*One Hundred Years of Photogrammetry**

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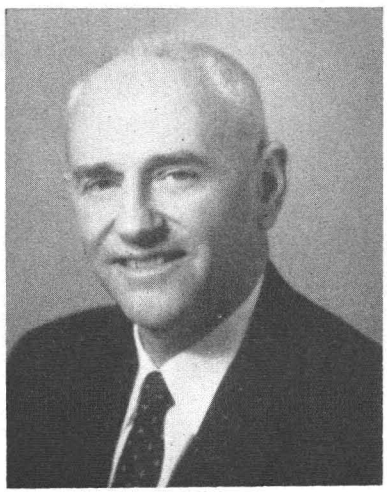
THERE are a good many reasons why the Babylonians, something over 2,000 years B.C., did not use photogrammetric principles in their map making. In those days maps were impressed on tablets of clay, admittedly an awkward material for use in the wide dissemination of information. Paper wasn't invented until a couple of thousand years later, and glass was not made in flat sheets for centuries after that.

But men prepared remarkably good maps. Ptolemy drew one on papyrus, showing a round world, with most accurate detail of the regions centering on the Mediterranean.

Paper is an essential in cartography today, and was first made in America in 1690. Then for another century or so, nothing else of photogrammetric or cartographic significance occurred.

The creation of an image for the first time was probably accidental, resulting perhaps from a pinhole in a box, or a sphere of glass—the fortuitous product of someone's fire on the beach. The second definite step toward a realization of photogrammetry was the first designed lens which was ground in 1812. Lenses, however, for a long time following this were pretty crude, producing severe color fringes, spherical aberration, astigmatism, and all of the other properties which the lens designer abhors. But in 1841 a lens was made which gave some glimmerings of things to come. It was the Petzval portrait lens, which produced a fine image covering a field of more than 20°, and had a speed of F/3.6. And a few years later came the ubiquitous Hypergon, covering 72°, but through the limiting stop of F/36. This lens was distortion free, but its resolution was still far from good.

Just about a hundred years ago, the emulsions of Niepce and Daguerre, coated on copper, with the lens—now nearly fifty years since its invention—and a balloon, were put together by an adventurer named Nadar to create the first aerial pictures. And the father of photogrammetry, the Frenchman Laussedat, drew a map on paper from Nadar's pictures.



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This early and remarkable combination for the first time of the elements necessary for photogrammetry, however, died a-borning. Even though the dry plate was invented in 1855, and was perfected to a point by 1874 where it would record a picture through a lens at F/16 in sunlight, with only 30 to 60 seconds exposure, photogrammetry as a practical thing was still a long ways off. In 1891 came film, although plates were still used for a considerable period of time in most photogrammetric operations.

The first practical commercial use of photogrammetry is credited to Deville, the Surveyor General of Canada, who made and used a photo-theodolite to take pictures from mountain tops in the Canadian Rockies in stereoscopic relationship, and who built a stereo-plotter by means of which the pictures could be viewed in three-dimensional relief so that a contour could be recognized, isolated as to elevation and drawn on paper. This was a great step toward reducing the wilderness to

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paper, and crude as the methods were, no one was prepared to squabble then, nor for a long time later, over hundredths of a millimeter.

Four years into this century Scheimpflug, the great Austrian inventor, was not content with a narrow-angle picture, and built an 8-lens camera, so that a picture from a balloon would make possible covering more terrain. Little did he realize that just the year before, in 1903, the Wright Brothers, at Kitty Hawk, had breathed life possibilities into the still picture business of photogrammetry as it stood that day. Unmindful of this fact and undaunted, Scheimpflug, however, took his eight oblique pictures, designed and built a transformer and rectified them into a unitary image. As a result he created a name the pronunciation of which today is the badge of the accomplished photogrammetrist.

Things rocked along for another ten years, until in World War I the stick and muslin airplane which up to then, quite unwanted and unsupported, had played the role of country fair thriller, graduated into practical use when put to work by both sides to observe the enemy. To begin with, these air mounted observers enjoyed a happy chivalry, with trophies from their ladies fair fluttering from their helmets in the open cockpit breeze, waving at one another when meeting in the skies, and carrying home verbal reports of what they had seen. Things soon, however, got grimmer, and passing pilots thumbed their noses or threw monkey wrenches or any handy missiles. Thus began the transition from chivalry, and soon they were shooting at each other with machine guns synchronized through the propellor blades. It was no longer possible to go about the leisurely job of observing by eye, and sketching on a board strapped to the pilot's knee. Now there were enemy planes aloft to harrass the observer. And so the aerial camera came into its element. Hung over the side it could in an instant record the total exquisite detail which a man unaided could never draw and never remember. The era of aerial photography was upon us!

In the meantime, terrestrial photogrammetry had been moving on apace. Von Orel had built his stereoautograph, which went a stride beyond Deville, placing the stereoscopic pictures in a very precise and ingenious mechanism for plotting pictures taken from accurately measured base lines at precisely known angles.

The airplane bobbing amongst the clouds on its most unstable platform could also produce stereoscopic pictures of sorts, but they were taken from uncertain base distances and at indeterminage angles; it seemed presumptuous indeed to think that such casual pictures could ever be used in the meticulous business of measuring for maps. Furthermore, in order to take pictures from the air on the slow emulsions of that day, faster lenses had to be devised for use, and speed in lenses like the Tessar was gained at the price of severe distortion.

During the period of World War I, it became apparent that a very useful, though crude, military reconnaissance type of map could be made by pasting overlapping pictures together into mosaics. And when World War I ended in 1918, and for some years thereafter, we were complacent with the American cartographer's Rubaiyat: "A picture worse, a jug of paste and wow!"

At this years Annual Meeting there are many exhibits from the early struggles of photogrammetry in the United States. In the early '20s there came to completion the brilliant Brock method; and several maps which you perhaps will see in the exhibit were made by photogrammetric means using the crude early parallax methods employed by Fairchild. What the Brock method accomplished by finesse the Fairchild method accomplished by generous field control. There was that graveyard of photogrammetry known as the Bushkill Quadrangle in Pennsylvania—the trysting ground for many a joust where photogrammetric spears galore were shattered into dismal ignominy against the sparkling armour of the plane-table.

The German photogrammetric invasion began about 1927 with the introduction of the Hugerschoff Aerocartograph; this was used experimentally by the U. S. Engineers and by the U. S. Geological Survey for the next seven years. In the meantime, Aerotopograph Corporation of America was organized in 1928; it was started by one of the beloved founders of this Society, Col. Claude Birdseye, and was supported by another of our charter members. Tom Pendleton, with Russell Bean as chief American technician, and Marshall Wright as a member of the sales oligarchy. This beautiful bubble burst into financial bits when the depression eliminated practically all potential clients from the market. The organization failed, and the pieces were picked up around the country by the U. S. Engineers and by commercial organizations. Included were two Aerocartographs, which were continued in government

and commercial use for many years, and the first Wild T-2 Theodolite to make its appearance in the United States.

Another depression casualty was Brock & Weymouth, which went out of business shortly after the crash of 1929. They had done a number of substantial jobs, the most spectacular of which was a topographic map of an extensive area around Boulder Dam for the Bureau of Reclamation. For a long time—perhaps to this day—a large mosaic covering an entire wall stands in an office of the Bureau of Reclamation at Boulder City, prepared from the photography of this survey. It was tragic indeed for American photogrammetry that the Brock system went into mothballs for about ten years beginning with 1930!

The depression was long, hard and technically disheartening. The government agencies had budgetitis and only two commercial aerial survey companies operated continuously through this period. Photogrammetry all but died. The Brock equipment was stored in the custodianship of a receiver. A tiny photogrammetric flicker was kept a-burning by the Aerocartograph in Los Angeles; the Fairchild organization was streamlined down to six employees, and about six dollars; this was all that was left after buying a C-4 Stereoplanigraph in 1934. It was in this same year that the Multiplex made its debut in the United States and was taken to the heart of the Geological Survey and the U. S. Engineers. Syracuse University also acquired one, around which they built their splendid course in photogrammetry.

Now for a considerable period before 1934 our military people had gone all out for multilens photography. In the '20s the famous Bagley five-lens camera was producing its maltese cross pictures, which the folks at Wright Field, using the Radial Control Method, were employing to create secondary map control and planimetric detail. One of the first great surveys undertaken with these methods was the Black Warrior River Project by the U. S. Engineers, participated in by some present members of our Society. This work was done about 1925, using enlargements as plane-table sheets.

So it was not surprising that in 1934, with the Stereoplanigraph, there arrived in the United States from Germany a four-lens camera, covering 100° on the diagonal, and fitting into a four-winged monstrosity on the Stereoplanigraph, producing contour maps therefrom. Next came a transformer by means of which these four pictures were rectified into a unitary 10″×10″ negative which was used to create about 200,000 square miles of very good photomaps for the Soil Conservation Service. Thus the mosaic and its reproduction as a photomap achieved some stature.

It was in this same eventful year of 1934 that Scott Reading founded the American Society of Photogrammetry. The charter members were a handful of enthusiasts gathered by Capt. Reading at his home: There was a happy atmosphere of conversation over cups of hot chocolate, pretzels and steins of beer, affectionately referred to as "stereoscopic oil." Thus the American Society of Photogrammetry was founded in the fellowship typical of good Americans and the seriousness of purpose to which our Society today stands a monument. Our first President was Col. Birdseye, and in the six ensuing years to 1940, the Society grew to a membership of 200 dedicated workers.

A very important invention in 1933 was the Topogon lens by Zeiss; by the time World War II was started, a similar lens had been put into manufacture by Bausch & Lomb under the name of "Metrogon." About 20,000 cameras equipped with Metrogon lenses were made by Fairchild during the war, but it was not until the war's end that these lenses, which really opened the era of aerial photogrammetry in the United States, were generally available for other than military use.

One of the milestones of early photogrammetry, after the formation of the American Society of Photogrammetry, was the mapping of Boulder Canyon by photogrammetric means, with pictures taken with a 4-lens camera, plotted in the C-4 Stereoplanigraph. This job is dramatic in more ways than one. As the gates of the fabulous dam were closed and the reservoir started to fill up, someone suddenly realized it might be very desirable to have a map of the original reservoir bottom so that studies of silt infiltration and similar subjects could be made. After a spot of budgetary legerdemain an order was given to make a topographic map; the flying got underway within less than 24 hours. Already the water had backed up about four miles, but fortunately it was in a narrow channel and the accumulated acre feet of water were comparatively inconsequential.

A revolutionary invention of 1935 was the Slotted Templet Method. This was received with great skepticism by U. S. Government authorities in Washington, and especially by some of our friends in Europe. It is interesting to view in retrospect the number of years

which elapsed between the invention of the Slotted Templet System and its general acceptance. Statisticians have computed that by now the cardboard slots cut out of the templets, if laid end to end, would go four times around the world. My statisticians tell me this would be thirty million templets, which only goes to show that we must not put all our credence in imposing mathematics.

To digress for a moment in retrospect, many of these fine achievements would not have been possible excepting for the amazing development by Eastman Kodak Company of a stable film base on which emulsion could be coated so that topographic work could be undertaken from the air without the weight and inconvenience of photographing on glass plates. And not only had the film base been improved, but it is interesting to ponder for a moment upon the miraculous developments of the emulsions themselves.

One of the slowest emulsions in the world is the human skin; this was invented a considerable period before the earliest dates with which we conjure in this report. If one were to lie face down in the sun and tape an average negative to his back, it would take a number of hours to make a satisfactory print. However, you would get one if your patience and disregard of pain permitted it. It would hardly be distortion-free.

The speed of emulsions had not been improved very much over the human skin by 1839, when it took approximately 4,000 seconds to expose a daguerreotype in sunlight through a lens stopped to F/11. It still took $\frac{1}{2}$ second in 1880, and 1/50 second in 1900, and 1/100 second at the time the American Society of Photogrammetry was started. Today under favorable conditions we can make this exposure in one 1/1,000 second. So from the time of Daguerre, 120 years ago, the speed of emulsions has been increased four million times.

But by 1937 we had reasonably fast emulsions; we had precision lenses, fine cameras, and plotting machines of the caliber of the Multiplex and the Stereoplanigraph C-4 by Zeiss. All of the other manufacturers of stereoscopic plotting equipment in 1937 were still utilizing narrow-angle cameras, with heavy emphasis on the use of photo-theodolites rather than taking the picture from the air. I do not mean to imply for a moment that they were not taking lots of pictures from the air in Europe. They had been taking and had been plotting them in their stereoscopic equipment from the twenties onward. The transition period was nearing its end in 1937, when the photo-theodolite was being relegated to very special cases and aerial photography was coming on at a gallop.

The first complete standard quadrangle which was mapped entirely by photogrammetric methods in the United States was the Soddy Island Quadrangle, mapped by Fairchild in 1937 under contract with the TVA. Prior to this time the tests of photogrammetric methods versus plane-table carried out in the Bushkill Quadrangle had been quite inconclusive. The Geological Survey had been using its equipment experimentally and for filling in some of the more difficult spots in areas of the West, but up to this time photogrammetry for quadrangle mapping had been distinctly an auxiliary process employing one Aerocartograph part time.

The Soddy Island Quadrangle was a $7\frac{1}{2}$ minute sheet. It was completely surrounded by recent standard topographic maps which had been produced by plane-table methods following U.S.G.S. techniques. The unhappy comparison between the two was a sore subject for a long time, but the man responsible for the Soddy Island demonstration and who really gave birth to the use of photogrammetric methods by the U.S.G.S. is today no other than the Chief Topographic Engineer of the U.S.G.S., George D. Whitmore. These tests at Soddy Island were received initially with despair, because along the four edges the matching was extremely bad. Everyone shook his head; Photogrammetry had tried; it was too bad but it had failed. Mr. Whitmore, however, was not so easily dissuaded. He ran some careful check surveys and when Mr. Whitmore checks a survey it stays checked. He proved—to everyone's amazement and the consternation of some—that in every instance of disagreement, the photogrammetric map was right and the plane-table map was wrong. This was the beginning of the end of the era of extensive plane-table sketching; it was the beginning of the modern era of topographic mapping where "90% and half an interval" can be said loud and clear and with full sincerity.

In 1939 Aero Service Corporation dusted off the Brock Method, and at last there were two commercial companies to breathe vigor into photogrammetry for every engineer in the land. These two companies, along with the mapping agencies of the United States, continued their activities in the interest of the war, but it was 1946—a span of many years—before they were able again to face the needs

of peace and industry.

During the war there were in the United States a lot of Multiplexes and one universal machine—the same old Stereoplanigraph C-4. Tri-Metrogon photography became the accepted tactical method of aerial photography. Unfortunately Multiplexes, and later in the war the Kelsh, were not very effective in plotting from 60° obliques. A few were equipped with Scheimpflugging lenses, but very little production was accomplished. About 1,250 quads of mapping were produced by varying means during this period; of these 244 were produced by the one universal in the country—you've guessed it—the same little old Stereoplanigraph C-4, eating throughout all those years out of the able hand of C. M. Cottrell, who for service decoration received a sad and serious case of ulcers.

The end of the war brought widespread acceptance of that most typical of American photogrammetric developments, the Kelsh plotter. Prior to the advent of this plotter there had been in the United States no 1,000 *C* factor machines excepting one. There were guite a few Multiplexes in the service of government agencies, but these had limped along at about 600 or 700 *C*'s. Immediately following the war there was a rush by commercial firms to get into photogrammetry and by government agencies to expand photogrammetric organizations. In the year or two following the war, even more Multiplexes were manufactured by Bausch & Lomb, and the first Wild A-5 was introduced in 1947. About this same time the Army Map Service brought to the United States a number of Stereoplanigraphs which had been in Germany at the end of the war. These instruments were distributed amongst various government departments; for the next several years both government agencies and many commercial companies proceeded to build up their capacity in stereoscopic plotting machines. By far the most popular machine has been the Kelsh plotter, which now is numbered in the many hundreds, if not thousands, while Wild, Zeiss, Santoni, and Nistri equipment have all come into this country and are used to a greater or lesser extent today.

The latest stereoscopic plotting development which has the United States agog is the Wild A-9 which plots from the very wide-angle RC-9 camera. This 120° lens is a step beyond the Aviogon of several years ago, which brought a new dimension to photogrammetry by its magnificant resolution, and by its corner illumination, which was increased at least 4-fold over the best previous 90° lens.

Today we hear rumors of a new series of Russian lenses designed to cover 9″×9″ negatives, which have been developed in varying focal lengths down to 1.85″ which covers in a single photograph 135° on the diagonal. While it has not been the privilege of many of us to actually see the work of this lens, it is reported from authoritative observers to be of excellent visual quality. This, then, represents the end of the road for multilens cameras originally designed for the purpose of giving wide-angle coverage.

This paper would not be complete without some reference to the very extensive use of Shoran and Hiran, Lorac, Radist and Decca, for precisely locating the horizontal position of the photographic airplane. Also APR, which electronically gives a profile of the ground to an extraordinarily high degree of accuracy, measured downward from a barometric elevation. Nor would it be complete without mention of the Geodimeter and Tellurometer—the former an optical-distance measuring device; the latter an electronic one, capable of doing first-order measuring and now being extensively used in the United States and knocking at the door of the theodolite. And hot off the press is the Doppler system for precise photo navigation.

And so we have come quickly along the road through 100 years of photogrammetry, from the day when there existed no air vehicle capable of carrying a camera; where there existed no suitable lens for taking the necessary precision exposure; where there existed no suitable film media to hold the emulsion; where there existed no emulsion capable of receiving an image fast enough to use in air vehicles. We have seen the imperceptible progress through these various shortcomings toward photogrammetry which suddenly launched into something real and vital with the stimulus of two wars. Today we have a method of photogrammetry which has greatly increased the quality of the average topographic work, reduced the price, decreased the time, and has perhaps done for mapping what the Model T did for motoring. We have seen in addition to these basic concepts of photogrammetry, a galaxy of auxiliary developments and improvements which leave photogrammetry today the readily available tool of everyone in need of a topographic map.