

Triangulation with Helicopters*

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BY FAR the most severe problem of running map control survey parties in remote areas is the problem of transportation. On triangulation problems it is not unusual to find the field party spending a good 80 to 90 per cent of its field time in traveling from one station to the next and in reconnaissance of areas to determine the selection of stations.

The use of helicopters in transporting triangulation crews of course is not new. The U. S. Geological Survey has used this method of transportation in Alaska, the southwest and in other places. Possibly private agencies have used helicopters from time to time. A description of such use by the K. B. Wood Company for a survey problem in Death Valley last year may be interesting and helpful.

In this case triangulation was used as a means of checking the accuracy of an analytical photogrammetric bridge. (1) To satisfy our company concerning the accuracies achieved by photogrammetric methods and (2) to make possible some experimental studies by this company of various methods of bridging adjustment. The object of the survey therefore was not to determine high order monumented positions but to develop a series of scale points tied to picture points on the ground, with an accuracy sufficient to warrant their use for map checking purposes.

The project was located between Searles Lake and Death Valley, a distance of something in excess of 40 miles. The area consisted of typical desert conditions with barren rocky peaks and large flat basin areas devoid of heavy vegetation. The ground elevations varied from 200 feet below sea level to approximately 6,000 feet above sea level. The only existing transportation in the area was a very low order road and this would permit passage by four-wheel-drive vehicles only under ideal conditions. The nearest town of any size was Trona; a round trip from this point to the center of the area required a good 7 hours by four-wheel-drive car.

The only alternative to using helicopter transportation obviously would have been to set up a series of camps and to supply these camps with water and groceries. In addition to the problem of housing a crew in the area was the hazard of going on foot from mountain peak to valley bottom under desert conditions. Unquestionably the helicopter was the method to be used for purposes of transportation because of the ease of transporting men from the mountain top to valley bottom and back to Trona every night.

The operating cost of using helicopters made mandatory a great deal of thought being given to increasing crew efficiency. The following plan of operation was therefore inaugurated:

1. No targets would be set in advance of triangulation. From a study of existing topographic maps and the topographic maps produced for the area, an approximate location of stations to be occupied was determined.

2. Three Kern 1 inch theodolites were used on the operation, with three theodolite operators. In this manner each theodolite was itself its own target and the angles of any given triangle were turned simultaneously.

3. One recorder was used for the entire operation and the angles observed were radioed to the recorder and were turned continuously until closure of the triangle came within allowable tolerances. No re-occupations were therefore necessary. The helicopter operated as a shuttle bus jumping one theodolite operator ahead as each subsequent triangle was closed, and then a new triangle would be observed.

The operation started from a base formed by U. S. G. S. stations Brown and Layton. In the net U. S. G. S. station VT was cut in, and final closure of the system was made on U. S. C. & G. S. station BM 5672. In the entire operation 18 stations were occupied in a distance of approximately 40 miles. The operation was carried out within a period of four days, with a

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crew of three theodolite operators, one helicopter pilot and one mechanic, utilizing three Kern theodolites and one helicopter.

Since standby time of helicopters is an excessively high item of cost, this operation had to be planned in such a manner as to take advantage of ideal weather conditions. The occurrence of storms and rainfall in the Death Valley area during the spring months is not a great possibility; in other areas such weather conditions may be the critical item in deciding whether this type of survey or some other should be used. The greatest hazard in the Death Valley as regards weather was the danger of high wind velocities; these occur frequently in this area. It was very quickly found that the limiting factor from the point of view of wind velocity was not the helicopter itself but the actual theodolite operation. In other words the helicopters were able to land and take off under conditions of wind which were unfavorable for stable triangulation operation.

An added advantage discovered in the course of this operation was that picture pointing and the selection of occupied stations became much easier when the station was approached by air. As the helicopter with one theodolite operator proceeded to the next station, the other two theodolite men would continue signaling with a heliotrope, as the helicopter descended to a picture point selected from the air. At the same time the photographs were studied for the best position from the point of view of picture pointing. When a point was determined the helicopter would descend, the operator continuing to observe the other two stations until he was on the ground. If either one of them went out of sight he would choose a new and higher elevation position. In this manner very little time was lost either in the selection of picture points or in finding a good position from which to observe the other two stations.

The ability of the helicopter pilot to maneuver the aircraft into almost any spot in this area was indeed miraculous. The only places where a competent pilot cannot safely land a helicopter is in narrow deep draws where there is insufficient room to obtain forward speed in a take-off. For triangulation operations such locations are rare but this limitation on copter use might be important in other types of control operations.

Kern Copters, Inc., at Bakersfield provided the helicopter operation for this project, furnishing a pilot, mechanic, helicopter and truck. The helicopter was

brought into the area on a trailer behind the truck. The truck was used to haul gasoline and to spot it in areas close to the operating area so to facilitate refueling operations. One of the weaknesses of present daylight helicopters is their short range; therefore a great amount of time is saved by setting up refueling stations close to the project. Mr. Forrest Raebel of the K. B. Wood Company was in charge of the operations at Trona and was directly responsible for the successful operation of this venture.

Even though the cost of operating helicopters is at the present time extremely high, the speed and efficiency of this operation made the project economical. In photo control operations usually speed is as important as cost and the necessity for getting through the area with preliminary control rapidly is of paramount interest. We feel these objects were well met on this operation.

Second order closures were obtained between all U. S. G. S. stations a third-order closure resulted however when tying between U. S. G. S. stations and the U. S. C. & G. S. station at the eastern end of the project.

It was felt that this lessening in the closing accuracy in tying in this last point was due to the two systems probably being adjusted separately and not tied into the original work. Vertical angles were observed on all legs of all triangles in both directions, reading the angles to the nearest second. After being correctly reduced and projected throughout the area between bench marks, a total vertical closing error of 0.82 feet over the 40 mile stretch was obtained. After adjustments through the system it was felt that this closing error was sufficient for checking of 10 foot contour accuracy throughout the project.

In conclusion it can be safely stated that the use of theodolites on simultaneous triangulation with helicopter transportation is a fast, efficient and economical operation provided its use is limited to the following conditions.

1. Daytime triangulation operation.
2. Areas where the terrain is fairly devoid of vegetation making landings possible throughout the project.
3. Where weather conditions will not cause delays and shut-downs in the operation. Standby cost of the pilots and mechanics on this operation would soon use up the advantages if weather shut-downs were frequent.
4. In areas where a good base of existing triangulation accessible with helicopters can be occupied.