by these photographs, suggesting that it was not widely used, and that it was not regarded as an important activity of sufficient significance to be included as an important part of the history of the intelligence effort.

#### Mosaics

Air photo mosaics ("assemblages") are often prominently featured in photographs documenting activities of Air Service units, and were included in syllabi and lesson plans of the Air Service schools. One comment from the "lessons learned" essays provides a jaded perspective on official practice at one headquarters: "The Photographic Section was rarely asked to make assemblages except for office ornaments." . . . "Not once was [a] large assemblage requested of an entire sector." (Air Service History, Vol. 4, p. 296).

#### Formalization

Although the overall curricula for instruction in aerial observation and photointerpretation was clearly organized and systematized, lecture notes, when available, suggest that instructor's lectures were highly individualized, apparently based upon personal experience rather than a formalized curriculum. For example, explicit listing of the "elements of image interpretation," a common component of later interpretation doctrine, does not appear in instructional or operational documents. Thus, there is little to suggest an effort to systematize interpretation strategies. The numerous field and technical manuals later so abundant during World War II are absent. Those military instructional materials now at hand that were prepared for publication as books or handbooks (e.g., Grieves, 1917) seem to focus upon map reading, with little or no reference to aerial photography. These observations suggest that the substantial experience gained from first-hand practice at the front was not institutionalized within the Air Service.


Figure 8. 2nd A.I.C. Aerial Photography School, Tours. Students examining a cutaway fuselage demonstrating mounting of aerial cameras oriented for vertical photography. U.S. National Archives and Records Administration, Still Pictures, E-4130.

## Aerial Mapping: The 29th Engineers and the U.S. Geological Survey

As aerial photointerpretation was maturing as a source of tactical intelligence, photography was also becoming a significant source of information for military mapping and geodesy. Artillery, the dominant arm of World War I combat, depends upon accurate topographic mapping. Although at a broad scale the front was geographically stable, at a local level the military situation was highly dynamic requiring constant revision of maps and map coverage. Routine operations required timely reproduction and distribution of maps and photographs to field units. Further, construction of logistical infrastructure, including rail systems, barracks, hospitals, and aerodromes often constructed under deadline to meet immediate demands of a dynamic military situation, required intensive mapping supported by aerial photography.

Aerial mapping operations differed from intelligence mission of visual and photoreconnaissance. Reconnaissance cameras soon were tailored for high altitude operations, with long focal lengths, to acquire detail from altitudes high enough to provide some protection from hostile fire. Aerial mapping must be supported by lower altitude photography, using shorter focal lengths to view broader regions encompassing the sparse network of landmarks and topographic control. (U.S. Army, 1919, Reports of the Commandants, Staff Sections, and Service, Vol. 13, p. 65).

Although the intelligence community was incremental in its development of methods for systematic "restitution" of aerial photography to remove positional errors, this issue was aggressively pursued by military engineers. Although reconnaissance and intelligence components of Air Service squadrons were clearly cognizant of the geometric qualities of aerial photographs and the difficulties of deriving accurate measurements, it was the Corps of Engineers that aggressively applied systematic photogrammetric analysis to derive detailed terrain data. Bagley's (1917) work applied photogrammetric methods to derive topography from panoramic photography, including an appendix applying photogrammetric principals to aerial photography, specifically noting (Bagley, 1917, p.64) the utility of "employment of aerial photographs in making military reconnaissance."

In August 1916, a Division of Military Survey was proposed as a component of the U.S. armed services. In January 1917, such an organization was established, and staffed initially by volunteer topographers and surveyors from the U.S. Geological Survey (USGS). Its initial mission was to prepare topographic surveys of military reservations, U.S. frontiers, and industrial complexes related to the war effort.

The 29th Engineers (eventually consisting of two battalions, without a regimental headquarters) was organized at Camp Devens (Ayer, Massachusetts) under the leadership of Glenn S. Smith, who had acquired familiarity with military surveys during his USGS service in the western United


Figure 9. 2nd A.I.C. Aerial Photography School, Tours, Mosaics and Drafting Department. Examination reveals use of templates, maps, drafting equipment, magnifying glasses, and adhesives. U.S. National Archives and Records Administration, Still Pictures, E-4160.

States. Many of the officers and senior enlisted personnel were also drawn from the USGS. The 29th Engineers arrived in France in December 1918. It established a base at Langres (Haute Marne), where it began production of battle maps: "The Base Printing Plant, established and operated by the 29th Engineers, was one of the best equipped plants of its kind in existence, as it had the most modern reproduction machinery and methods, and it was able to reproduce a large majority of the maps with which the American armies were always supplied. The total number reproduced and used between July 1 and November 11, 1918, was in excess of five million. The study, restitution from aerial photographs, and overprinting of the enemy's defensive organization on these maps to make the Battle Map, or *Plan Directeur*, and the establishment of artillery firing data." (U.S. Army, 1919, Vol. 13, Reports of the Commandants, Staff Sections, and Services, p. 8).

In January 1918, when the U.S. First Infantry Division assumed its position at the front, in the Toul sector, it requested a detachment of 29th Engineer specialists to support division headquarters: "There was need at division headquarters of a topographic officer and draftsmen to make hasty drawings, sketches, and diagrams for the general staff of the division, study aeroplane photographs of enemy territory, to keep up to date the sector maps showing both intelligence and operations information, to distribute maps, and to collect and forward to the corps at prescribed intervals the corrections in trenches and other military features for incorporation in new editions of the battle map at army headquarters." (U.S. Army, 1919, Vol. 13, Reports of the Commandants, Staff Sections, and Services, p. 53).

From this statement, and others, it is clear that expertise in applications of aerial photography formed an important dimension to the operations of the 29th Engineers. Over time, such requests multiplied to the point that support of division and corps headquarters staffs become a drain on the resources of the 29th Engineers: another indication of the demand for practical expertise in applications of aerial photography.

Coll *et al.* (1953), in their review of contribution of aerial photography to military mapping in World War II, commented on the relationship between stabilized front upon the mapping mission: "The stabilized trench warfare of World War I accustomed American Artillery Units to the highly accurate large scale (1:20,000) battle map for firing on unobservable targets . . ." (Coll *et al.*, 1953, p. 64). Their statement forms a comment on the high caliber of the AEF's military mapping during World War I, as seen from a post-World War II perspective.

## Effective Organization of the Photointerpretation Function

Of the numerous technical and organizational obstacles encountered in the development of effective aerial photo reconnaissance, perhaps the most serious was the organization and staffing of the photointerpretation function. Although key expertise resided, at various stages in the evolution of aerial

photoreconnaissance, within the realms of the pilot, the observer/photographer, and the photointerpreter, the prevailing organizational structure formalized the photointerpretation function as the responsibility of the intelligence officer: "The mission was not considered completed until plates had been identified with respect to their location on the terrain and the interpretation completed and reported to the tactical authorities concerned. Report on interpretation was rendered in every case by the intelligence officer, not by the observer, whose report merely recounted the routine incidents of the flight." (Air Service History, Vol. 1, p. 181).

The *status quo* of the day placed interpretation in the domain of the Branch Intelligence Officer (BIO), mentioned previously. The BIO held a staff assignment, usually without direct practical experience with, or even a conceptual understanding of, photographic intelligence. As intelligence is a function of all combat units, no special qualifications were considered as prerequisite for this assignment. But, because of the sudden appearance and rapid evolution of photographic reconnaissance, only the junior officers would be prepared with the skills and perspectives to master, or to supervise, photointerpretation duties. This context can account for comments such as the following: "It is not believed that . . . full benefit was obtained from the work of the photographic section because of the inadequate training and lack of knowledge on the part of Intelligence officers who did the interpretation." "They had no knowledge of the use of the stereoscope and it was only toward the latter days of the war when photographic sections forced stereoscopes upon them that they knew such a thing existed." (Gorrell, Roll 24, p. 141).

By the end of the war, there was widespread concern expressed within the AEF about the effectiveness of its photointerpretation effort, the efficient flow of photographic intelligence from its source to the front-line commander, and the status of photoreconnaissance (Gorrell, Roll 24, pp. 293–295) within the AEF.

## Summary

World War I formed the incubator for the development of aerial photography and photointerpretation. Prior to the war, military leaders and institutions expressed little interest in aviation, not to mention aerial reconnaissance. (General Ferdinand Foch's oft-quoted statement, in 1911, that ". . . aviation is a good sport, but for the army it is useless" illustrates this attitude.) Yet, once the conflict was underway, the early loss of traditional reconnaissance capabilities created a niche closely matched to the capabilities of aerial reconnaissance. Its demonstrated practical value drove the integration of technology, organization, and skilled personnel to create a new and effective reconnaissance capability.

The World War I experience provides some glimpses into the future evolution of the photointerpretation. Even at this early date, outlines of later capabilities are recognizable, including registration of images, stereoscopic photography, systematic detection of changes, and the transfer of relevant detail from one medium to another: capabilities that define the field as a distinct body of knowledge and practice.

Yet, these achievements failed to produce an enduring organizational response. For two decades (to the eve of World War II) the field struggled (with notable exceptions) to regain the momentum that had been underway during 1918: "After World War I, interest in photo intelligence diminished practically to the vanishing point. As a result, at the outbreak of World War II, the Armed Forces were caught with obsolete cameras and no organization, equipment, or trained personnel to exploit what was to become a major source of intelligence." (*Infantry Journal*, 1949, p. 28).

Aside from a few visionaries, ". . . no one in the Air Service gave a tin nickel for the advancement of aerial photography." "Furthermore, neither the infantry nor the cavalry understood the value of photography." "In fact, its safe to say that while the U.S. Army cared about reconnaissance, it cared very little about reconnaissance from the air . . ." (Goddard, 1969, p. 21).

"Like the rest of the Army, the AEF tended at first to emphasize the development of fighting units to the neglect of supporting organizations. By the time photo reconnaissance aviation assumed its proper position in relation to fighting elements it was too late to make the radical changes that full exploitation demanded." (Coll *et al.*, 1953, p. 463)

Thus, as World War I concluded in 1918, the practice of aerial photointerpretation had progressed beyond the ability of the organizational infrastructure to sustain progress of the previous years and to consolidate its progress. The end of the war also ended the incentive to sustain progress, and to continue investment in photographic reconnaissance and photointerpretation.

Failure in the inter-war era to value aerial reconnaissance as an essential component of intelligence formed a precursor of the events of the following decades, in which military aerial photoreconnaissance and its civil counterparts "failed to thrive." During the postwar era, success of photoreconnaissance was, of course, clearly linked to broader uncertainty and dispute about the role of aviation: a debate fought at the highest levels of U.S. military and civil leadership. The result was that the value of photographic reconnaissance was not recognized by military or civil leadership. Its value was unproven in the civil arena, institutions lacked a compelling social incentive to invest in an effective and proven technology, and recognition of its capabilities was delayed by decades.

Practices of this era established the threads of technology, methodology, and procedure that formed foundations for later photographic technology, flight operations, and interpretation methodology. However, it is context for these technological innovations that may form the era's most significant characteristic. The aerial camera and the practice of aerial reconnaissance originated through first-hand experimentation and improvisation by front-line practitioners without direction from senior leadership, and without (as would be the case later) the support of a formalized research and development bureaucracy.

Origins of aerial reconnaissance were based upon the availability of two ostensibly incompatible technologies (the camera and the airplane) that could be modified for new applications. Technical expertise, workforce, and production facilities were available in reasonable proximity to the front to permit rapid response to the needs of field units. Development of early aerial photography was characterized by a wide variety of alternative camera designs, rapid abandonment of impractical configurations, a focus upon optimization for human factors, and evolution towards development of the capabilities of the aerial camera to provide accurate measurements. The local, bottom-up, character of innovation probably accounts for the uneven support, slow pace of institutionalization that aerial photography encountered during the interval 1919 to 1939. Aerial reconnaissance's origins in front-line improvisation provided advantages for innovation during the conflict, but formed a disadvantage later, in the form of weak institutional and societal support during the inter-war era.

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### A Note on Sources

In 1918, Col. Edgar. S. Gorrell, U.S. Army Signal Corps, was directed to prepare a history and final report on U.S. air activities in Europe during World War I. Gorrell and his staff solicited documents, photographs, reports, and essays from throughout the AEF Air Service at the conclusion of the conflict. Material from this vast and rich collection, gathered before first-hand evidence was destroyed or dispersed, was later distributed in various forms within the military services, but the materials were never fully edited or widely distributed. However, a microfilm record of Gorrell's collection (58 reels of 35 mm microfilm) is available at the U.S. National Archives (College Park, Maryland) as "Gorrell's History of the Air Service, AEF." (M990). It is referenced here as "Gorrell," with reference to specific locations within the (National Achieves and Records Administration) (NARA) microfilm. Although some of Gorrell's material has been used to prepare Mauer's *The U.S. Air Service in World War* I (1978), the two works differ in character and organization. Other NARA material used for this article has been identified by record group, date, and the identity of the correspondent or title of the document.

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