Reinhard Hugershoff*

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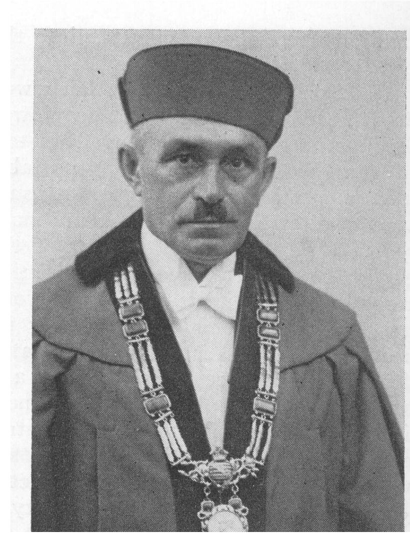

Fig. 1. Prof. Dr. Eng. Reinhaard Hugershoff.

His masterpiece, the Aerocarograph, introduced in the U. S. in 1927, opened a new era of mapping performance and aerotriangulation

To my knowledge this is the first Memorial lecture at an ASP convention which is dedicated to an outstanding pioneer of our science, whose contributions have significantly influenced our present state of the art. Our rushing times are so liable of making us take too many things for granted and letting us forget the sources of our scientific and technical wealth. We should, therefore, consider it our solemn duty to stop once in a while and reflect on the legacies from which we so richly benefit today. Photogrammetry still is a relatively young science, yet there are already a number of great achievements whose authors should never be forgotten in our photogrammetric community.

As a prelude to what I long to see as an established observance of future gatherings of photogrammetrists, I shall attempt to convey to you a picture of the life of one of our earliest pioneers at the dawn of a new era. That era is marked by a sort of revolution, unbloody but daring and fierce. At times it reverberated with plenty of verbal thunder. One of its instigators was *Reinhard Hugers*hoff, a young scientist, researcher and adventurer at the Institute of Technology 'of Dresden, Germany (Figure 1).

We turn the wheel of history back to the first decade of this century. There was peace for a while, the country's currency was on the gold standard, prosperity reigned, the pollution index of air and water was unheard of, and the noise level was in the low decibel numbers. There were well established institutions which provided maps of the country. They were artfully engraved with hachures which faithfully depicted the hills and dales. These maps were made by the honorable profession of certified landsurveyors and were, therefore, perfect. There was no way of telling whether they were wrong. There were also vast territories on earth still unexplored and unsurveyed. Scientific expeditions to explore and exploit them offered adventure and discovery.

Reinhard Hugershoff had finished his studies of geodesy and surveying, was serving as a scientific assistant, and had obtained his doctor's degree in engineering at the Institute of Technology at Dresden, Germany. He realized his chance for colonial experience and joined in 1907 a scientific expedition into the African tropical jungle. He was assigned the task of surveying the track which was to stretch over several hundred kilometers. This required astronomical observations, triangulation, compass and barometric recording to map the travelled route. He learned a very hard lesson through almost superhuman effort and tropical disease. Upon his return he reviewed his records and came to the conclusion that the result, although scientifically satisfying and valuable, was pitifully meager in the light of the labor and hardship of two years that he had endured. So he began to investigate and develop more efficient equipment and procedures in order to be better prepared for future similar ventures into the unknown.

Terrestrial photogrammetry was fairly well advanced. The von Orel Stereoautograph was already in operation for mapping from terrestrial stereograms, but existing portable field instrumentation was not fit for exposure to severe tropical environment. Aerial mapping photography was still a dream of the future. So he concentrated his inventive talent on the improvement of the surveyor's compass, an inclinometer, an automatic recorder of bearings and distances, a calibrated tape for optical distance measurements, and a light-weight metric photographic camera combined with a transit. These first instruments reveal already the designer's preference for small dimensions, which we find reflected in all of his later creations. Utter simplicity of operation and portability were of course requirements of ultimate importance in forbidding environments.

Hugershoff's dreams of future peaceful adventures were shattered with the beginning of the first world war, but ironically, it gave him a greater chance to put his inventive capacity to work in a new direction. Aerial photography and photointerpretation in the theaters of military operations gained first priority. It is not surprising that he, by now a fully established professor of mathematics, meteorology and surveying, was called upon to develop means to utilize the projective relationships between the aerial photograph and the terrain to extract map information. The procedures which he

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outlined for troop use were, in the beginning, purely graphical in nature and permitted the finding of the exposure station, the nadir distance, and pertinent orientation data of the mostly high oblique exposures and the transfer of image points into existing maps of the front lines. With the use of overlay perspective grids he performed a rapid daily supplementation of map data. His future developments resulted in a military photogrammetric system which began as a computational operation that yielded the exterior orientation of each individual photograph. Besides slide rules and hand-cranked desk computers, more complex instruments were now needed to obtain angular measurements directly from the photographs. Hugershoff adapted the then already known photogoniometer and modified it for use in the newly trained photogrammetric survey units of the field army.

The photogoniometer (Figure 2) has a plateholder which can be tilted on a horizontal axis, and a transit telescope which rotates about the perspective center of the photograph. The exterior orientation of the photograph was used to adjust the plateholder. The spatial angular relationships between image rays were now measured and their horizontal and vertical components read from the circles of the instrument.

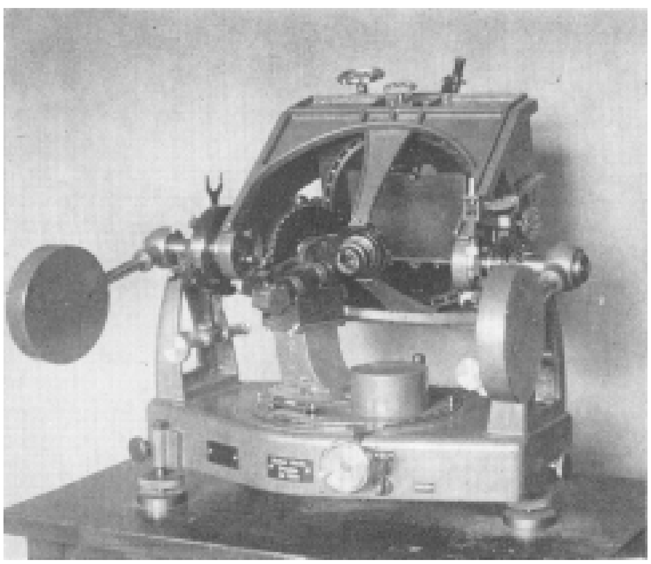

Fig. 2. The Photogoniometer.

In 1916 followed a logical expansion of the system by the simultaneous use of two overlapping photographs oriented in two photogoniometers (Figure 3). Attached to the vertical axis of rotation of each telescope was a straightedge which materialized the horizontal component of the line of sight. If conjugate image points were sighted in both instruments, the resulting intersection of the two straightedges resolved the horizontal position of the corresponding object on the ground. And finally, a third pivoting straightedge slaved by mechanical means to the vertical movement of the telescope, furnished the elevation of the object relative to a chosen reference plane.

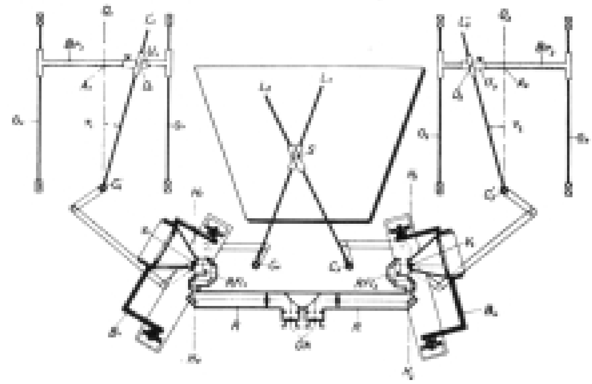

Fig. 3. Schematic diagram of two photogoniometers coupled for overlapping potographs.

Herein lies the basic concept out of which arose the first analog plotter, which, in 1921 was announced as the *Hugershoff Autocartograph* (Figure 4). The vertical component of the line of sight of each goniometer was represented by a pivoting straightedge which produced an intercept on I a vertical scale placed automatically at the intersection of the two horizontal straightedges. This solution of somewhat mechanical complexity added automatically the altimetric map information without computation and, thereby, the unparalleled possibility of constructing a topographic map with all planimetric features and contour lines in a continuous process.

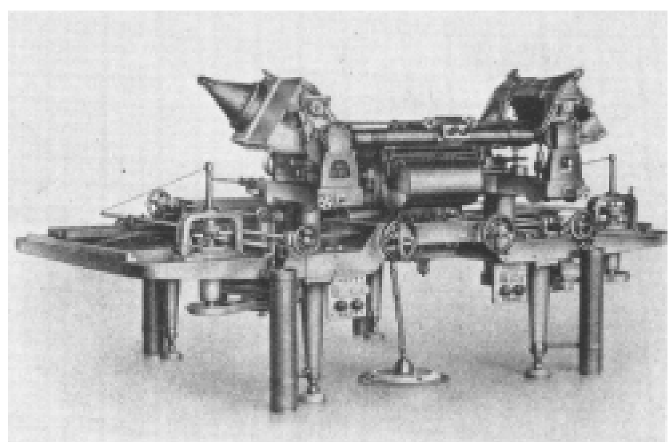

Fig. 4. The Hugershoff Autocartograph.

The translation of this concept into hardware had to be accomplished in post-war times marked by extreme austerity, famine, a creeping monetary inflation, shortage of materials and machines, and thousand other calamities big enough to kill the initiative and perseverence of the strongest will. However, Reinhard Hugershoff endured. He had joined hands with two like-minded men, a resolute father-and-son team, the elder, Oskar Messter, inventor and authority on Cinematography, credited with building the first successful automatic aerial film camera during the war, the younger, Edward 0. Messter, a far-sighted enthusiast and hard working organizer. He is an Emeritus member of our Society.

In the precision machine and optical shops of G. Heyde in Dresden, Germany, rose the first model of a full-fledged mapping machine, a universal apparatus for plotting from terrestrial, aerial vertical, oblique and convergent photography. Its public announcement immediately aroused as much interest of the civilized world as it brought out the doubting Thomases in the *prophet's own homeland.* Study groups from European and far-away countries came to investigate and test. Competitive parties from France and Italy raised their eyebrows. The promises and claims were rather high and not all of them were proven. Operational procedures were still in the developing stage. Fortunately they were soon greatly advanced by Otto Von Gruber's famous publication in 1924, "Single and Double Point Resection in Space," which added to the more-or-less empirical process of finding the orientation of the photographs in the plotter the scientific and all encompassing basis. A first production series of Autocartographs went to foreign countries, the first engineering model was sent to Japan, one prototype was installed in the Central mapping agency of the German government for evaluation and gained acceptance after exhaustive tests.

The decade between 1920 and 1930 marks the period of an international race and rapid development of photogrammetric instrumentation. Italian, French and Swiss firms exploited different approaches in their plotter designs; England entered the game much later. A heated contest and the battle of patent priorities began. The triumvirate, Messter-Hugershoff-Messter, and a group of young and devoted assistants, technicians and designers labored long day-and-night hours in designing, building and testing. They attacked with sharp pens and in vocal debates the voices of the adversaries. On the home front they battled the conservative land surveyors who in self defense rose to defeat the revolutionary concept of a superior system that they feared would undermine their job security.

On the scientific level we find that Prof. Otto von Gruber became Hugershoff's foremost critical opponent. He was backed by a powerful group of men of the Zeiss Works where the development of the Bauersfeld Stereoplanigraph had begun, i.e., the analog plotter that, in its latest perfection, is well known as the elite instrument among the popular direct projection plotters. The German technical literature of those years gives evidence to the heat of the intellectual fight and temperament of these two scientists. Nobody would ever have expected that a few years later both men, in a dramatic move, joined hands and henceforth congenially worked together on the common goal. This happened in 1931, when the Messter organization merged with the photogrammetric department of Zeiss to form the Zeiss Aerotopograph Company, and Hugershoff became a member of the scientific staff of the Zeiss Works. The pooling of the scientific resources and the productive power of both organizations led for a while to their domination of the world market in the photogrammetric instrumentation.

Hugershoff's enormous creative record in those times prior to the merger with Zeiss is manifested by an amazing variety of new products, instrument components and some imaginative designs that ran far in advance of his time. He endeavored to create a comprehensive photogrammetric system of compatible, well-matched components. The earliest products were aerial cameras with glass plate magazines (Figure 5), hand-held or spring-suspended for oblique photography overboard. When vertical photography through a hole in the floor of the fuselage became the prevailing technique, ring mounts with provision for drift correction and overlap finders were added. For more economic angular coverage, which then was little over 50°, two-lens cameras with convergent axes followed. When film (although of still questionable dimensional stability) became available, and square formats were adopted, Hugershoff designed automatic aerial cameras and invented several forms of optomechanical overlap regulators. As a lover of small dimensions he adhered to picture formats of 12 × 12 cm. and 18 × 18 cm. and short focal-length lenses with the angular coverage of 65°. He believed strongly in the capability of the optical industry to make lenses of rigidly controlled distortion and superior resolution to permit a reduction of the aerial negative in the preparation of the diapositive plates for the plotting machine. He regarded the film camera as the only practical solution in mass producing aerial photography.

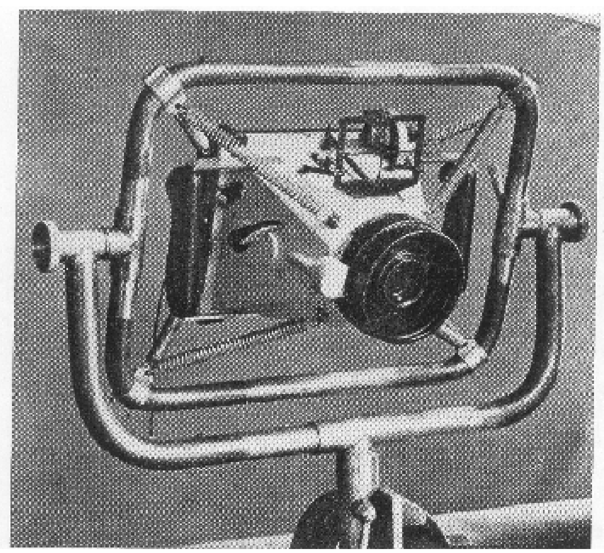

Fig. 5. Spring-suspended glass-plate aerial camera for oblique photography.

His memories of the African jungles led him to develop a colonial survey instrumentation that would compete with the eagle's view high in the sky to which he had looked up so jealously in his expeditionary years. He devised a small camera of 6 × 6 cm. (2½ × 2½ inches) format and 6.5 cm. focal length (Figure 6), suspended it in a ring mount, provided a hand-cranked pendulating movement, by which sequential exposures could be made as verticals or obliques of 25° nadir distance alternately tilted to the left and right of the flight line. It was an extremely elegant design and could be carried quite easily in a travel bag.

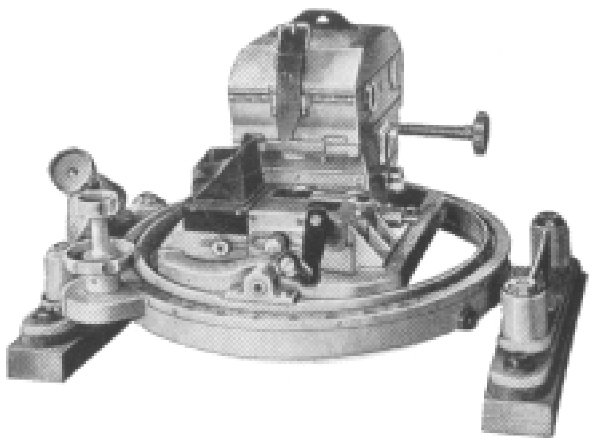

Fig. 6. A 2½ × 2½-inch aerial film camera with its mount could be carried in a suitcase.

Other system components, built as engineering samples were: (1) a small semiautomatic rectifier contained in a carrying case, out of which it rose ready to use when the lid was unlocked; (2) a stereoplotter of the direct projection type called "Aerosimplex" (Figure 7). Unlike its successor, the Multiplex, and our American developments, the two images were projected from beneath on a light table and observed side by side through a mirror stereoscope. A pair of parallel-guided floating marks were rigidly connected with the scribing tool. Extension of control and continued mapping was possible with a switch of the mirror arrangement of the stereoscope); and (3) a flight path recorder named *Quo Vadis* was conceived as an aerial navigation aid. It consisted of an intervalometer for drift and ground speed determination, a compass, and a mechanical computer which split the aximuthal direction of the flight movement into two mutually rectangular components. These were transmitted to the plotting table where a pencil traced the ground course. Tests of this device at Wright Field showed the basic soundness of the concept, but the lack of a stabilized platform and the complexity of operation, particularly, when flying curves, was found too demanding.

Simultaneously with these developments Hugershoff pursued the creation of new terrestrial instrumentation intended to open new fields to photogrammetric activities and to give the landsurveyor better means for supplying ground control and other supporting information:

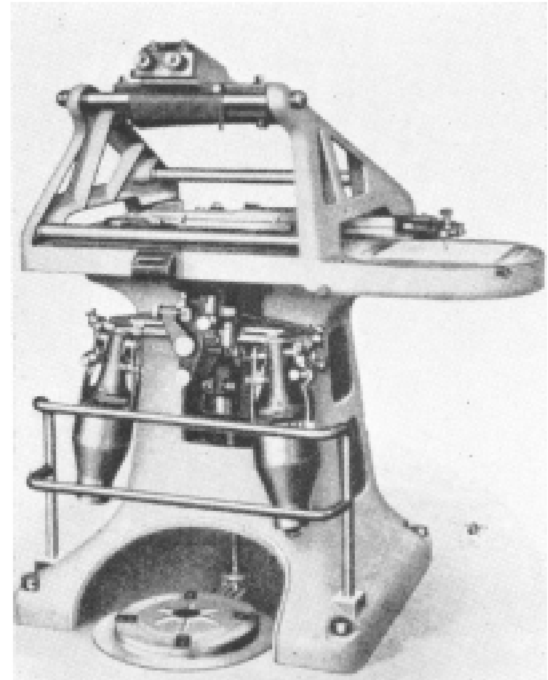

Fig. 7. The projection-type Aerosimplex plotter was a forerunner of the Multiplex.

(1) A *coast survey camera* for use on ship board. Suspended in stable equilibrium at the mast of a ship sailing along the coast line, the survey camera would be pointed shoreward and normal to the ship's course. Synchronously with the coastal picture a second lens pointing horizontally seaward would project the sea horizon on the same picture.

(2) *A universal phototheodolite* (Figure 8). This was a rugged instrument which maintained its calibration in tropical environment and withstood the hazards of mountain climbing. It had a tiltable camera, an eyepiece attachment to the focal-plane frame, converting the camera into a transit telescope. It provided the optical components for precise camera orientation, base line and other geodetic measurements. It was used in 1930 on an expedition under Col. C. H. Birdseye into the Black Canyon of the Colorado River to survey the construction site of the mighty Hoover Dam. The construction of the large scale map 1:600 with a contour accuracy of I foot would have been completely impossible without this universal instrument or by any other method.

(3) An intriguing invention was the *Stereotachygraph* (Figure 9). It consisted of a stereoscopic range finder supported like a transit telescope, a circular plane table mounted centrally under the range finder and a plotting device geared to the movements of the rangefinder. The floating mark in the binocular field of view appeared projected into the terrain and could be placed by the range finder mechanism on the surface of the ground. The oblique distance to the terrain point was reduced optically to the horizontal distance and applied manually to the direction ruler that carried the plotting pencil. The oblique line of sight, represented by a pivoting

straight edge, resolved the elevation difference between the instrument horizon and the terrain point. The similarity of this solution with the one used in connection with the photogoniometer and the Autocartograph is obvious. The photographic imagery of the object is here replaced by the object itself.

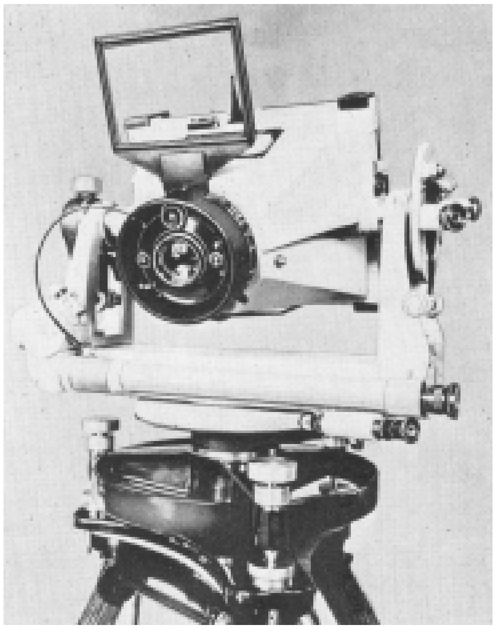

Fig. 8. Universal Phototheodolite.

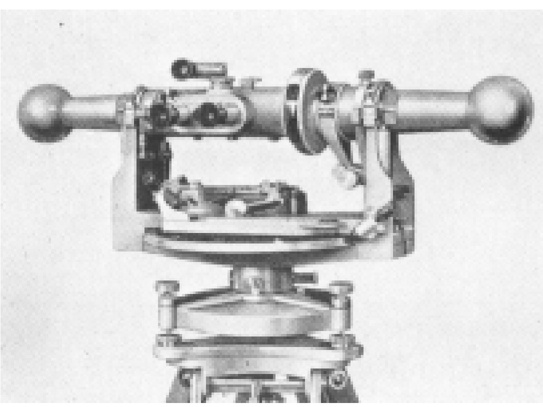

Fig. 9. The Stereotachygraph was a range finder-planetable combination.

In a further exploitation of his invention, Hugershoff added automation to this instrument in a manner that in turning two handwheels the operator could follow any terrain feature or contour line while the pencil continuously recorded these movements on the plane-table sheet. This instrument, the Autotachygraph, was successfully used in 1929 by an American Construction Company in building the southern portion of the trans-Persian railroad which runs from the Caspian Sea to the Persian Gulf. It was also tried out here in Washington by Col. Birdseye's brother Sidney who did not fully agree with Hugershoff's predilection for small dimensions when applied to instrument tripods. It is regrettable that this instrument has fallen into oblivion. Our electronic technology might have found it challenging to try image-correlation in rangefinder optics and automatic terrain mapping to replace *old fashioned photogrammetry*.

(4) Another novelty and departure from conventional design was the single-light source, single- measuring mark *stereocomparator* (Figure 10), an elegant and compact design that placed the two photos back to back in parallel vertical planes. The optical components of the binocular observation system remained stationary while the plate carriers moved along X- and Y-tracks. We find this concept partly preserved in the Zeiss-Oberkochen precision stereo comparator.

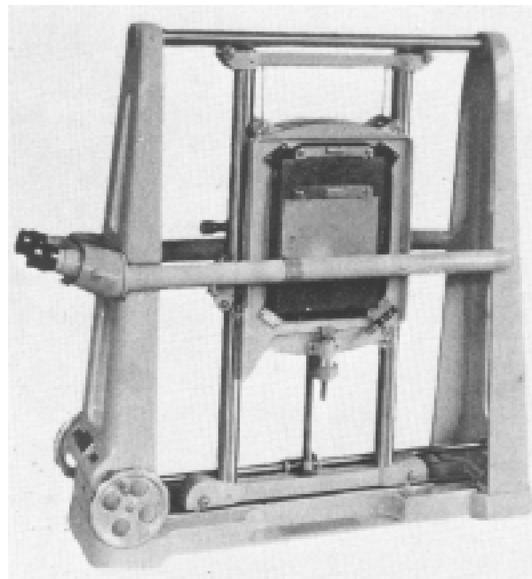

Fig. 10. This Stereocomparator was the forerunner of the present PSK model.

(5) Next in line was an advanced *stadia transit* (Figure 11). It had a set of three telescopes with one common eyepiece. The center one served for sighting a vertical stadia rod which had two auxiliary scale graduations. One lateral scope provided the distance reading automatically reduced to horizontal distance, the third scope reading gave the elevation difference between the station and the terrain point. A rodman had to operate the auxiliary scales.

An achievement of far reaching consequence stirred the photogrammetric community when Hugershoff disclosed a new plotter design, the Aerocartograph, in 1926. He had never been satisfied with his monstrous Autocartograph, although it had proven meanwhile its competence and had produced topographic maps which met government standards. But its complexity had baffled many people. One Czechoslovakian admirer had sketched his impression in a comic strip (Figure 12) which clearly shows the magic of its functioning. Another enchanted listener had found it hard to imagine how this machine would fit into an airplane. So, simplification and compactness were the guidelines that hopefully would lead to an instrument that could be placed on the Professor's oh-so-crowded desk! That was wishful thinking, but nevertheless, worth trying.

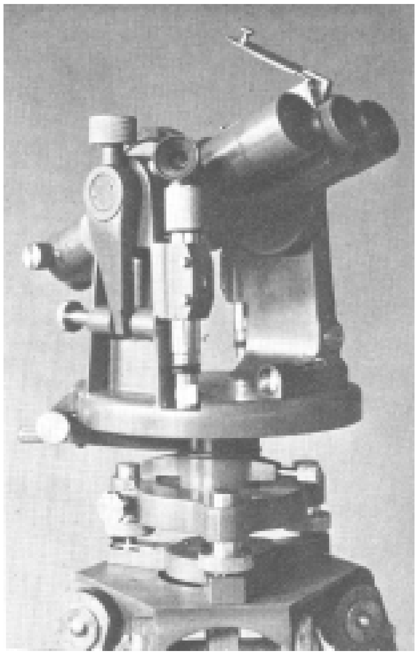

Fig. 11. The Stadia Transit had three telescopes with a common eyepiece.

Fig. 12. A Czechoslovakian comic depicted the Autocartograph.

The point of departure was the goniometer component of the big machine (Figure 13). The sets of straightedges that had presented the components of the spatial directions of sight rays were replaced by a spatial guide rod and a novel resolver element that delivered horizontal rotations to the goniometer plate holder, and vertical rotations to the front components of the observation telescope. An optical cross-over switch was placed in the path of the image rays on their way to the eyepieces exchanging the left and the right fields of view. This opened the way for ortho- and pseudo-observation of the stereo model and, consequently, for the extension of control over sequential photos. Thus, analog-aerotriangulation came into being. The engineering model did not fit on the Professor's desk, but it had lost considerable weight, its shape was graceful and its structural dressing was of the *see-through* variety.

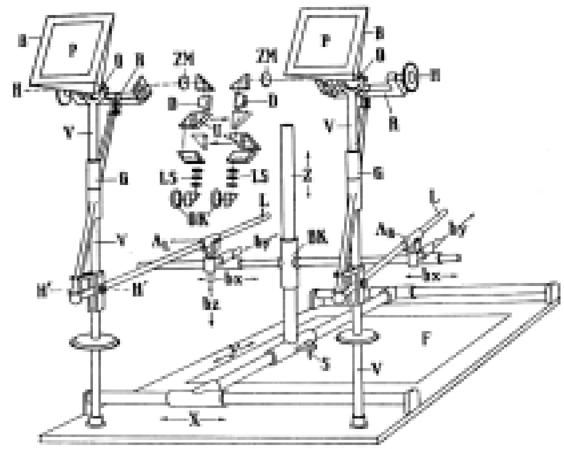

Fig. 13. Schematic view of the Aerocartograph.

There was a celebration in the exhibition hall of the second International Congress of Photogrammetry in Berlin 1926. There occurred a touching moment when Zeiss people, still passionate competitors at that time, came visiting the Hugershoff stand. Among them was Carl Pulfrich (Figure 14), the highly respected senior Zeiss scientist and inventor of the *floating mark.* He was visibly pleased. He spontaneously congratulated Hugershoff for what he thought was the greatest accomplishment, namely having given photogrammetry an *instrument* instead of a new *machine.*

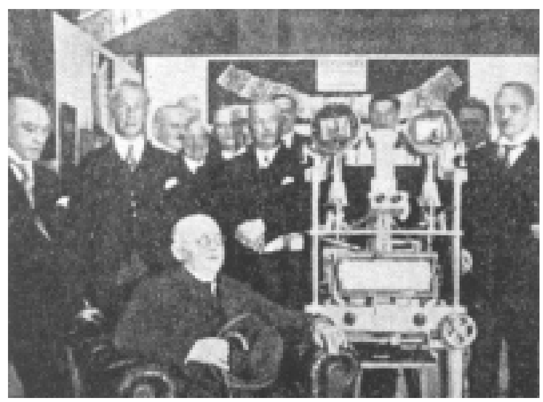

Fig. 14. A photograph of the Aerocartograph taken in 1926 in Berlin during the Second International Congress of Photogrammetry shows Prof. Hugershoff on the extreme left and Prof. Dr. Carl Pulfrich seated.

The second model of the Aerocartograph grew a little in three dimensions because his inventor had to concede that the time for general acceptance of reduced diapositives had not come yet, but the instrument was again a universal plotter accepting all categories of aerial and terrestrial photographs.

The first Aerocartograph arrived in USA in 1927; the Professor himself introduced it to the U. S. Geological Survey. His presentation aroused considerable interest in governmental and military agencies. The first test program proved to be too ambitious. Many obstacles such as the use of conventional American commercial film of uncontrolled shrinkage properties, and of camera lenses of dissimilar and vaguely determined distortion curves had to be overcome before the error propagation through a triangulated strip could be held within tolerance limits. Nevertheless, the mapping results were far superior to those of the graphical radial line method of control extension practiced in those days. After correcting the initial shortcomings, a number of Aerocartographs were successfully used in a variety of large U. S. mapping projects. Probably the most interesting and demanding was the survey of the Hoover Dam (Figure 15) site by terrestrial photogrammetry mentioned in connection with the universal phototheodolite. In military mapping the plotter was extensively used in aerial triangulation over inaccessible regions, and in plotting from vertical and oblique exposures of the US Army Air Corps 5-lens camera. This was accomplished with an Aerocartograph of the Corps of Engineers which was substantially modified at Wright Field for this special application.

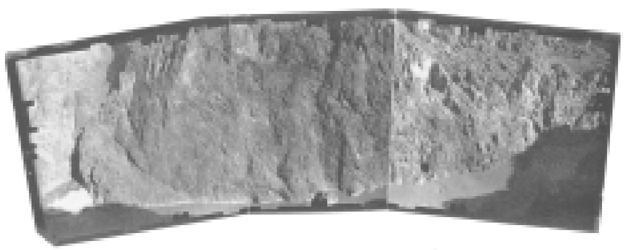

Fig. 15. Mosaic of photographs taken with the phototheodolite of walls of the Colorado River canyon, and plotted later with the Aerocartograph in preparation for building Hoover Dam.

The Aerocartograph was Hugershoff's finest but not his last contribution. Some others not mentioned so far were the camera-testing theodolite, the stereometric twin cameras for short-range photogrammetry, the "Small Autograph" for terrestrial and short-range mapping, a meteorological transit for atmospheric observations and several simulators for military operations.

After 1931 his inventions and constructive ideas were consummated with those of his Zeiss colleagues and, therefore, did not appear under his name. Up to that time he had acquired many basic patents, authored a series of books, among them a comprehensive text book on photogrammetry, and on *Applied Mathematics in Forest Engineering.* He had published a long list of papers in journals of several European photogrammetric societies. He was an acclaimed speaker at conventions and congresses of the International Society of Photogrammetry.

Considering the fact that each new instrument design had required a comprehensive research and development program, one might be led to believe that such intense activity would have filled his living days to the very limit. But we have only touched one chapter of his daily chores. Hugershoff was also a University Professor and, at times, Dean of the Forest Academy, a part of the Technical University of Dresden. Figure 1 shows him wearing the official robe of that high office. He wears the golden chain of the founder of the Academy, King Johann Georg of Saxony whose picture appears in the medallion.

Hugershoff's greatest popularity lay in his teaching capacity. He quickly won and retained the attention of his young students by the clarity of his speech, his mastery of making complicated problems simple and by his jovial reaction to their pranks. Roaring laughter made the hushed halls of the College tremble when Hugershoff in class spiced his lectures with spirited humor. The Convention Hall of the Photogrammetric Society was always filled for that same reason when he was on the program.

He was an admirer of the great philosopher poet Wolfgang von Goethe. We heard him often quote from Goethe's *Faust,* as, e.g., *A new day lures me to new shores,* or from the Bible, I *must work as long as it is day. Night will come, when one can work no more,* and he did not abstain from a frequent use of the flagrant line from Goethe's famous Drama *Goetz von Berlichingen.* And it may be admitted here, that some of his joking remarks were stronger than that Goethe word.

Excluded from his preferences for small things was the low-voltage electric gear of those days. His collective term for these products was a four letter word understood by everyone without saying. Even today we can sympathize with him on this subject when we struggle with the electric systems of our automobiles. But I suppose, if he were a witness to the present state of the art of electronics, he would join the Committee on Computational Photogrammetry.

The portrait which I have tried to paint of this friend of people and humble laborer with unspoken faith in the eternal laws of the universe, is not complete without mentioning his scientific hobby: genealogy. His family archive contained leather-bound tomes of ancient prints, handwritten parchments, church registers, periodicals. He had made a systematic search for the ancestral branches of his breed. He had traced the direct lineage of the Hugershoff's back to the sixteenth century. The coat of arms adopted in 1712 (Figure 16) can still be found in a leaded window of Hamburg's church of St. Jacobi. A printed book of his genealogical findings and an artistic design of the "family tree" was dedicated to his only son Hugin with his handwritten inscription

Fig. 16. Coat of arms of the Hugersoff family.

A glance up to your ancestors is a glance up to eternity.

Let me close with a fitting reminder of what I said in the opening paragraph speaking of our heritage with which we are so richly blessed, by quoting another Goethe word which reads:

What you inherit from your fathers must first be earned, before it's yours.