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Survey Project Planning

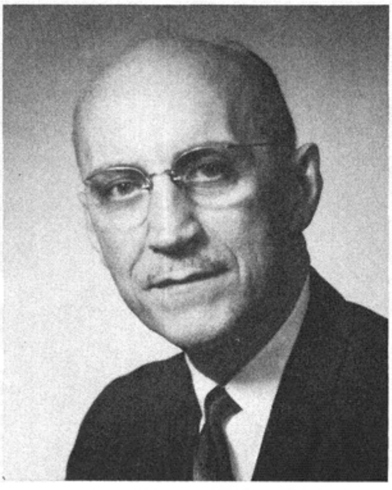
Photo scale, flight direction, camera type, accuracy specifications, contour interval, ground surveys, logistics, etc.

I HAVE TAKEN THE liberty of maing my own definition of *survey project* in the assigned title of *Survey Project Planning*. I made this interpretation on the basis of the organizations sponsoring this meeting.* I shall attempt to show the advantage of planning and discuss some of the work items warranting serious consideration on overall projects, which start with aerial photography and end with a topographic map and cadastral data.

I have selected special-purpose type projects requiring maps and data for consideration, rather than general purpose maps such as the excellent quadrangle maps produced by the U. S. Army Topographic Command and the U. S. Geological Survey. Special-purpose projects normally require various types of data at larger scales, smaller contour intervals, and showing more detail than general-purpose maps. There are no limits to size and shape of special-purpose projects. They may be defined as the area above or below a certain contour or between top and bottom contours by township, range and section lines; by latitude and longitude; by plane coordinates· a strip of a designated width between certain points, or just an outline on some type of map. Such data may be required for exploration, railroad, highway or transmission line location and/or design, hydroelectrical projects, irrigation, flood control, storm and sanitary sewer location and design, real estate development, plant site location and design, and a host of other purposes.

THE FIRST AND most important item of consideration on any special purpose project is an analysis of the requirement. What data are required? Why are the maps and data required? How will they be used? When are the data required? An analysis of the requirement will generally dictate accuracies, scales, contour intervals, detail to be shown, etc. This analysis should be made jointly by professional personnel familiar with the overall requirements of the project and professional personnel thoroughly experienced in photogrammetry, surveying and mapping techniques.

The characteristics of the aerial camera are an important item of consideration, although other items must be taken into consideration before reaching a final decision concerning the aerial photography. Most projects can satisfactorily be photographed with the normal type precision camera having a focal length of 6 inches. However, if relief is not severe and vegetation does not present a serious problem, consideration must be given to cameras having a shorter focal length. On some projects, vegetation may dictate the use of longer focal length or reducing overlap between adjacent photographs. Before a final decision can be reached concerning the



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aerial camera, the control problem must also be considered. If analytical aerial triangulation is to be used to supplement ground control, then the characteristics of the aerial camera become increasingly important. It has been our experience that substantially better results can be obtained in extending control by analytical aerial triangulation methods if the camera has eight fiducials, or preferably a camera platten that has a pattern of reseau markers. Cameras with only four fiducials do not provide adequate information concerning the demensional characteristics of the aerial photographic negative.

The flight direction can best be determined after the location and accuracy of existing control within or near the area is known, and at least a tentative plan made for establishing additional control. It is frequently desirable to extend flight lines beyond the project area in order that existing control, a road, or clearing where additional control can be established, will be covered by the photography.

Flight height is an important consideration, as this will govern the number of flight lines and photographs required to cover the area. Flight height is controlled by the type of stereo-plotting instruments available for compilation and the predominent features to be plotted. Greater flight heights can be used for 1st order instruments such as Wild A-7, A-8, B-8's and Zeiss C-8's as compared to Kelsh and Balplex. However, if the area comprises a great mass of straight line-features, such as roads, streets, alleys, buildings, property lines, etc., Wild A-8's, Kelshes and the Balplexes have certain advantages. On the other hand, areas of extreme relief will eliminate consideration of the Kelsh and Balplex instruments.

The season of the year during which the work is to be accomplished is also an important item of consideration. In normal topographic mapping where vegetation is a problem, aerial photography should be accomplished when the vegetation is defoliated and the ground is free from snow. This normally allows only a brief period in the spring and in the fall when aerial photography can be accomplished. Some special purpose projects develop and have a sufficiently high priority that mapping must proceed immediately even though foliage conditions are undesirable. This results in photogrammetrically compiling the maps of areas sufficiently free of vegetation and field completing the remainder of the area by expensive ground survey methods. In such instances, areas where the ground is obscured should be contoured as accurately as possible by photogrammetric methods, and the contours in such areas should be shown by dashed lines to indicate probable inaccuracy. Under no consideration should field completion be started until the survey engineer and the overall project engineer review the photogrammetrically compiled map. The dashed contours, in most cases, will give a reasonable portrayal of the topography and may indicate areas where expensive field completion is not necessary. Although this procedure is normally less expensive than mapping the area entirely by ground survey methods, the cost of proceeding on projects at unfavorable times frequently increases the cost of a project by a significant factor.

ABSTRACT: *On special purpose projects, such as highway and railroad location and design, dam, reservoir and irrigation studies and design, etc., a complete analysis of the project survey and mapping requirement is essential. What accuracies, scales, contour intervals are necessary to provide engineers, planners and administrators the data required? When are the data required for use on the overall project and what areas or data are required first? Only after these decision are made can effective plans be made for such items as aerial photographic scales, flight direction and type of camera; location, accuracy and density of ground surveys; map scales and contour intervals; logistics and numerous other items. Without proper advance planning for all phases of a project costly delays are likely to occur.*

ON MOST special-purpose type projects the cost of establishing the necessary ground control will run from 25 to 50 percent of the total cost. Therefore advance planning to the maximum extent feasible is necessary for field survey operations. Access to the area, topography and vegetation within the area generally control the locations for establishing ground control. For planning ground control, copies of the best available maps should be obtained together with information concerning all previously established horizontal and vertical control in or near the area. Unfortunately, instances occur where the only available maps of an area under consideration are aeronautical charts at a scale of 1:1,000,000, showing 1,000-foot contours. We have this exact problem on a 400-mile microwave project in Iran at the present time. In such cases you are faced with the problem of making a field reconnaissance of the area or making many assumptions. Fortunately, better information is available for most projects.

An analysis of topography, location and accuracy of the existing control, vegetation and access to areas where control can be established will normally govern the flight length and direction. In areas of difficult access the use of analytical aerial triangulation becomes mandatory from a time and cost standpoint due to the flexibility in locating new control points to be established. On projects requiring several parallel flight lines or a pattern of flight lines in many directions, analytical aerial triangulation has many distinct advantages. For example, analytical aerial triangulation permits proposed control-point locations to be shifted up or down a flight line several models without seriously affecting accuracy. In some parts of a project area it may be impossible to establish or identify ground control due to vegetation, relief or access. Analytical aerial triangulation based on properly planned aerial photography and ground control normally eliminates the necessity of establishing ground control in the more difficult areas.

It has been found that analytical aerial triangulation accuracies are normally increased if it is possible to panel the control-point locations prior to aerial photography. By advance planning the locations for control points can be determined and panelled prior to aerial photography. On sizeable projects helicopters can be used to great advantage in panelling. As soon as all the panels are in place the photographic airplane can be mobilized. Once the panels are in place field control operations can proceed even before the photography is completed. In many areas it is impossible to make positive photoidentification of natural features to the required degree of accuracy. The rms errors in the overall analytical block adjustment are always less when control points are panelled. Occasionally it is found that the best access is through the more densely-wooded portion of the area where natural features, suitable for photo-identification are not available. Rather than to run spur lines a considerable distance to identifiable features, it is often advantageous to suspend panels near treetop level and plumb the location and elevation to the ground.

The availability, location and accuracy of existing control will determine whether additional basic control needs to be established or whether only supplementary control is required. Accuracy of ground control for analytical aerial triangulation is far more critical than if individual models are all entirely controlled by ground surveys. *The accuracy of analytical aerial triangulation is normally better than third-order ground surveys.* It is our normal procedure to establish horizontal control to second-order or higher accuracies, or at least to keep third-order supplemental lines limited to a very short distance.

On a project recently completed for the Arizona Highway Department the closure on the horizontal control was one part in 89,000 and all vertical control points were a part of a first-order level line. This particular project was flown at a flight height of 6,000 feet, and 16 models in a single flight line were required to cover the area. Horizontal and vertical control points for analytical aerial triangulation were located in the end models and near the center of the area. All control points were panelled prior to photography. In addition to the required control, five well distributed control points were panelled and carried through the analytical,-program as passpoints without using the field survey X, Y, Z-values. When the X-Y-Z values of the analytical solution were compared to the withheld field survey positions of the panelled points, the average error in the X direction was 0.26 feet, or 1/23,000th of the flight height; the average error in the Y direction was 0.32 feet or 1/18,750th of the flight height, and the average vector error was 0.41 feet or 1/14,500th of the flight height. The average error in elevation was 0.16 feet or 1/37,500th of the flight height. These high accuracies on the test points probably would not have been achieved if all ground control had been of a lower order of accuracy.

The methods to be used in establishing field control can best be selected as a result of advance planning. Horizontal control from location-to-location may be established by triangulation, trilateration or traverse or any combination of these three methods. The *ABC* system should be considered. The method or methods selected will depend almost entirely upon the character of the topography, vegetation and access. Without advance planning it cannot be known whether the control can best be established from ground locations or whether it is more practical to use some type of tower.

If towers are necessary, what type and height of tower is required? In some applications local native materials may be used to build towers. On other projects, prefabricated towers are more appropriate. For many years it has been normal practice to use all steel Bilby-type survey towers. On a current project in Thailand and Laos where transportation of equipment is very difficult, we are using Bilby-type towers with the inner tower of steel and an outer tower of aluminum. The heavy steel inner tower is necessary for rigidity and stability because 1:50,000 closures are required, whereas the light-weight aluminum outer tower greatly reduced transportation and erection problems. The use of the light-weight aluminum outer tower is particularly important on projects where the towers are moved by helicopters, and of significant value if they are moved by ox cart. If the area is reasonably accessable and the vegetation is low, portable towers attached to jeeps, pickup trucks or tractors should be considered.

IT IS ALWAYS DESIRABLE for all surveys and maps to be based on standard horizontal and vertical datums, However on some special purpose projects, where no existing control on datum exists within the area, the cost of bringing control on datum into the area, and tieing back to the same or other control points on datum, cannot be justified.

Future survey requirements on special purpose projects must be considered. Most special purpose projects eventually involve construction. It is, therefore, desirable to establish bench marks and horizontal monuments in the area for later use in detailed surveys and contruction stakeout. On some projects it is desirable to place a considerable density of panels on the ground prior to aerial photography and to determine analytically the X, Y, Z-values of such points for later use. George Katibah of the California Highway Commission recently demonstrated, with considerable success, the practicality of using X, Y, Z analytical values of panelled points as a basis for highway stakeout. In any event, whether the initial surveys are on datum or not, all major survey points should be appropriately monumented and referenced. If surveys made on a local datum are properly monumented, referenced, and are made to a reasonable degree of accuracy, they can be tied to datum at a later date, recomputed and used for general purposes.

CARE MUST BE exercised in selecting map scales, contour intervals and detail to be shown. In selecting map scales it is frequent that the project engineer or planner will believe he needs a large scale map, such as 50 or 100 feet per inch, compiled to standard accuracy specifications, although actually all he needs is more paper-space for making trial locations, designs, etc. On occasion, photographic enlargements from scales of 100 feet per inch to 50 feet per inch, or from 200 feet per inch to 100 feet per inch, for use as working maps will meet this requirement, and standard accuracy applied to the smaller scales is entirely adequate. The same is frequently true concerning contour intervals. One- or two-foot contours are of little or no value where they are only a few hundredths of an inch apart at the map scale. For small, relatively flat areas, such as valley floors within an otherwise rolling to rough area, consideration should be given to an appropriately dense pattern of spot elevations determined analytically. Such elevations can be determined to an accuracy of less than one foot for a very minor cost compared to the cost of flying, controlling and compiling 1- or 2-foot contours for such areas.

Many projects require extremely large scale maps, showing contours at small intervals, compiled to standard accuracies and where adequate justification exists such maps should be compiled. The overall cost of topographic mapping increases rapidly as the scale increases and the contour interval decreases. On significant projects where little or no existing data are available it is sometimes desirable and economical to map the entire area at a smaller scale and larger contour interval for reconnaissance and general planning purposes, and later map all or parts of the project at larger scales and smaller contour intervals. For example, initially an area could be mapped at a scale, of 1:12,000 with a 10-foot contour, or a scale of 1:2,400 and five-foot contour and general investigations and plans made from such maps. If more accurate elevations of critical points are important to the engineer and/or planner in making general plans, they can be determined analytically to an accuracy of a foot or two. The general plan based on such maps could easily indicate that only one-third or possibly one-half of the proposed project area was worthy of mapping at a larger scale and smaller contour interval. In the case of transmission line location the 1:12,000—10-foot map would cover a much wider area from a single flight, thus making it possible for the transmission engineer to consider several alternate locations where right-of-way or topography is a problem.

FREQUENTLY special-purpose projects require all surface data, such as poles, wires, fire plugs, manholes, catch basin inlets, etc., be shown together with subsurface information such as invert elevations, sewers, pipe, cables, etc. Paneling some of the surface features prior to photography is desirable. Determining the location and depth of subsurface features always presents a problem and warrants considerable research and planning before quoting a fee or completion period for such work.

Most-special purpose projects require cadastral data to be shown on a separate copy of the topographic maps, or a planimetric map. Some require a separate map or plat of each property ownership. These data are required in varying degrees of accuracy and completeness. The overall project requirements should be carefully studied before cadastral work is initiated. In some instances only reasonably accurate and complete cadastral data are required for interior tracts, whereas greater precision is necessary for property corners around the perimeter of the project.

Initially the requirement may be to assemble copies of all available deeds and plats, and from the data they contain make the best overall adjustment possible to the accurately compiled map. If some visible evidence of survey or property lines appear on the aerial photographs, and the property data is reasonably accurate and complete, an acceptable adjustment can be made. The next phase normally requires more complete and precise cadastral data for all or a part of the project area.

The recovery and identification of property corners can range all the way from a relatively easy task to one approaching the impossible. In areas where property corners can be found it is desirable to panel them before the overall project aerial photography. In the event time does not permit panelling property corners prior to accomplishing the project photography, and a helicopter is assigned to the field survey operation, the helicopter can be used for the aerial photography of the panelled corners. In the event the corners are photographed from the helicopter, the photographs are normally at a different scale and a zoom stereoscope is required for transferring the panel location to the project photography. By re-runing the analytical aerial triangulation with the corner locations as passpoints, X, Y and Z values, if necessary, are obtained of all panelled or photo-identified corners.

IVERSE COMPUTATIONS will give the bearing and distance between each property corner and from these data the computer quickly gives the area of each property. If desired, the output from the computer may be used as input for an automatic dataplotter for plotting the property boundaries on the topographic maps or plotting individual property maps. The accuracy of the $X,Y,Z,$-values of property corners from the analytical solution will depend on the scale of the project photography and the accuracy of the ground control used as a basis of the analytic aerial triangulation solution. It is normally reasonable to expect an X, Y and Z analytical accuracy of about 1/10,000th of the flight height. In other words, if the aerial photography is accomplished at a flight height of 10,000 feet above the ground, it is normal to expect X, Y and Z accuracies approximating one-foot.

Where property corners cannot be recovered, then normal land survey methods are required to establish or re-establish the corner location. In such cases the X and Y values of corners established by ground surveys can be used with the analytical values of panelled or identified corners to complete the property boundary definition.

NO PLACE occurs in the entire surveying and mapping procedure where some advance planning is not warranted. It will save countless dollars and days, weeks or months of critical time. Some projects justify a greater planning time and expense than others. We are currently mapping an area of about 3½ million hectares in Thailand and Laos. This project well justified a trip to the project area and a complete aerial and ground reconnaissance before methods, procedures and a general plan of operation could be prepared. Had we estimated the time and cost required to complete this project without making the detailed field reconnaissance, our cost estimate would probably have been in the neighborhood of one-half million dollars less than the estimate based on factual data. Examples of the costly items that would not have been included are:

- Terrorist and guerrilla gangs, reported to be from Red China and North Vietnam, inhabited the heavy jungle areas, and their activities had a serious effect upon our rate of progress. We had approximately 175 surveyors on this project for a period of 20 months, which is substantially longer than would have been otherwise estimated.
- With the exception of the three cities within the area, it was found that food and water suitable for non-residents was non-existent and at times the city water and food was a problem.
- Only two paved roads, generally bisecting the area in a north-sourth and east-west direction, were suitable for continued automobile and truck traffic. This necessitated extensive use of helicopters and ox carts.
- The tree height within the area according to available information seldom exceeded 80 feet; however, it was found that the trees in a substantial part of the area were actually 100 feet or more in height. Thus if survey towers of only 80 feet in height had been sent to the project, survey operations could not have progressed without extensive clearing.
- Even the best and most complete advance planning can not be expected to eliminate all problems. The subject project area was divided by the milewide Mekong River with about one-third of the area in Laos and two-thirds in Thailand. No difficulty was encountered in moving U. S. personnel and native skilled labor such as party chiefs, recorders and instrumentmen from one country to another; however semi-skilled and unskilled labor such as rodmen, brushcutters, packers, cooks, tower erectors and similar personnel, who could be trained in a reasonable period, could not be moved from one country to the other. Accordingly, our plan of operations was to complete the survey work in Laos and then move to Thailand and recruit and train the necessary personnel. When only 45 days work remained to be completed in Laos, security conditions developed which necessitated immediate demobilization of all personnel from Laos until hostile conditions could be resolved. Thus, about 100 personnel had to be terminated in Laos and a similar number hired and trained in Thailand. Some 60 days later security problems were resolved and the Thai personnel had to be terminated and Laotian personnel reemployed. As you can well imagine we could only find a small percentage of the Laotian personnel previously trained.

Probably the most important item to consider in planning a project is the capability of the personnel available. Are long-term employees whose abilities are known available to staff the project completely, or is it necessary to send a small group of key men and have them recruit and train local personnel? The latter is frequently the case, particularly on overseas projects, due to local politics, laws and regulations. This makes the selection of the key personnel very critical and careful attention must be given not only to professional and technical ability but to ingenuity, health, language, personability, diplomacy, ability to train others, etc. Of these, ingenuity is one of the more important. Your advance plan cannot be expected to cover all contingencies, nor can it be a completely detailed plan. Your project engineer must have the capability to fit the overall plan to the area and to modify it as necessary to overcome unforeseeable conditions. As stated in the Robert Burns poem "To a Mouse": *The best laid plans of mice and men often go astray*!
