USE OF HELIUM GAS BALLOONS AND RADIO COMMUNICATION IN ESTABLISHING HORIZONTAL TIE POINTS FOR AERIAL MAPPING

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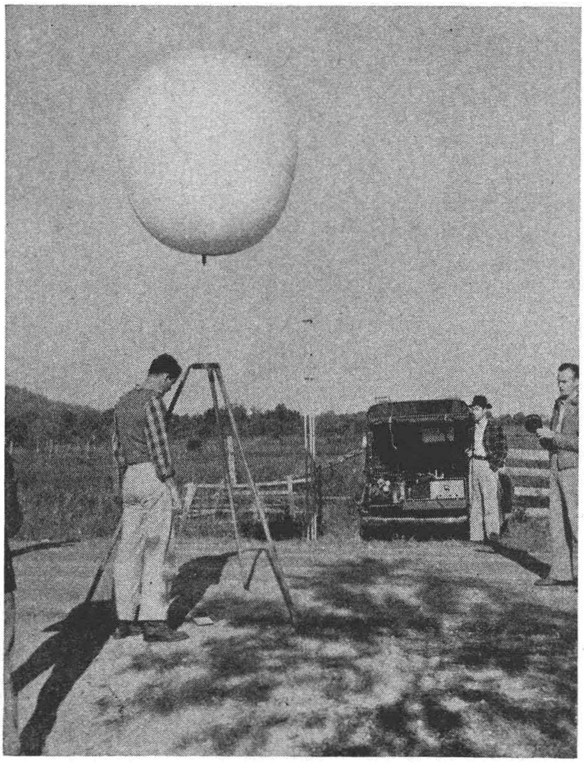
INTRODUCTION.—The following report was made to the Chief of Engineers, U. S. War Department, by Lt. Col. T. F. Kern, District Engineer for the Little Rock Engineer District, and has been circulated within the Department of the Corps of Engineers. The report was prepared by James W. Littleton, Principal Assistant of the Surveys and Mapping Section of the Little Rock Engineer District, under the supervision of Francis P. Newman, Head of the Surveys and Mapping Section, and the field operations were executed by William T. Ryall, Party Chief of a field survey group.

The Little Rock District now has six multiplex units operating two shifts per day that are utilized for National Defense, reservoir, and general flood control mapping. With the contouring and drafting costs greatly reduced by their use, an extensive study was made to try to reduce the costs of field surveys necessary for the establishment of horizontal and vertical ground control with the results as submitted.

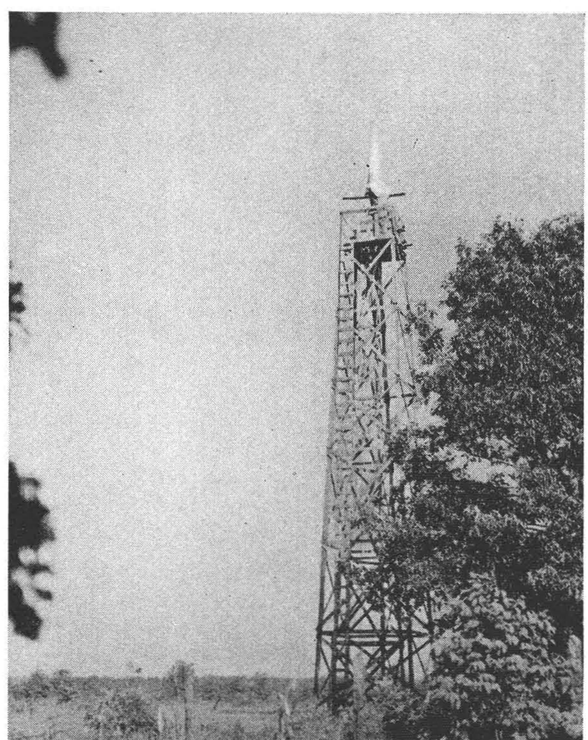
General.—The terrain in the drainage area of the White River and its tributaries in Arkansas and Missouri presents a major problem in the establishment of horizontal ground control for photogrammetric mapping. The slopes from the hilltops to the narrow valleys are covered with dense timber and rock cliffs. Base horizontal control of third order accuracy or better may be established in this territory without great difficulty as carefully selected peaks along the hills or mountains may be occupied by short towers and a triangulation scheme formulated, but the usual method of using transit traverses to constitute the secondary ground control or aerial photograph ties would be a very hazardous and expensive operation. A further breakdown of the triangulation network into a complex scheme of much smaller triangles using tower signals cannot be considered because of the numerous towers required, the intervening land masses, and the high percentage of the area covered by thick timber. Experiments with ascending balloons as a substitute for triangulation towers have been most favorable and resulted in the adaption of their use by the Little Rock District for the establishment of secondary control in rough, timbered terrain.

Problem.—The establishment of control for photogrammetric mapping of reservoir areas with 10-foot contour intervals on a 1:20,000 scale by multiplex methods was the objective.

Method.—As there was practically no existing horizontal control, a triangulation scheme covering the area to be mapped was established. The distance between stations was governed by the existing peaks that could be used to complete strong figures without building high length towers and to utilize several Forestry Service towers as stations that were existing in the territory. The distance between intermediate stations was then from two to five miles apart. Where necessary, 10-foot to 60-foot towers were built from rough, cheap lumber purchased locally in the area. These towers were allowed to remain in position after completing the triangulation as they were inexpensive and were to be used later in



Guying balloon over collimator. Radio setup, truck, and helium tank may be seen in background.



Triangulation tower constructed from cheap lumber purchased locally to the job. The balloon is "cut in" simultaneously from at least three of these stations.

the establishment of the secondary control. The triangulation was completed by a 10 second theodolite and the bearing computed between stations.

A small area around each triangulation station was whitewashed before the area was photographed by aerial photography so the triangulation stations might be identified on a photograph index, and on the photograph also as tie points. Indexes compiled from the aerial photographs in rough mosaic form were reproduced at a reduced scale of approximately one inch to the mile, and the triangulation scheme, to indicate bearings between stations, was surcharged thereon for field use.

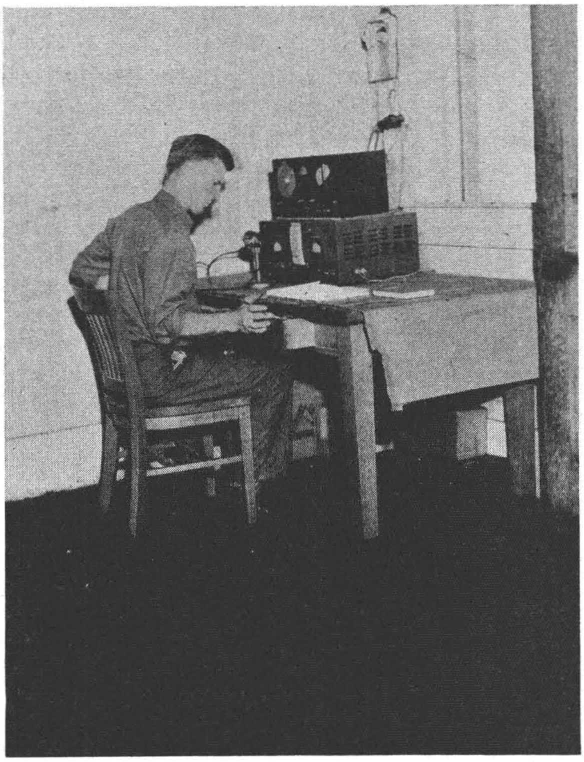
To efficiently operate a secondary control party of the type to be described, 20 men and a party chief were needed and a large outlay of equipment. Five instrumentmen with one helper each were stationed at different towers throughout the area to be worked. Each instrumentman was equipped with a 20-second transit, sending and receiving radio set complete, pack boards, photograph index, and line rod. Two tie selection parties, each equipped with high wheel type trucks, a helium drum, photograph index, aerial photographs, pack boards, collimator and mirror, and a sending and receiving radio set complete, were sent along roads and trails to occupy picture tie points such as road intersections, fence intersections, lone brush, etc., that had been selected in the office by the party chief.

The party chief selects by the use of a stereoscope the tie points to properly control the area. He also indicates the scaled bearing to each proposed tie point on the aerial index, assigning each a number. The personnel of each of these tie point groups consists of a surveyman to direct the operations and operate the radio, a responsible subsurveyman to operate the collimator, and three laborers to guy a suspended balloon. The party chief operates a monitor radio sending and receiving set in the field office and directs operations for any question that may arise.

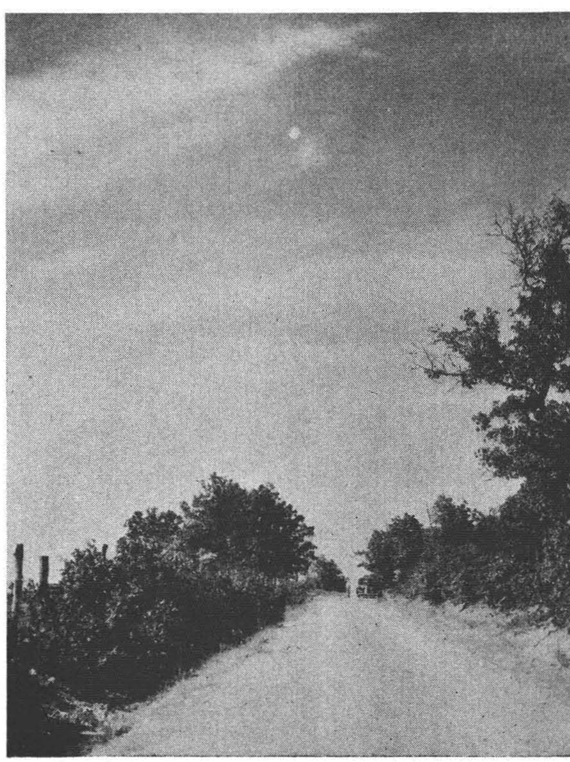
To begin a day's operations, each of the five instrumentmen and their equipment are dispersed to their respective tower stations from which they are to operate. The transit and radio equipment are carried up the towers by means of specially designed pack boards. The small power unit and battery for the radio are left on the ground, but connected to the radio on the tower to eliminate vibration on the tower and static caused by the motor. A board is placed under the battery to prevent its "grounding out." An aerial is strung from the triangulation tower to a nearby tree or other support.

The instrumentman sets up his transit, finds a triangulation tower or other azimuth reference in the vicinity for a back sight, refers to his photograph index and orients his instrument with the scaled bearing indicated for the direction to tie point No. 1 of the day's work. He next locates his helper on the ground in a convenient opening, preferably 400 to 900 feet from the tower in the direction of the first tie point to be made. The power unit and radio are then tested and the radio cut in to stand by.

One truck proceeds to the vicinity of tie point No. 1 and the other to the vicinity of tie point No. 2. Upon arriving as near as possible to the tie point in the truck, the radio equipment to be used is assembled, and, if the truck cannot reach the immediate vicinity of the proposed tie point feature, pack boards are used to transport the radio equipment to the point. An uninflated balloon is taken from the truck and incased in a skeleton holder. This holder is made of one-inch wide strips of soft, durable cotton bunting spaced 18 inches apart so as to assume the shape of a sphere 48 inches in diameter as the balloon is inflated. The balloon is inflated to the proper diameter from the helium gas in the helium



Party chief operating monitor radio station from field office.



Ascending balloon over picture tie point as viewed from a distance.

drum. If the tie point to be used is any appreciable distance from the truck, the balloon is incased in a soft, durable cotton bag for protection from punctures should it come in contact with limbs, wires etc., in carrying it to the point.

Upon reaching the point, the radio equipment is placed into operation and all instrumentmen notified that the balloon will soon be ready to ascend. The tie point is pricked with a needle on the corresponding aerial photograph, circled and briefly described on the reverse side of the photograph. A more thorough description is made in a field notebook. A collimator, with right angle cross wires in its 8-inch tripod head and legs approximately 8 feet long, is set directly over the picture tie point. By means of a plumb bob, a mirror is placed directly under the collimator head. Next, three light linen fishing lines, each approximately 400 feet in length and wound on reels, are attached to three sides of the balloon skeleton. The balloon is allowed to ascend vertically by means of the three reels and lines that may be guyed by three laborers spaced around the tie points. The balloon ascends slowly and the instrumentmen on the triangulation towers are informed by radio that it is coming up. They in turn notify the operator as soon as it is sighted. When as many as three of the instrumentmen can see the balloon, it is allowed to ascend no further and the instrumentmen are informed to be ready to clamp their sight on the balloon at the moment a signal is given that the balloon is centered over the tie point using the collimator. Each instrument is clamped at the instant the signal is given and the instrumentman informs the operator at the tie point that he caught the balloon. The balloon is then reeled down and placed in the cloth cover to be held without deflating in the back of the truck while transporting it to the next tie point. The equipment is reassembled at the truck and transported to the vicinity of the next scheduled tie point.

After the instrumentman clamps his sight to the balloon, he projects it to the ground to a line rod by signalling to his helper who is already in the approximate line of sight. When this sight is estaglished, the angle from the tie point to the back sighted triangulation station is measured six times direct and six times reversed. This completes the field operation for the first tie point of the day and the instrumentman begins to try to contact balloon party No. 2, which should be ready for operations at the next proposed tie point. The angles are checked by the party chief in the field for errors and forwarded to the District Office for computation. The completed scheme is computed by third order triangulation computation methods.

Description of Radio and Balloon Equipment.—The radio receiving and sending set used was the crystal controlled type and operated on an assignment of 2,300 kilocycles. A regulation 6-volt automobile storage battery was used and charged by a 7.5 volt, 150-watt generator. The generator was worked with a small 0.4 h.p. air-cooled motor.

The balloons used were purchased from the Dewy and Almy Chemical Company and were their "Darex No. 350" type. The helium was obtained from the Bureau of Mines at Amarillo, Texas. One drum will fill four balloons.

Costs.—The following is a comparison that will show the difference in cost by using the balloon method instead of the usual traverse method as experienced on the mapping of the second reservoir project worked by the Little Rock District in using this new method. These costs include all overhead charges.

Reservoir area: Current River near Doniphan, Missouri.
Area to control: 440 sq. miles.
Area to contour: 130 sq. miles (approximate multiplex plotting incomplete).
Estimated costs using traverse for secondary horizontal control:

Alignment of mirror under collimator head by the use of a plumb bob.

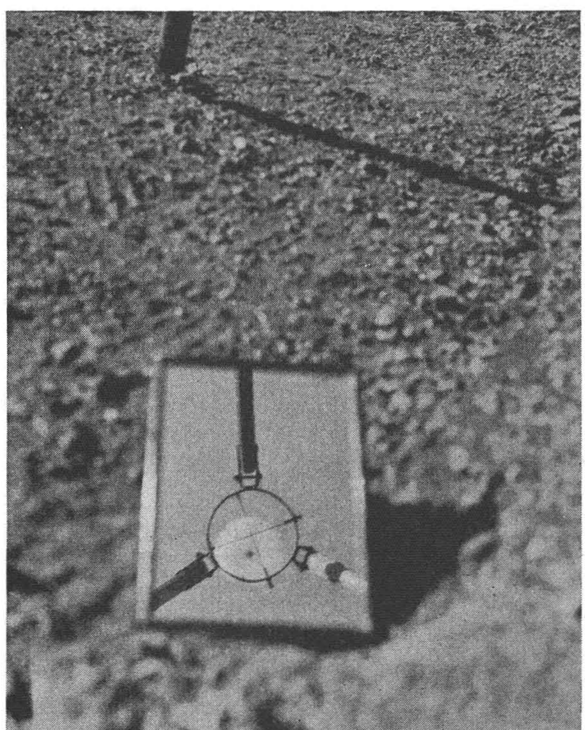


Image of suspended balloon and collimator head as viewed in mirror.

Triangulation reconnaissance	$ 430.00
Triangulation tower construction	2,250.00
Observing angles (base triangulation)	1,350.00
410 miles of 3d order traverse @ $30 per linear mile (estimated)	12,300.00
Computations (estimated)	610.00
Total horizontal control costs	$16,940.00
Actual costs using balloon triangulation for secondary control:	
Triangulation reconnaissance	$ 430.00
Triangulation tower construction	2,250.00
Observing angles (base triangulation)	1,350.00
Secondary balloon triangulation	6,020.00
Computations	420.00
Total horizontal control costs	$10,470.00
Savings in control establishment	$ 6,280.00
Savings in control computations	190.00
Total savings by using balloon method	$ 6,470.00

Accuracy.—The accuracy of the balloon triangulation was found to be a great improvement over the third order traverse method. In computing the geographic positions of any tie point from three or more triangulation stations, the maximum difference of closure was never over 12 feet and seldom as much as 5 feet. These differences when adjusted for the three or more triangles involved in the scheme should never deviate from the true geographic position more than 5 feet. As the traverse lines when used are routed through several tie points, they may extend 20 miles between ties and errors accumulate to as high as 20 feet.

If a large error is made in the balloon triangulation operations only one tie point will be affected and this may be eliminated without seriously affecting the mapping process whereas an error in a long traverse line might affect several points for which the major part of the line would have to be rerun. On the first project worked with balloon triangulation four tie points were eliminated and two tie points eliminated on the second project in making a total of 625 horizontal photograph ties.

Another questionable feature of the method was whether the balloon would be exactly vertical over the tie point when the signal was given for the instrumentmen on the towers to clamp their sights. By sighting on the mirror under the collimator with two transits located 500 feet from the point and at right angles to each other, it was found that the sight projected to the balloon as high as 300 feet above the point always fell somewhere on the balloon when the signal was given or never over 24 inches off the true vertical.

A very desirable feature of the balloon triangulation is the confidence that the multiplex operators have placed in its accuracy. They were inclined to question traverse tie points rather than readjusting their models to fit the control.

Recommendations.—Balloon triangulation is not recommended for mapping small or untimbered areas. It would not be practicable to train personnel for the different procedure and purchase radio and balloon equipment for mapping an area less than 200 sq. miles. The method cannot be used during high winds so the personnel assigned to the work should also be experienced in the establishment of vertical control so they may be shifted to other work without loss of time.

The process is very interesting to the field personnel as it is not so monotonous as traverse work since more progress can be accomplished with less effort. It is recommended to break the customary routine of close, strenuous chaining up and down steep hills through thick woods and using close setups as experienced when traverse is used.