Jan. 24, 1933. L. J. R. HOLST 1,894,953

ART OF MAKING MAPS FROM PHOTOGRAPHS

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Fig. 1.

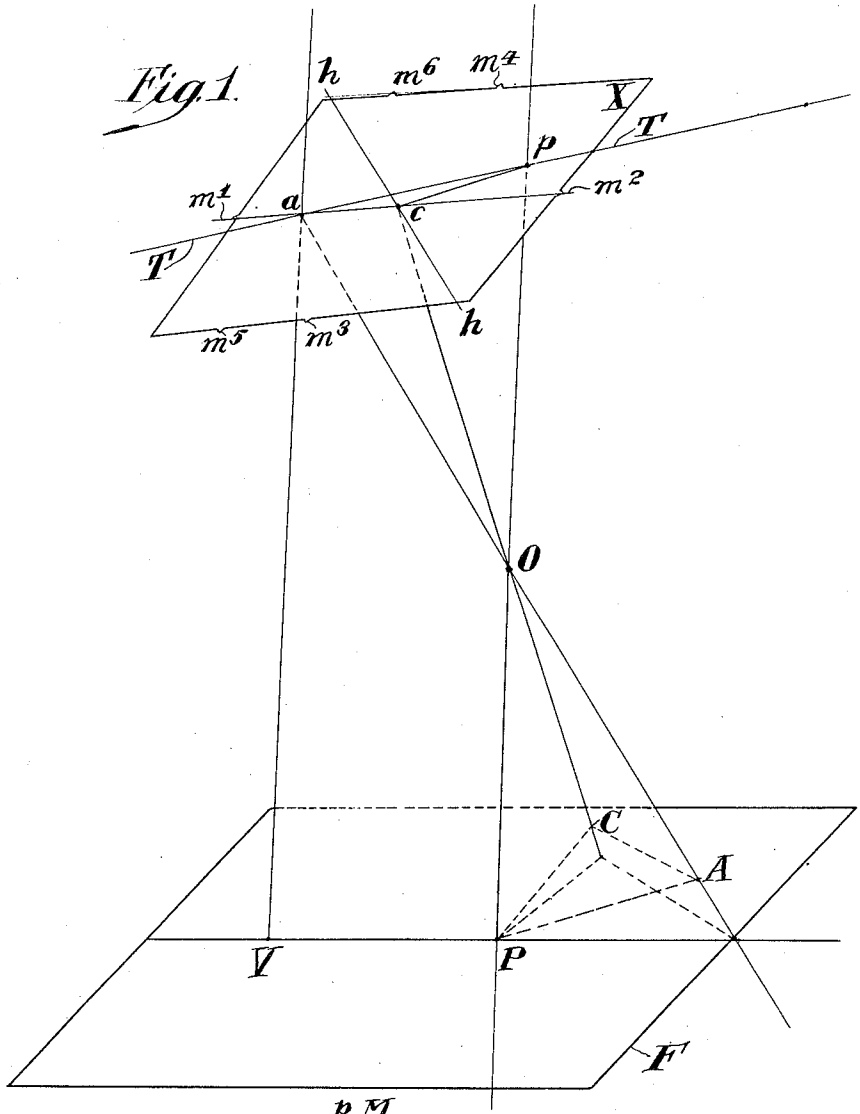
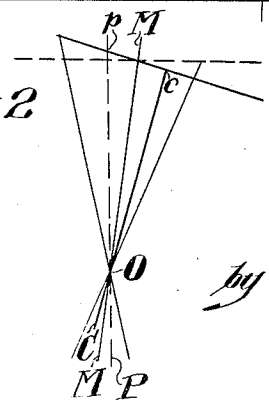


Fig. 2.



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Fig 11.

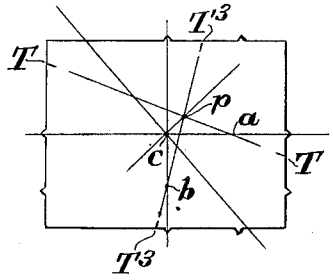


Fig. 3.

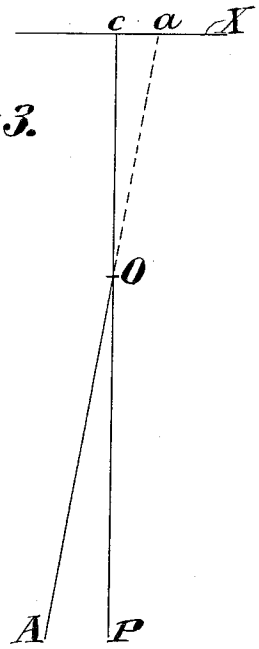


Fig. 3a.

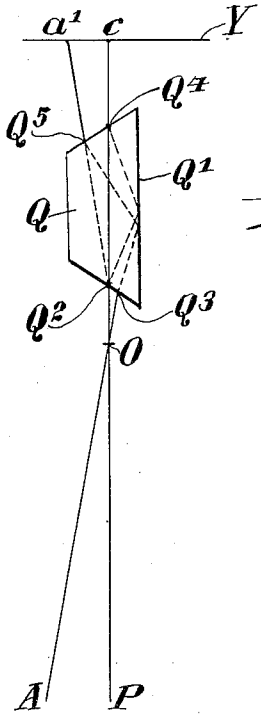
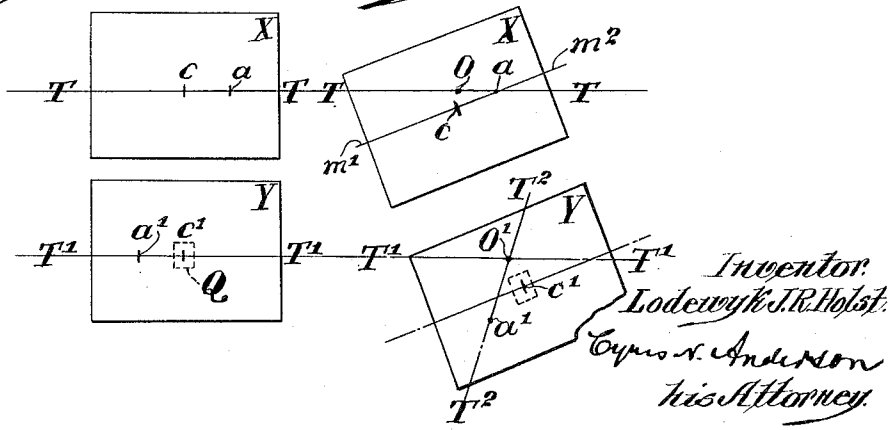


Fig. 4.

Fig. 4a.



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Fig. 5.

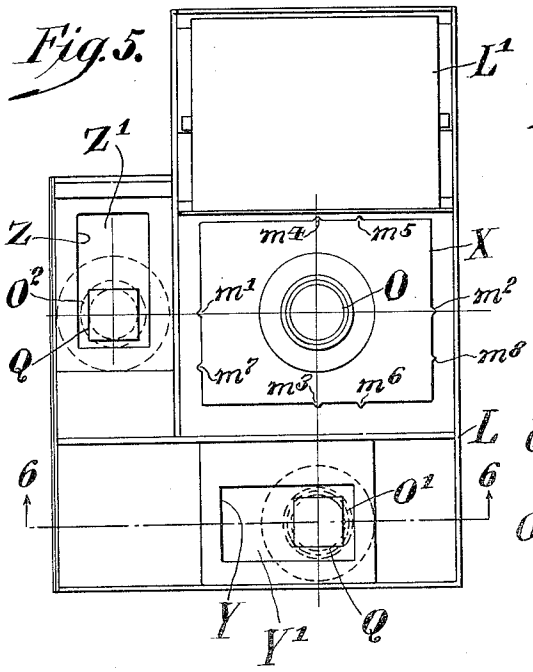


Fig. 6.

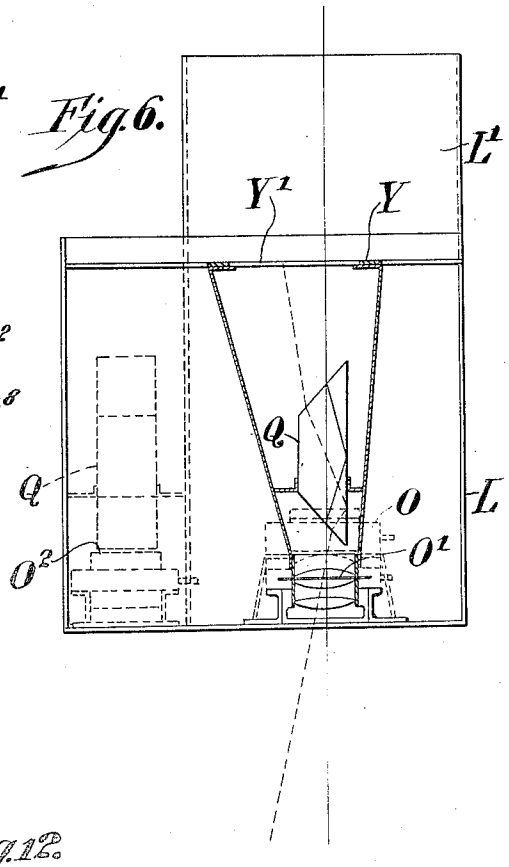
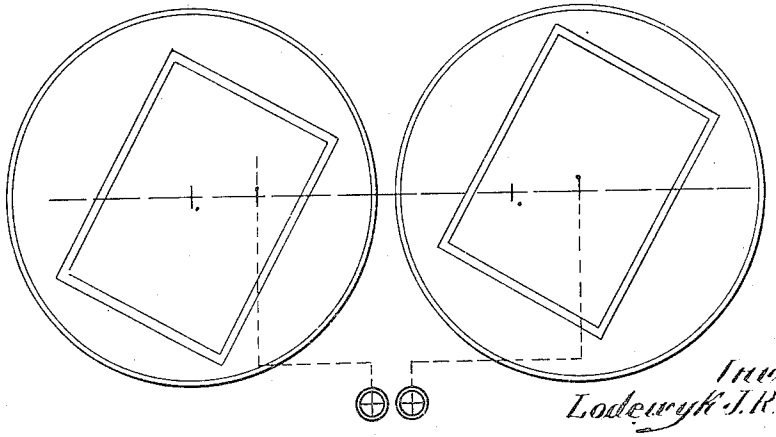


Fig. 12.



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Fig. 7.

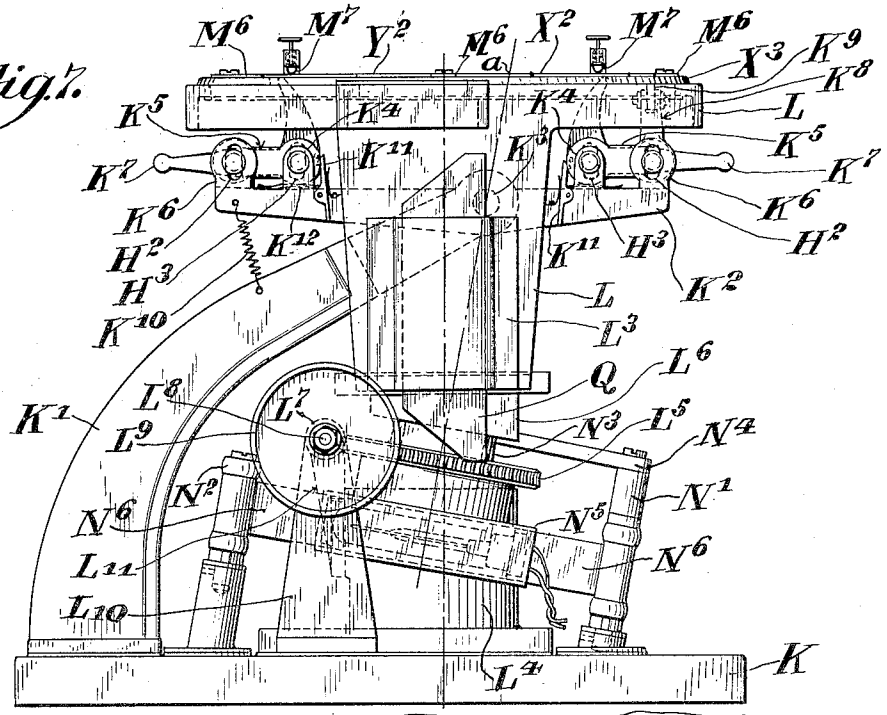
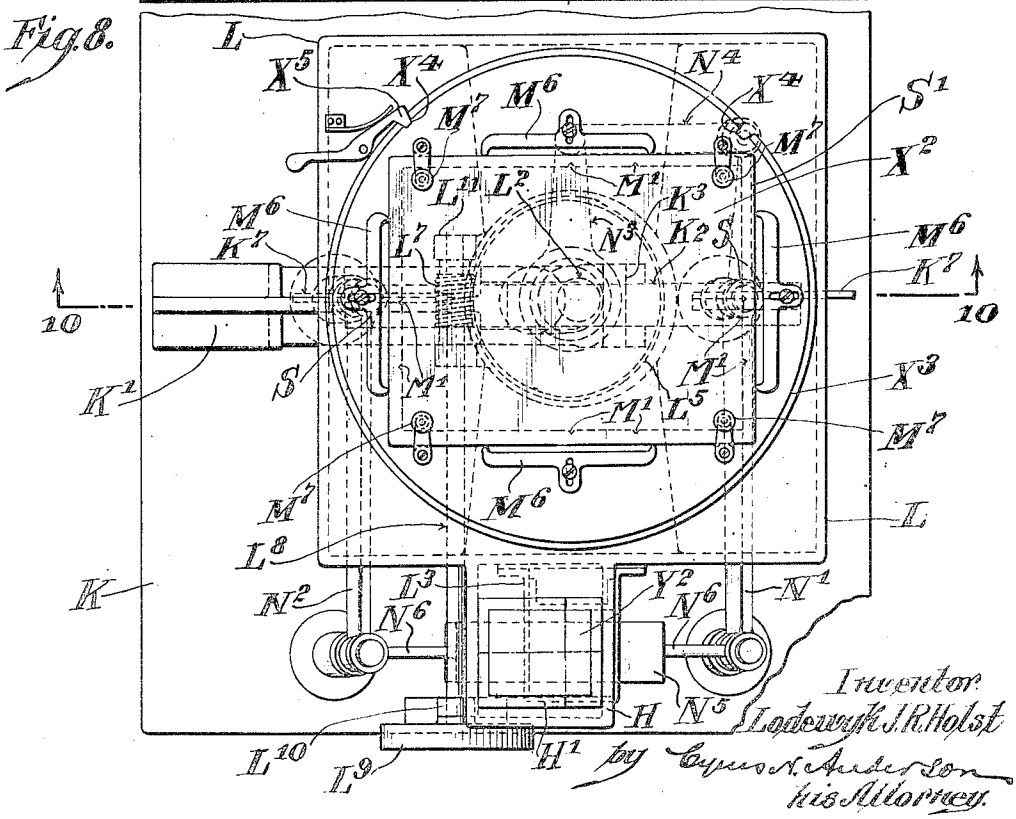


Fig. 8.



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Fig. 9.

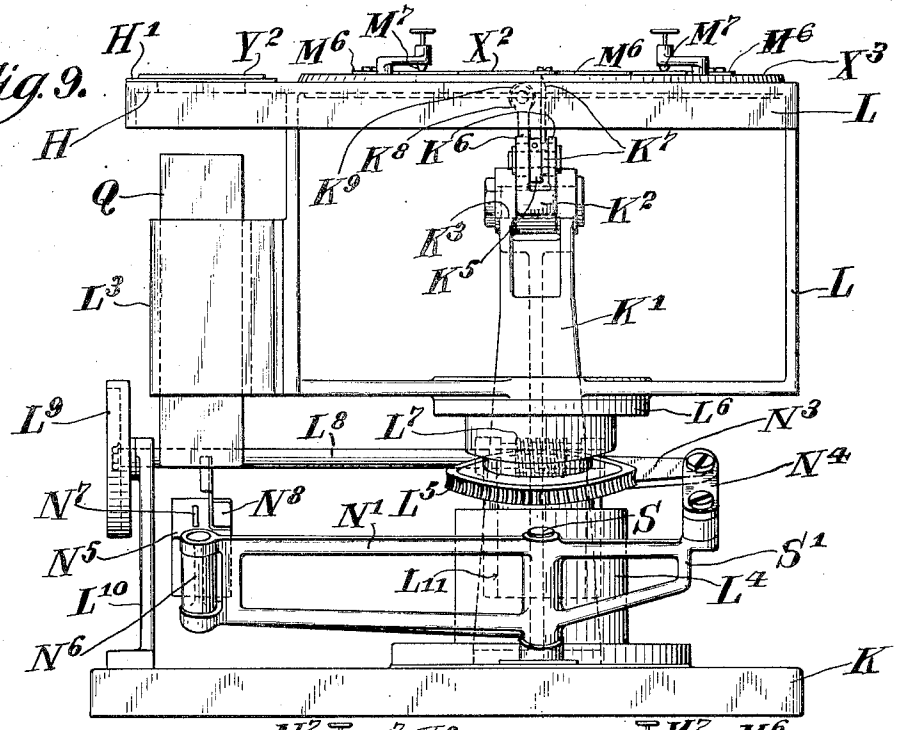
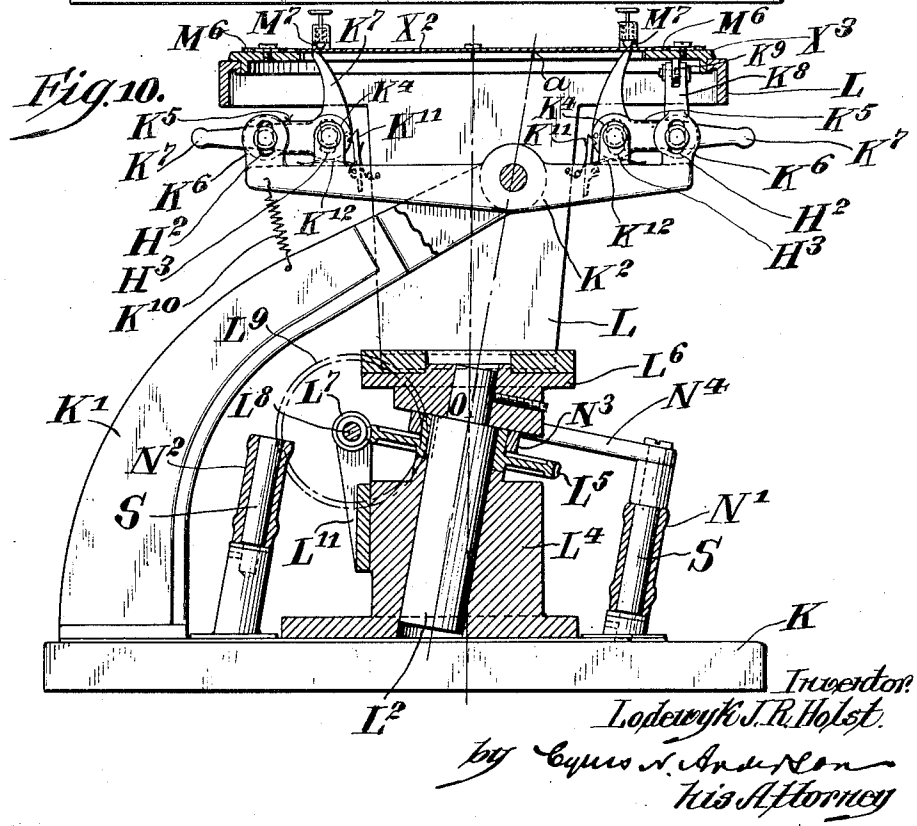


Fig. 10.



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UNITED STATES PATENT OFFICE

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ART OF MAKING MAPS FROM PHOTOGRAPHS

Application filed May 15, 1926. Serial No. 109,257.

It is well known that a series of overlapping views, either in horizontal or in oblique planes of projection, can be converted to the usual orthographic projection of a map and that the stereoscopic relationship between the overlapping sections of adjoining views may be used to measure elevations and to draw contour lines if the actual position of the plane of projection of the views so used with relation to a horizontal plane be known.

As no dependable means to stabilize aerial cameras in a horizontal plane has, as yet, been found various methods to determine the plane of projection either by computation or by empirical methods have been proposed. According to the methods heretofore in use computation of the plane of projection requires knowledge as to the orientation and the relative elevation of at least three ground points occurring in each view, thus necessitating a considerable amount of instrumental surveying throughout the photographically surveyed area in addition to the laborious and difficult work of the computation itself. The empirical method requires only the knowledge of the relative elevation of four points in each view and consequently requires much less field work than other methods heretofore employed but depends for its practical success largely on the experience of the operator handling the correction projectors and other special apparatus used in connection with said method. However, the chief drawback of the empirical method is that it does not provide ready means whereby the influence of lens elevation difference on the observed errors can be differentiated from the influence of tilted projections whenever both these errors are present simultaneously.

The purpose of my invention is to provide means whereby these short-comings or difficulties are obviated by a suitable arrangement of a plurality of cameras having a common focal plane and associated parts of an aerial camera structure and by the use of a new and novel tilt indicating instrumentality in which optical properties imparted by the cameras of the camera structure to views exposed simultaneously therein permit the mechanical determination in each view of the point where a vertical line through the lens pierced the common image plane at the instant of exposure.

Knowledge of the position of this point (which will be referred to hereinafter as the point p), furnishes complete information as to the position of the plane of projection or image plane, and consequently such views or images can be re-projected so as to produce the true equivalent thereof in a horizontal view from the viewpoint of the original tilted exposure. Such knowledge also furnishes information as to the true base length between adjoining views or images and as to the true flying line, so that the correct center of projection thereby becomes available for the making of the plotted photographic traverse, which constitutes the framework upon which the orthographically drawn map finally is constructed.

A general object, therefore, of the invention is to provide a method as well as means for carrying out the method, whereby the results as above indicated may be obtained without the necessity of an instrumental survey in the field to be photographed and of which a map is to be reproduced from the said photographs.

It also is an object of the invention to provide mechanical means whereby the image plane of the camera (which is the image surface of the camera plate) may be placed in position identical with that which it occupied at the moment of exposure, except as to altitude, so that the image thereon may be reprojected onto a horizontal plane to produce a correct image in conical projection of the area shown in the view or image.

The only field information required in the practice of my invention is a suitable distance measurement to allow the determination of the exact scale in which the map is to be drawn, but if dependable altitude gauges were or should become available to aviators, even this distance measurement could be dispensed with.

I shall now proceed to a description in detail of my invention in which I shall point out the method or manner in which the same

may be carried out and the principle upon which it is based. In order that the invention may be more readily understood I shall refer in the description to the annexed drawings forming a part of this specification and in which—

Fig. 1 is a schematic perspective view showing or indicating an image plane X having a lens axis c O meeting at the point O a vertical plane P p a V which rests on or intersects a horizontal plane F;

Fig. 2 is a diagrammatic view of a horizontal image plane and a tilted image plane, the former being shown by dash lines and the latter by a solid line, both having a viewpoint O in common, the planes intersecting in a line indicated by the point M at equal distances from the optical centers of the respective images;

Fig. 3 is a diagram illustrating or indicating a focal plane X and its lens axis O c standing in a perpendicular O P and the slanting ray A O forming an image point at a;

Fig. 3^a is a similar diagram, a double reflecting prism Q being shown in position intermediate the viewpoint or center of the lenses of the camera and the image plane with its reflecting surface parallel to the lens axis O c, illustrating the manner in which the ray A O of Fig. 3 is reflected to a point a^1 in a focal or image plane Y at a distance $c\ a^1$ which is equal to but in reverse direction to the distance $c\ a$ in Fig. 3;

Fig. 4 is a diagram in plan view of the focal or image planes X and Y showing the location of the centers of each plane and of the image points a and a^1 when the said planes occupy horizontal positions;

Fig. 4^a is a diagram of the focal or image planes X and Y with the traces T T and T^1 T^1 as they appear respectively in either image plane when the lens axes of both planes are inclined to the extent shown by the lines O c and O^1 c^1, which are the projections on the image planes X and Y after rotation about an axis corresponding to the line O a of Fig. 3, and also illustrating how the trace T^1 T^1 of a vertical plane parallel to the vertical plane T T before entering the prism Q is twisted by that prism after emergence therefrom so that it extends in the direction T^2 T^2;

Fig. 5 is a diagrammatic plan view of one form of structure comprising three cameras, with each of two of which is associated a double reflecting prism Q, the said two last mentioned cameras being regarded and designated as auxiliary cameras, while the other of the said cameras is regarded and designated as a principal camera, the said view also indicating the principal focal or image plane X of the said principal camera and the auxiliary focal or image planes Y and Z of the auxiliary cameras;

Fig. 6 is a diagrammatic elevational sectional view on the line 6—6 of Fig. 5;

Fig. 7 is a view in front elevation of a tilt indicator by means of which the exact position, except as to altitude, of the focal or image plane of the camera at the moment of exposure may be determined;

Fig. 8 is a top plan view of the said indicator;

Fig. 9 is a view in end elevation looking toward the left in Fig. 7;

Fig. 10 is a view in central elevational section taken on the line 10—10 of Fig. 8;

Fig. 11 is a diagrammatic illustration of a view as imaged upon the principal plane X with the tilt indications marked thereon by means of the tilt indicator; and

Fig. 12 is a diagrammatic illustration of two corrected views as imaged upon the principal focal or image plane X of the camera structure, the said views being lined up in correct alinement for stereoscopic observation and contour measurement and drawing.

In Fig. 1 the line O c represents the lens axis, the point O being the viewpoint or point of the lens system from which the view or image is projected onto the upper image surface X which is normal to the axis O c of the lens system of the principal camera structure. The line m^1 m^2 is the longitudinal center line of the principal image surface X and the point a, located in this line, is determined by the intersection of the line m^1 m^2 with the imaginary line m^5 m^6 drawn through marginal markings formed as a part of the image and being images of markings upon the aperture of the camera. The vertical line P O p passes through the viewpoint or lens center O and pierces the plane X in the point p, which is the image point of the ground point P of the vertical line P O p through the viewpoint or lens center O.

The line a V represents a vertical dropped or drawn to the ground through the point a. As the viewpoint or lens center O lies in the vertical line P p and as the point a lies in the vertical line a V the ray O a lies in its entirety in the vertical plane determined by these two vertical lines a V and P p. Consequently the object A, of which the point a is the image, must also lie in this vertical plane. As the image points a and p are located in the principal image plane X as well as in the vertical plane P p a V the line a P constitutes the direction of the trace T T of these two planes. The downward continuation of the lens axis c O constitutes the locus for the ground point C. Consequently the triangle formed by the image points a c and p is the image of the actual triangle formed by the ground points A C and P, no matter what the relative ground elevations of these points may happen to be.

The camera structure, which is more fully

described hereinafter, furnishes exposures or images in each of which the points a and c can be located by means of the marginal markings m^1 to m^6, and the viewpoint or lens center O, which bears a fixed and unchanging position with respect to the said points a and c, is thereby made known so that it is possible to support each view or image plane in such position that a vertical plane cutting the same contains one vertical line which passes through a and one which passes through the viewpoint or lens center O, so that a line O a will lie in the said vertical plane. It remains to determine, however, how much the said view must be rotated around the line O a as an axis of rotation in order that it shall assume with relation to the vertical plane so established the same position it occupied at the instant of exposure at which time the image was formed. Such determination may be effected and is made possible by means which are diagrammatically illustrated in Figs. 3 and 3a of the drawings.

In Fig. 3 the point O represents a viewpoint; that is, a center point of the lens system of a camera located vertically above the ground point P, and A is an object the image of which is represented at a. The lens axis O c is in the vertical line P O and consequently the focal or image plane X is in a horizontal position. In Fig. 3a a prism Q of the double reflecting type is shown with the lens axis indicated by O c passing therethrough. The said prism is so positioned that the emergent part of the axis Q^4 c of the lens axis is in true alinement with the incident portion thereof O Q^2. The ray A O is the same as the ray A O in Fig. 3 and enters the prism at the point Q^3. This ray is refracted, as indicated, to a point on the reflecting surface Q^1 of the prisms from which point it is reflected to the point Q^5 at the upper end of the prism and emerges from that point in the direction Q^5 a^1. The line Q^5 a^1 makes the same angle with the lens axis O c as is made therewith by the ray O a in Fig. 3 but in reverse position with respect thereto; that is, the image point a^1 occupies a position spaced 180° from the position of the image point a. As the angle between rays before and after passing through the prism has not changed in magnitude the size of the image formed by such rays will be identical with the image as formed or as it would be formed in the absence of the prism. But where the prism has been employed it will be found that the focal or image plane has receded, as compared with the focal or image plane in Fig. 3 where there is no prism present, by an amount depending upon the index of the prism glass and the size of the prism.

If two cameras be joined together with their lenses in the same horizontal plane and a double reflecting prism, such as described, be placed above the lenses of one of the said cameras and in the axis thereof, a simultaneous exposure of the plates of each camera will result in the formation of two image points of an object, such as the object A, in 180° relationship to each other, as is diagrammatically shown in Fig. 4 of the drawings in which both focal or image planes are located in horizontal planes. Under the conditions as stated, with the lenses in the same horizontal plane, the image plane of the lens with which is associated the prism will be located in a plane above that of the image plane of the lenses of the other camera. In Fig. 4 the focal or image plane of the camera with which no prism is associated is indicated by the reference letter X, while the focal or image plane of the camera with which the prism is associated is indicated by the reference letter Y. In the focal or image plane X the image of the object A will be found in the point a and in the focal or image plane Y the image point of the said object A will be found in the point a^1. The distances of these points from the centers c and c' are the same but in opposite directions, as has been indicated hereinbefore.

A further property or characteristic of a double reflecting prism is that upon rotation it causes images which are formed by rays which pass therethrough to rotate through angles twice as great as the angles of its own or actual rotation. This fact is illustrated in Fig. 4a of the drawings. In this figure it is assumed that the lens axis O c has moved out of its vertical position by rotation around the light ray O a so that the length O c on the focal or image plane X in said Fig. 4a will be or constitutes the projection of the tilted lens axis O c in the said focal plane X. The angle through which the lens axis O c has rotated is represented by the angle O a c, as shown in plan in Fig. 4a. Recalling that the line O a has been considered as the axis of rotation and that it has not been displaced, it will be clear that the line T T which passes through O and a is the trace or line of intersection of the vertical plane containing the axis O a with the tilted focal or image plane X.

Since the focal or image plane Y is rigidly connected with or joined to the focal or image plane X it is clear that its lens axis and the prism Q must necessarily have turned through exactly the same angle as the lens axis of the focal or image plane X. In the image produced by rays passing through the prism which rays have been caused thereby to turn through twice the said angle the image point a^1, corresponding to the image point a, will be found in a line T^2 T^2 deviating by an angle 2 O a c from the direction T^1 T^1 parallel to T T upon the focal or image plane X with respect to the line m^1 m^2. This angular relationship constitutes the means whereby I am enabled to correctly reconstruct the relative

positions of the vertical plane P p a V with respect to the focal or image planes X and Y.

It should be noted that the use of a double reflecting prism in the manner heretofore explained in association with the lenses of one of the cameras results in indicating the relative position of the center line m^1 m^2 of the exposure in the image plane X with respect to the trace T T of a vertical plane which contains the lens vertical P O. However, this is not sufficient to enable the actual location of the point p to be determined because the focal or image plane X can be turned from a horizontal position around an axis at right angles to the plane P p a V without changing the location of its trace with this plane. Therefore it becomes necessary to provide a second auxiliary camera with its auxiliary focal or image plane Z and a second double reflecting prism arranged in right angular relation with respect to the focal or image plane Y so as to yield a second trace T^3 T^3 passing through an image point b. The image point b is located at a point arbitrarily selected on the transverse mid line m^3 m^4 at the point of intersection of said line with an imaginary line m^7 m^8. Preferably and in practice the image point b should be selected at a point in the mid line m^3 m^4 the same distance from the point c as is the point a from the said center c. By thus locating the image points a and b the same distance from the point c the operation of determining the position in space of the image plane at the moment of exposure with respect to a horizontal plane is simplified. (Fig. 11.) This trace is determined by another plane containing the lens perpendicular P O to determine by the intersection of the two traces so produced the actual location of the point p.

The camera structure which is used in the practice of my invention is equipped with three cameras, two of which include double reflecting prisms associated with the lenses thereof, which cameras may be referred to as auxiliary cameras, while the other camera is not provided with such a prism and is referred to and regarded as the principal camera.

Before proceeding with a more or less detailed description of the cameras and the lenses I shall refer to Fig. 2 which consists of a diagram showing a dotted horizontal image plane and a full line tilted plane having a common viewpoint or lens center, indicated at O. The plane of the drawing comprises the lens vertical O p and the tilted lens axis O c. It will be noted that the point M, called the mid-point, is in a horizontal plane at the same distance from p (which in this plane coincides with the point where it is pierced by the lens axis) as it is in the tilted plane from c, the latter indicating the point where the lens axis pierces the full line tilted image plane. This fact holds true for any degree of inclination of the lens axis O c as the line O M is the symmetry line of the figure. The point M consequently is the only image point in the plane of tilt which has not been displaced relative to the point c by the tilting of the image plane, since it is the only image point which is situated in both the vertical plane O p c and the horizontal and tilted image planes. When the tilt is reduced to zero M confounds itself with c and p. This distance from c is the tangent of the angle $\frac{pOc}{2}$ and as that angle is always small M may be located without error midway between the points c and p of any tilted image at one half the tangent of the angle p O c.

From the preceding explanation it will be understood that my present invention is based upon two geometrical propositions, namely, first, that there always is one and only one vertical plane which can be made to contain two points not situated in the same vertical line, namely, the point O and a; and second, that any flat surface is determined by three points not located in the same straight line, namely the points O a and c.

It is further to be noted that in arriving at the actual position of the camera and of the planes of the surfaces of the plates upon which the images are formed at the instant of exposure, I have had no recourse whatsoever to known orientation or elevation of any ground point appearing in the views or images, but by means of my invention the position of the camera and of the image plane at the moment of exposure is determined from information contained in the images themselves.

It is to be noted also that the purpose of my invention may be accomplished by locating the double reflecting prisms of the auxiliary camera structures below the lenses of such structures instead of in the image spaces of the said cameras above the lenses. Optically the results are precisely the same and for some purposes this suggested arrangement offers advantages in the design of the camera.

The frame L of the camera structure, as shown in Fig. 5, is divided into three main sections. The largest of these sections is occupied by the lenses designated as O in this figure whose focal or image plane is that which hereinbefore has been referred to as the principal image plane X and the plate magazine L^1. This section also contains operating mechanism which however forms no part of the present invention and for that reason is not shown.

The lenses designated O^1 and O^2 of what has been referred to heretofore as the auxiliary cameras are located in the smaller sections of the frame or body L at equal distances from the lenses O of the principal camera. This permits the construction of

the tilt indicator to be simplified. However, there is no theoretical condition which requires that these distances shall be equal. It is preferred that the lenses O, O^1 and O^2 shall be located in lines or planes arranged in right angular relation to each other, the principal lenses O being located at the angle formed by the meeting of these lines. This is the arrangement when the structure is viewed in plan. However, this arrangement is a matter of convenience and not a necessity.

The lens of each of the two auxiliary cameras with viewpoints O^1 and O^2 cooperate with a double reflecting prism Q (Figs. 5 and 6). The reflecting surface of the prism associated with the lens of the camera having the viewpoint O^1 is parallel with the plane including the axes of the cameras having the viewpoints O and O^1 respectively; whereas the reflecting surface of the prism cooperating with the lens of the auxiliary camera having the viewpoint O^2 is parallel with the plane including the axes of the cameras having the viewpoints O and O^2 respectively. The apertures of the auxiliary camera structures which are located in the focal or image planes Y and Z of the two auxiliary cameras preferably are equal in size, but also preferably considerably smaller than the aperture in the principal camera structure which is located in the principal focal or image plane X of that structure. This is a possible arrangement because the images produced by the auxiliary cameras need not be larger than may be required to contain the images of the objects depicted in the points *a* and *b* previously explained and as projected through their respective prisms. Furthermore, by reducing the size of these auxiliary cameras the bulk and weight of the camera structure as a whole is reduced and kept within reasonable limits. The apertures of the camera structures which are located in the focal or image planes Y and Z are closed by flat glass plates Y^1 and Z^1 which are provided with longitudinal and traverse center lines which have been carefully etched and filled in so that they may be photographically reproduced in the pictures produced by the auxiliary cameras for purposes which will be described fully in the description of the tilt detector. The exposure aperture located in the focal or image plane X is provided with marginal markings corresponding to the markings m^1 to m^8 shown in the diagrams of the focal or image planes heretofore referred to to indicate the optical center and the location of the points *a* and *b* in the principal image as hereinbefore explained.

For constructional reasons the focal or image planes X Y Z preferably are located in the same plane, hence the lens O of the principal camera structure is located in a plane extending transversely through the camera structure above the plane in which the lenses of the auxiliary lens structures are located. This is illustrated in Fig. 6.

A camera structure of the character described embodying my invention should be provided with a release mechanism for the shutters, which is designed to release the shutters of the three cameras simultaneously in order that the exposures may be made simultaneously. Any suitable release mechanism may be employed.

In the use of the camera I preferably employ roll films for the auxiliary cameras because in so doing the sequence in which these small exposures follow each other cannot be lost, but the employment of such films is not an essential condition for the achievement of the purposes of my invention and consequently any other suitable sensitive film or plate may be employed without departing from the principle of the invention.

I shall now proceed to describe the tilt detector, which is illustrated in Figs. 7 to 11 inclusive of the drawings, and which is adapted to be employed for the purpose of ascertaining the exact position of the principal image surface or plane of the plate of the camera at the moment of exposure. In the said detector means is provided for supporting the plate of the principal camera and the film or plate of one of the auxiliary cameras with the image planes or surfaces thereon in exactly the same relative positions that they occupied in the camera structure. In other words, these planes or surfaces upon the plates or films occupy exactly the same relative positions in the detector device with respect to each other as the focal planes X and Y and X and Z occupied with relation to each other at the moment or instant of exposure. The negative plates of the principal camera and the auxiliary camera Y are shown at X^2 and Y^2, respectively, in Fig. 8 of the drawings. The plate X^2 is supported upon a turn table X^3 within which an opening or aperture is provided over which the plate X^2 extends, as is clearly shown in Fig. 10 of the drawings. The turn table is provided with a couple of notches X^4 formed in the peripheral edge thereof with which notches a spring actuated lock catch X^5 is adapted to engage to lock the turn table in either of two positions in right angular relation to each other. By this means the plate X^2 can be placed in such position with respect to the aperture over which the negative Y^2 is located as shown in Fig. 8 of the drawings that the negative bearing the focal plane or image surface Z of the camera O^2 shown in Fig. 5 when substituted for the said negative Y^2 will occupy the same relation with respect to the negative plate X^2 as is shown in Fig. 5 and as it occupied at the moment of exposure when the images upon the three plates or films of the cameras were formed.

By providing means which enables the support, consisting of the turn table X^3, to be rotated through an angle of 90° so as to produce a 90° change in the position of the plate X^2, I am enabled to employ a single tilt indicator or detector for comparing both of the negatives of the auxiliary cameras with the negative of the principal camera for the determination of the traces of both of the auxiliary vertical planes. The ability to adjust the turn table as stated avoids the making of different adjustments of the negative X^2 thereon. It may be noted that the aperture in the turn table is provided with a series of notches therein designated M^1 which correspond to the notches m^1 to m^8 appearing in the aperture of the camera and which have been imaged upon the negative X^2. In mounting the negative plate X^2 upon the turn table it is positioned with respect to the aperture therethrough so that the markings m^1 to m^8 thereon coincide or correspond with the notches M^1 in the edge of said aperture. The negative plate X^2 is held in that position by means of adjustable lock bars M^6 which are mounted upon the turntable and may be adjusted so that inwardly extending projections at the opposite ends thereof contact with the edges of the said plate so as to prevent displacement thereof in any direction in its own plane. Additional holding means for the plate are provided which consist of spring pressed plungers M^7.

A support or holder H is provided for supporting the negatives produced by the auxiliary cameras. It consists of a plate projecting from one edge of the top plate of the frame L of the tilt indicator or detector. The said projecting supporting plate H is provided with an aperture over which is mounted a glass plate H^1 upon which the negatives produced by the auxiliary cameras are adapted to be supported. The negative Y^2 produced upon the camera O^1; that is, the camera shown at the lower side of Fig. 5 of the drawings, is shown in Fig. 8 as being mounted upon the said plate H^1. The said glass plate is provided with cross lines etched therein with which the corresponding photographically reproduced lines of the auxiliary images are placed in registry. The etched lines in the said glass plate H^1 are so placed with respect to the markings M^1 in the aperture of the turntable that when the negatives of the auxiliary cameras are placed on the said plate with the photographically reproduced lines in registry therewith the said negatives occupy exactly the same position with respect to the negative plate X^2 as that obtained between the negatives in the camera structure.

The negatives when placed upon the glass plate H^1 may be held in position thereon by placing thereover a plane sheet or plate of glass.

Upon a base plate K a bracket K^1 is provided. Said bracket is provided with a forked upper end in which is pivotally mounted a double armed lever K^2 upon a pivot pin K^3. The lever K^2 is provided with upwardly extending lugs K^4 at points between its pivot and its opposite ends upon which the inner ends of two links K^5 are respectively pivoted. The outer free ends of these links extend between and are guided by a second set of lugs K^6 provided at the outer ends of the said lever. Knives K^7 of sickle or right angular shape are pivoted to the outer free ends of the links K^5 the pivots extending through openings in the handle portions of the knives and the opposite ends thereof extending into guiding slots H^2 in the projections K^6. The knives K^7 are provided in the portions thereof between the right angularly related handle and blade portions with curved slots H^3 through which the pivots for connecting the links K^5 to the projections K^4 extend. These slots permit vertical movements of the inner end portions of the knives. The upper ends of the vertical portions of the knives K^7 are ground to sharp edges. As shown in Fig. 9 these edges are formed by grinding one side of the upper end portions of the vertical parts thereof. By thus grinding the knives they may be sharpened by regrinding from time to time without changing the positions of the cutting edges thereof with respect to the vertical plane in which the said edges are located. One of the lugs K^6 on the shorter arm of the lever K^2, as shown in Fig 10, is provided with an upward extension K^8 upon which is mounted a roller K^9 which contacts with the under side or surface of the turn table X^3. The said roller is held at all times in contact with the under side of the said table as a result of the tension of a spring K^{10} and the lever K^2 at all times in parallel relation to the turn table.

The bracket K^1 previously referred to is supported on the base plate K in such position that the plane in which the cutting edges of the knives are located and in which they operate coincides with the vertical plane which includes the slanting axis of the rotatable shaft support L^2 upon which the frame L and other parts of the structure as shown are supported. The said axis corresponds to the line O *a* previously herein referred to.

The cutting edges of the knives K^7 are adapted to be held out of contact with the bottom surface of the negative plate X^2 by means of spring-pressed catches K^{11} which are adapted to engage pins which project laterally from the said knives at points adjacent the angles between the horizontal and vertical portions thereof. The catches K^{11} are mounted upon the lever K^2. Springs K^{12} which are located between the lever K^2 and the inner ends of the knives K^7 operate upon

release of the catches K^{11} to elevate the knives into position with the cutting edges thereof in contact with the lower side of the negative plate X^2. When the cutting edges of the knives are in contact with the under side of the plate X^2 depression of the outer ends of the handles thereof will cause pivotal movement of the said knives to form scratches or marks in the emulsion upon the under side of said plate near the opposite edges thereof in line with the trace of the vertical plane through the axis of the pivot pin L^2 (corresponding to the line or axis O *a* previously referred to) with the plane of the image surface of the plate no matter what position the latter may occupy with respect to the said axis.

The frame L is provided with a suitable support L^3 within or upon which the prism Q is supported. The said prism is supported in proper position underneath the negative plate or film Y^2 previously referred to. The relative positions of the prism Q and the negative or film Y^2 are the same as that which existed between the corresponding prism and the film or plate in the auxiliary camera. The prism Q and the frame L are rigidly joined or connected together so that any turning motion imparted to the frame will cause a corresponding turning motion of the prism.

The slanting or inclined pivot pin or support L^2 previously referred to is mounted in an inclined opening through a block L^4. The said block is provided with a centrally located projecting portion, as shown in Fig. 10 of the drawings, the upper surface of which occupies a plane which extends at right angles to the axis of the said pivot pin or support L^2. The said surface forms a thrust bearing or thrust surface for the hub of a worm wheel L^5 which is keyed to the said pivot pin L^2. The upper end of the pivot pin L^2 is reduced in diameter, as indicated, so as to provide a shoulder upon which is supported a disk designated as a whole as L^6. The upper surface of the said disk lies in a plane parallel with the plane of the turn table X^3. The frame L and disk L^6 are so constructed that the vertical distance from the point O shown in Fig. 10 (which corresponds to the viewpoint O of the lens system of the principal camera previously referred to) to the center point of the top surface of the turn table X^3 is equal to the focal length of the lens of the principal camera of the camera structure. The point O is located at the intersection of the vertical line therethrough and the line O *a* shown in Fig. 10 and represents the location of the second nodal point of the lens or lens system of the principal camera of the camera structure. For the purpose of effecting rotation of the worm wheel L^5 together with the pivot pin L^2 and parts supported thereon I have provided a worm L^7 mounted upon or formed upon a shaft L^8. A hand wheel L^9 is provided upon one end of the shaft for the purpose of effecting rotation thereof. The said shaft is mounted in brackets L^{10} and L^{11} which in turn are mounted respectively upon the base plate or member K and block L^4 of the structure.

As a part of the tilt indicator or detecting structure I have provided the parallel levers N^1 and N^2 which are supported upon pivot posts S which are parallel with the axis of the pivot pin or support L^2 and likewise with the line or axis O *a*. The said pivot posts are located in the same vertical plane as the axis of the pivot pin or support L^2 or with the axis line O *a*. For the purpose of effecting pivotal movement of the levers N^1 and N^2 about their pivots I have provided a radial lever N^3 which is mounted upon and keyed to the hub of the worm wheel L^5 so that when the latter is rotated the arm is likewise rotated and a link N^4 one end of which is connected to the outer end of said arm and the other end of which is connected to an arm S^1 formed by an extension of one of the levers N^1 or N^2. In the construction as illustrated the arm S^1 constitutes an extension of the lever N^1. I have provided a lamp box N^5 the opposite ends of which are connected by means of bars N^6 to the outer swinging ends of the parallel levers N^1 and N^2. The bars N^6 have pivotal connection with the levers N^1 and N^2. The combined length of the lamp box and the bars N^6 is such as to hold the levers N^1 and N^2 in parallel relation to each other.

The upper surface of the lamp box is provided with a narrow slot N^7 through which the light emitted from a straight filament shines in a vertical upwardly extending plane. The inner edge of the said slot toward the pivot pin L^2 is located so that it occupies a position in exact parallel relation to the vertical plane which includes the axis O *a* (as shown in Fig. 10) and at a distance from said plane which equals the distance from the centers or viewpoints of the lenses of the auxiliary cameras to the center or viewpoint of the lenses of the principal camera in the lens structure previously referred to. For the purpose of shielding the light through the slot N^7 I have provided a shield N^8 which is located inwardly of the said slot, as shown. The said shield is provided with a flange which extends outwardly and which is parallel with the upper or top surface of the lamp box N^5 and the outer edge of which is located in exact vertical alinement with the inner edge of the slot N^7. In other words, the outer edge of the flange of the said shield is located in or is included within a vertical plane which likewise includes the inner edge of the slot N^7. As a result of this arrangement a vertical beam of light is caused to be

sent through the prism Q mounted in the holder L^3 the inner edge of which beam cuts the image surface of the negative film or plate Y^2 shown in Fig. 8 in a trace or along a line parallel to the plane through the line O *a* shown in Fig. 10 which is coincidental with the axis of the pivot pin or support L^2.

Upon rotation of the frame or body L of the tilt indicator or detector to effect rotation or change of position of the prism Q and the lamp box N^5 about the axis O *a* the distance of the visualized vertical plane produced by the beam of light through the slot N^7 from the immovable vertical plane through the axis O *a* remains at all times equal to the distance between the centers of the lenses or lens systems of the principal and auxiliary cameras upon imaginary or real rotation of the latter about a corresponding axis or line O *a*. This is due to the fact that the lamp box is supported upon the parallel bar mechanism previously referred to.

It will be understood that when the tilt indicator or detector is adjusted into position to support the negative plates or films in positions representing the image surfaces thereof as occupying a horizontal plane or horizontal planes at the moment of exposure, the reflecting surface of the prism Q in the detector is arranged at right angles to the direction of the vertical plane visualized by the beam of light through the slot N^7 of the lamp box N^5. At such time the inner edge or surface of the said beam will be or appear in line with the long center line of the image surface of the negative plate or film Y^2. In other words, the inner edge or surface of the said beam will be in line with the long center line of the aperture in the support for the negative plate or film Y^2 and in parallel relation to the vertical plane through the axis O *a* (shown in Fig. 10). Upon rotation of the frame or body L (upon which the negative plates or films X^2 and Y^2 or X^2 and Z^2, as the case may be, are supported) about or around the axis O *a* in which rotation the prism Q participates, the effect of the latter will be to turn the trace of the plane visualized by the beam of light through the slot N^7 with the image plane or surface of the negative plate or film Y^2 or Z^2, as the case may be, out of parallel relation with respect to the center line of the said image plane. Due to the presence of the double reflecting prism Q the angle between the trace of the visualized plane with the center line of the plane or image surface of the negative plates or films Y^2 or Z^2, as the case may be, will be twice as great as the angle between the fixed vertical plane including the axis O *a* and the center line of the plane or image surface of the negative plate X^2.

When the inner side or edge of the light beam passes through the image point a^1 upon the secondary or auxiliary negative plate or film Y^2 (the image point a^1 upon the secondary or auxiliary negative film or plate corresponding to the image point *a* upon the plate X^2) it will be understood that a condition has been reproduced in which the relative positions of the two vertical planes through the lens centers of the cameras by which the plates X^2 and Y^2 were produced are identical with what they were at the moment or instant of exposure of the cameras to produce such images. After adjustment of the frame or body L so as to reproduce the conditions just stated and while occupying such adjustment the knives K^7 are operated to place markings upon the under side of the principal negative plate X^2 to indicate thereon the direction of the trace of the visualized plane with the plane or image surface of the negative film or plate Y^2.

Heretofore in this description it has been considered that the negative film or plate Y^2 has been supported in the auxiliary aperture of the tilt indicating device, the said negative having been produced by the auxiliary camera shown at the lower side of Fig. 5 of the drawings.

The fact that the turn table X^3 may be turned through an angle of 90° so as to place the negative plate X^2 in a position at right angles to that in which it is shown in Fig. 8 has already been adverted to. In other words, the turn table may be adjusted so as to change the left hand end of the negative plate X^2, having reference to Fig. 8 of the drawings, from the position shown into a position in parallel relation to the aperture of the support for the auxiliary films or plates. When this has been done and the negative film or plate bearing the image corresponding to the focal or image plane Z previously referred to is substituted for the negative film or plate Y^2, the said plate will occupy the same relation to the plate X^2 as it occupied in the camera structure. Therefore, it will be seen that the same operation as has been described in connection with the negative plates X^2 and Y^2 will yield the traces of vertical planes including the axes through image points *b* and b^1 upon the principal plate X^2 and the auxiliary plate corresponding to the focal or image plane Z corresponding to the vertical plane through the axis O *a* and the visualized vertical plane through the image surface of the negative film or plate Y^2, as previously described. Since both of these traces contain or include the vertical line through the lens center (O in Fig. 10) their intersection will mark a point *p*, which is the point where the vertical line through the center or viewpoint of the lens of the principal camera met the image surface or plane upon the negative when the exposure was made or took place. The ascertaining of the position of the point

p in the image, which is the image of a point P vertically below the center or viewpoint of the lenses or lens system of the principal camera, furnishes information as to the magnitude and location of the angle between the vertical line dropped from the point P through the lens center and the line from the said lens center to the center of the focal or image plane, which enables the positioning of the negative plate of the camera containing the image thereon in the identical position it occupied with respect to a horizontal plane at the moment of exposure.

It will be apparent that by the combined action of the camera structure, including three cameras preferably though not necessarily arranged in relation to each other as shown in Fig. 5, and the tilt indicator or detector, I am enabled to determine the actual position in space of the focal or image plane of the principal camera (as well as of the auxiliary cameras) at the instant of exposure without the necessity of recourse to any measurements of ground points which occur in the views.

As soon as two or more overlapping aerial exposures have been marked in the manner as above described and as diagrammatically shown in Fig. 11, they are ready to be inserted in any known type of correcting projector and to be adjusted therein so as to yield by reprojection the correct equivalent horizontal view from the viewpoint of the lens of the camera at the moment of exposure. These horizontalized views are then ready to be placed in proper alinement in known manner in a measuring stereoscope as is diagrammatically illustrated in Fig. 12 of the drawings. This brings the points p in each view and their conjugate points in a straight line parallel to the line uniting the axes of the eye pieces of the stereoscope.

My invention comprehends both the method or art of procedure as above outlined as well as mechanical means for ascertaining the exact position in space of the focal or image plane of a camera with respect to a horizontal plane at the moment of exposure of the sensitive plate of said camera.

It will be seen that by my invention I have produced in a camera structure a plurality of images not less than three, at a single exposure, the images of points in two or more of the cameras being displaced with respect to the images of the same points of the other or remaining camera, referred to as the principal camera, through definitely related angles so as to produce means whereby the images may be compared to ascertain the angle of tilt of the focal or image plane at the moment of exposure.

In the accompanying drawings I have illustrated and have herein described the preferred means and method at present known to me of carrying out or practising my invention, but it is to be understood that the principle of my invention may be carried out by the employment of other mechanical means than that illustrated and by the employment of instrumentalities of modified construction without departing from the spirit of the invention, as disclosed herein, and that the steps to be followed may be modified within the scope and principle of the invention.

Having herein disclosed my invention, including among other things a combination of mechanical and optical devices whereby the properties of perspective may be imparted to photographic images which in themselves are sufficient to enable a reconstruction of the true plane of projection without the aid of further information derived from ground measurements, I hereby claim the same as follows:

1. The art of producing topographic maps of ground areas by means of aerial photography which comprises the production of a plurality of images having a common focal plane, a common viewpoint and all exposed at the same instant, one of said images constituting the principal image and the others constituting auxiliary images, the said auxility images being generated by means, including a reflecting surface, causing known displacements of image points in the said auxiliary images with respect to the corresponding image points in the principal image when their common focal plane deviates from a horizontal plane, and thereafter comparing the relative positions of these several image points to determine the position in space of their common image plane with respect to a horizontal plane at the instant of exposure.

2. The art of producing topographic maps of ground areas by means of aerial photography which comprises as steps the simultaneous exposure of a plurality of cameras having a common focal plane, causing during said exposures relative displacements of corresponding image points in the several images, the said relative displacements being in predetermined angular relation with respect to certain fixed directions in said focal plane, and thereafter comparing the positions of said relatively displaced image points to determine the exact position of the common image plane with respect to a horizontal plane at the moment of exposure.

3. The art of producing topographic maps by means of aerial photography which comprises as steps the simultaneous production of a plurality of photographic images at a single exposure, the images occupying fixed positions with respect to each other, causing during said exposures predetermined angular displacements of the image points in all of the said images except one, with respect to a selected direction fixed with relation to the images, thereafter visualizing a vertical

plane parallel to a vertical plane including a vertical line toward the ground from the viewpoint of the image in which the image points have not been displaced, and a line extending from said viewpoint, which line is angularly related to the said vertical line and which pierces the image last referred to, ant causing the trace of said visualized plane with one of the images in which the image points have been displaced to pass through an image point corresponding to a certain image point selected in the image wherein the image points have not been displaced and also causing the trace of the said visualized vertical plane with the other of said images in which the image points have been displaced to pass through another image point corresponding to another selected image point in the image in which the image points have not been displaced, and indicating upon the image in which the image points have not been displaced traces parallel to the traces of the said visualized vertical plane with the images containing the said displaced image points, to thereby determine the exact position of the image plane of the lens of the camera at the moment of exposure.

4. The art of producing topographic maps of ground areas by means of aerial photography which comprises as steps therein the imparting of different perspectives to a plurality of images produced simultaneously, thereafter associating two of the said images with means for visualizing a vertical plane through the said respective images, the said vertical plane being parallel with a vertical plane including a vertical line from the viewpoint of the said images toward the ground and a line extending from the said viewpoint in angular relation to the said vertical line and piercing an image with which such visualizing means is not associated, and adjusting the said respective images until the said visualized vertical plane includes both the said vertical line and a selected image point in the respective images with which such visualizing means is associated, the said selected image point in one of the said images being different from the selected image point in the other of said images, the said visualized vertical planes cutting the plane of the said images and indicating the traces of the said vertical plane with the said images.

5. The art of producing topographic maps of ground areas by means of aerial photography which comprises the simultaneous production of three photograpic images of a ground area, one of the said images constituting a principal image and the other two thereof constituting auxiliary images, causing image points to appear in the auxiliary images in angular relation with respect to certain fixed directions in both the principal and auxiliary images supporting the principal image and the auxiliary images successively in the same relative positions with respect to each other that they occupied at the moment of exposure, selecting a point in a center line of the principal image in a vertical plane which also comprises the view point from which said image was taken, the said plane representing a fixed plane, then causing a beam of light to extend vertically and successively through a corresponding center line of the respective auxiliary images, the plane of the said beam being parallel with the said fixed plane, thereafter turning the said images around an axis coincident with the slanting line connecting the said point located in said center line of the principal image and a viewpoint of said image, maintaining the visible vertical plane of light through the auxiliary image in parallel relation to the fixed plane, simultaneously moving the center lines of the principal and auxiliary images in angular relation to the fixed and visual vertical planes respectively, causing the change in the angle between the plane rendered visible by the beam of light and the center line of the auxiliary image to be twice as great as that of the angle between the center line of the principal image and the said fixed vertical plane, and thereafter indicating upon the principal image the direction of the trace of the fixed vertical plane with the plane of the principal image.

6. The art of producing topographic maps of ground areas by means of aerial photography comprising as steps therein the production simultaneously of a plurality of negatives of a ground area, thereafter supporting said negatives in the same relative positions with respect to each other that they occupied at the moment of exposure, visualizing a vertical plane which comprises a downwardly extending vertical line from the viewpoint from which said negatives were taken and a line extending from said viewpoint in angular relation to said vertical line to a selected point in an image, the said vertical plane adapted to include a selected image point in one of said negatives and another selected image point in another of said negatives, the lines of intersection of the said visualized vertical plane with the images upon said negatives indicating the traces of said plane with the image planes of said negatives, adjusting the said negatives until the traces of the said vertical plane with the plane of the images thereon include the respective selected image points, the position occupied by the second image plane when the trace thereon, as thus visualized, includes the said selected image point constituting the exact position of the image plane of said negatives with respect to a horizontal plane at the moment of exposure, and thereafter producing from one of the said plurality of negatives by projection a horizontal equiva-

lent view thereof in the view point from which said last named negative was taken.

7. Apparatus for making maps from aerial photographs comprising means for supporting a principal image and a corresponding auxiliary image in the positions relative to each other which they occupied at the moment of their formation by exposure, a support for said means mounted to rotate about an axis slanting with respect to a vertical line and passing through a point corresponding to the anterior nodal point of the lens of the principal image and through a point of that image, means to effect visualization of a vertical plane parallel to the vertical plane containing the said axis, said plane so visualized passing through the auxiliary image, means operating upon rotation of said support to maintain the said vertical planes a distance from each other equal to the distance between the points corresponding to the centers of the lenses by means of which the said principal and auxiliary images were formed, the rotation of said support and principal and auxiliary images supported thereon around said axis causing an image point in said auxiliary image corresponding to the image point at the point in the said principal image where it is pierced by the said axis to fall in the trace of the visualized vertical plane and the auxiliary image plane, and means to mark the principal image at such time to indicate the direction of such trace thereupon.

8. Apparatus for making maps from aerial photographs comprising a tilt indicator having means for supporting a plurality of simultaneously exposed photographs in the same position relative to each other that they occupied at the moment of exposure thereof, means adapted to visualize a vertical plane, the said plane forming a trace with the image plane of one of said photographs and the said indicator also having means to mark the direction of a parallel trace made by a parallel vertical plane with the image plane of another of said photographs.

9. Means for making photographic maps of ground areas by the employment of aerial photographs, one of said photographs constituting a principal photograph and the others auxiliary photographs, which means includes a tilt indicator which comprises a rotatable support for the said photographs, means for locating the said photographs upon the said support in the same relation to each other that they occupied at the moment of exposure of the negatives thereof, an inclined pivot upon which the support for the said photographs is mounted, means for visualizing vertical planes through the said auxiliary photographs, means for maintaining the said visual planes in parallel relation to a vertical plane through the axis of the said inclined pivot upon rotation of said support about said axis, the principal and auxiliary photographs upon such rotation moving in directions crosswise of the said vertical planes so that the angularity of the traces of the vertical planes through the said photographs with respect to the longitudinal and transverse center lines of the said photographs is varied, means for causing the variation of the angle of the trace of the visualized vertical plane with respect to the longitudinal and transverse lines of the auxiliary photographs to be twice as great as that of the longitudinal and transverse center lines of the principal photograph with respect to the trace of the vertical plane through the axis of the said inclined support with said principal photograph, and means for marking upon the principal photograph the direction of the trace of the visualized vertical plane with the image plane of the auxiliary photograph at the moment when the image point in said auxiliary photograph corresponding to the image at the point where the axis of the said inclined support pierces the image plane of the principal photograph comes into line with the visible trace on said auxiliary photograph.

10. Means for making photographic maps of ground areas by the employment of a plurality of aerial images one of which constitutes a principal image and the others constituting auxiliary images, the said images being formed simultaneously upon a plurality of sensitized plates held in fixed relation with respect to each other, which means comprises a tilt indicating device having means for supporting a plurality of said plates, one of which is the principal image plate, in the same relative positions with respect to each other that they occupied at the moment of exposure, said means being rotatable about an axis tilted with respect to a vertical line, means for adjusting said plates around said axis into the positions with respect to a horizontal plane which they occupied at the instant of exposure in the camera, means for determining when the said plates have been adjusted to such positions, said means including a device for visualizing a vertical plane including a vertical line from the viewpoint from which the images were taken and the said tilted axis, so that it may be ascertained when the trace of the said vertical plane with the plane of said auxiliary image passes through an image point therein corresponding to a selected image point in the principal image, and means for marking the principal image plate when in such position.

11. Apparatus for making maps from aerial photographs comprising plates having thereon principal and auxiliary images, the said principal image including image points which are duplicated in the auxiliary images, the positions of the said image points in the

auxiliary images being shifted with respect to their positions in the principal image in goniometrical function of the tilt, means for supporting the principal image plate and an auxiliary image plate in fixed relation to each other, means for rotating said supporting means about an axis tilted with respect to a vertical line, and means including a device for visualizing a vertical plane through said auxiliary images parallel to a vertical plane including said tilted axis and a vertical line toward the ground from the viewpoint from which the said principal image was taken for determining when the said plates have arrived at positions occupying the same relative position with respect to a horizontal plane as that which they occupied at the instant of exposure to produce the images thereon.

12. A tilt indicator for use in the making of maps from aerial photographs comprising means for supporting principal and auxiliary image plates in fixed relation to each other, a rotatable support for said means, the axis of said support extending at an acute angle to a vertical line extending toward the ground from the viewpoint from which the principal image was taken, means for determining the trace of a vertical plane through an auxiliary image plate including an image point of a certain ground point, said plane being parallel to a vertical plane including the said axis and a vertical line extending toward the ground from the viewpoint from which the said principal image was taken, and means for marking the trace upon the principal image plate of a parallel vertical plane including therein the image point of the same ground point.

13. Apparatus for producing maps from aerial photographs which comprises a device for ascertaining and determining the tilt of the image plane of a photograph at the instant of exposure, which device comprises means for supporting a plurality of images in the same relation to each other as that which they occupied at the instant of exposure, a rotatable shaft for supporting said image-supporting means, the axis of said shaft extending at a predetermined acute angle with respect to a vertical line from the viewpoint of the lens system of one of the cameras by which said images were produced and being inclined with respect to the plane of the said images, and means for determining when the said images occupy positions upon the tilt-indicating device in a plane having the same angular relation to a horizontal plane as that in which they were located at the instant of exposure.

14. Apparatus for producing maps from aerial photographs which comprises a device for ascertaining and determining the tilt of the image plane of a photograph at the instant of exposure, which device comprises means for supporting a plurality of images in the same relation to each other as that which they occupied at the instant of exposure, a rotatable shaft for supporting said image-supporting means, the axis of said shaft extending at a predetermined acute angle with respect to a vertical line from the viewpoint of the lens system of one of the cameras by which said images were produced and being inclined with respect to the plane of the said images, means for rotating the supporting means for said images relatively to each other, and means for determining when the said images occupy positions upon the tilt indicating device in a plane having the same angular relation to a horizontal plane as that in which they were located at the instant of exposure.

15. Apparatus for making maps from images simultaneously exposed, the sensitive plates upon which the said images are formed being supported at the moment of exposure in fixed relation to each other, one of said images constituting a principal image and the other images constituting auxiliary images, the said apparatus comprising rotatable means for supporting the said images in the same positions relative to each other that they occupied at the moment of exposure, the axis of rotation of the said support being inclined with respect to a vertical line including the viewpoint of the principal images, means for causing rotation of said support about the said inclined axis to cause the plane of said images to assume positions in planes having different angular relations to a horizontal plane, a device for visualizing a vertical plane through the auxiliary images parallel to a vertical plane including the vertical line from the viewpoint of the said principal image and the said tilted axis, and means for indicating upon the said principal image traces parallel with the traces of the said visualized vertical plane with the said auxiliary images.

16. Means for making photographic maps of ground areas by employment of aerial images, the said images being formed simultaneously upon a plurality of sensitized plates held in fixed relation with respect to each other in a common focal plane, one of which images constitutes the principal image and the others auxiliary images, which means comprises, in combination, a rotatable support for supporting the said plates with the images thereon in the same positions relative to each other that they occupied at the instance of exposure, the said support being rotatable about an axis inclined with respect to a vertical line including the viewpoint by which the principal image was made, means for rotating said support about said inclined axis, a device for visualizing a vertical plane through the auxiliary images, and means for maintaining the said plane in parallel relation to a vertical plane including the said axis

and a vertical line including the viewpoint of the principal image.

17. Means for making photographic maps of ground areas by the employment of three aerial images, the said images being formed simultaneously in a common focal plane, one of which images constitutes the principal image and the other two auxiliary images, which means comprises a support for supporting the said images in the same relation to each other as that which they occupied at the moment of exposure, the said support being adjustable about an axis inclined to a vertical line including the viewpoint of the primary image, means for adjusting the said support around the said inclined axis so as to vary the angle of the plane occupied by the said images to a horizontal plane, means for determining when the said images have been adjusted into a plane having the same position with respect to a horizontal plane as that which they occupied at the moment of exposure, the said means including a device located underneath an auxiliary image upon said support for visualizing a vertical plane through the said auxiliary image, and means for maintaining the said vertical plane during adjustment of the said images around the said axis in parallel relation to a vertical plane including a vertical line through the viewpoint of the said principal image and the said inclined axis.

18. Means for making a photographic map of a ground area by the employment of aerial images, the said images being formed simultaneously in a common focal plane, one of which images constitutes a principal image and the other two auxiliary images, the auxiliary images being so located with respect to the primary image that lines drawn from the centers of the auxiliary images to the center of the primary image intersect at right angles to each other, which means comprises, in combination, a support for the said primary image and an auxiliary image, the said support being rotatable about an axis tilted with respect to a vertical line extending through the viewpoint of the principal image, means upon the said support for holding the said principal image, which means is adjustable through 90 degrees about an axis at right angles to the plane of said image so that the said principal image may have the same relation upon said support to the said auxiliary images that it had at the moment of exposure, means for causing rotation of said support and the images carried thereby about the said tilted axis, a device for visualizing a vertical plane through the said auxiliary images to provide visual means for ascertaining when said plane passes through certain image points in said auxiliary images corresponding to selected points in the primary image, the said plane being parallel with a vertical plane including the said tilted axis and one of the said selected points in the primary image when the latter occupies one position and the other selected point in said primary image when the latter occupies its other position, and means for holding said visualized vertical plane in parallel relation to said vertical plane including the said tilted axis.

19. Means for making a photographic map of a ground area by the employment of aerial images, the said images being formed simultaneously in a common focal plane, one of which images constitutes a principal image and the other two auxiliary images, the auxiliary images being so located with respect to the primary image that lines drawn from the centers of the auxiliary images to the center of the primary image intersect at right angles to each other, which means comprises, in combination, a support for the said primary image and an auxiliary image, the said support being rotatable about an axis tilted with respect to a vertical line extending through the viewpoint of the principal image, means upon the said support for holding the said principal image, which means is adjustable through 90 degrees about an axis at right angles to the plane of said image so that the said principal image may have the same relation upon said support that it had at the moment of exposure to each of said auxiliary images, means for causing rotation of said support and the images carried thereby about the said tilted axis, a device for visualizing a vertical plane through the said auxiliary images to provide visual means for ascertainng when said plane passes through certain image points in said auxiliary images corresponding to selected points in the primary image, the said plane being parallel with a vertical plane including the said tilted axis and one of the said selected points in the primary image when the latter occupies one position and the other selected point in said primary image when the latter occupies its other position, and means for indicating upon the primary image the directions of the traces of said visualized vertical plane with the said auxiliary images.

20. Apparatus for making maps from aerial images produced upon simultaneously exposed plates, one of the said images combining a primary image and the other auxiliary images, the said apparatus comprising a support for said images, said support having means for holding the said images in the same relative positions with respect to each other as that which they occupied at the moment of exposure, the said supporting means being rotatable about an axis tilted with respect to a vertical line through the viewpoint of the primary image, means for causing rotation of the said support about the said tilted axis to adjust the images into the same plane with respect to a horizontal plane as

that which they occupied at the instant of exposure, a device for visualizing a vertical plane through the said auxiliary images, said plane being parallel with a vertical plane including a vertical line extending toward the ground from the viewpoint of the primary image and the said tilted axis to afford visual means for ascertaining when the traces of the said first named vertical plane pass through certain image points thereon corresponding to selected image points in the primary image, means for maintaining the said visualized plane in parallel relation to the said vertical plane including the said vertical line and tilted axis during the rotation of the said images about the said tilted axis, and means for indicating upon the primary image the directions of the traces of the said visualized vertical plane with the said auxiliary images to determine the position upon the primary image of the image of a ground point vertically below the viewpoint of the primary image.

21. Apparatus for making maps from a plurality of images simultaneously produced, one of said images constituting a principal image and the others auxiliary images, the primary and auxiliary images exposed in the same viewpoint and the image points in the auxiliary images occupying different positions with respect to selected directions extending at right angles to each other from those which they occupy with respect to corresponding directions in the primary image, which means comprises a support for supporting the said principal and auxiliary images in the same relative positions with respect to each other that they occupied at the moment of exposure, the said support being rotatable about an axis tilted with respect to a vertical line from the viewpoint of the camera by which the principal image was produced, the said axis meeting the said vertical line at the said viewpoint, means for rotating the said support about the said tilted axis to cause the images carried by said support to assume positions in different planes having different angular relations to a horizontal plane, and means operatively related to the auxiliary images when mounted upon said support for determining when the said images reach a plane corresponding to that which they occupied at the moment of exposure.

In testimony that I claim the foregoing as my invention, I have hereunto signed my name this 23rd day of April, 1926.

LODEWYK J. R. HOLST.