APPLICATION OF AERIAL MAPPING TO HIGHWAY CONSTRUCTION

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Photography was applied to surveying long before the introduction of the airplane Photographs were taken from points on the ground with a photo theodolite in which glass plates were placed in a vertical position An instrument called a " Comparator " was used for measuring coordinates of points on the glass plate, after which, by the application of geometric principles, it was possible to construct a map Terrestrial photo surveying, however, has found but very limited use. One interesting application might be mentioned—the determination of the highest peaks in the continental divide for fixing the boundary of southeastern Alaska.

Courses in Photographic Surveying have been given continuously at Syracuse University since the establishment of the College of Applied Science. On account of the limited application—and due to the broadening of the Civil Engineering Courses—Photographic Surveying was dropped by many of the American Universities.

With the advent of the airplane, a new interest has been created in Photographic Surveying, and its field of application has been greatly broadened.

In order to stimulate interest in this work, The Guggenheim Foundation for the Promotion of Aeronautics has made a generous contribution to Syracuse University for assistance in establishing courses in Aerial Surveying and Mapping.

Although German Universities and German instrument manufacturers have taken the lead in this work, there are yet many problems to be solved It is hoped that America will contribute its share in this important field of research.

It is quite improbable that the transit will ever be entirely superseded by the aerial camera. There will always be operations demanding the use of the transit, such as establishing points on the ground for construction purposes, and the definition of property boundaries But it is indeed probable that in extensive topographic mapping the aerial camera will in the future be used so exclusively as to reduce transit work to a minimum. Moreover, when one considers that only two-sevenths of the earth's surface has been mapped, he realizes that this work presents vast possibilities for the application of aerial surveying

Aerial surveying has introduced a new type of map known as a "Mosaic." It is made by assembling a series of photographs—reduced as nearly as possible to the same scale—properly matched and oriented with respect to each other Some ground control is of course required for the construction of the best mosaics.

There is in reality no possibility of having aerial photographs on a definite scale throughout, unless the exposures are made with the plates precisely horizontal, and unless the entire terrain is level. Even then, were the scale to be known, it would be necessary to know the focal length of the camera and the exact height at the instant of exposure or to scale known ground distances. Of course the ground never presents a level surface, and the other conditions are difficult to fulfill.

For instance, research has failed to disclose a method for holding the camera in an airplane so that the plate will be horizontal. Level bubbles are attached to cameras the same as they are to transits, but they are affected by the unstable condition of the airplane, and by changes in speed and direction of flight. Gyroscopic instruments have been tried to eliminate the tilt of the camera, but without success. The amount of tilt may however, be minimized to as small as one degree by a skillful pilot cooperating with an expert photographer using a suitable form of camera suspension.

Photographs are perspective projections on which the scale is the ratio of the focal length of the lens to the height of the lens above the ground. It is, therefore, apparent that even if the absolute elevation of the lens at the instant of exposure are known, areas on the same photograph having different elevations will be shown to different scales Very sensitive barometric altimeters have been perfected, but a simultaneous reading on the ground is required for the calculation of the elevation of the lens. Experiments are being made with radio waves for determining airplane elevations. A solution of this problem would add greatly to the safety of flight not for photographic purposes but, for example, in fog when the ground cannot be seen at all

A camera with a 12-inch cone—the commercial term for focal length—will take a photograph on a scale of 1 in 5000 at a very moderate altitude of 5000 feet above the ground Photographs have been taken from altitudes as high as seven miles. The size of the usual photograph in American cameras is 7 by 9 inches with the 7 inches in the direction of flight It will cover a distance of 0 55 mile on the ground. The displacement of points due to changes in elevation is greater on the edges than at the center. An overlap of 60 per cent is, therefore, required in the direction of flight, exposures have to be made every 13 seconds for a ground speed of 60 miles per hour.

Due to the required frequency of exposure as well as the additional weight of glass plates, film rolls are generally used. The Brock Camera perfected by the Brock & Weymouth Company of Philadelphia, is the only exception. Some aerial cameras have plate adapters which have a limited use. The usual film is subject to variable shrinkage in the process of development. It is claimed, however, that the Agfa Aerochrome Film, manufactured in Germany, has a uniform shrinkage. This film is now being given a field test in this country.

In spite of the fact that mosaics cannot meet the requirements of an accurate map, they are of considerable value to the engineer. These inherent defects are outlined so the engineer will know what to expect from a mosaic. They should be really called "aerial mosaics" rather than aerial maps, which will be described later.

The majority of aerial surveys executed by the numerous commercial companies in the United States are of the mosaic type. Many of these mapping companies are a part of, or closely affiliated with aviation companies. Nearly all of the Army and Navy aerial mapping is of this class. The U. S. Geological Survey and the U. S Coast & Geodetic Survey have used aerial mapping over areas which are not accessible to land methods, such as the Mississippi River delta, and as a supplementary aid to ground methods

Mosaics are very useful in highway planning. Frequently the planning of a highway system is delegated to a non-technical board, who are abled to interpret a mosaic equally as well as the trained engineer. Mosaics show a vast amount of detail which cannot be obtained from the usual map Traffic congestion may be studied and improvements involving new rights of way may be determined

Dean A. N. Johnson presented a paper last year before the Highway Research Board in which an excellent analysis was made of a traffic survey compiled from an aerial mosaic of the 29 miles from the Baltimore City line to Washington. The flight was made at an altitude of 3600 feet; 127 exposures were made in an elapsed time of 27 minutes, making exposures every 13 seconds.

There are a good many other uses for aerial mosaics and frequently they are used by several departments of city, county and state governments. They may be employed for assessment purposes, and by city and county planning boards Many states are making special geological surveys to study materials available for highway construction In flat country rights of way for pipe lines and transmission lines have been acquired, and the lines laid out by the exclusive use of aerial surveys.

The requirement of a 60 per cent of overlap in the direction of flight previously mentioned, makes it possible to view two photographs of the same area taken from two different positions of the airplane by means of a mirror stereoscope (Figure 2), or by a magnifying stereoscope. The ground can then be viewed in relief, and a preliminary estimate may be made of the amount of grading involved in a highway improvement Geological formations may also be studied.

Attempts have been made to construct topographic maps from mosaics by using them as plane table sheets and determining elevations by the usual ground methods The stereoscope is used as an aid in plotting contours The angular value of radial lines drawn from the optical center of a horizontal photograph to any other points is not affected by the ground relief. A photogoniometer is an instrument for measuring angles on aerial photographs with a high degree of precision. By a system of intersecting radial lines, maps to a true scale may be constructed However, more satisfactory methods for constructing topographic maps from aerial photographs which also give more accurate results are now available.

Multiple lens cameras are used to increase the width of an area covered by a single line of flight. News reports of Captain Ashley C McKinley's Photographic Survey with Commander Byrd in his South Polar Expedition state that his photographs will cover a strip seven miles wide. This could only be accomplished at the reported altitude of flight with a multiple lens camera or by oblique views described later The Bagley Camera used extensively by the U S Geological Survey and the U S Coast and Geodetic Survey was a three-lens camera, the two side lenses being placed at angles of 35 degrees. It has now been superseded by a four-lens camera and a five-lens camera is being planned The oblique views must be rectified by an apparatus called a " transformer " which is a combination of a camera and a printer, before they can be used for mapping purposes.

The mounting of an aerial camera permits the taking of an oblique view as well as a nearly vertical one. An oblique view is a perspective picture which shows relief to the naked eye Preliminary studies for bridge approaches as well as the elimination of crossings of highways by railroads at grade can be made from oblique views

The Canadian Government has made extensive use of oblique aerial surveys in mapping their vast inaccessible areas of forest and lake country which are generally of very low relief The distance of the horizon line from the center of the plate permits the calculation of the tilt of the camera. The focal length of the lens and the height of the camera are the only additional data necessary for compiling by the principles of perspective geometry, a plotting grid diagram by which line maps may be constructed from the oblique views No economic method has yet been developed for plotting contours from oblique views These Canadian maps drawn on a scale of four miles to the inch will undoubtedly serve as the basis for planning highways when sufficient resources are discovered to warrant the development of these outlying territories.

For many engineering projects including highway construction, a topographic map is indispensable It is possible to compile topographic maps to a true scale from aerial photographs The field work of taking the photographs is identical with that for aerial mosaics. Photographs should overlap 60 per cent in the direction of flight

Figure 1 illustrates one of the principles used P_1P_1 and P_2P_2 are two horizontal photographs in which the lens shown at L_1 and L_2 are at the same altitude " H " above a datum plane. The point " A " has an elevation " h " above that datum plane The image of the point " A " is shown as " A_1" and " A_2" on the photographs P_1P_1 and P_2P_2 respectively The focal length of the camera is " f " $L_1A'_2$ is drawn parallel to L_2A_2 The parallax of a point may be defined as the algebraic difference of the two distances in the direction of flight from the optical centers of two horizontal photographs showing the images of the same point taken from two different positions of the camera at equal altitudes above a datum plane The parallax of the point "A" is designated by "p" and is shown by the line $A_1A'_2$ in Figure 1 Equations (1 to 7) show the method of calculating the elevation of the point "A" as well as the "X" and "Y" coordinates from the optical center of the photograph

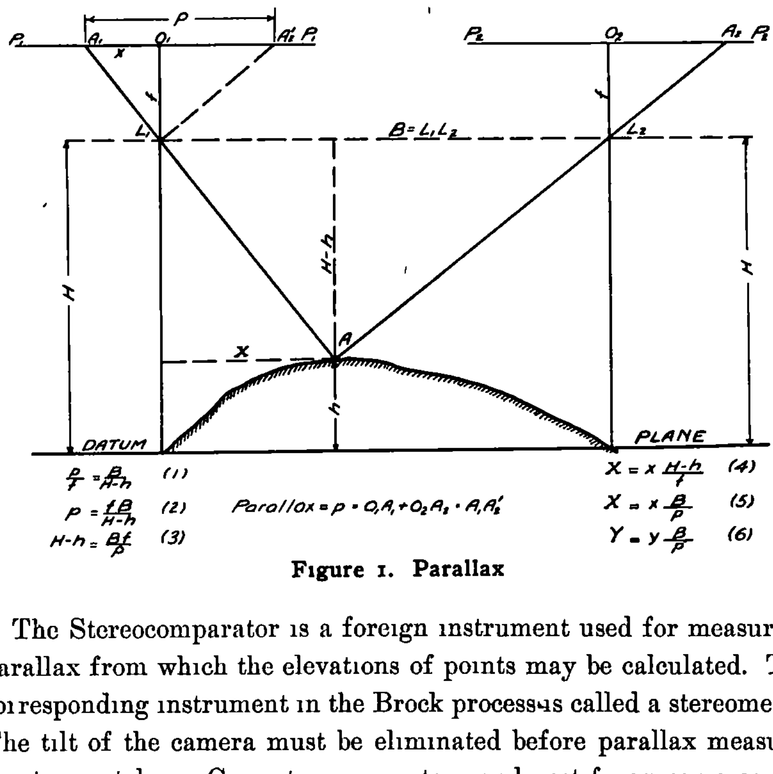

Figure 1. Parallax

The Stereocomparator is a foreign instrument used for measuring parallax from which the elevations of points may be calculated. The corresponding instrument in the Brock process is called a stereometer The tilt of the camera must be eliminated before parallax measurements are taken. Correcting projectors and rectifying cameras are used This is often the most difficult step in the process.

In the Brock method for constructing topographic maps from aerial photographs, positive glass plates are made from a set of overlapping negatives The optical centers are marked, and the positive plates are then horizontalized and placed on a Stereometer table (Figure 3.)

The plates are properly aligned for stereoscopic vision and the micrometer is set to read the computed parallax for points of known

Figure 2. Fairchild Mirror Stereoscope

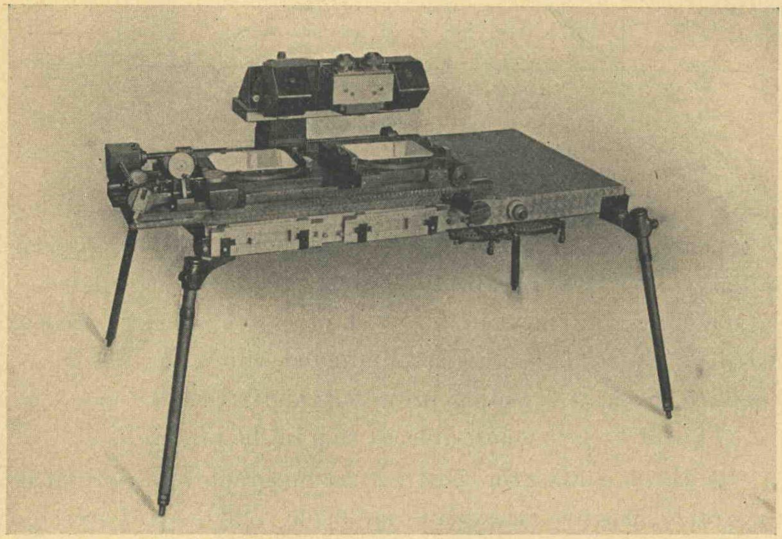

Figure 3. Brock Stereometer

elevation. The spread between the plates is then set to correspond to calculated parallax for the elevation of a contour line A cross hair or a floating mark is made to touch the ground in the stereoscopic view and its path will make a contour line directly on one of the glass plates As every contour line would be plotted on a different scale, it is necessary to reduce them to the same scale before combining them in a finished map.

The ground control necessary is the difference of elevation between several points on every set of plates and a known distance about every 20 miles Great accuracy is claimed for the Brock method due to the exclusive use of glass plates instead of films, and to the extreme accuracy of the correcting projector for eliminating the tilt of the camera. An additional advantage of this process is that several sets of plates can be worked simultaneously.

German investigators have developed a process for making contour maps from aerial photographs by a somewhat different method. Stereoscopic methods are used in conjunction with a pantographic plotting device. The stereoplanigraph for the automatic plotting of maps from aerial photographs taken with axes at any angle, and developed by the Carl Zeiss Company of Jena, is now being improved. The Autocartograph, devised by Dr. R. Hugershoff about 10 years ago, has been recently replaced by an improved type known as an "Aerocartograph." (Figure 4.) Several of these machines are now in use in the United States, and are also being used in other countries

The method of the Aerocartograph may be described as aerial triangulation, depending upon the angular values obtained from the overlapping photographs by two photogoniometers so coordinated as to furnish stereoscopic vision. It is not necessary to eliminate tilt of the photographs by a separate process; it is done in the machine itself. A set of overlapping photographs are oriented from three known points. A pointer is made to follow the ground in the stereoscopic view for an elevation corresponding to a desired contour. A pantograph can be geared to transfer the path of the contour to a drawing of any desired scale. Two drawings to two different scales may be made simultaneously.

After one pair of plates has been completed, the forward plate remains properly oriented and the backward plate is replaced by a new one. The stereoscopic view is now reversed and the new plate is

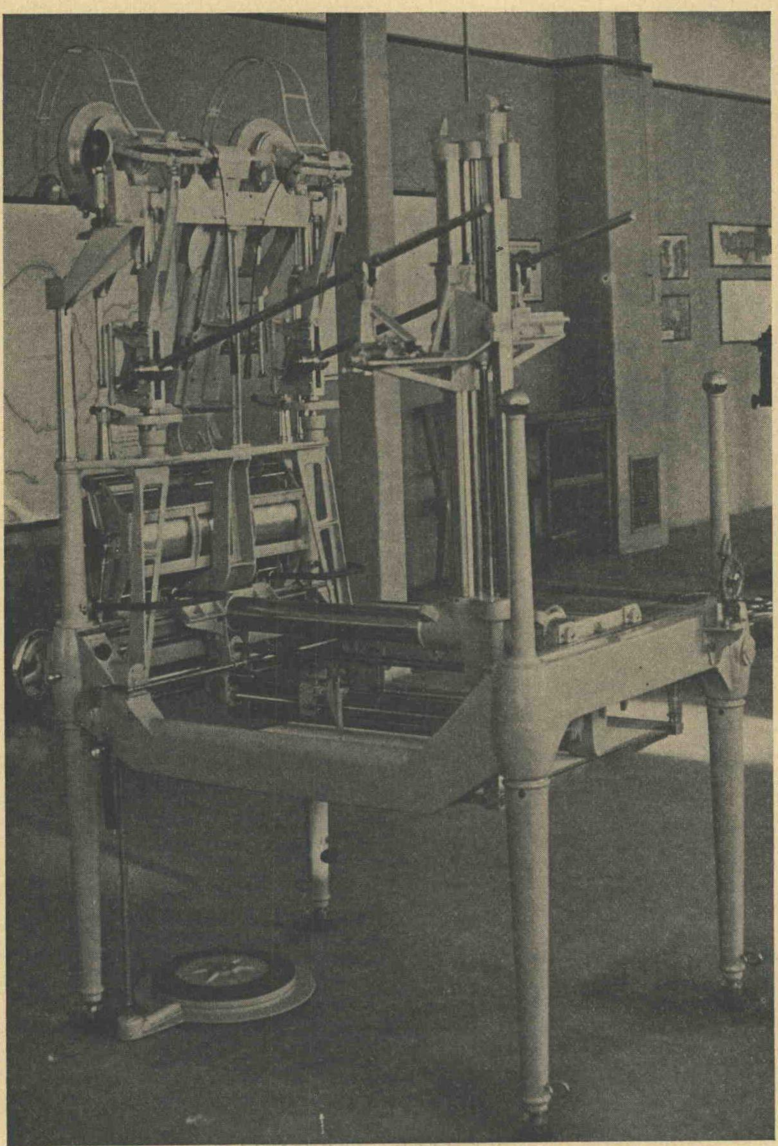

Figure 4. Aerocartograph

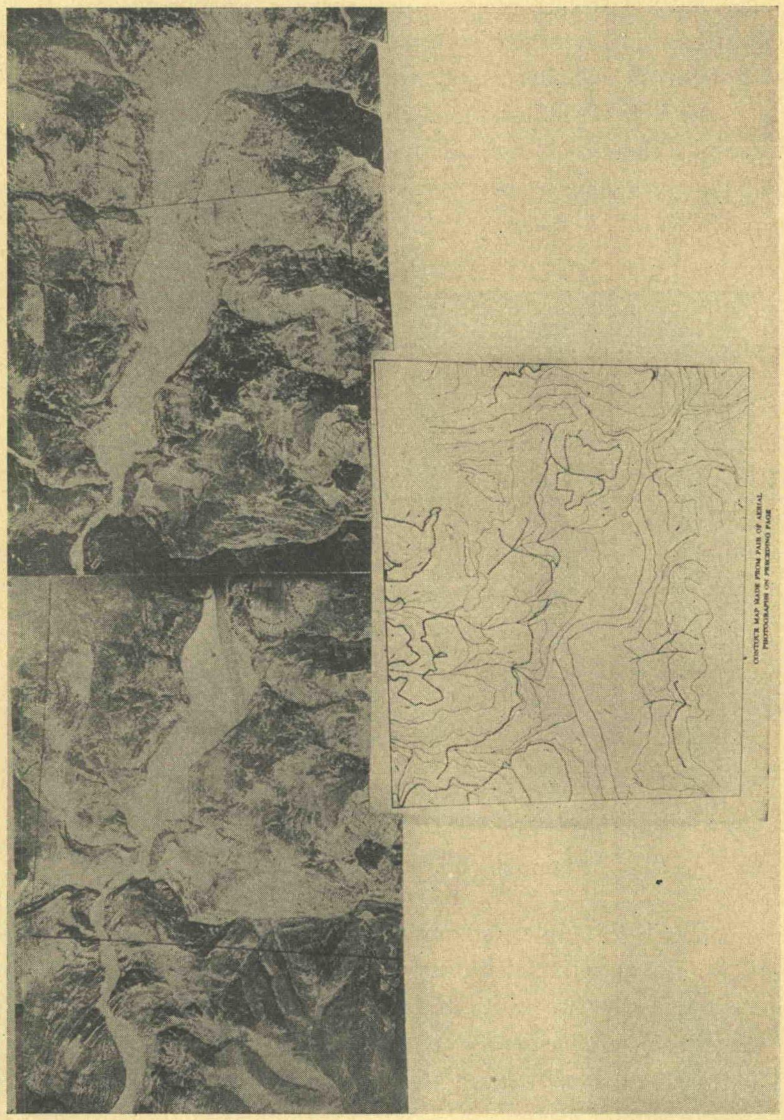

Figure 5. Contour Map from Pair of Aerial Photographs

brought into proper orientation, and the process is continued. It is claimed that a minimum amount of ground points are necessary for this method as each plate is oriented stereoscopically from the preceding one, and not from a new set of points. The laborious process of rectifying the photographs is eliminated. It is also claimed that the cost of the work is much lower. Sufficient work has not as yet been done in the United States with the Aerocartograph to allow a comparison with the Brock method. Figure 5 shows the two overlapping aerial photographs and the corresponding topographic map constructed with the Aerocartograph.

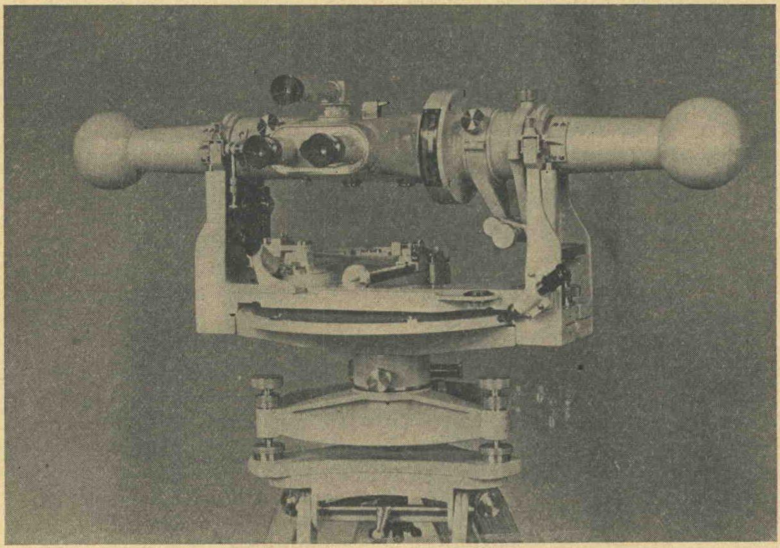

Figure 6. Stereo-Autotachygraph

Stereoscopic principles have been applied to aerial photographs in estimating the quantity of timber on a forest area. A relationship has been established between the diameter of the tree and the area of its top which can be measured stereoscopically.

The Stereo-Autotachygraph (Figure 6) is a combination of a plane table, range finder and the stereoscope. Distances and elevations of objects may be determined by merely viewing an object, dispensing entirely with the rodmen and chainmen. It has been used successfully by an American contractor in railroad construction in Persia. It may be used economically on preliminary and final cross sections in highway construction, especially in difficult topography.

The Autogiro (Figure 7) is a new type of heavier than air aircraft. It cannot be called properly an airplane because it lacks the planes or wings. It is stabilized by a revolving overhead rotor which resembles somewhat the overhead propeller of a heliocopter. It is now being manufactured in the United States. It is claimed that it will take off and land in a distance of 100 feet and can do 105 miles per hour with

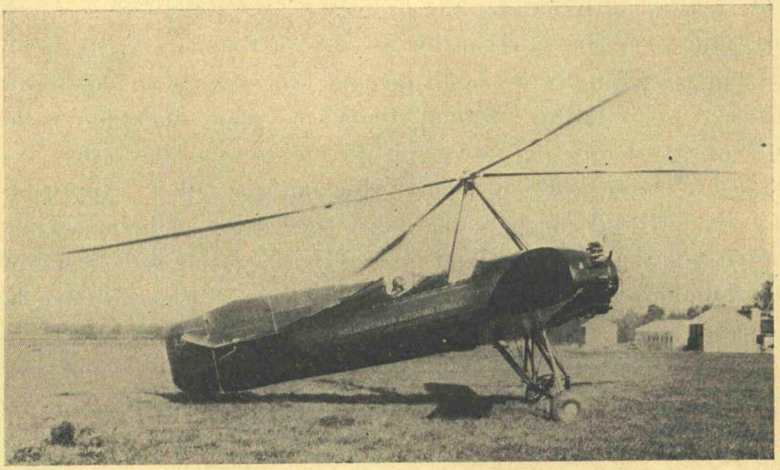

Figure 7. American Built Autogiro

a payload of 400 pounds. It has the additional qualities of being able to fly low and slow at a speed of 25 miles and a few feet off the ground if desired and at 12,000 feet if necessary. It has a cruising radius of 500 miles. Such an aircraft may have possibilities of solving some of the present problems involved in aerial surveying and mapping. The expected improvements in the instruments used for Aerial Surveying may also be of great value in increasing the safety of flight.