*Instruments for Marking Natural Points and Producing Artificial Points in the Preparation of Aerial Photography for Aerotriangulation**

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ABSTRACT: *The preparation of aerotriangulations consists mainly in the selection of natural tie points between the various models and flight strips, or in the production of artificial ones. The paper discusses the respective conditions and describes simple instruments for marking or constructing such points.*

SCOPE OF PROBLEM

FOR aerotriangulations of single strips or blocks *transfer points* are required for tying-in the various models or flight strips. At the same time, these points shall be used as control points in the subsequent orientation of the photographs for plotting purposes. Due to the systematics desired for aerotriangulation, it is indicated to select such prints as close as possible to the photo-centers and the corners of the "optimum model space" which is given by the end-lap and side-lap of the consecutive photographs or the strips, respectively. As a rule, the "optimum positions" for such transfer points are determined in contact prints in the course of the preparatory aerotriangulation work. In the diapositives used for aerotriangulation, the points can then be selected within a certain tolerance circle. The points shall be *unambiguously* marked, so that they can be clearly identified both as to position and elevation, in order to save time in the plotting process. The two resultant possibilities are to select natural image details or to create artificial points.

Natural points offer the advantage that they can be used in the aerotriangulation for both planimetric transfer and height transfer, and that their position in consecutive photos, and especially in those of adjacent flight strips is "a priori" correct, so that maximum accuracy can be expected in plotting. However, topographic details can only scarcely be used for this purpose, since they will frequently not be available in the immediate neighborhood of the "optimum" position and because they will mostly be insufficiently defined as points, with the exception of intersecting boundaries and field corners. On the other hand, however, there will always be a large number of tiny image details, especially in large-scale photography, such as clods in the middle of fields, stones, isolated grass tufts, etc., which are clearly reproduced in all photos in the form of bright or dark dots. These details which in the photo will often be as small as 0.01 mm., are excellent transfer points; they must only be *unambiguously defined* for the operator of the plotting instrument, so that they can be easily recognized among the multitude of similar, adjacent image details. Owing to the fact that the photograms are always observed in pairs in the plotting instrument, it will be sufficient if such points are marked only in the central one of three consecutive photos.

Artificial points are used almost exclusively for the transfer of *horizontal position* in aerotriangulations, so that they need be marked in only *one* photo, too. For *height transfer* a clearly visible, for instance horizontal "patch of terrain"—which need not necessarily be punctiform—must be marked close to the artificial point, so that the latter may be set "under monocular observation" with the aid of the elevation thus obtained. In the case of points located on slopes, also the elevation of the contour line which would pass through the point may be used as a datum height. Artificial points for *tying-in the various flight strips* must be stereoscopically transferred with great accuracy from one flight strip to

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another. In this case, the accuracy of transfer which will be directly introduced in the subsequent measurement, will depend both on the experience and the stereoscopic vision of the operator as well as on the instrument used for transfer.

Consequently, the two problems encountered are:

1. *Unambiguous marking* of punctiform, natural details without damaging them. Only moderate accuracy is required of such a mark, since it is only identification which must be ensured.
2. *Production of artificial points*, and if necessary, their *stereoscopic transfer* to adjacent photos. Maximum accuracy is required for stereoscopic transfer, since it is impossible to subsequently correct a point which was transferred inaccurately.

After a careful study of this matter and comprehensive investigations, Zeiss-Aerotopograph has marketed the following small point marking and transfer instruments for the solution of these two tasks.

Marking Devices for Marking Natural Image Details

The marking device illustrated in Figure 1 consists of a rectangular metal frame in which on the one side a mechanical marking device, and on the other side a glass plate with point setting mark are accommodated in such a way that they can be rotated. Both these parts are connected by a lever mechanism and can be alternatively hinged down onto the seating face of the frame, i.e. the image plane. Setting mark and marking device can be so adjusted one with respect to the other that the mark will be exactly in the center of the circle. For setting the point mark on an image detail selected for marking during stereoscopic examination of the various combinations of photos, the marking device is displaced *free-handedly* over the diapositive or the negative. Then, a circle of 1 mm. diameter can be engraved around the respective point in the emulsion of the photo with the aid of the marking cylinder. Extensive tests have revealed that with such a diameter the center of the circle, i.e. the respective terrain point, can be accurately located with the eye, and that on the other hand the area within such a circle will be sufficient for clearly recognizing the immediate surroundings of the point in the course of subsequent stereoscopic plotting.

In addition, a point mark in the center of the identification circle can be produced with the aid of a second knurled knob intended for producing *artificial points*.

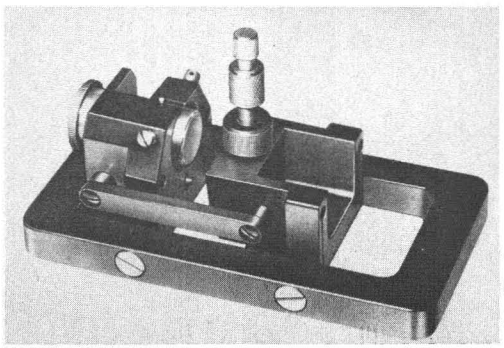

Fig. 1. *Marking Device* for providing natural image points with an identification circle. Independently, also points can be produced with the aid of the upper one of the knurled cylinders.

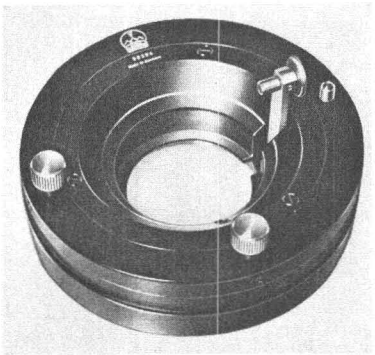

Fig. 2. *Snap Marker* for the production of artificial points.

Snap Marker for the Production of Artificial Points

P. Dongelmans of the International Training Centre, Delft, developed a *Snap Marker* for point marking (Figure 2). A metal frame which is set on the photo to be marked contains an adjustable plexiglass disk with setting mark. This setting mark—a steel ball of 0.2 mm. diameter—protrudes from the lower side of the plexiglass disk which in turn exercises a slightly resilient pressure on the photo. For exact setting, it can be displaced in the metal frame in x- and y-direction with the aid of two knurled screws. *Points are marked* by means of a small spring-loaded hammer striking the steel ball. The latter will produce a circular hole of 0.1 mm. diameter in the emulsion of the diapositive, surrounded by a black bulge.

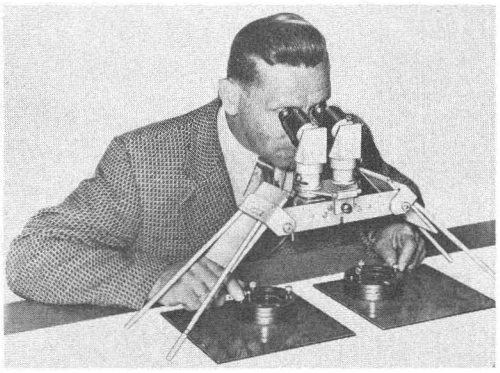

FIG. 3. Transfer of artificial points in diapositives placed on light box, in combination with a mirror stereoscope equipped with six-power monoculars and Dove prisms.

For the construction of artificial *tie points between adjacent flight strips* two such Snap Markers are placed on the respective diapositives of the two strips oriented on a light box. Once both instruments have been approximately set by hand with the aid of the precision setscrews, the Snap Markers are so displaced under a stereoscope that they will produce an artificial model point which appears to sit on the terrain *free from parallaxes*. The points thus set in both images are then marked by releasing the little hammers. For better judgement of the residual parallaxes, Dove prisms may be used in combination with the monoculars of the respective stereoscope. These prisms will make it possible to convert y-parallaxes into x-parallaxes which can be perceived stereoscopically.

SETTING INSTRUMENT FOR THE TRANSFER OF ARTIFICIAL POINTS ALREADY MARKED

In addition, the case may present itself where a point *already marked* shall be transferred to other photos. The point produced in the emulsion by the steel ball is of a slightly smaller diameter than the steel ball itself, so that it would be covered by the latter, if such a ball were used for re-setting. Therefore, a special *setting instrument* is required for re-centering the setting mark on the marked point. This setting instrument is provided with a plexiglass disk in special metal mount. Apart from a point setting mark of identical size as the steel ball in the Snap Marker, this disk carries very close to the former a somewhat larger annular mark. Both these marks can be exchanged in their position with a high degree of accuracy by simply changing the position of the metal mount on a gear rim. In practical work, the following procedure is employed:

At first, the annular mark is centered on the point marked in the diapositive with the aid of two knurled screws. This can be achieved with great convenience and accuracy, since a small, white zone will—if perfectly centered—appear between the marked point and the annular mark. Once this has been accomplished, the setting mark proper is moved in the place of the annular mark by changing the position of the mount in the gear rim. The stereoscopic transfer and marking of the respective point in the other stereo photo can then be accomplished, as described above, with the aid of a *Snap Marker* placed on the second photo.

The considerable advantage of the Snap Marker over any previous design is the fact that *setting mark and marking tool are identical*. This eliminates practically any error between setting and marking in the stereoscopic transfer of points. The convenient arrangement of the precision setscrews, the smooth adjustment of the plexiglass disks due to the use of countersprings, the change-over device in the setting instrument as well as the type of marking itself guarantee extraordinarily smooth operation.

ACCURACY OF ARTIFICIAL POINT TRANSFER

In order to judge the accuracy with which artificial points can be transferred to adjacent photographs, the following experiments were made:

1. Common construction of points in two

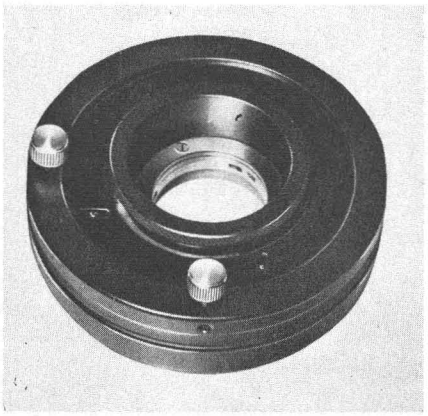

FIG. 4. *Setting instrument* for transferring marked points.

adjacent photographs with the aid of two Snap Markers.

2. Transfer of points already marked in one photo with the aid of one setting instrument and one Snap Marker.

Each series of tests was made up of 40 point transfers, with 20 tests each made with and 20 tests *without* the use of Dove prisms (conversion of y-parallaxes into x-parallaxes). Six-times magnification was used for stereoscopic setting. The image coordinates of marked points were measured with an accuracy of ± 0.2 microns (double settings) in the Carl Zeiss universal measuring microscope, after which the coordinates of all points of one photo were numerically transformed to those of the other photograph. Identical contact prints were used as "adjacent" photos, so that the coordinate differences obtained after transformation are a direct measure for the accuracy of transfer.

Both series of tests show similar results, i.e. the following mean square coordinate differences:

dx (μ)	dy (μ)	
± 3.8	± 3.4	with Dove prisms
± 4.7	± 7.2	without Dove prisms.

For comparative purposes, 20 additional "natural" image details were selected as transfer points and marked by identification circles in two photos with the aid of the Marking Device. The respective measurement and transformation of the image coordinates of these points produced mean square coordinate differences of $dx = \pm 3.2$ microns, $dy = 5.1$ microns, which are essentially due to the different photographic reproduction of these details in the two photos.

Summary

Nowadays, both methods, viz. marking natural, punctiform details or that of engraving artificial points, are used in practical photogrammetry for the preparation of aerotriangulations. Apart from personal preferences for one or the other of these methods, the following should be said:

The production of *artificial points* will yield uniform point marks, which must, however, be identified by an additional symbol to be added by hand. Experienced operators with excellent stereoscopic vision must be employed for point transfer of maximum accuracy. Two instruments are required for transfer.

Natural details can be marked without excessive precision with the aid of one single Marking Device for the production of annular marks. It must first be checked, however, whether the respective detail is clearly visible in all combinations of photos. There will be no transfer errors if natural points are used. On the other hand, however, the accuracy of transfer in the aerotriangulation itself may—under certain circumstances—be influenced by the different photographic reproduction of the respective detail in the various photos.

Depending on local conditions and the character of the terrain, both methods will frequently be combined. The direct use of natural points is especially suited in the case of deserts with rich detail, and open country, while the production of artificial points may be favorable in the case of dunes and shallows poor in detail, and occasionally also in extensive forest areas. For both these methods *modestly priced* instruments are available in the form of the aforementioned designs. In combination with simple magnifying stereoscopes equipped—if possible—with Dove prisms, these instruments can be used in *large numbers* for mass production. The production of *uniform* artificial points as is possible with the aid of the Snap Marker may gain additional importance, if an automatic point setting on the scanning principle should be employed in future plotting equipment. In addition, the Marking Device for the production of annular marks can be used to advantage for preparing slotted templet triangulations on contact prints or on Correctostat templets.