The Development of Analytic Aerotriangulation

It awaited the availability of the programmable electronic computer

G. C. TEWINKEL
LA GRANDE, OR 97850

A HISTORY of the development of analytic aerotriangulation is treated in depth in the fourth edition of the *Manual of Photogrammetry* (Slama, 1980). Understandably, these few pages are not intended to repeat that story.

One might well ask why the development occurred at all and why notably in the United States. Of the dozen or more circumstances that helped promote the development, two of them were particularly timely and important: the contemporary development of the programmable computer and the teaching of the principles of analytic photogrammetry at Syracuse University.

Prof. Earl Church, himself a graduate of Syracuse, had been a mathematician at the U.S. Coast & Geodetic Survey in Washington, D.C. In 1924 he resigned his post and returned to Syracuse, New York to conduct a family business as well as to join the faculty of the College of Applied Science as professor of photogrammetry. This was the first institution in the United States to offer bachelor and master degrees in civil engineering with a specialty in photogrammetry—a score or more years before other schools entered the field. At that time photogrammetry was scarcely practiced in this country. No appropriate textbook was available—Church published in 1938 an early edition of *Elements of Photogrammetry* to aid him in his teaching efforts.

Church used analytic geometry as a tool to explain and teach photogrammetry, instructing his students to compute examples of space resection problems using desk calculators. The classes were small but, over the years, 50 or more students had graduated. Essentially all of them became employed in the leading mapping and photogrammetric organizations of the nation.

Church frequently told his students about the ENIAC computer (c. 1938) being built for U.S. Army ballistics calculations. Other computers were eventually marketed. By the 1950s, when computers began to become available for many applications, numerous Syracuse graduates who were unafraid of, and had confidence in, analytical calculations were in positions of responsibility: analytical aerotriangulation blossomed on several fronts. World War II had added impetus to the applications of all aspects of photogrammetry by making funds available for added personnel, research, and instruments.

General photogrammetric techniques and applications in Europe preceded those in the United States. In 1910 the International Society for Photogrammetry was formed (later "and Remote Sensing" was added to its name) and it included Commission III, Aerotriangulation. The quadrennial congresses were attended by several Americans. We are celebrating the organization of the American Society of Photogrammetry in 1934, for many years a member of the International Society. ASP published a journal containing informative articles on the theory and practice of photogrammetry, as well as a series of manuals beginning in 1944—one may tend to underestimate the society's importance in all of the aspects of photogrammetric development.

A German photogrammetrist published a book on the subject (von Gruber, 1932), which included a pair of projective equations, with the observation that the equations were too complicated for practical application. Nevertheless, they were eventually applied in the United States by Schmid, Brown, Kennefick, Harris, Tewinkel and others. Schmid wrote of them (1952) when he was employed in Aberdeen, Maryland (working with the ENIAC computer). Schmid later transferred to the Coast & Geodetic Survey where he applied the same equations to a world-wide control survey network using cameras on the ground to photograph satellites at night on a background of star images (see article by Swanson, page xxxx in this issue). These equations resemble those of classical geodetic triangulation, and they are solved in the same general manner.

As indicated in the ASP *Manual* (Slama, 1980), many other aerotriangulation solutions were developed based on other mathematical principles. Examples include those of Dr. Paul Herget of Ohio State University, G. H. Schut of the Canadian National Research Council, and Robert E. Altenhofen of the U.S. Geological Survey. A paper by Lucas (1984) described the sort of results that can be obtained by analytical aerotriangulation. Photographs at 1:20,000 scale were obtained of part of Ada County, Idaho, for which 285 were flown in the east-west direction and 115, north-south. They were used to determine the positions of 346 pre-marked section corners, using 17 control points, resulting in a standard error of only 5 centimetres (2 inches).

In addition to those few photogrammetrists named above, a large number made important contributions to the development of analytical triangulation over the years. Their names are listed in the ASP indexes (1980, 1983). At a further risk of omitting some, several are nevertheless mentioned because their contributions were extensive and ought not to be overlooked.

Prof. Friederich E. Ackerman of Stuttgart Uni-

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versity contributed in 1966 to the success of the ASP/ISP symposium on aerotriangulation at the University of Illinois when he showed that control points were not needed in the interior of photogrammetric blocks if the area is bounded by a series of control points on the perimeter.

Carl J. Born, Robert S. Brandt, Charles W. Price, and others of the Army Map Service in the early 1950s developed a successful system of first-order instrument aerotriangulation followed by a graphic analysis of the error curves which were laid out on two or three table tops and constructed with long fiberglass splines (dowling).

Duane C. Brown, mathematician, was associated with Dr. Schmid at Aberdeen, Maryland, was employed in ballistics at Cape Canaveral, and later was a self-employed consultant preparing computer programs on analytical aerotriangulation for the Defense Mapping Agency Aerospace Center St. Louis. He also invented and marketed a comparator and published many papers.

Dr. Frederick J. Doyle, a graduate of Syracuse University and ITC (Delft), served as photogrammetry professor at The Ohio State University, cooperating with Dr. Herget in the development of the coplanarity system. Later, Doyle became chief scientist at the Autometric Corp. where he worked mainly on analytical photogrammetric applications. He was president of ASP in 1969 and of ISPRS 1980-1984. He has been a driving force for satellite applications for the U.S. Geological Survey.

Dr. Bertil Hallert of Sweden developed and published widely on methods of first-order instrument error propagation. During the 1950s he served at The Ohio State University and the U.S. Army Engineer Research and Development Laboratories in Ft. Belvoir. A forte of his was the theory and application of least squares.

Prof. H. M. Karara served as the head of the photogrammetric unit at the University of Illinois, publishing numerous papers on aerotriangulation. He hosted the ASP/ISP aerotriangulation symposium in 1966.

Morton Keller prepared, until he retired, nearly all of the computer programs developed for analytic aerotriangulation at the Coast & Geodetic Survey (National Ocean Survey) and was co-author of numerous bulletins on the subject.

Maurice E. Lafferty applied analytic aerotriangulation techniques economically to private land surveying problems.

Robert A. Matos conducted (c. 1963) extensive research studies on analytic aerotriangulation at the U.S. Army Engineer Research and Development Laboratories at Ft. Belvoir, Virginia, applying mainly the Herget approach.

Chester C. Slama worked as a mathematician under Dr. Schmid at the National Ocean Survey on the world-wide satellite triangulation program. He greatly improved the accuracy of the conventional NOS analytic aerotriangulation system by including a reseau plate in the aerial camera, applying stellar camera calibration, flying blocks in both directions, premarking all ground points under consideration, and using a precision comparator (Slama, 1978; Lucas, 1984). He was editor of the fourth edition of the ASP *Manual of Photogrammetry*, and was the author-editor of Chapter IX on aerotriangulation.

Dr. Kam W. Wong serves under Dr. Karara at the University of Illinois, specializing in analytical aerotriangulation. He published numerous papers and is author-Editor of Chapter II, Basic Mathematics, in the ASP *Manual of Photogrammetry*.

For the record, it is stated in the ASP *Manual of Photogrammetry* that "The Coast & Geodetic Survey was the first United States mapping organization to have achieved an operational system of analytical aerotriangulation."

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