

Fortunately, by the time of the VII International Congress of Photogrammetry in 1952 there will be much more comparative data available regarding the different instruments and processes. At the U. S. Engineer Research and Development Laboratories in Ft. Belvoir, in the U. S. Geological Survey, the U. S. Coast and Geodetic Survey, and several commercial agencies, apparatus of several different makes and countries of origin is now working side by side on the same or similar projects. The results obtained will give the International Technical Commissions much to discuss that will be of interest to photogrammetrists everywhere. We hope that Dr. Saralegui will take part in the study and discussion of these results.

## SPECIFICATIONS FOR AERIAL PHOTOGRAPHY AND MAPPING BY PHOTOGRAMMETRIC METHODS FOR HIGHWAY ENGINEERING PURPOSES\*

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### INTRODUCTION

**T**HE Boy Scouts of America, have a motto, "Be Prepared." It is a good motto for everyone. We should all be prepared.

Dr. Kellogg has given an excellent talk this morning, pointing out the need for preparedness in the development of the agricultural resources of the world. The highway engineer's problem, of course, is parallel to that in agriculture. We must have transportation to be prepared, and the highways are the means for providing transportation to help make Dr. Kellogg's program become a reality. But we cannot build highways until they are properly located; and we cannot properly locate highways unless we have the essential information in sufficient amount at the time needed, Photogrammetry, of course, is a means of getting the information to the degree required. Then the highway engineers are prepared.

But the highway engineers must know what information they will need and, in order to get that information, they must be able to define it in the form of specifications. Today, that is our problem. We are trying to become better prepared to go ahead in that particular endeavor.

Specifications for aerial photography and mapping by photogrammetric methods for highway engineering purposes are not yet standardized. There is no consensus of what they should contain. Opinions range from one extreme to another. Some specifications now in use merely call for an aerial photograph or a map; others may include every detail that can be thought of about the photograph or the map, and how they shall be obtained.

It is the intent in this brief paper to provide an outline of specifications for consideration, and to indicate certain items that should be discussed for inclusion in the specifications. In this way, specifications written in the future can be improved. We also may be able to standardize their provisions as far as practicable. The experience of many aerial photographers, photogrammetrists and the highway-engineer-users of the aerial photographs and maps can be combined

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for the mutual benefit of everyone. The advantages of working toward such a goal should be obvious.

Specifications for construction of railroads, highways, public and private buildings and water works, for example, have been written for a half-century or more. Aerial surveying contracts for highways were almost unknown ten years ago. However, we can draw upon the experience in the other fields and use the best procedures developed through the years. In doing this, we constantly must keep in mind that aerial photography and photogrammetry employ new methods, new terms and new techniques. In them, the time factor, the weather, the topography and ground cover, the experience of the photographer and the mapper, and the type of aerial photograph and map required must be correlated.

First of all, the writer of the specifications should know exactly what type of aerial photograph and map will fulfill his particular needs. He also must have a knowledge of the techniques of aerial photography and mapping by photogrammetric methods that will be employed in taking the aerial photographs and in producing the maps. And above all, he must keep in mind the purpose of all good specifications: (1) to obtain what is needed and (2) to do it at the least cost in conformity with the quality and the accuracy of the aerial photographs and maps required.

Secondly, the writer of specifications must make a choice between two possible alternates in the matter of furnishing information to bidders.

1. He may furnish the bidders with all necessary information that will enable them to prepare bids with the least possible field exploration of the area to be photographed and mapped, or

2. He may require that the bidders be responsible in every respect for the determination of conditions affecting the specified work and its cost.

But regardless of the alternative selected, prudent bidding will always require knowledge of local conditions and consideration of basic factors, among which are the following:

The weather record and the prevailing winds, as related to the taking of aerial photographs and the making of ground control surveys.

The approximate percentage of the area to be photographed, or photographed and mapped, that is covered with vegetation.

The major types and the record of minimum, maximum and average height of vegetation.

The places accessible by ground and by air travel.

The elevation of the topography, including the extreme high and low, as well as the average, together with its general characteristics and directional pattern.

An outline of the existing horizontal and vertical ground control surveys, the datum and coordinate grid system, and the position of existing survey control on an adequate map together with its description, when available.

Whether the first or second alternate is chosen would depend upon the answers to many questions, among which are the following:

How much time can be allowed potential contractors to prepare bids?

How will the quality and the accuracy of the required aerial photographs and maps be affected by the choice?

How will the cost of the work to the contracting authority be influenced?

Is such information at hand in the contracting officer's organization?

Are the bidders more efficient in obtaining exactly what is essential for prudent bidding?

Beyond such basic considerations, the writer of the specifications must make a classification of material to be written into the specifications, and set up ap-

propriate divisions for it. Some ideas on this task will now be proposed as a basis for discussion.

The specifications might be divided into several divisions according to the material classified for inclusion under appropriate headings. As an example, specifications might be prepared on the basis of 5 divisions:

- Division 1, containing general covenants and requirements
- Division 2, a general description of the work to be accomplished, by items or by stages
- Division 3, the specific needs and special items essential in the work
- Division 4, ground control surveys
- Division 5, time schedule of accomplishment and the bid schedule.

Let me explain in more detail the character of material that might be in each of those divisions.

### DIVISIONS IN THE SPECIFICATIONS

#### DIVISION I

The first part of specifications, written for many types of work, sets forth the general requirements and covenants, which include, in connection with the contractors' responsibility to be correctly and fully informed, sections on:

- (1) The terms used of special significance and their abbreviations;
- (2) Bidding or proposal requirements and conditions; including the prequalification and competency of bidders, and the need for complete examination of the local conditions and all details of the project requirements;
- (3) The award and execution of the contract;
- (4) The scope of the work in the contract;
- (5) The control of the work;
- (6) The control of the materials;
- (7) The legal relationships and the responsibility to the public;
- (8) The prosecution of the work, and the program required; and
- (9) Methods of measurement and payment.

Many engineers are likely to look upon those sections as routine and particularly applicable to certain fields of engineering, as for highways. However, the definition of terms is believed to be of vital importance in Specifications for Aerial Surveying purposes. The subjects of prequalification and competency of bidders are ones that should be prepared with extreme care. The other sections require special adaptation to fulfill needs in the aerial photography and mapping field.

Beyond that, a second division will set forth the specific work to be contracted for.

#### DIVISION II

*Division Two* includes a general description of the work to be accomplished. In one method, a detailed description is given in an orderly manner of what is required, considering each item in its normal sequence, by:

- (1) Description;
- (2) Materials and their use;
- (3) Methods or procedure to be followed;
- (4) The method of measurement of the item; and
- (5) The basis of payment.

In such a procedure, nothing is said about the type of equipment which should be used. Materials and method are so adequately set forth that only

particular types of equipment could fulfill the requirements, although they are not designated by name.

In the field of aerial photography and photogrammetric methods of mapping, however, methods and procedures are frequently named or known by the type of equipment. Consequently, that method might be very difficult to follow when writing specifications for such purposes.

For highway engineers' use, aerial photographs and topographic maps must frequently be obtained to fulfill needs in a series of coordinated stages to accomplish best results. For example, there are three consecutive stages in highway location for which aerial photographs and maps made by photogrammetric methods may be procured.

They are:

- Stage 1. Reconnaissance over a wide area to determine all feasible alternate routes.
- Stage 2. Reconnaissance of the alternate routes, comparing one with another to select the best route for survey.
- Stage 3. Preliminary survey of the best route to determine the position for the highway on that route.

Because of the foregoing, several contract stages are frequently required to complete an engineering project, accomplishment of the work in the preceding stage being essential before the next stage can be undertaken. In addition, each stage has its individual requirements, particularly as to area, scale, quality, accuracy and the time in which the photographs and maps must be delivered.

To fulfill such needs, another method of writing *Division Two* might be found more appropriate; such as:

(1) Statement of work to be performed in each stage, which should be a complete description, including: location, dimensions and boundaries of the area or areas to be photographed and mapped to particular scales and contour intervals.

(2) Setting forth the responsibility of the contractor to complete the work for each stage within the time limits specified, acknowledging, of course, that there are factors—such as weather and laws—over which the contractor would have no control and that would be equitably considered as a time extension factor by the contracting officer as the work progressed.

Supplementing those points, requirements should be given outlining the responsibility of the contractor to attain quality and accuracy necessary for the stage in which the aerial photographs, the photographic mosaics, and the maps will be used. But do not ask for more quality and accuracy than are needed.

Special requirements are often mentioned in *Division Two*, such as calling for aerial photographs of special scale or angle of obliquity of certain areas or particular sites, the main objective being to relate everything required to the highway engineering stage in which it will be used.

Still another method of writing *Division Two*, without naming the stage of highway location in which the photograph or map is to be used, might be by specifying:

(1) Photographs from high altitude to small scale—that would be suitable for reconnaissance purposes;

(2) Photographs from low altitude to large scale—that would fulfill requirements for route reconnaissance and mapping for the preliminary survey to follow;

(3) Precise photography of a route band of topography, adequate for mapping by photogrammetric methods for highway location, or of specially designated areas and sites for structures, such as: bridges, interchanges, overpasses, retaining walls, special drainage, controlled access, etc.

Once *Division Two* has been completed, *Division Three* is prepared to include

all details necessary to assure that all needed products will be obtained, including supplemental materials.

#### DIVISION III

*Division Three* would include sections on specific needs and special items essential in the work, such as:

- (1) Indexes of the aerial photographs;
- (2) Indexes of the maps;
- (3) Special photographic enlargements or reproductions;
- (4) The overlap and accuracy of the photographs;
- (5) The accuracy of the maps in the vertical and horizontal planes;
- (6) Scale of the topography, cultural features, and all representable details to be shown on the maps;
- (7) Methods to be used in checking the accuracy of the photographs and the maps, including the contours and all features on the map;
- (8) Designation of the type of material that may be used in the original compilation and the copies of the maps, contemplating that such materials will be suitable to meet all accuracy requirements set forth previously;
- (9) The character of lettering and delineation of contours, planimetric detail and symbols that must be used;
- (10) The size of the photographs and of the map sheets;
- (11) The type and the quality of photographic materials to be used, including the method of processing when such may affect results or when special results are required;
- (12) The responsibilities of the contractor in determining the names of places, streams, highways, railroads, electric power transmission lines, telephone lines, streets, political subdivisions, municipalities, counties or parishes and townships and their boundaries, etc.

Supplemental statements are made in those sections setting forth the amount of detail desired in designating drainage areas, wooded areas, and soil conditions, that are obviously determinable from the photographs and representable on the map sheets. Mention is also made of requirements regarding the delineation on the map of rivers, streams, lakes and other water bodies, fences, stone walls, buildings, bridges, railroads, highways, roads, streets, trails, electric power transmission lines, telephone lines, pipe lines, and so forth, all according to size and symbol to be used. The requirements are established in regard to spot elevations that shall be shown on the map at easily seen and described places, such as at road and fence intersections, on bridges, on summits, in saddles of hills or mountains, on walls, drainage structures, buildings, etc.

Requirements of the coordinate grid system to be used on the map or mosaic are stated, as for example, whether it shall be at 5-inch or 10-inch intervals representing specific ground distances. The accuracy at which the coordinate grid shall be drawn, and whether the grid shall be based on an assumed origin, or on the state plane coordinate system established for the region are specified.

The contour interval and accuracy, and the accuracy in position of all contour lines and planimetric details within the grid system, are designated, either in terms of a representative fraction or an allowable error in fractions of an inch at the finished scale of the map. Datum plane for the contours is designated, whether it may be assumed or shall be the datum of mean sea level established by the Coast and Geodetic Survey or by another responsible datum-establishing authority.

In every section of *Division Three*, reasonable latitude is permitted. This is done in order that contractors having special equipment, skills, and experience may use their particular methods to economically produce photographs and maps in conformity with what is needed.

The order of writing the sections in this division is not fixed. The scheme used should conform to the sequence in which the work would be accomplished.

The next division of the specifications might contain information and requirements about ground control surveys.

#### DIVISION IV

*Division Four*, on ground control surveys, would include essential information about such surveys, mentioning that

- (1) available for immediate use
- (2) to be done by the contractor
- (3) to be furnished when practicable by the contracting officer.

In this division there should be included sections on the accuracy to which the ground control surveys shall be made, horizontally and vertically.

The type and number of ground survey control monuments that shall be set in the ground and shown on the map for future use are specified. The monuments should be of permanent character, referenced, findable and accessible at a later date when the fourth stage of the highway location is undertaken. Monuments not intervisible should have an azimuth mark that is visible from them. They are required when engineers are staking the highway alignment, grade line, cross sections and structures on the ground in readiness for construction of the highway.

#### DIVISION V

*Division Five* might be the last one in the specifications. It would be the time schedule of accomplishment that must be attained and the bid schedule, which would set forth the items of work required for the particular project, arranged in an orderly manner for bidding and for payment. The time schedule is one that will require prudent analysis to be both practical and feasible.

Some bid schedule items and several units of measure that might be chosen for those items have been listed separately for consideration and discussion by the panel; they need not be repeated here.

#### SPECIAL TOPICS FOR PANEL DISCUSSION

In addition to the general form of the specifications, for which some suggestions have now been made, there are many topics that must be written about in the various divisions of the specifications, on which opinions may vary. Some of those topics will be given later to the panel group, not to express an opinion on what should be written about them, but to place them before the panel for discussion. Upon analysis of the record of the discussion, the importance of each topic, and what should be written about it in the specifications, should become evident.

The topics are listed separately. The order should not be considered a criterion of the importance of a topic.

In concluding this paper, it is admitted that there are a number of points not mentioned which will be considered important by many writers of specifications for aerial photography and mapping by photogrammetric methods. The time element, for example, may make it desirable to require a high performance bond. And there are many details that might be handled in special provisions.

The broad question of whether the contractor may properly be required to use certain methods and equipment merits more attention.

Subcontracting would provide another field for lengthy discussion.

Where, because of lack of time, omissions have occurred in this paper, it is hoped that you will make them known for the benefit of everyone.