Photographic Targets for Markers of Survey Control[1]

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Benefits of accuracy in ground surveys to control aerial photographs in mapping by photogrammetric methods for the preliminary survey of highways are greatly enhanced when reliable and efficient methods are employed to utilize such control. Photographic targets of symmetrical shape, and suitable size and color, when properly placed over control points before aerial photographs are taken of the highway route band, not only increase the benefits of accurate ground control, but improve the efficiency and certainty with which the control can be used while the maps are compiled. Also, use of photographic targets implements as well as decreases the cost of staking the highway on the ground in the location survey stage. Similar advantages are gained by the availability of targets when supplemental control is bridged photogrammetrically.

Types of targets are discussed and illustrated. The principles of designing their size, shape, and spacing, and of placing them to prevent obscuration by tall trees and buildings are presented.

● AERIAL PHOTOGRAPHS are perspective views of the ground. They contain images of the ground and details of objects on it, as registered by the effect of light on chemicals which form a uniform coating on smooth base material as film, glass, or paper. The accuracy of maps made by use of aerial photographs reflects the precision capabilities of the photogrammetric system used and the ability of the mapper. Completeness and exactness are also dependent upon the type, quality, and amount of information the mapper has at hand, sees, and chooses to use. To achieve the utmost in accuracy during use of photogrammetrically compiled maps for highway engineering purposes, it is necessary to attain precise coordination of the position of basic control with its map and numerical position (as plane coordinates) and its physical location on the ground. This is true whether the basic control is established by ground surveys or by photogrammetric methods.

In mapping with precise photogrammetric instruments and in using maps produced thereby, a higher degree of accuracy may be attained if methods are devised and employed which promise certainty of identification and preciseness in coordination of positions on the ground with images on the aerial photographs and stereoscopic models formed therefrom for the mapping. Some procedures rely solely on the use of natural objects on the ground. Such objects often form faint and irregular-shaped images and patterns on the photographs, which lack point finiteness and are extremely difficult or impossible to use for horizontal and/or vertical control during the mapping operations. Often there are large areas where the photographic patterns lack well-defined images with point finiteness, because the patterns blend imperceptibly from image to image. Images with point finiteness, which may be visible on the photographs and could increase accuracy in the use of control, are often unidentifiable or inaccessible on the ground. There are many occasions when a lone small

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bush in a forest or field can be positively identified on the photographs and used during the mapping operations. It is extremely difficult for the map user or surveyor to be sure he has identified and found the identical bush on the ground. In contrast, photographic targets placed on the ground remove confusion for the field survey parties when it is essential that they determine on the ground horizontal position and/or elevation of each point used or to be used in the stereomodels for mapping operations or for the measurement of profile and cross-sections. Moreover, natural and man-made features are both subject to change during the time lapse between photography for mapping by photogrammetric methods and actual use of the maps. Instances of this are where fence lines and field cultivation lines may change, where bushes and lone trees are cut down, and where a point on the bank of, or a rock in, a stream or lake becomes covered by a change in water level. Furthermore, many objects, such as trees, power line poles, and rocks in a stream, cannot be occupied by a surveying instrument when it becomes desirable to do so. All of these drawbacks will result in a loss of precision when the map user attempts to position-survey accurately on the ground from plane coordinates and elevations determined from the map. Consequently, it can be seen that it is better to place artificial markings of selected points on the ground to assure positive identification and utmost accuracy.

Geometrically designed photographic targets should be placed over points for which coordinate positions are to be bridged by photogrammetric means or are to be determined by ground survey methods. These coordinate positions are essential for control of stereomodels in the mapping operations and for points of origin and closure in subsequent surveys on the ground, such as testing the maps and staking (with its rights-of-way) the designed highway for construction. The target should be centered over the station marker, existing or set, in the ground at the point for which a coordinate position is known or is to be determined. Placement of the targets should be accomplished on the ground before the photography is taken. This procedure will aid in achieving efficiency, accuracy, and permanency, and save both time and money in the mapping; in using the maps; in alignment, structure, and right-of-way computations by use of plane coordinates; and in all stakeout work on the ground.

Close coordination between target placement and photography crews will assure best results. Lapse in time between their operations should not be so great that action of people, animals, or weather will destroy the targets' usefulness before the photography is completed. Also, very close coordination may be advantageous as a means of avoiding trespass claims and speculation. If the ground location of property corners, section corners, existing survey station markers, etc., were determined previously by reconnaissance, they could be targeted rapidly at the appropriate hour before the photographic flights are made. If necessary, the targets could be removed as soon as each photography mission is completed.

Materials for constructing the targets may be varied according to requirements for a particular project, taking land use, weather, and accessibility into consideration. In most cases, black or dark red muslin or black tar paper and white or yellow muslin would be suitable. Usually, black or dark red muslin is better than black tar paper for target centers where intense darkness is desirable. Black and white lime or similar materials may be better to use where targets constructed with muslin or tar paper might be destroyed by humans or animals before the photography is taken, especially in arid regions. Moreover, painting may be more advantageous where a target is placed on rock, or on a road. Plastics, plywood, masonite, cardboard, or similar materials (appropriately painted) will be more suitable for use under certain circumstances and conditions, as for example, where animals will destroy the muslin for its sizing or its other animal uses, and where the route to be photographed is in a very humid region.

Target dimensions must be predicated on the type of photogrammetric instruments that will be used, the extent to which bridging will be done photogrammetrically, and the scale of photography necessary to accomplish the required mapping. This is so, whether the mapping is to be topographic or planimetric, or whether profile and

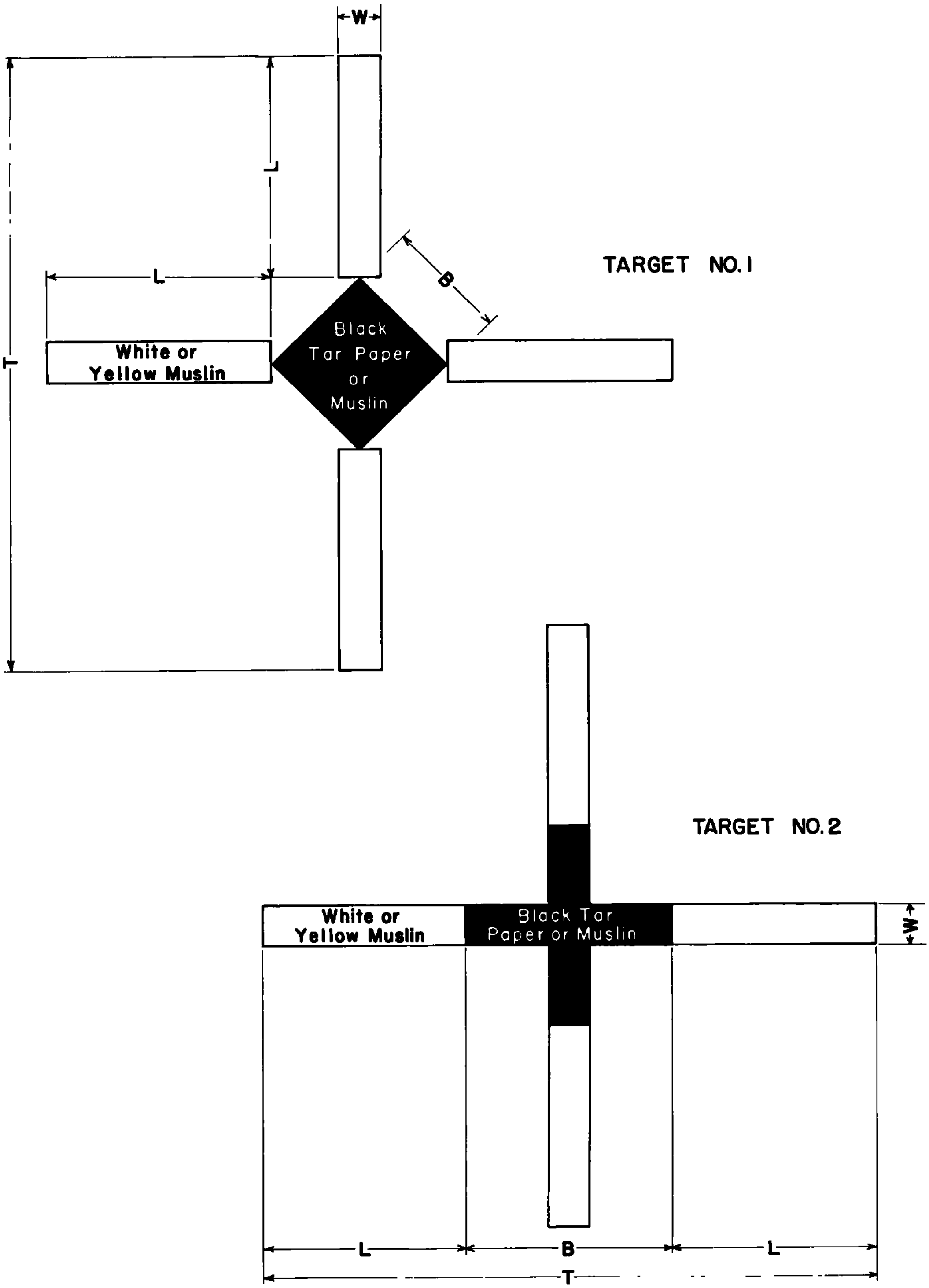
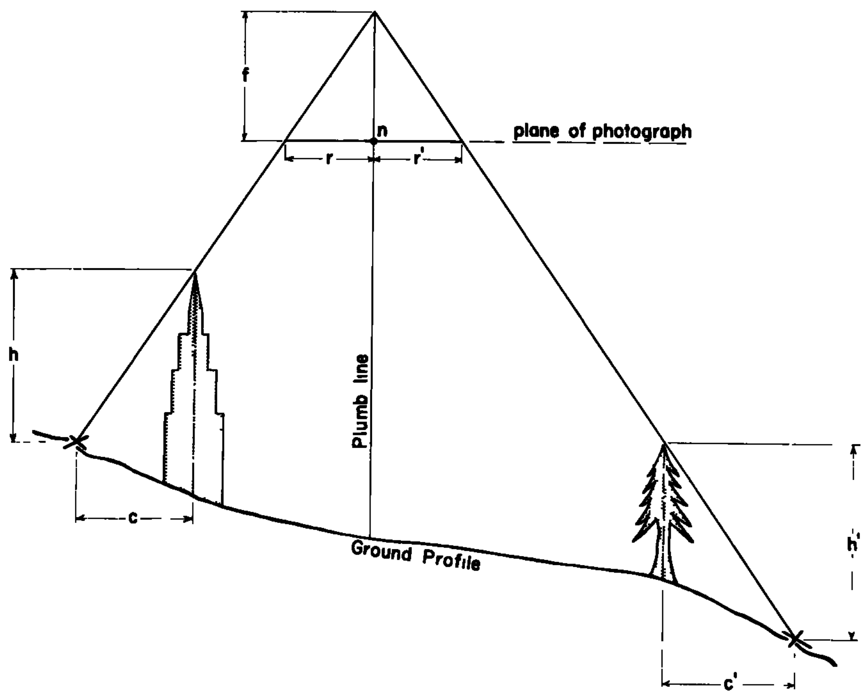


Figure 1. Sample photographic targets: these targets were designed for placement on the ground to produce a well defined symmetrical image on aerial vertical photographs. (Targets must be centered on station marker, hub, or other position markers in the ground.)



f = camera focal length

r & r' = radial distance on the photograph from the nadir point (n) to image of the top of the tall object.

h & h' = height of top of the tall object above the level of the target on the ground.

C & C' = horizontal distance on the ground obscured by "perspective layover" of image on photograph. This clearance from the object must be attained when the target is placed on the ground.

From Similar Triangles:

$\frac{C}{r} = \frac{h}{f}$ Thus: $C = \frac{rh}{f}$ and $C' = \frac{r'h'}{f}$

Figure 2. Clearance necessary to prevent obscuration of a target's image by "perspective layover" of a tall object.

cross-sections are to be measured photogrammetrically in conjunction with or independent of mapping. If the targets are to be used on markers of basic control points for bridging as well as for mapping, the dimensions must be designed so that the image of each target will be sharply defined as an easily identifiable image on the small scale bridging photographs and, at the same time, on the large scale mapping photographs. Moreover, each target must not be so large or irregular that its precise geometric center over the station marker cannot be determined when the photographs are projected for mapping by photogrammetric methods at the required scale.

The dimensions on the photograph of the image of a target may not always be proportional to its actual dimensions on the ground. This is due to the infringement of light emanating from light colored parts of the target or lighter tone areas surrounding it over the contiguous and darker portions of the target and adjacent dark ground. As a result of this infringement, the actual image size on a photograph of a dark object on the ground will be smaller than calculated and the image of a light object will be larger. The degree of photographic enlargement of objects light in color will depend upon lighting conditions, shape of the object, type and color tone of adjacent ground or objects, and the apparent image motion while the camera shutter was open.

Points to be considered include the effect of the infringement of white over black upon position accuracy, the target shape as seen on the aerial photographs, and the size of the target to be constructed on the ground. The visual appearance of the image of certain types of targets may bear little resemblance to their appearance on the ground, particularly on small scale photography. It is very important, therefore, that targets be designed and placed so that their images produced on photographs will permit precise determination of their geometric center over the marker on the ground. This image centering of the target on the marker must be achieved although infringement of light areas over dark areas has changed the over-all appearance and dimensions of the image of the target as compared to its dimensions on the ground.

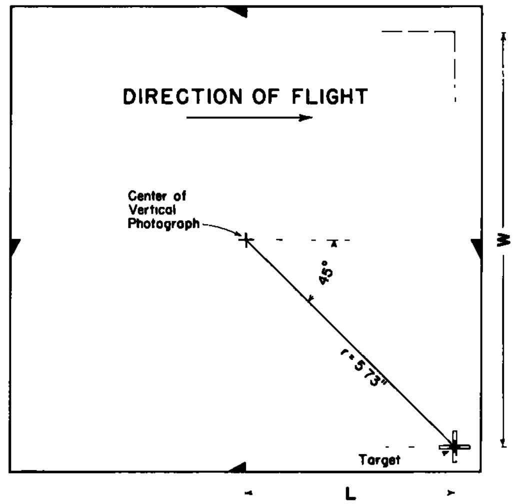


Figure 3. Extreme position of a photographic target on one photograph of a stereoscopic pair. Dimensions (L and W) of usable portion of one 9-in. x 9-in. photograph of a stereoscopic pair when minimum endlap is 55 percent. (L=45 percent x 9-in.=4.05-in.; W=90 percent x 9-in.=8.10-in.)

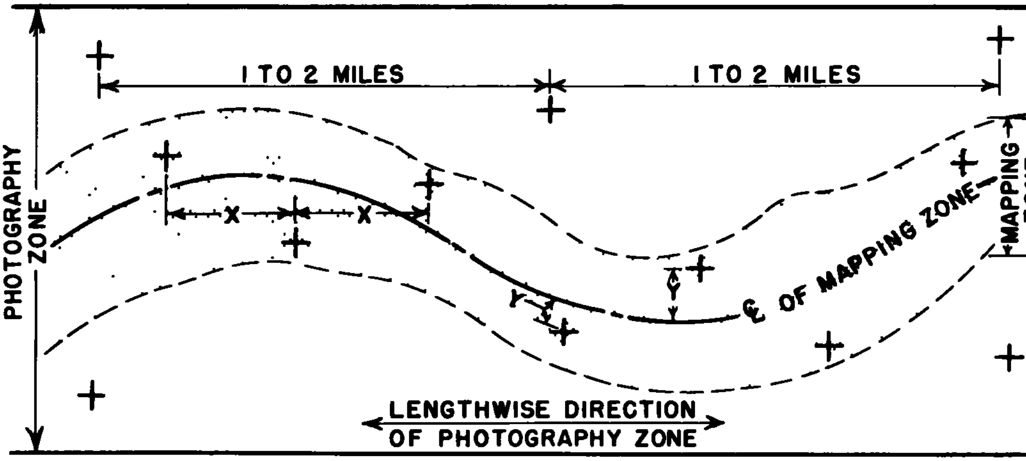
During photogrammetric bridging and mapping operations, accuracy of positioning of the image of any target will be dependent upon how well its center can be estimated visually; whether its shape appears symmetrical or irregular. In addition, white areas in the target's image will be "fuzzy" or "soft" in the stereoscopic model, and under such conditions it will be extremely difficult to determine precisely when the floating dot of the photogrammetric instrument is in contact with the ground. These limitations adversely affect the accuracy of the horizontal positioning to a small degree and the vertical accuracy to a large degree. If an area of dark color tone is provided at the geometric center of the target, both horizontal and vertical accuracy of photogrammetric plotting will be improved. Nevertheless, each target must contain white in contrast with the dark, the white being essential for ease and certainty in finding the target and the dark for greater accuracy. Under unusual conditions, however, an all black target in fully open areas where no shadows could occur and where the ground is all white or very light in color tone would be satisfactory.

The simplest type of target to meet all these conditions is a cross. Its separate dimensions should be appropriately proportioned. If the length of the arms of the cross is too short in relation to the width of the arms, the infringement of white over black will result in an irregular white image instead of a cross. Neither "T"- nor "L"-shaped targets should be used.

Figure 1 shows two cross-type targets which will produce images of suitable shape and relative dimensions if the following rules are applied:

Targets 1 and 2. Total length (T) in feet should be approximately one-fiftieth of the photography scale expressed in feet to one inch. Width of leg (W) in inches should be approximately one-sixtieth of the photography scale expressed in feet to one inch. The length of T should be within the limits of T (feet) equals (1.2 to 1.4) times W (inches).

Target 1. Length of leg (L) in feet should be approximately ten twenty-sevenths of the total length in feet. The dimension in feet of the black central square (B) should be not less than one-fifth nor larger than one-fourth the total length in feet.



+ = Targets within mapping zone for control of stereoscopic models. These should be placed where they will be visible from any possible camera position.

+ = Targets outside the mapping zone for correlation between separate stages of mapping. These must be placed in visible position within the photography zone.

X = Spacing along lengthwise direction of route photography zone. This spacing in feet should be two times the scale of photography expressed in feet to one inch. For example, if the photography scale is to be 500 feet to one inch, place targets at intervals of 1,000 feet.

Y = Spacing normal to centerline of mapping zone. This spacing should be random. Placement on alternate sides of the centerline of mapping zone is recommended.

Other targets should be placed, as desirable, for certainty in photogrammetrically positioning property corners or lines, ground control station markers (both basic and project), and other points essential for both mapping and engineering uses of the maps.

Figure 4. An example of the suggested placement of photographic targets.

Target 2. Length of white leg (L) and length of each part of the black cross (B) in feet should be one-third of the total length in feet.

The dimensions of each target to be constructed on the ground should be governed by the smallest scale photography on which an image of the target must be seen. These dimensions may be determined by considering the relationship of the scale of the map manuscripts to the mapping photography, and to the scale of bridging photography when it is to be used. The projection enlargement ratio of the scale of the stereoscopic model in each photogrammetric instrument to the scale of the aerial photographs must also be considered.

As a starting point, the scale of the map required is known. Using the Kelsh stereoplotter for six inch focal length photography, the projection enlargement ratio (1) is 5 or 7, according to type of instrument. The Kelsh stereoplotter for eight and one-quarter inch focal length photography has an enlargement ratio of 4 or 5, according to the type of instrument. The enlargement ratio is variable in first order instruments (2). In photogrammetric work for highway engineering purposes, a practical maximum enlargement ratio to employ in these instruments is 8. Other instruments have projection ratios of 2.4 and 3.4. Thus, the scale of the mapping photography will be $^{10}/_{24}$, $^{10}/_{34}$, $^{1}/_{4}$, $^{1}/_{5}$, $^{1}/_{7}$, or $^{1}/_{8}$ the scale of the maps, depending on the photogrammetric instrument to be used.

To assure meeting accuracy requirements, the scale of the bridging stereomodels usually should be no smaller than one-half the scale of the mapping stereomodels. Accuracy may be acceptably sufficient at times, however, if the scale of the bridging models is one-third the scale of the mapping models. The bridging scale should

TABLE 1

TARGET DIMENSIONS ON GROUND

	Scale (ft to 1 in.)	Dimensions				
Photography	Total Length (T), (ft)	Leg Width (W), (in.)	Target 1 (center portion a black square)		Target 2 (center portion a black cross)	
			Black Square (B), (ft)	White Leg Length (L), (ft)	Black Cross (B), (ft)	White Leg Length (L), (ft)
250	5	4	1	2	2	2
500	12	9	2.5	4	4	4
750	15	12	3	5.5	5	5
1200	24	20	5	8.5	8	8
1500	30	25	6	11	10	10
2400	48	40	10	17	16	16
3000	60	50	12	21.5	20	20
4800	96	80	20	34	32	32
Site Mapping[1] 20 to 50	6 to 9	6	2	2 to 3	2 to 3	2 to 3

[1] Normally, control for site mapping would be obtained by methods other than by bridging photogrammetrically.

seldom, if ever, be as small as one-fourth the mapping scale.

As for mapping, the scale of the bridging photography will be $^{10}/_{24}$, $^{10}/_{34}$, $^{1}/_{4}$, $^{1}/_{5}$, $^{1}/_{7}$, or $^{1}/_{8}$ the scale of the bridging model, according to instrument.

As an example, it may be assumed that topographic mapping at a scale of 100 ft to 1 in. is desired and that the instrument to be used is a Kelsh stereoplotter with an enlargement ratio of 5 using 6-in. photography. For the mapping, the required photography scale is 5 x 100, which is 500 ft to 1 in. For the photogrammetric bridging, it may be assumed that a first order type instrument is to be used, and that the scale of the bridging models is to be one-third the scale of the mapping models. In such a case, the scale of the bridging models will be 300 ft to 1 in. Using the practical maximum enlargement ratio for the first order instrument, the required bridging photography scale is 8 x 300, which is 2,400 ft to 1 in.

By applying the rules given previously, dimensions of the two suggested types of targets to produce a suitable image at the scale of 2,400 ft to 1 in. may be determined as follows:

For Target 1 and Target 2

$$\text{Total length (T)} = \frac{2,400}{50} = 48 \text{ feet}$$

$$\text{Width of leg (W)} = \frac{2,400}{60} = 40 \text{ inches}$$

$$\text{Proportions} = \frac{\text{L (ft)}}{\text{W (in.)}} = \frac{48}{40} = 1.20 \text{ feet per inch}$$

For Target 1

Black central square (B) = $^{1}/_{5}$ x 48 = 9.6, use 10 ft

Length of leg (L) = $^{10}/_{27}$ x 48 = 17.7, use 18 ft

For Target 2

Length of black cross (B) and Length of white leg (L) = $^{1}/_{3}$ x 48 = 16 ft

To produce a well-defined geometric image of the targets suggested, on photography at some commonly used scales, recommended on-the-ground dimensions for constructing the targets are listed in Table 1.

Applying the rules given and used in the examples and in compiling Table 1, image sizes in inches on the aerial photographs will be approximately within the limits given

TABLE 2

TARGET DIMENSIONS ON AERIAL PHOTOGRAPHS[1]

Total Length T		Leg Width W		Target 1 Black Square B		Target 1 White Leg L		Target 2 Black Cross B		Target 2 White Leg L	
min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
1/50	1/12	1/750	1/190	1/250	1/62	1/150	1/37	1/150	1/37	1/150	1/37
.02	.08	.0013	.0052	.004	.016	.0067	.0267	.0067	.0267	.0067	.0267

[1] All dimensions are inches.

in Table 2, assuming a scale ratio of not more than four to one between the scales of mapping and bridging photography. Whenever the ratio between such scales is three or two to one, image size of targets should not be allowed to become smaller than the minimum in Table 2. The maximum size, however, should be either 3 or 2 times larger than the minimum, in the same proportion the scale of the mapping photography is larger than the scale of the bridging photograph. Moreover, targets for photography of scales other than listed in Table 1 should be designed similarly so that image sizes will be within the limits given in Table 2.

If each target placed on the ground is to serve the purpose for which it is designed, its image must be visible on photographs which might be taken from any possible position of the aerial camera. Photographic displacement of tall objects, however, obscures the ground between the object's base and its top. This is called "perspective layover." The ground area obscured in consequence of perspective layover depends on the scale of the photograph, slope of the ground, the height of the object, and its location on the photograph. Since the target's position on the photograph usually cannot be predicted before photography, it must be placed on the ground at a sufficient distance from tall objects, such as buildings, trees, walls, and monuments, so that their perspective layover cannot obscure the target's image. The distance from tall objects at which a target must be placed to preclude its obscuration by perspective layover may be determined by utilization of principles illustrated in Figure 2.

Experience has proven that, to assure visibility of each target, it should be anticipated that its image on vertical photographs somewhat "randomly taken," will possibly be at a maximum practical distance from any photograph's center. Assuming a minimum endlap of 55 percent on a 9- by 9-in. photograph, and that the image of the target may appear at the intersection of a line 45 deg to any line joining the fiducial marks and a line parallel to, and 0.45 in. from, the edge of the photograph, as illustrated in Figure 3, this anticipated maximum distance is 5.73 in. There are conditions, however, which may limit the usefulness of a target unless it lies at a distance of less than 5.73 in. from the center of a photograph. For example, when using Metrogon lens photography in a Kelsh stereoscopic plotter the cams do not correct for lens distortions beyond 5.0 in. from the principal point. On Aviogon lens photography the fiducial mark enclosures, which appear in the corners of the photographs, extend to within 5.65 in. of the center. By anticipating that each target may lie at an r-distance of 5.73 in. from any photograph's center, its placement on the ground will be where obscuration of the target by perspective layover of tall objects cannot occur.

Knowing the aerial camera focal length and applying the previously mentioned principles, clearance from perspective layover of tall objects can be attained by placing each target at the clearance distance, minimum (C) and desirable (C'), determinable by use of the equations in Table 3. In these equations, h is the height of the top of the object above level datum of the target.

For certainty in identification and use of vertical control, the elevation of targets placed within the mapping zone should be determined by spirit level or other accurate methods. The elevation of the corner points used to level each stereomodel for mapping

TABLE 3

HORIZONTAL CLEARANCE FOR TARGETS

Camera Focal Length (in.)	Horizontal Clearance Around Target Minimum	Desirable
6	C = 0.75 h	C' = 1.0 h
$8\frac{1}{4}$	C = 0.55 h	C' = 0.7 h
12	C = 0.40 h	C' = 0.5 h

is, depending on accuracy requirements, sometimes obtained by other means, such as photogrammetric bridging, or surveys on the ground by trigonometric leveling or barometric altimeter. The effects of small discrepancies in elevation at these points will be minimized within the mapping zone by the positive identification and utilization of the accurate elevation of targets within that zone. The plane coordinates of these targets, determined by photogrammetric bridging or ground control surveys, will be used as horizontal control for scaling stereomodels for the mapping and as plane coordinate points of origin for staking the designed highway alignment on the ground.

Spacing of these targets in the mapping zone should be governed by project requirements. Best results are achieved, however, when a minimum of two targets appear in each stereomodel. To be reasonably certain of fulfilling this requirement, target spacing, in feet, along the lengthwise direction of the route zone to be photographed for mapping by photogrammetric methods should be about two times the scale of the mapping photography expressed in feet to one inch. Target spacing normal to the centerline of the mapping zone should be random and targets should be placed where they will be visible from any camera position. Some of the targets should be placed over station markers which are not within the probable construction limits of the highway, in order to preclude their destruction during construction operations. Such targets should be placed close enough to the centerline of the mapping zone, however, for convenience in use on the ground when the highway is staked for construction. Placement of many of the targets alternately on one side and then the other side of the centerline of the mapping zone will be helpful in attaining greater accuracy. Wherever a P-line traverse, or a designed centerline has been staked on the ground before photography, however, targets should be placed advantageously over instrument points and other accurately positioned line stakes to attain the spacing interval required by the photography scale.

Where ground cover is tall and dense, the route zone may be photographed and mapped at suitable scale, an initial alignment determined, tentative grade lines and cross-sections measured, and clearing limits established. Once the best location, based on this initial design, is cleared and rephotographed, the surface of the ground can be accurately mapped for accomplishment of detailed design, measurement of grading and other quantities, and preparation of construction plans. To establish control for initial mapping of the route before it is cleared, for accurate mapping after the clearing is done, and for mapping, as desired, after construction to determine pay quantities, some targets should be placed outside the initial mapping zone, but still within the photography zone. Two such targets, which will not be disturbed during clearing or construction operations, should be placed at each end of the route zone, and others at intervals of about one or two miles along the route (Figure 4). Such targets will assure that positioning and coordination will be accurately accomplished in all three mapping operations without need for establishing basic control other than for the initial phase. Thus, systematic errors between the separately compiled maps may be kept to a minimum, if not entirely eliminated, and the optimum accuracy attained in each operation, regardless of which photogrammetric system is employed.

It may be of interest to note additional advantages in placement of photographic targets before photography is accomplished. The photography crew has positive visual guidance available on the ground, which adds certainty to their attaining exactly the photographic coverage required, without any likelihood of having to make several trial photographic missions. Targets enable field survey parties and the photogrammetric instrument operators to save time and thus decrease the cost of their work, because delays and errors resulting from misidentification of natural images is eliminated. These targets also enable photogrammetric instrument operators to determine whether there is image movement in the photography. This is accomplished by detecting where targets appear to "dig" or to "float" unnaturally. Each photogrammetric instrument operator can maintain consistently greater accuracy throughout his work by the elimination of doubt and the reduction of random errors, which would otherwise occur when photographic targets are not provided.

Ground and aerial photographs of various targets are included to illustrate good and bad types and proportions.

REFERENCES

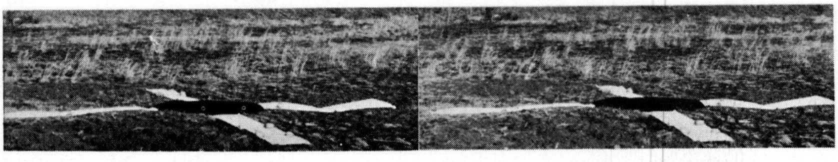
1. "Relationships in Contour Interval, Scales, and Instrument Usage," HRB Bulletin 157 (1957).

2. Manual of Photogrammetry, American Society of Photogrammetry, Second Edition (1952).

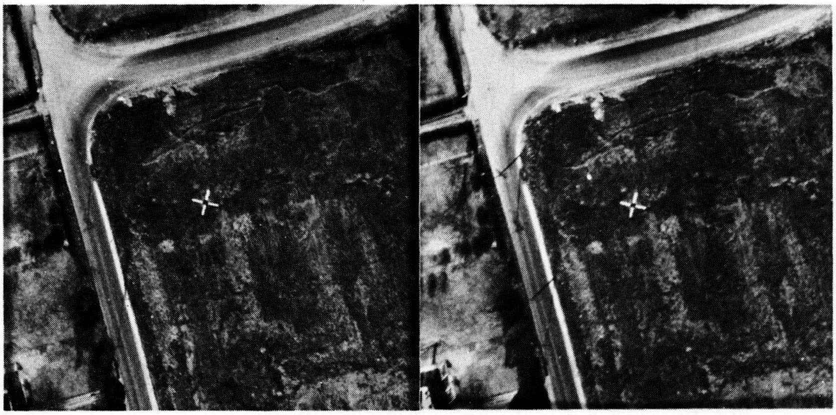
Appendix

Nineteen stereograms were selected to illustrate various types of targets used on several projects. Ground views are not of the same targets in the aerial views. Their similarities, however, are described. In the aerial views target images were small at contact scale, and for ease in their examination and certainty of reproduction herein, they were enlarged two diameters in preparation of the stereograms. The image of each target in the aerial stereograms is therefore twice as large as it actually appeared on the aerial photographs.

Stereograms 1 through 7 are of targets recommended as most suitable. Stereograms 8 through 14 are of targets which are usable and will serve well under special conditions. Stereograms 15 through 19 are of targets which contain unsatisfactory characteristics as noted.

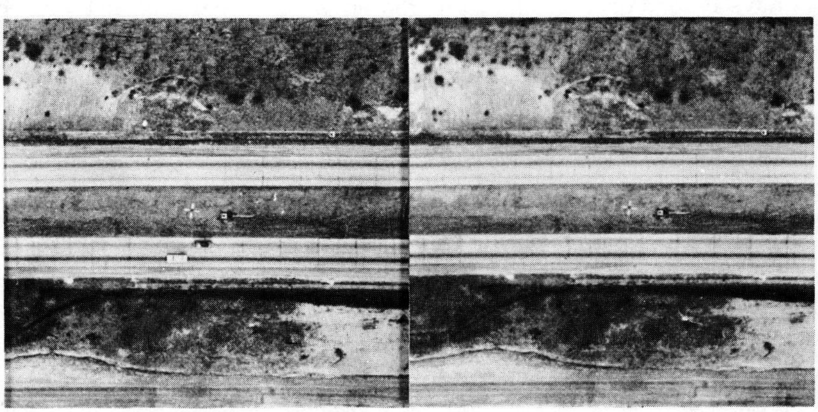


Stereogram 1. Ground view of cross-type target with central square. Material used is dark red and white muslin. This target is similar to Target No. 1 described in the paper. It is easily placed and removed as necessary, has reasonable durability, and its symmetry over the station marker remains in its image on the aerial photographs. Refer to illustration in Stereogram 2.



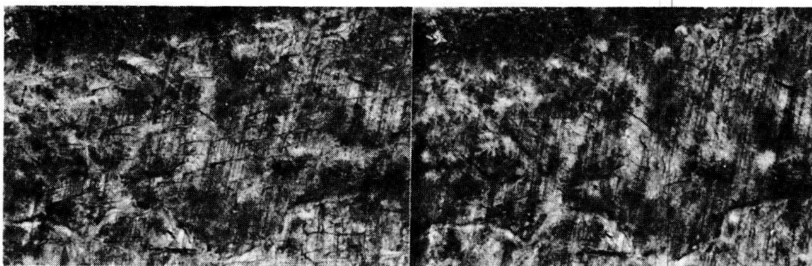
Stereogram 2. Aerial view of cross-type target, similar to the one in Stereogram 1. Bordering ground area has dark tone. Consequently there is considerable contrast between this area and the white legs, and little contrast between it and the dark red central square of the target. Target proportions are similar to those in Table 1 of the paper, but the dimensions are twice as large as necessary for the photography scale. (As seen here, however, the target appears four times as large as required for photogrammetric work because the photographs, as noted in the general explanation for all stereograms, are enlarged to twice their contact-print scale.)

Stereogram 3. Ground view of cross-type target. Materials used are dark red and white muslin. This target is similar to Target No. 2 described in the paper. Its other characteristics are similar to Target No. 1, as illustrated in Stereogram 1 and 2.



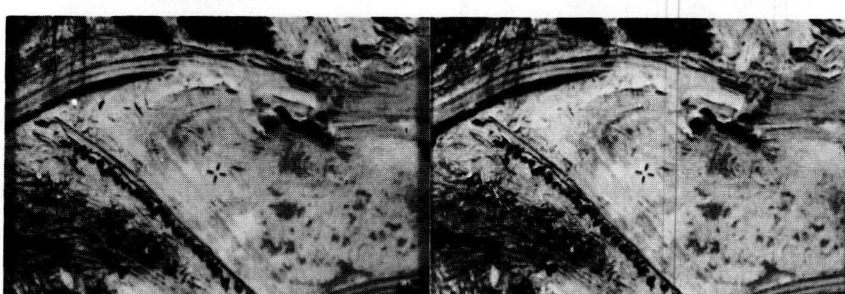
Stereogram 4. Aerial view of cross-type target similar to the one in Stereogram 3. This target was placed in the median strip of a 4-lane highway near a drainage inlet which appears on its right. A moving vehicle appears on the left photograph only. Grass area bordering the target is dark in color tone. Consequently the dark portions of the cross are only slightly darker than the grass. Target proportions and dimen-

sions are similar to those in Table 1 of the paper. The natural overriding of white on dark tone details, however, causes images of the white legs to appear wider and longer proportionally than the black central portion of the cross.

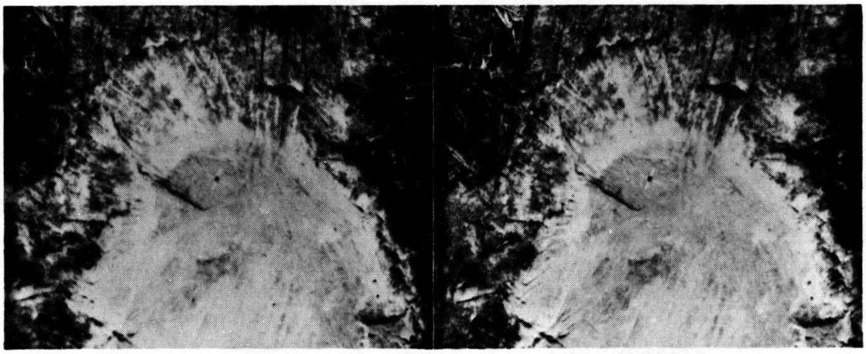


Stereogram 5. Aerial view of cross-type target, similar to Target No. 2 in the paper, placed in deciduous tree area without any clearing being done. Materials are black and white muslin. Magnification will reveal that, while the width of both black and white strips are the same on the ground, the white image is much wider than the black. Symmetry in the target's image is maintained, although this target was set 54 days before the photographs were taken. In the meantime there had been two snowfalls and enough rain to melt the snow.

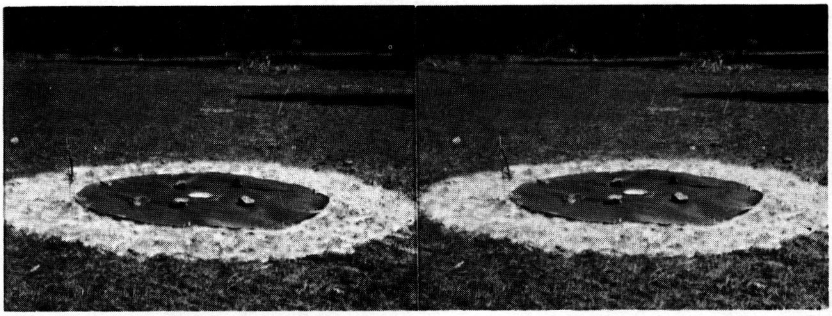
Stereogram 6. Aerial view of two cross-type targets, with white muslin legs. The small target at the left has a central black muslin square the same as Target No. 1, and the large target at the right has a central red muslin cross the same as Target No. 2 in the paper. For these photographs, the small target conforms in all respects with the dimensions in Table 1, and the other is twice as large. The small target was placed 54 days before photography, and the large one 5 days. Weather conditions for the small target were the same as for the target in Stereogram 5, whereas there were only 3 days of rainfall after the large target had been placed.



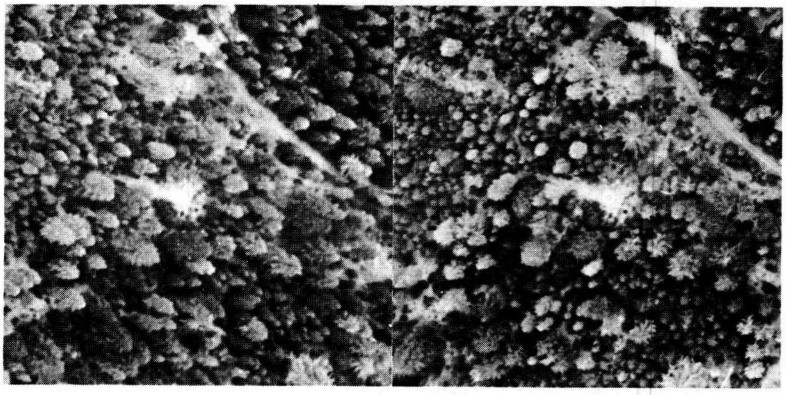
Stereogram 7. Aerial view of cross-type with legs of dark red muslin, and no central portion. Light color tone of ground makes dark legs easily identifiable, permits them to retain their symmetry, and eliminates need for central portion. Over-all ground dimensions of the target are the same as shown in Table 1, but width of dark red legs are twice as wide. On these aerial photographs, however, over-riding of light color tones over the dark red has reduced their black image width one half. A target of all dark legs should not be used wherever dark shadows might be cast by vegetation or buildings.



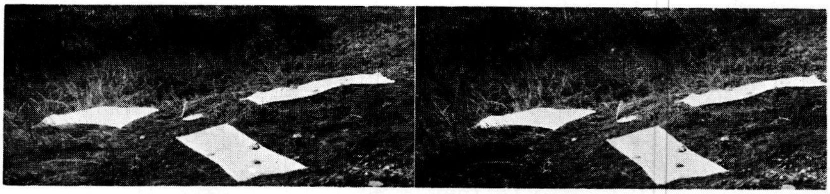
Stereogram 8. Aerial view of cross-type target in light color tone area. The legs are white muslin and the central portion is dark red muslin. On the ground dimensions vary slightly from those given in Table 1, the leg length being 1¾ longer and leg width ⅛ narrower. Light color tone of area prevented the white legs from over-riding adjacent ground. Consequently they appear narrow and faint.



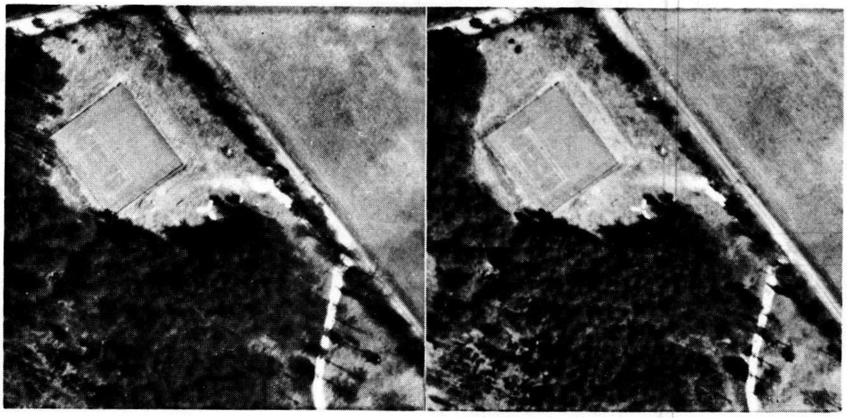
Stereogram 9. Ground view of bull's-eye type target. Station marker is centered by white paper pie plate over black tar paper bordered by white lime. This type of target is difficult to construct unless lime or similar material is used.



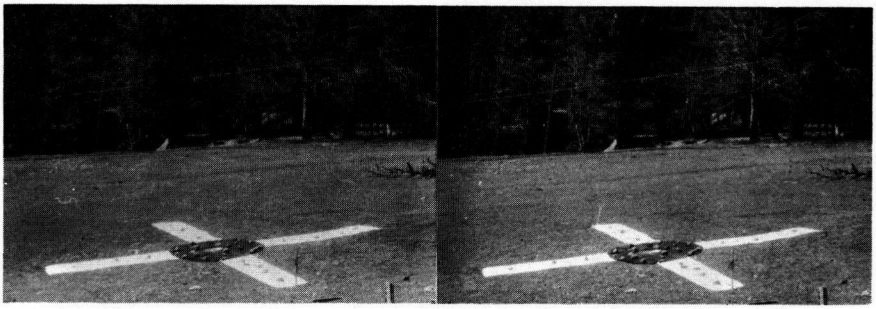
Stereogram 10. Aerial view of bull's-eye type target similar to the one in Stereogram 9. It should be noted that the white lime circle, although uniform in width on the ground, is not uniform in width on the aerial view. This is caused by the variable amount the white has over-ridden the adjacent areas. The central black area, however, is fairly symmetrical; thus centering on the station marker in the photogrammetric operations would be fairly precise.



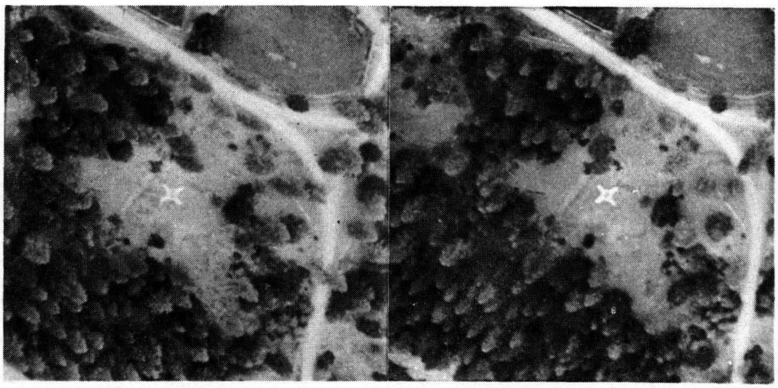
Stereogram 11. Ground view of three-legged target of white muslin. Station marker is centered by white paper pie plate over small triangle of black tar paper which has nearly the same color tone as adjacent ground. The guard stake leans toward the station marker.



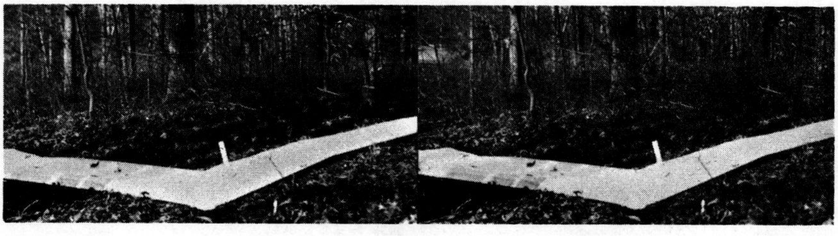
Stereogram 12. Aerial view of three-legged target similar to the one in Stereogram 11. It is difficult to place symmetrically each leg of this target with respect to the station marker. It is therefore not the best type of use, although it is easy to identify.



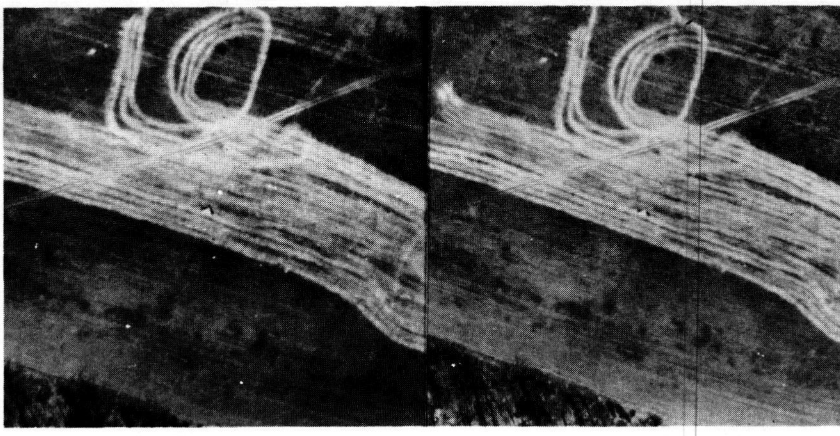
Stereogram 13. Ground view of cross-type target in which the white legs are too wide in proportion to their length and to the size of the central dark portion. Materials used are black tar paper, centered by a white paper pie plate over the station marker, and white muslin.



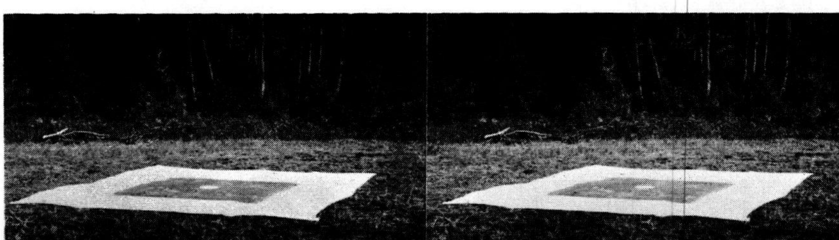
Stereogram 14. Aerial view of cross-type target similar to the one in Stereogram 13. The dominance of white over the adjacent ground and central dark portion of target has caused the image of this target on the aerial photographs to have the appearance that the central black portion was bordered by white when the target was set on the ground. This, of course, is not the case as can be seen in Stereogram 13. Excessive width of white legs in proportion to their length and to the central dark area is evident.



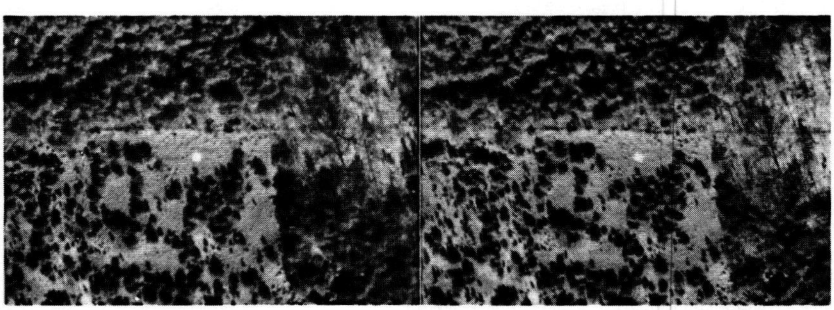
Stereogram 15. Portion of ground view of L-shaped target of white muslin, black omitted. The station marker is at the inside corner of the "L" toward which the guard stake is leaning. On a target of this shape, the over-riding of white on adjacent areas will displace the image corner from true position of the station marker on the ground.



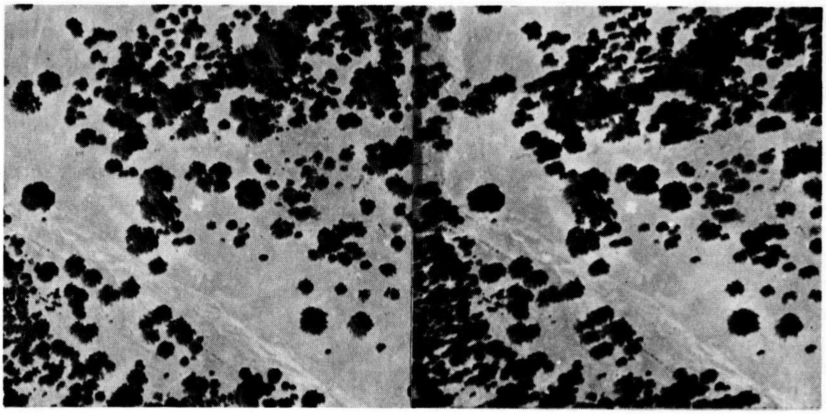
Stereogram 16. Aerial view of L-shaped target of white muslin on inside and black tar paper on outside. Because of light tone of adjacent ground, the tar paper was used in this area to attain sufficient contrast, but this use does not preclude the undesirable over-riding of white and resultant displacement of image at station marker.



Stereogram 17. Ground view of square target of black tar paper on inside, centered by paper pie plate over station marker and bordered by white muslin. Over-riding of white on other images decreases effectiveness of dark center area.



Stereogram 18. Aerial view of square shaped target, similar to the one in Stereogram 17, showing effect of white over-riding central dark portion to such an extent that the symmetry is decreased and center of the target on the station marker is not accurately discernable.



Stereogram 19. Aerial view of cross-type target constructed of white muslin and black tar paper. The white has completely over-ridden the black. This is because of improper proportions, white portions of the cross being too wide and short, and the black too small. The cross appearance has almost disappeared, there is no black to be seen. Consequently the stereoinstrument operator cannot be sure when the floating mark is on the station marker, which was at the center of the cross at the time the target was placed on the ground.

Discussion

W. S. HIGGINSON, Sloan and Associates, Pasadena — Targets for control points certainly remove a source of confusion from mapping projects. This is because they make possible the positive identification of surveyed points serving as control. Thus, they should be used wherever possible.

There will always be mapping projects, however, where it will not be feasible to place targets, and other instances where targets once placed will not be in place when the photography is taken. These situations should not prevent a thorough study of targets and their uses in order to establish a uniform practice in relation to their shape, use and distribution.

It should be realized at the outset that a stereophotogrammetric "bridge" is dependent on all points that are read in the traverse. Many of these points must be natural image points, since it would be impossible and impractical to attempt to locate the proper position of all pass points before the photographs are taken. This does not mean that since all bridge points or pass points cannot be ideal that it is not worth while to use targets on existing control or wherever control coordinates will be determined.

The design of targets may be based on personal opinion. As a result, targets may be of various shapes and sizes (crosses, L-shape, V-shape, T-shape, squares, circles, and other designs), any of which may be used to identify a particular point on the ground. Considerations leading to uniformity and the universality of these designs is well worth while. The diagram of targets as submitted by the author should produce excellent results. However, there are some features of these designs that could be eliminated and simplified without impairing their effectiveness. In this respect, a plain circle is suggested. The circle has no points, intersecting lines, or anything to scatter light rays, which usually results in exaggerated line dimensions or a diffused line between the dark and the light tone colors. The use of a circle eliminates all design problems except the diameter of the circle. The weight of the line could be heavy enough to make it visible in any photographic range; that is, for high altitude very wide lines and larger diameters would be used and for low-altitutde photography these dimensions could be reduced. The degree of accuracy with which one can set a pointer in the center of a circle depends on the diameter of that circle and this value can be determined easily before the photographic mission.

Random targets would not be an economical practice because "bridge points" or pass points must be selected within a rather limited area, and this area could never be determined previous to the photographic flying. A limited number of random targets would be of value in that it would provide a check of ground identification of points that were not targeted.

As Mr. Pryor has pointed out and clearly illustrated, contrasting tone values for markers and background are essential for positive identification within the accuracies desired in the large scale mapping. Information of this nature should be made use of in planning for all mapping projects.

It should also be pointed out that for almost any target, other than the circular type, it is necessary to cover the ground marker itself with the target material. This situation may not be too serious. It may be necessary, however, for the field engineers to examine, during their operations, the ground points targeted to serve as control for the mapping.

WILLIAM T. PRYOR, Closure — A few of Mr. Higginson's comments require amplification, inasmuch as the seeming conflict which he presents does not actually exist.

Mr. Higginson wholeheartedly accepts the fact that targets should be used wherever possible because of the certainty with which control points identified thereby can be utilized. He agrees that wherever natural image points are used simultaneously with targeted control, such control enables the photogrammetric instrument operator to localize errors or discrepancies which often occur. Whenever markers of control are not targeted, errors caused by incorrect identification of natural images tied to control are difficult, if not impossible, to reconcile; also, the essential reconciliation becomes costly in terms of the frustrations and time losses.

His suggestion that the design of targets may be based on personal opinion is acceptable to a certain extent—during the experimental use of targets. Personal opinion cannot govern, however, once the best shape and size for targets has been determined according to topographic and ground cover surroundings, and to photography and map scale requirements. Experiments indicate that overriding of white portions on dark portions of targets that are not symmetrical, as L-, V-, and T-shaped targets, invariably causes an image pattern displacement on the photographs with respect to the ground position of the point for which they were placed to identify and accurately mark. The circle- and cross-type targets, when symmetrical, do not contain such displacement. The center they establish, by their symmetry as images on the photographs, provide an accurate "pin point" for the actual position of the surveyed control points they mark on the ground; thus systematic errors resulting from undesirable displacements are avoided.

Experience has shown that it is easier to place the cross-type target than the concentric circle-type target. An exception of course would be the painting of an appropriate "bull's eye" on portable, durable materials such as metal, plywood, or masonite. An important fact to remember, however, is that materials used to construct targets should not have the tendency to cause "glare" from certain sun angles. This characteristic often photographically obliterates to ineffectiveness one of the images of a stereoscopic pair.

Mr. Higginson's comment regarding targets randomly placed seems contradictory, inasmuch as he mentioned in one sentence that their placement would not be an economical practice and in the next that they would be of value. The specific and random placement of targets on surveyed markers and on points for which control is to be bridged, as outlined in the paper, will achieve optimum results for the instrument operators and for highway engineers whose responsibility it is to stake the highway on the ground after it has been designed by use of the photogrammetrically compiled maps. It is believed that Mr. Higginson has overlooked the use benefits of targeted control, which are often greater after the mapping has been completed than while map compilation is in progress.

Mr. Higginson's thought that each target, except the circular type, must cover the marker is not in agreement with the author's experience. As necessary, any marker need not be covered by the target. Targets of any shape placed symmetrically over the marker can easily be center-opened, as desired, wherever the marker has been covered by the target. This can be done during the targeting operation or whenever the marker has to be occupied during ground survey work.

To complete or amplify some parts of the paper the following comments are offered:

Targets, as markers of survey control, can be as durable or perishable and removable as land use, climatic conditions, and engineering requirements demand. Targets constructed of cloth have provided satisfactory contrast and shape on photographs taken two months after placement of the targets, although they had been subjected to three heavy snowfalls which were melted away successively by heavy rains before weather was suitable for photography. In other cases, targets of painted plywood provided excellent photographic images in regions having a humid climate, where rainfall occurred periodically for six months or more before suitable photography was obtained.

In arid regions, lime or white cement and blackened lime or cement, distributed within the boundaries of a target templet, has been effective after rain, although it is not as resistant to the effects of weather as cloth, plywood, metal, and durable materials. The principal advantage of lime and cement is that animals do not destroy targets constructed of such materials to the same extent they will destroy targets constructed of wood, cloth, or plastic.