*The Vital Communications Link— Photoidentification of Horizontal Control**†

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ABSTRACT: *Photoidentification procedures constitute the single, essential tie between field-established horizontal control surveys and the aerotriangulation phase of photogrammetric mapping. Radically altered concepts in the determination and use of horizontal control information have imposed new standards on photoidentification requirements and compelled the reevaluation and strengthening of photoidentification techniques.*

The Geological Survey's research project on target design is described briefly and current photoidentification attitudes and practices, largely derived from this study, are presented. Included are outlines of acceptable field procedures, details on artificial paneled targets, methods for using "natural" targets, and solutions to the more difficult targeting situations.

INTRODUCTION

THE photogrammetric community is witnessing the emergence of a new and challenging era in map-making. Important new advances are being reported on every side in great profusion, so much so that it is sometimes difficult to keep abreast of the field. Modernization through automation, analytical procedures, or improved design is evident in almost every phase and every instrument that concerns us. In short, in just a few years photogrammetric mapping has become a highly developed applied science. Why then must we concern ourselves with such an elementary, routine task as the identification of horizontal control?

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Some insight into the reasons for concern may be found by reviewing briefly the radical changes that have occurred in the map-makers' ways of obtaining and using horizontal control. In the days when topographic mapping was strictly a field procedure, the recovery and use of horizontal control were relatively simple and straightforward. The topographer plotted the station coordinates on his map base, found the monument in the field, oriented his planetable over the monument, set his alidade over the plotted point and was ready to begin his mapping operations. Today, with most of our maps photogrammetrically-compiled, the necessity of identifying and using field-established horizontal control in office procedures has greatly complicated the problem. Yet in the interest of map accuracy the photogrammetrist must be supplied with essentially the same capability in this respect that his erstwhile counterpart, the field topographer, once enjoyed.

TRENDS IN PHOTOGRAMMETRIC REQUIREMENTS FOR HORIZONTAL CONTROL

One of the early and long-used photogrammetric methods of extending horizontal con-

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trol involved the stereotriangulation and subsequent adjustment of individual strips of photographic coverage. The method had several weaknesses, among them the inability to develop the evidence necessary to challenge the credibility of any horizontal control save that contained in a redundant situation within a single stereomodel.

With the advent of the stereotemplet method of aerotriangulation adjustment, horizontal scale solutions were afforded much-needed additional strength. For the first time the simultaneous block adjustment of a number of strips resulted in the achievement of a common scale in all parts of all flights. Also, as instrumentation was refined and skill and confidence in the new method were developed, the self-checking characteristics of stereotemplets began to be used to advantage in the detection of incompatible or erroneous control data within a templet assembly. When these errors were of significant magnitude, the responsible control stations could not be used in the assembly lest they impose improper restraints on the system that would jeopardize the accuracy of the resulting map.

Whenever a stereotemplet assembly has a redundancy of photoidentified horizontal control, erroneous stations can often be removed without detrimental effect on the scale solution. In many other instances, however, map-makers are faced with minimal control situations for which reliable scale solutions become impossible in the face of erroneous control data. A step-by-step review of the data must then be made in order to determine the source or sources of error. In many cases the difficulty is caused by inadequate or erroneous photoidentification that can be resolved only by returning the data to the field for reidentification. This leads directly to one important reason behind the need for accurate identification of control. The stereotemplet method, in common with other, newer block methods of photogrammetric aerotriangulation, makes possible a considerable reduction in the number of control stations that are needed to produce an acceptable scale solution. Furthermore, today's high field costs make it mandatory for all map-makers to plan for the field phases with extreme care. Thus, while a minimal control pattern is certainly the most economical, it can be used successfully only when *every* station in the pattern is precisely and unmistakably photoidentified.

Future Horizontal Control Requirements

Turning now and looking ahead, what sort of problems regarding the accuracy of horizontal control and the communication of control data will map-makers be facing in the immediate future? In field surveying operations the new electronic distance-measuring devices, including the Tellurometer, Geodimeter, Electrotape, and Hydrodist are rapidly assuming a major role. The Geological Survey's latest contribution to field survey procedures is a new method of obtaining mapping control called "The Airborne Control System."[1] The system combines the best features of the helicopter, the hoversight, and an electronic distance-measuring device to determine accurate ground point positions and elevations. It is especially effective in wooded or limited-access terrain. All of these new advances are expanding field survey capabilities to a point where it will be possible to obtain an accurate horizontal control net at an optimum distribution in an economical manner.

Meanwhile, newer and more refined horizontal aerotriangulation systems, including the ITC-Jerie Analogue Computer, several semianalytical methods, and various systems of analytical aerotriangulation are being introduced. While some of these are still largely in the developmental and testing stages, their accuracy potentials are admittedly superior to those of currently operational control extension methods.

Thus, there are two relatively strong successive mapping phases—horizontal control surveys and aerotriangulation—which are showing definite signs of becoming even stronger. Between them, there is but a single tie—photoidentification. It is the vital link by which field-established control data are communicated to the aerotriangulation procedures. Will the benefits of all the progress being made in these two phases be rendered ineffectual by the use of identification procedures that are inadequate to the task? To forge the photoidentification link of the mapping chain most effectively use must be made of an identification technique that is capable of transferring the highly accurate field-surveyed control into the precision methods of aerotriangulation without significant error.

[1] Loving, Hugh B, "Airborne Control System," *Surveying and Mapping*, March 1963, Vol. XXIII, No. 1, pp. 91–97.

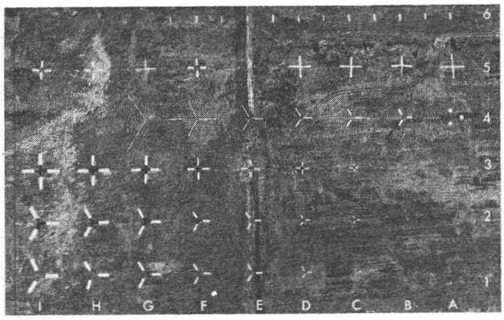

FIG. 1. U. S. Geological Survey target testing array at Chantilly, Virginia.

Since the requirements for this vital tie between field and office have become progressively more stringent in the past few years, it is not surprising that many private map-making firms and governmental agencies, both here and abroad, have found it necessary to take a long, hard look at their photoidentification practices.

About four years ago the Geological Survey become acutely aware of the fact that its own control identification procedures were becoming inadequate in the face of the rapid, drastic changes that were taking place in the aerotriangulation requirement. The existing chapter of the Survey's Topographic Instructions on control identification, issued just five years earlier, had already become obsolete and serious consideration needed to be directed toward its improvement.

TARGET DESIGN RESEARCH

The practice of targeting horizontal control prior to aerial photography appeared to hold attractive possibilities for improving the sagging communications link. In order to increase the Geological Survey's basic knowledge of this subject and to determine the most effective means of applying targeted control techniques in our own photoidentification procedures, a research project on target design was initiated in 1960 and was completed about a year later.[2] In the interest of brevity, only a brief description of the highlights of the investigation will be given here.

About 40 acres in a remote corner of the Dulles International Airport property at Chantilly, Virginia, were made available through the cooperation of the Federal Aviation Agency for use as a target testing area. Targets of various sizes, patterns, and materials were laid out in an open field, while others were placed in nearby wooded areas of various densities.

Figure 1 illustrates the open-field target array as photographed from 1,000 feet. Forty-three four-legged and three-legged targets were laid out in graduated sizes to correspond with the nine flight heights proposed for the project. Single strips of 14 different types of panel material were also laid out (Row 6 in Figure 1) to test their usefulness and durability over long periods.

Figure 2 is a close-up ground view of a representative test target in the open-field array. Each white cotton panel in this particular target (located at C-3 in Figure 1) was 5 feet long, $1\frac{1}{4}$ feet wide, and set back $2\frac{1}{2}$ feet from the center. The black center cross was made of percale, also $1\frac{1}{4}$ feet wide.

Standard mapping coverage of the target area was obtained at nine flight heights ranging from 1,000 to 23,500 feet in three seasons—late fall, winter, and early spring. Stereomodel evaluations were made to determine most suitable target configurations, minimum target dimensions for various flight heights, best materials, the effect of seasonal changes on detectability, and most effective means for securing targets to the ground.

RECOMMENDED PHOTOIDENTIFICATION PROCEDURES

The findings of the target study provided the essential guidelines for rewriting the chapter of the Geological Survey's Topographic Instructions dealing with the photoidentification of control.[3] The new instruc-

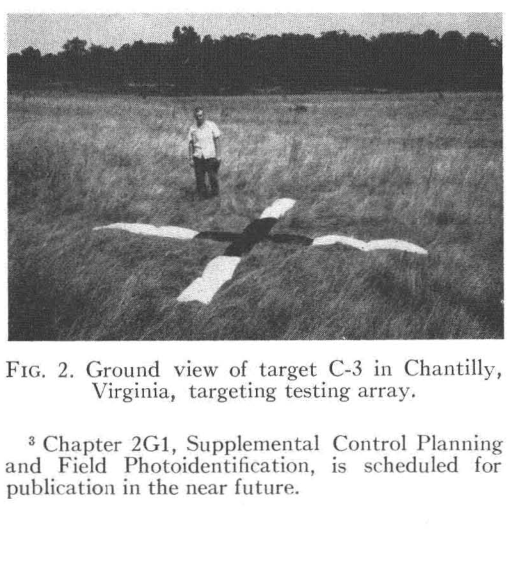

FIG. 2. Ground view of target C-3 in Chantilly, Virginia, targeting testing array.

[2] Landen, David "Research on Target Design for Photoidentification of Control," *Geological Survey Professional Paper 450-B*, pp. B137–B140.

[3] Chapter 2G1, Supplemental Control Planning and Field Photoidentification, is scheduled for publication in the near future.

tions list the acceptable procedures for horizontal control identification in descending order of merit as follows:

1. Artificial targets (for example, paneled photo-targets) at control stations for recording on compilation photography.
2. Natural targets (such as discrete crossroads or small lone trees in the vicinity of control stations) located by geodetic surveys and recoverable on compilation photography.
3. Artificial targets at control stations for recording on low-altitude supplemental photography with later transferral to compilation photography by appropriate stereoscopic methods.
4. Image reference points in the vicinity of control stations, located during basic control surveys or later by auxiliary azimuth-and-distance surveys.
5. Image reference points located by plane-table surveys.

The most reliable procedure, that of targeting control stations for compilation photography, requires careful planning and liaison on the part of all concerned, but the attendant accuracy advantages in the photogrammetry phases make the extra effort worthwhile.

In order to create an uncomplicated, easy-to-remember Geological Survey instruction, a standard four-legged, cross-shaped target pattern with minimum dimensions was established for use with all compilation photography flown at altitudes up to 12,000 feet and all supplemental photography flown as high as 5,000 feet. The dimensions of this minimum size target, illustrated in Figure 3, were designed for a white target placed against a background providing good contrast. Polyethylene film 0.006-inch thick is generally recommended for white panels. Unbleached white muslin, cotton sheeting, and bunting (flagging) material are also satisfactory. Where background contrast is uncertain, black cloth strips of the same width should be added at the center to complete the cross-shaped pattern in a manner similar to that shown in Figure 2. Black percale cloth and black tarpaper are satisfactory materials for these strips.

For compilation photography flown higher than 12,000 feet, the following panel sizes and panel set-backs are recommended for the standard four-legged pattern:

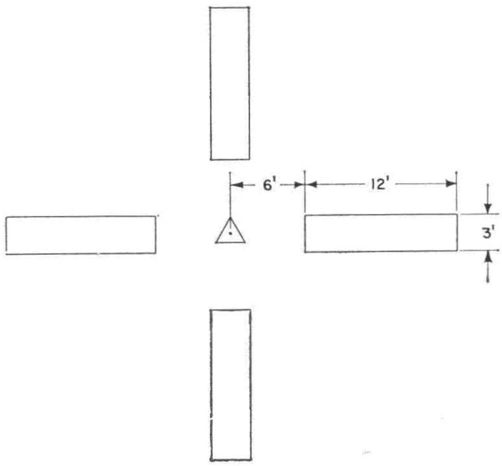

FIG. 3. Recommended target pattern of minimum dimensions.

Flight Height	*Panel Size*	*Panel Set-Back*
12,000–16,000 ft.	4×16 ft.	8 ft.
16,000–20,000 ft.	5×20 ft.	10 ft.
20,000–24,000 ft.	6×24 ft.	12 ft.

Whenever a target background, such as beach or desert sand, can be expected to photograph white or in very light tones, the entire target should be made of black material or a dark red or dark green material, if black is unavailable. All dark-colored targets should be at least two feet wider than white targets designed for similar altitudes in order to offset the well-known "bleeding" or halation tendency of such black-on-white combinations. Such undesirable "bleeding" tendencies can be minimized by avoiding photographic operations during the middle part of the day.

In the Chantilly target design research project a supplementary study was made to determine the best ways and means for solving a most difficult control identification problem, that of targeting in evergreen woods. It was found that in areas partially covered by evergreen trees, successful targeting can be accomplished by increasing the length and width of the panels substantially beyond normally recommended values, and by orienting the panels in directions that take advantage of the existing openings between the trees.

When a horizontal control station is located under a dense or complete foliage canopy of evergreens, it may be necessary, before targeting, to clear a more-or-less circular area around the station to a radius that approximates the height of the surrounding trees. Incidentally, an excellent, long-lived natural target can be created in these situations by leaving one lone tree of proper size standing in the middle of such a clearing.

This latter technique would involve the procedure listed second in the above order of preference, the use of what the Geological Survey calls "natural" targets. The new chapter on photoidentification defines such a target to be "any type or arrangement of discrete existing ground detail that is uniquely suitable for control identification purposes by virtue of unmistakable configuration and/or recognizability" both on the ground and in the photographs. When a single such "natural" target can be found in the vicinity of a control station, it can often serve as an effective substitute for artificially targeting the station, provided the ground point thus defined has been identified on the photography, and its geodetic position has been established by appropriate and accurate measurements.

As indicated by the definition, natural targets may be divided into two rather general categories depending on whether the identifiability of the selected ground detail is based primarily on configuration or on recognizability. In the first of these groups the ground detail should be such that it photographs in a pattern of imagery that facilitates identification and the precise recovery of a discrete ground point position in photogrammetric usage. The image pattern usually selected resembles that of an artificial target. While it may have two, three, four, or more legs, these must form reasonably large angles of intersection and define a single, positively-identifiable position both in nature and on the photographs. Road intersections, fence-line intersections, railroad grade crossings, and similar ground features may serve as natural targets of this type.

The second category of acceptable "natural" targets includes isolated objects that are recognizable because they are unmistakably distinctive both on the ground and in the photographs. The photographic imagery of such targets should be sharp, discrete, free from obscuring shadows, and preferably just large enough to be seen on the print without magnification. An isolated bush, cactus, small tree, or similar identifiable lone object may generally qualify as a natural target in this group.

The facts and figures given in this paper represent current photoidentification attitudes and practices of the Geological Survey. Undoubtedly, further changes will become necessary as newer, more capable photogrammetric and field surveys instrumentation and techniques are brought into production use. Even today, it can be foreseen that the character of the photoidentification procedures of the future will be dictated in large measure by the more rigorous input requirements of the new methods and the instrumentation and techniques available at the time for executing the photoidentification task.

Summary

In view of the past experiences and probable future trends in the determination and use of horizontal control information, mapmakers must continue to press for the utmost in reliability and accuracy in photoidentification procedures. By adding as much strength as possible to this important link between field and office operations, we will be able to decrease materially a significant source of our mapping errors, and also we may expect to achieve accurate scale solutions with a minimum amount of control. Furthermore we will get more and better maps for our mapping dollars.