Photogrammetry in Practice

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Photogrammetric Mapping: A Chain of Events

The chain of events includes determining the requirements of the map, planning, control, aerial photography, compilation, manuscript verification, and drafting.

ABSTRACT: *Mapping, by photogrammetric methods, requires a rigorous routine of events that are interrelated. This paper discusses, in layman's terms, the interrelation of the chain of events needed to accomplish an acceptable mapping project.*

INTRODUCTION

THIS PAPER discusses the events that must take place in order to provide maps by use of photogrammetric techniques. Each of the events is a link in a chain of tasks that are interdependent and, unless each is properly executed, the chain will break and the final product—a map—will be inadequate to do the required job. The chain of events is discussed in simple terms without much technical jargon in order to interest the uninitiated or nontechnical map user. The technical photogrammetrist should also be concerned that the links in the photogrammetric chain are well thought out and designed to strengthen the final product. A strong final product cannot be obtained without a strong chain unless, of course, "dumb luck" wins again.

WHAT FOR THE MAP

The photogrammetric practitioner must listen well to the one desiring a map. The needs for a map must be well expressed, not in its technical details at first, but for what its use will be. A map for design of a building complex of high cost and difficult design requires special specifications. A map to show hiking trails, vegetative types, and normal topography requires another set of specifications.

User and mapping engineer must interact during the stages of setting specifications. Items, such as the following, must be explored and agreed upon:

- What are the minimum requirements for elevations on the project? Can the need for elevations be shown by one foot or five feet contours? What will be required?
- Having determined elevation requirements, at what scale must the map be? This requires a knowledge of horizontal accuracy specifications, and the effect of scale on the required contour interval (is there space to properly depict terrain at the selected scale?). Will too large a scale affect map usefullness because of too many sheets, or will a smaller scale better suit the needs?
- What must be shown on the map? Are all cultural details needed? Do we need fire hydrants, manholes, light poles, and other specialized ground features depicted? All features that the map user requires must be stated in detail.
- Could details that are often difficult to depict be adequately shown by use of an orthophoto base with a minimum of cartographic enhancement? What are the minimum cartographic enhancements?
- What special features need to be emphasized? For instance, in mapping for a water reservoir project the proposed water retaining structure area may require one-half foot contours at large scale such as 1:240, the proposed flooded area at a relatively smaller scale, and the area of proposed drawdown at another scale and contour interval.
- Does the mapping project require that the map be tied to a geodetic grid? Will a local coordinate system be adequate?

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- What benchmarks and other control stations are needed in order to tie paper (map) design to the ground?
- When must the map be delivered?

Each project has its own set of requirements, and the remaining links of the mapping chain cannot be properly constructed without a full understanding of the map needs. Requirements determined by the user and mapping engineer must be documented. An example: Who will check the map accuracy? Who is responsible? What guarantees will the mapping contractor, as a professional, provide? At this state of the chain of events, the only concerns should be what does the user want and can it be produced.

Planning

Each planning process is different and totally dependent on the capabilities of the remaining links. This process must be accomplished in some detail before the user can be told if the map can be produced and for what cost. This also should determine "go", "no go" situations and provide alternative solutions to the users. At this point, considerations must be given to

- Map requirements;
- Terrain and vegetative cover of the area to be mapped;
- Available control in the area;
- Aerial photography available or to be acquired;
- Resources available;
  - Photography acquisition;
  - Field control personnel and equipment availability;
  - Office control equipment;
  - Stereo compilation equipment;
  - Availability of qualified personnel to do the work;
  - Drafting resources, personnel, and equipment;
  - Field completion checking personnel; and
  - Final reproduction capability.

All of these considerations must be evaluated. Consideration of having others do part of the work, and their technical reliability and dependability to meet target delivery dates, must all be considered prior to the "go", "no go" decision.

At the completion of this link, the photogrammetric engineer can go to the user and provide costs and dates of delivery for one or more map products. It is ethical to announce the nonability to perform at specified map requirements and to explain why. Someone with other resources may be able to do the project, but if it can't be done, such should be stated.

Control

After planning and agreement with the map user that a specified product can be produced, geodetic control is the next important link. We have determined the broad aspects of the control needs in planning, but other important details must be tackled at this point. Are the existing geodetic controls in the area sufficient to produce map quality? What should be done to strengthen the control net? What datum, new control points, where from, and at what accuracy? Will control be established in a dense enough pattern to control each aerial photograph, or can aerial triangulation techniques suffice? Will more field-placed vertical points be needed to assure quality of elevations? The field control aspect of each project requires human resources "in the field" and is one of the most expensive links. It must be done, but only to the extent that it will substantially contribute to required mapping accuracy.

Marking of control, if control is a requirement, is important in order to ensure that the control is properly identified on the aerial photography. The field marking requirement must be carefully tied to the aerial photography link. Ground marks must be large enough to be seen on the aerial photographs, but not be so large as to cause wide degree of variance in the stereoplotter measurement. Ground placement of marks must be closely coordinated with time of flying of photography, or they may be destroyed before the flight takes place.

With necessary ground control, well marked, this link is closed by aerial photography.

Aerial Photography

The aerial photographic aspect of mapping is a complex link in itself. It is a combination of aerial platform (airplane) to hold the aerial camera, an aerial camera with mapping characteristics, proper type of film emulsion, proper exposure and processing, and proper care and reproduction of the processed film.

To properly take aerial photography, it must be planned so that the scale of the photography is large enough to allow for the required map accuracy to be attained and have the resolution to allow seeing objects that need to be mapped. Scale of photography must be determined so as to be compatible with the stereo instrument and the required map scale. Scale can also limit the type of aircraft that is required to fly the photography. You cannot use a jet aircraft to fly 1,000 feet above ground in rough terrain, nor can you expect a piston-engine aircraft to fly 45,000 feet above terrain for acquisition of small-scale photography.

The aerial camera is an expensive, complex, optical-mechanical device that can be equipped with lens systems of various focal lengths. Cameras certified for mapping have lenses especially tested for resolution, radial and tangential distortion, and have the ability to hold the film flat at exposure time.

Marriage of the camera and the airplane must be done. The airplane needs a proper opening for the camera lens, electrical equipment, and other support equipment. This requires FAA certification.

Each mapping project may require a special film emulsion. Black-and-white film is most popular, but natural color and color-infrared film have many characteristics that may be beneficial, again depending on map requirements.

With proper placement of line of flight and the correct flight height, the right airplane and camera must be on course and the film properly exposed in order to get the required image on film.

Processing of the film is equally important. Improperly processed film defeats the purpose of the camera accuracies. Film too densely processed or excessively stretched in the processing will cause built-in inaccuracies that cannot always be corrected in the map compilation process.

After good photography has been obtained, we can proceed to the next interdependent link.

Compilation or Stereoplotting (Instrument-Operator Interface)

The links, so far, have been important contributors to the final product; they are accomplished, however, with a certain independence. Field control could have been done without knowledge of aerial photography acquisition, except for premarking of ground points. In this link, the needs, planning, control, and photography come together to provide the ingredients for a map. The compilation or stereoplotting aspect can be in two areas.

If field control was designed to be supplemented with office-derived control, the aerial triangulation (office) process will normally take place prior to compilation. Basically, this process utilizes field control as the basic or minimum control. The basic control is photogrammetrically extended to provide additional or supplemental control points in sufficient numbers and properly located on the photographs so as to allow the stereo instrument operator to make a set up. Prior to compilation on a stereoplotter, each stereoscopic pair of aerial photographs should have a minimum of four identified points of known position. The operator sets up or orients the photographs to a compilation manuscript on which these supplemental aerial photograph control points have been plotted in their exact relative position "on the ground." This manuscript is a stable base material on which the map will be compiled. The aerial triangulation process can save much effort in any project because it reduces expensive field control requirements that would otherwise be needed.

The stereoplotter operator places the aerial photographs in the stereoplotter and adjusts the photographs so that they match or fit the manuscript within prescribed tolerances. The operator then draws all the needed detail seen on the aerial photography. This results in drainage, culture, vegetative delineation, contours, etc., drawn, usually in an unfinished form, with pencil or ink.

Stereoplotting has been a subject of lively discussion among photogrammetrists. Stereoplotting instruments come in varied size, cost range, and with manufacturer or user accuracy specifications. Some instruments have the capability of being used to make more exacting measurements than others. Modern stereoplotter instruments vary in price from $30,000 upwards to a quarter of a million dollars. The type of instrument to be used was considered in the planning phase. The most complex interface with the stereoplotter is not an electronic black box, but the human operator. A poor operator can render results from the best stereoplotter instrument worthless. We talk about having good instruments, but how do we quantify the operator of the instrument? The operator requires mechanical skills, ability to interpret aerial photography, excellent vision, ability to concentrate for long periods, and must have the integrity and conscientiousness to be faithful to the product being worked on. The operator, too often, has been ignored. The operator must be on a preventive maintenance schedule much like an instrument or machine. Good physical and mental conditions are necessary, and the ability to see must be continuously monitored and corrected. A good instrument, interfaced with a good operator, should produce good results. (We like to brag about the type of instrument we have, but how often do we brag about the operator?)

The compilation phase produces a map on which topography, culture, hydrographic features, and others have been faithfully presented on a stable base material. Even if this work has been accomplished with integrity, it may need to be field verified. If so, this will have been specified in the planning and needs assessment process and field verification should be done prior to beginning final drafting.

Manuscript Verification

Many times, at the user-need link, it will be determined that field verification of the final map will be made or required by the photogrammetrist. This is usually done to assure that the map can be field used as specified and that features interpreted by the stereoplotter operator are verified. Verification is usually done by a visit to the mapping area where samplings are made of various features on the map manuscript. Items such as:

- profiles field run between the easily identifiable points on the map to check out contour accuracy;
- checkout of openings, special features such as manhole covers, stream crossings, etc., for proper relative placement and rendering;

- visually checking transport-system routes; and
- other special map needs.

Most of these checks are accomplished on a statistical-sampling basis, and, usually, items to be field verified are determined by study of the map prior to the field visit. For some mapping projects, where little significant cultural detail exists and the stereomodel and related to the map can verify topographic accuracy. Map manuscripts must be field checked if it is a user requirement. Field checking must be discussed and its accomplishment designated. It is an important part of the agreement and may have far lasting effects in the future as to dependency of the map products, should some type of litigation take place about the map or its use.

DRAFTING

The drafting process completes the map. It is the process that turns a manuscript into a final product that "looks like what we wanted." The field verification and production links produced a map that had the functional accuracies needed to satisfy some specific requirement. The map is a tool to be used in doing something, but not an end in itself. The drafting process is directly related to things like (1) how many copies are needed; (2) how it is to be reproduced; and (3) how many features are needed in different colors (color separation), or will just the draft manuscript from the stereoplotter with minor drafting be adequate. These must be agreed to in the first needs link. Drafting considerations should consider items such as:

- line quality, ink, pencil, scribing;
- feature labeling, free hand, mechanical lettering, stickup;
- need a reproducable; how—diazo, litho, other;
- need final reproducable on stable base material—copy also;
- will a reduced scale map be needed to show whole area as project; affects lettering, line weights, etc.;
- want to extract parts of map at different scales for rendering, etc.

Final drafting can make or break a finely forged chain of events. Like all the links in this photogrammetric chain, they must all carry the load.

Drafting does not complete the chain reaction. As a professional, we need a final check on the whole process, the final edit. This sounds like an epitaph, and it can be if the other links are not properly done. If the final edit is not done, it can be the photogrammetric engineer's last job.

Minor corrections, overall process review, and field review have been a continual process in the chain of events. Each "professional" in the chain did his best, but, yet, the final edit must be done. This isn't the nitpicking aspect of the job, but catches the gross errors that have been overlooked because "no one would ever do that." "Ya, they didn't." This edit is where you put your name on the line and weld the final link on the chain—you did it!

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