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Photogrammetry: 1776—1976*

Many individuals contributed to the development of photogrammetry during the past several hundred years.

Two hundred years of history are hardly more than the average life span of three generations. It may, therefore, appear to be a brief story to tell.

However, there exists a variety of developments of theories, inventions, instrumentations, and ever growing applications throughout the world, so that no presentation can be complete and totally objective with regard to who was first to create the basic theories, find practical solutions, and design workable instruments. Some of these questions are very difficult to answer.

Therefore, I shall begin with one statement that can hardly be contested: Two hundred years ago, there lived 1600 Indians on what is now the fairground of this City (Seattle), and there was no *registered* or *certified* photogrammetrist among them! In other geographical locations, however, have roamed some smart characters 200 and many more years ago who, by our standard, would probably qualify for those titles. I shall attempt to portray these people to you and briefly mention their accomplishments rather than deal with confusing technicalities.

The Dawn of the Story

Leonardo da Vinci (1492), the famous Italian painter of *Last Supper*, invented the Magic Lantern, not quite so sophisticated as the Kodak Carousel, and suggested the parachute and the helicopter principle. Oughtred of England (1574) made a slide rule, a little less pocketable than Texas Instrument's electronic version. Napir (1614) computed the logarithmic tables and Pascal constructed the first hand-cranked desk calculator, the most durable among our improved version. Somebody invented (1630) the Stork's beak, which we call Pantograph; Newton and Leibnitz (1700) conceived differential and integral calculus, and started a 300-year headache of aspirants to academic degrees! But nobody seems to know who deserves a monument for dreaming up "Matrix Algebra."

Among the more tangible possessions of our heritage we find Albrecht Duerer, German painter and engraver, who (1525) outlined the laws of perspective and constructed a device to make true perspective drawings.

The Florentine painter Jacopo Chimenti (1600) drew the first stereogram with remarkable precision, but committed some y-parallax errors in the lower portion of the model space.

The German philosopher and mathematician Heinrich Lambert (1759), in his treatise "The free perspective", dealt with the inversion of the central perspective, the resection in space of corresponding image rays, and thereby laid the ground work for the process which, 100 years later, was named Photogrammetry.

These are some essential implements that lay at the door-steps of the bicentennial period of 1776-1976, ready and waiting for the arrival of one major missing module that would permit one to permanently retain those illusive optically produced images. Chemistry made its first contribution with the discovery in 1759 by a German chemist that silver nitrate blackens upon exposure to light. It took 80 years of further research by German, French, and English chemists to find a solution which subsequently was called the "heliographic" process.

The Formative Years

During this period, optical advancements contributed additional useful components, such as the zonal lens named Fresnel lens after its inventor (1800); the Wollastone prism for the camera lucida (1807); the Porro prism for optical image rotation (1804); the

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Wheatstone reflecting stereoscope (1838) and the Brewster prism stereoscope (1844); a Petzval lens for metric photography; the variable diaphragm for objectives (1810); and the anaglyph filters for viewers and projectors by Rollmann (1853). Scientific research had produced a treatise by G. Schreiber (1829) on "process and formulae for air topographic equations and determination of the camera station," the physiology of visual perception (1838), and basics of stereovision (1844).

L. J. Mandé Daguerre, painter and physicist, presented the result of his labors as "Daguerrotypie" to the French Academy of Arts and Sciences (1837). Although the process was still far from being practical, it was immediately evident that the now sustainable perspective imagery produced by a camera lends itself for measuring purposes.

The imperfections of the process were soon overcome through intensified chemical research. New industries arose. George Eastman founded a factory in Rochester, New York. Landscape and portrait photography, the "Parlor Stereoscope," and Stereo-Peep-Shows became the attractions of the century. Military leaders began to employ balloon-, kite-, and rocket-photography as strategic weapons. Emperor Napoleon ordered the balloonist Nadar in 1859 to furnish reconnaissance photography in preparation for the battle of Solferino (Austria).

In the United States during the Civil War years (1864) balloon photographs were made over Boston, during the Battle of Fair Oaks, and over the city of Richmond. Grid overlays were used to transfer target points into existing maps.

In the Franco-Prussian War of 1870, a Prussian flying photographic studio made stereophotos near Paris, and a field photo detachment provided reconnaissance photos and a series of stereo pictures of the fortifications of Strasbourg (Alsace).

France's foremost promoter of photosurveying was Colonel Aimé Laussedat. He constructed photo equipment for terrestrial work. He called his process "Iconometry" and applied it to reconstruction of classical architecture (1850) and to rooftop photography for the mapping of Paris (1861). He was the winner of a first contest on "the accuracy of maps constructed from perspective photographs" and received the science award, a gold medal. His many scientific and technical contributions earned him the title "Father of Photogrammetry." The term photogrammetry was coined in 1867 and internationally accepted, even by most Americans.

Terrestrial photogrammetry became well entrenched in Italy, Sweden, Canada, Alaska, and in Russia. The pace of theoretical and practical developments accelerated when George Eastman (1890) replaced the photographic dry plate with roll film. A British patent introduced stereo viewing by polarized light (1891); Stolze (Germany) discovered the floating measuring mark (1892); and a stereoscopic telemeter was constructed by Zeiss, Germany (1893).

The Austrian Theodore Scheimpflug wrote in 1897 a paper on "opto-mechanical coincidence in stereo orientation of balloon and kite photography." He developed the theory of the double projector (a direct projection instrument for mapping) and a photo transformer; and he discovered the geometry governing the sustained focus in optical rectification of photographs, which we call the "Scheimpflug condition." This led to the invention by French and German designers of various forms of linkages called "inversors" which, combined with related components for maintaining projective conditions, are important mechanisms in today's autofocus rectifiers of German, Swiss, and Swedish designs.

Sebastian Finsterwalder, the German glacier specialist, wrote his comprehensive dissertation in 1899 on "the Fundamental Geometry of Photogrammetry" concerning basic problems of resection in space, orientation of stereo pairs, and envisioning the process of aerotriangulation.

After the turn of the century, new technologies excited the minds of many productive and legendary inventors. In 1900 the dirigibles Zeppelins and Parsivals appeared in the sky, and the Wright brothers made their first powered flight, heralding the heavier-than-air photoplatform.

In 1902 Dr. Carl Pulfrich designed the stereocomparator, which became an important module in the parade of analog plotters soon to appear over the horizon.

Almost simultaneously Dr. H. G. Fourcade, surveyor in the British forest service of far-away South Africa, had disclosed in 1901 to the Philosophical Society in Cape Town an almost identical invention, a measuring stereoscope employing grid plates instead of Pulfrich's x-y coordinate scales. It seems, therefore, appropriate to speak of a Fourcade-Pulfrich invention which to the present day contributes the most important component in the analytical treatment of photogrammetric tasks. Fourcade also developed in his South African seclusion a goniometer-type mapping device and a stereo projection plotter. His pioneering efforts found little public support and recognition by his government authorities.

Also in 1902, the Canadian E. Deville designed a mapping instrument for terrestrial photography using a Wheatstone stereoscope and physical tracer point in the model space. He called it "Stereo-planigraph."

The Contest of the Champions

A first technical breakthrough into the age of automation occurred in 1907 when the Austrian Ritter von Orel found a solution for mechanizing the construction of maps from terrestrial photograms, which so far had implied point-by-point measurement, computation, and plotting. The Zeiss Works supplemented his first prototype with a Fourcade-Pulfrich stereocomparator and a geometrical linkage known as the "Zeiss parallelogram." The final design permitted continuous operation without computations. It was named "Orel-Zeiss Stereoautograph." When this plotter was placed on the market in 1908, a new photogrammetric mapping industry began in Austria and practically all European countries and South America.

The now fast-growing number of photogrammetric practitioners of Austria, France, and Germany organized in 1909 the International Society under the presidency of the Austrian Edward Doležal who created the International Archives for Photogrammetry. Today, this organization comprises 43 National Societies. It held its XIII Congress recently in Helsinki, Finland.

The First World War, 1914-1918, stimulated further development through the growth of air power of the military forces of Europe and America with primary emphasis on cameras for reconnaissance, training of photointerpreters, and graphical methods for updating maps in the theaters of operation. Advanced developments were (1916) in the United States the multilens (Bagley) cameras and in Germany the automated strip camera by O. Messter (1917) which produced valuable mosaics. The German 380mm long range railroad guns firing on Paris created a sensation. Their emplacements were the most hunted targets for reconnaissance photography and bombing missions.

Intense activities began almost immediately after the armistice in Italy, Germany, and France which signaled the birth of the analog plotter instrumentation based on a variety of optical, opto-mechanical, and fully mechanical solutions of the universal restitution problem.

In 1917 Max Gasser, vigorously fighting Bavarian inventor, had already built an experimental model of a double projector plotter for vertical aerial photography patterned after Scheimpflug's concept of 1897. His patent was kept secret by the German armed forces, but they failed to envision its military potential.

The Roman, Umberto Nistri, in 1919 made a double projection plotter nicknamed "Big Bertha" using alternating image projection on his experimental model; he later successfully advanced to stereo-plotters of different concepts.

Professor Reinhard Hugershoff, a German inventor of remarkable productivity in the geodetic and photogrammetric field, conceived the first universal stereo-plotter in 1921 for terrestrial and aerial photography by employing the Porro-Koppe principle (i.e., observation of imagery through the camera lens). In 1926 followed the first universal plotter for extension of control and triangulation capabilities.

The German Zeiss Works produced the first model of a universal direct projection stereo instrument, the Stereoplanigraph, in 1923, accredited to W. Bauersfeld, their Chief Engineer. Over a period of 20 years, a series of refined models was built to meet the demands of major mapping organizations throughout the world.

The mastermind in these developments was Bauersfeld's scientific advisor, Professor O. Von Gruber, internationally known by his "double point resection in space" which provided the mathematical foundation for the now routine procedure for stereo operators when orienting vertical photographs in plotting machines.

In 1933 the Aeroprojector Multiplex, an instrument of modular design, gained worldwide distribution, was used in many nations by their armed forces, was also built in the United States and England, and is still considered the workhorse in some government and private mapping organizations.

Heinrich Wild, the inventor, who had aroused the surveyor's profession with the revolutionary theodolite with glass-engraved circles in 1920, entered the production of photogrammetric plotters with a first model of an "Autograph" for terrestrial photography. He added in 1926 a modified version for mapping from vertical aerial photos. The Wild Heerbrugg (Switzerland) establishment has continuously supplied the world demand for aerial mapping equipment, keeping well abreast of technological advancements to this day. This also applies to the firm of Kern, Aarau, producer of the mechanical category of high precision plotters and notorious for their Swiss craftsmanship.

Professor Santoni of the Officine Galileo in Florence, Italy also entered in the photogrammetric arena in 1920 with a plotter named Autoreductor, followed in 1925 with a new concept named Stereocartograph, and created in the ensuing period (1933-1964) a multiplicity of plotters for terrestrial and aerial work. Outstanding designs are the Aerosimplex series culminating in the Stereocartograph Model V, which displayed mechanical compensation solutions for model deformations caused by mechanical and optical anomalies in the map production chain.

The French contributions to the growing competition among inventors began in 1919 with a plotter by Predhumeau, followed by several models of Stereotopographs designed by G. J. Poivilliers, which became for several decades the national equipment for the French Central Mapping Agency.

R. Ferber of the firm Gallus presented in 1933 a direct projection plotter with alternating projection of imagery (revived later with the U.S. Geoelogical Survey stereoalternator). He added to his third model a scanning attachment for orthophotography, based on an idea first introduced in 1931 with a "rectifying instrument for hilly terrain" by O. Lacman in Germany.

Vivian F. Thompson of Great Britain had in 1908 constructed field photo surveying equipment and conceived a stereocomparator with a plotting mechanism which showed certain similarities to the von Orel idea of 1907. British surveyors, however, favored the traditional planetabling and, when they later accepted aerial photography, preferred graphical techniques, the "Arundel Method" and the topographical stereoscope with grid plates, made by Barr and Stroud in England.

In 1935 Professor E. H. Thompson offered a new solution of opto-mechanical plotter design based on Fourcade's principle of 1901. His first model was destroyed in World War II. In 1954 a new design, the Thompson Watts Plotter, was accepted by the British Government Survey agencies together with Thompson's progressive developments in its use in connection with analytical photogrammetric triangulation.

Sweden's contributions to the advancement of photogrammetry stem from its early application of terrestrial and aerial photogrammetry to national mapping and road construction.

Dr. Bertil Hallert assumed a leading role in error investigations, in orientation procedures on plotting machines, and in establishing standards for their calibration. He is best known as the Socrates of "The Standard Error of Unit Weight" and remembered as Sweden's photogrammetric ambassador to the United States with a "distinguished lecture series" in 1968.

Russia's role, only fractionally known up to 1950, is that of a consumer of a large number of European instrumentations for photographing and mapping the vast territories of Eastern Europe and Asia. There are, however, some noteworthy native accomplishments in optics and mechanics which illustrate the policy of independent developments dictated by the country's priorities. N. Russinow developed in 1940 the Russar, a camera lens said to cover a field of 120°; S. D. Konschin built a stereocomparator-type instrument; S. D. Drobyshev in 1957 developed an optical projection plotter named Photocartograph; and Romanowsky built a two-stage mechanical stereo projector using affine transformation.

The American Venture

Historical records relating to photogrammetric developments on the North American continent start with the dawn of the 19th century. The United States' oldest survey institution, the Coast and Geodetic Survey, originally named "Survey of the Coast", had its beginning in 1807. The gradual development of photogrammetric technology toward the end of the century was attentively awaited as a hopeful solution to the growing need to map the nation's coastlines and update its harbor charts.

With the advent of the airplane in the early 20th century, Captain O. S. Reading contributed a notable solution to acquiring aerial photography with large ground coverage. His unique 9-lens camera had a compound field angle of 140°. A photo transformer and rectifier equipment produced unequalled terrain coverage and photographic quality.

The U.S. Geological Survey, founded in 1879, introduced photo surveying with terrestrial panorama cameras in Alaska. With the advent of aviation, domestic and foreign technical progress was continuously evaluated for its merits in order to expedite current mapping routines. Colonel C. H.

Birdseye, the Survey's first Chief Topographic Engineer in 1919, was a strong believer in the possibilities that photogrammetry could revolutionize the conventional mapping routine and meet the national demands for up-to-date maps.

In 1921 the Orel-Zeiss Stereoautograph and photo-acquisition equipment was loaned from the German producer for two test surveys. The results of both met accuracy standards. but the method was judged too expensive and rejected.

In 1927 Professor Hugershoff was invited to introduce his Aerocartograph. A very demanding test of the plotter's aerotriangulation capability was made and an intensive training period followed. The instrument was put in service in 1929 for contouring rugged topography in National Parks and Canyon areas of the West. In 1933 the slotted templet method, the forerunner of modern block triangulation, was extensively used. It reduced drastically expensive ground control requirements.

The Survey's research and model shop, headed by R. K. Bean, began after World War II with many instrumental improvements. It produced a new version of the Multiplex-type plotter, the ER 44 (Balplex) projector; the triangulation instrument Twinplex; and several models of Orthophotoscopes. It promoted (1948) the Kelsh Plotter, an instrument based on the Scheimpflug-Gasser-Ferber inventions (1906-1914-1934) to a higher degree of range and accuracy. This brought the instrument to wide distribution and success in the Western Hemisphere.

In 1936 the Tennessee Valley Authority began the extensive hydroproject of the river's watershed. Under the direction of T.P. Pendleton, the entire basin was mapped using photogrammetric triangulation, with Multiplex equipment.

The U. S. Army Corps of Engineers established in 1931 a Research Detachment at Wright Field with Captain Bruce C. Hill in command in order to study the feasibility of stereotriangulation with the Hugershoff plotter and the adaptability of the Multiplex for field use in military operations. The Multiplex was chosen to become standard Corps of Engineers mapping equipment. After securing a domestic production facility, the Bausch & Lomb Optical Company began production of photogrammetric equipment in Rochester, New York about 1935.

The acceptance of photogrammetric methods by Canada occurred at a somewhat faster pace. The French-born topographer Edouard Deville, who in 1885 became Surveyor General of the Dominion, was commemorated in 1975 with a monument in Yoho National Park as "Canada's Father of Photogrammetry." He used plane table non-stereoscopic photogrammetry in the mountain regions of the West and conducted the International Boundary Survey in the Rockies and the Canada-Alaska boundary survey in 1893. In 1902 he conceived a plotting instrument named after him. In 1919, as a member of the Air Board, he organized oblique photography from flying boats, and he introduced the projective grids (the Canadian Grid Method) for transfer of image points to grid positions on the map. The vast eastern plains and lake regions were successfully covered with planimetric maps. More recently, uncharted regions in the far north have been covered by tri-metrogon photography.

The National Research Council of Canada, founded in 1933, provided camera calibration, designed a radial stereo plotter, and developed the airborne radar altimeter and an orthophoto stereo plotter.

Private enterprise in the United States has made valiant contributions to the progress of methods, equipment, and publicity. Major Edward H. Cahill and Arthur Brock invented an independent mapping process, well adapted to American principles of division of labor. All system components—a precision aerial plate camera, a rectifying projector, and a stereometer and zonal transformer—were fabricated in the Philadelphia Tool Works of Arthur and Norman Brock. Known as the "Brock and Weymouth Method", it has produced maps of high accuracy and topographic fidelity, since about 1922.

Leon T. Eliel was one of the early American pioneers on the West Coast who engineered photogrammetric surveys with improvised instruments of his own design. As a manager of the Western Division of Fairchild Aerial Surveys, he constructed transforming equipment for multi-lens cameras in 1929 and later acquired a stereoplanigraph for topographic mapping from 4-lens camera pictures.

The Aerotopograph Corporation of America was formed in Washington, DC, in 1929 with Colonel Birdseye as its president. Among many major mapping projects, the survey of the Hoover Dam Site in the Black Canyon of the Colorado rated as a classic example of the performance of terrestrial photogrammetry under most exacting conditions.

Many other American mapping companies have followed. Not all of them have weathered the storms of the early period. Others have grown to become large and progressive components of a new and prosperous industry, which today comprises over 60 private enterprises that are active within and beyond the borders of our continent. With them has arisen through the last three decades a highly diversified industry, which supplies domestic and foreign needs with hardware and software in all conceivable fields of photogrammetric utility. According to American Society of Photogrammetry (ASP) statistics, over 25 major producers of optics, cameras, restitution equipment, and photo and electronic products on American soil represent today a noteworthy segment of our national economy.

In order to supply the growing number of mapping establishments with academically trained photogrammetrists, the time had come to provide learning opportunities on domestic soil. In 1929 the first school of photogrammetry opened at New York State University in Syracuse. Professor Earl Church was its first Ordinarius. His approach to photogrammetry was mathematical. In 20 years of teaching he laid the cornerstones for "analytical photogrammetry." Al Quinn in his recent Memorial Lecture named him the "American Father of Photogrammetry." A number of U.S. universities have followed his lead and offer well-equipped training courses.

The Second World War made heavy demands on all existing instrumentation processes and trained personnel. It strongly accelerated the development of aerial reconnaissance and aerial navigation aids. It exposed drastically the potential of photogrammetry for purposes of assault and defense on land and sea. It made "photo-interpretation" a new and most important science. The outstanding American war accomplishments were the "Sonne" shutterless strip camera with stereo lens cones and gyrostabilization and the technique of aerial night photography.

The postwar years brought for European countries an amazing recovery from destruction and chaotic conditions. Out of the ashes arose a new era of vigorous activity, which today is trying to catch up with the lead that American science and technology has gained through superior research capability, expanded production capacity, and government supported programs for basic research, applied mathematics, physics, chemistry, and electronics. The gradual penetration of photogrammetric instrumentation by semiconductor and computer technology has immensely widened its applicability, speeded up its productivity, and refined the accuracy of its diversified end-products.

Our Own Era

With the advent of the Space Age, we have fully emerged from the sanctuary of past history and entered the scene of our living presence as witnesses or, perhaps, contributors to spectacular accomplishments. In a hopeful spirit, we have arrived at our nation's bicentennial, to which ASP has made a lasting contribution by honoring one of our nation's pioneers who helped build greatness and progressiveness in our land. At Hopi Point on the South rim of the Grand Canyon stands a monument to Colonel Birdseye, ASP's first president, as a reminder of the spirit and courage that moved our forebears and as a guide post for future generations to follow in their footsteps.