

## Some Problems Confronted in Selection of Triangulation Stations in Western Panama<sup>1</sup>

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The triangulation stations in this study and the problems arising from their selections are only a small part of one of the greatest geodetic surveys: the Inter-American Geodetic Survey, established in 1946 as an All-American continental project, carried out jointly by the United States and seventeen Latin American nations. The Inter-American Geodetic Survey, as its name implies, is not a map-producing agency but a geodetic survey which establishes control points throughout the American continents. Each of these control points is a permanent structure, of which the exact latitude, longitude, and elevation is known. The Inter-American Geodetic Survey utilizes the natural topography and landscape where possible, with the stations spaced about ten miles apart in flat terrain and fifty miles or more in mountainous areas.

Selection of any triangulation station in a geodetic survey must be an arbitrary one, the decision being made in the field at the time of the survey. A triangulation station is the point in a survey at which a set of measurements is based. In order for these measurements to be accurate, the surveyor at one station must be able to set two or more other stations to form the basic triangles necessary for the survey. The selection of each station presents a variety of complex problems which can be solved only by the surveying party in the field.

In Western Panama, the predominate method of selection of triangulation stations was done by the use of aircraft. Using the methods of aerial triangulation, the surveyor was best able to make the decisions accurately and quickly pertaining to station selection. By flying each line of sight projecting from the proposed station, the aerial observer, who was usually the party chief, was able to determine the best stations in the triangle or quadrangle before the surveying party occupied the station. The party chief was able to obtain mean compass bearings to and from each of the other stations, enabling him to prepare a rough map for the use of each surveying or light-keeping party. Since all triangulation is done at night, this greatly facilitated the work of the station observer.

The task of the party chief in selecting the control stations from the air is "verifying intervisibility", or making certain that his selected stations were higher than the nearby hills with clear lines of sight to each of the other stations. From the air, using the airplane compass, he was able to make a sketch map and note the estimated azimuths to the other stations, and prepare the first briefs which later were developed to be a complete station description. The station was then marked from the air by dropping aluminum foil on the slopes of the hill. The party chief then prepared a description of the best approaches to the station, locating water supplies, if possible, and temporary or permanent landmarks to guide the surveying party which followed.

In the selection of the triangulation stations, the primary consideration of the party chief was the line of sight to each of the other stations in the quadrangle. The party chief had to ascertain the best position on each particular hill or ridge, determining the true height of the hill rather than the apparent height as indicated by the vegetation growth. There were sometimes instances in which stations were selected from the air with narrow margins in the line of sight, only to find that after the stations were occupied that trees or other obstructions blocked the line of sight from the ground, requiring the use of the Bilby tower.<sup>2</sup>

<sup>1</sup> Data gathered while writer worked with the Inter-American Geodetic Survey (IAGS) in Western Panama

<sup>2</sup> Portable Steel Tower.

The party chief also had to consider the accessibility of the proposed stations. Since most of the area, in particular the Atlantic coastline, is almost uninhabited, with little access to the interior uplands, the party chief had to select the station which had the easier approach. In most instances, the party chief had to arrange transportation to station location by a combination of transportation facilities. Generally the field party was transported by landing craft to a point along the coastline which afforded the best passage to the interior, usually a river or stream. If there were no native villages along the stream or coast, the party took with them native pack-bearers to carry the equipment and supplies to the station. From the coast, the party usually attempted to follow a stream or river to the closest point near the actual station site, then crossed through the rain forest to the summit. The field party took with it only those supplies which were necessary for subsistence until they reached the station location, plus the equipment and instruments which could not be dropped free-fall from a small liaison aircraft. The packers, however, did not remain on station during actual triangulation, but returned to their village or to the coast to await the completion of the survey before returning to the station to bring the equipment back to the coast. This procedure was followed where possible due the expense of pack-bearers.

The average time needed in reaching a station near the coast is about four days. There are, however, some stations which have required as much as ten days or two weeks to reach. One of the most difficult stations to occupy in Panama was Station Orange, in Darien, which required forty-three days for the trip.

There are, of course, many problems which arise with the use of aerial triangulation. There are problems of weather and winds, and of the mechanical condition of the aircraft itself. Since the type of work necessitates the use of small aircraft with limited range, there must be some type of landing field and central base of operations from which to work.

While the surveying party is in the field, there must be constant communication between the field stations and also between base operations and the stations. The party chief, at the base operations, does all computing of data furnished him by short wave radio from each triangulation station. The surveying party must remain on location until the desired accuracy of triangulation is achieved. To insure this accuracy, the surveyor measures each angle thirty-two times. When the arc or quadrangle "closes", the party chief sets in motion the facilities of transportation, notifying the packers to return to the station site and bring the party back to the base headquarters, or sends them back to the field on another location.

The aircraft crew must also be in daily communication with the surveying party. Since the individual station party takes with it only those non-durable goods which cannot be dropped from the air and but enough food and supplies to last until they reach the station, the aerial crew must be prepared to supply them with food and equipment immediately upon their arrival at the station site. These goods must be dropped free-fall, without parachute, from low altitude. If the package dropped from the air should miss the narrow ridge or mountain peak, the ground party may spend days searching for it, or it may never be found in the dense undergrowth of the mountain slopes.

There were also serious problems due to weather and climatic conditions, which at times hindered the supply and reconnaissance missions of the aircraft. Most of the air masses are unstable in Western Panama resulting in convectional cloud formations in the late morning and afternoon which may cover the higher stations, making it impossible for the aircraft to supply the ground party. The airplane, therefore, has its greatest value in the early morning, before the cloud formations build up, or in the late evening, after the cloud formations have raised above the station.

Another problem is that of the prevailing winds and air masses. Since the small liaison aircraft must fly at a low speed, and at a close distance from the ground to insure accuracy in the air drops, it is particularly vulnerable to the unusual and treacherous air currents associated with mountain conditions. This is particularly true in flying near stations which are on or near the continental divide, where an air mass may move up or down a mountain slope at great speed.

The climate, of course, affects the entire operation of the geodetic survey. To insure the greatest accuracy, all triangulation is done at night, using signal lights to pinpoint the stations. The survey, especially in the humid tropics, must be conducted during the dry seasons, in order to avoid the most cloudy conditions. The problem of clouds obstructing the line of sight, along with fog and mountain haze is a serious one, sometimes forcing the surveying party to remain on station several weeks waiting for rain and fog to lift. When this happens, new problems arise. Men on remote stations may run out of food or water, and at times are isolated by flood waters. Frequently triangulation parties may take arms with them to provide for fresh meat supplies while on station.

The problems and the methods used in their solution which were encountered in Western Panama are by no means unique to any specific geographical location or survey. Regardless of procedure or purpose, any survey, whether it is geodetic or geographic in nature, will be confronted with a multitude of similar problems, and their solution can only be done by the surveying party in the field at the time.