eliminate the latter by adjusting the base. This procedure should be repeated until both points are free from errors. In normal exposures the change of the base has an influence on *by* which corresponds to $HL-HR$. By changing *bx* we have to change *by* proportionally.

In order to reconstruct the three-dimension situation to a two-dimension plane, it is necessary to have a set relationship between points on the photographs and model-scale. This is the case for the X, Y, Z axis in a normal exposure, provided the front is parallel to the base. It applies in the case of a swivel exposure only for the Y axis. In order to compensate for the X and Z differences in the swivel exposure which are caused by the angle-shift from normal, we use the following method:—

> The actual distance between the two control points is known. By rotating hand wheels X and Z we are able automatically to check and bring all surface points on the true horizontal plane. After this we draw our model in the elevation plane as if it were a normal exposure by using hand wheels X, Y and foot disc Z for distances. This plane is then reconstructed in accord with the distance between the control and all other surface points on the new true plane. A height check at control points 1 and 2 will insure us that the heights are correctly set. See Figure 6. (The point G in this figure is the photogrammetrical determined pass-point.)

SUMMARY

It has been shown that accurate economic and rapidly constructed models can be formed through using this method.

Our experience has included the construction of 54 models. This provided the opportunity to prove that the method is workable in a great variety of situations. Its accessibility to any object makes it far superior to the classical method.

The results indicate that the photographic method is sufficiently accurate for obtaining objects.

In closing we should point out that while our remarks apply only to Architecture, the method can also be used in Archeology, Mining Development and other civil engineering constructions.

ACKNOWLEDGMENTS

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*Forestry Applications of Aerial Color Photography**†

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AERIAL photography has played an important role in developing forestry since first applied in 1920 and particularly after 1940 in the U. S. and Canada. It is highly valued by foresters, because it serves as an excellent record of contemporary forest conditions. In fact, aerial photographs comprise one of the best obtainable forest records, since they can be consulted and supplemented at any time. Foresters have made use of aerial

(*Abstract is on next page.*)

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photography in four major fields: 1) mapping, 2) interpretation of forest conditions, 3) mensuration, and 4) reconnaissance and management planning.

Forest mapping is concerned with preparing planimetric base-maps and detailed topographic maps of forest property. Map preparation is greatly facilitated by the use of aerial photography; this leads to greater efficiency and economy of manpower, field surveying time, and cartographic operations.

The field of interpretation of forest conditions is concerned with the identification and spatial distribution of vegetative types and plant species. Forest cover types are delineated on the basis of differences in species composition of the dominant tree layer, stand height and density, and site. With adequate filed experience, it is possible to interpret and delineate cover types from aerial photos of scales as small as 1:25,000.

In forest mensuration, aerial surveying methods have proved to be less expensive and often more accurate than ground cruising. Stand volume and conditions can be directly or indirectly determined from aerial photos. At the present, indirect methods of using aerial photography in forest inventories are most widely accepted. In the stratified and random sampling techniques, plot locations are first established on contact prints, and then located in the field and cruised by conventional methods. The volume of the entire forest tract is then calculated by expanding the data from these sample plots. Areas occupied by the different forest cover types are determined directly from the aerial photos by simple methods, such as the dot-grid or line-transect.

Reconnaissance and forest management planning also benefit from the bird's-eye view of an entire forest property provided by aerial photography. It reveals the pattern of local physiography, forest cover types and stand conditions, and the progress of logging and management operations. The timber cruiser can utilize aerial photos as one of the most efficient and economical means of locating valuable timber species and stands. In non-developed and inaccessible forest tracts, it is often the only practical means. The logging engineer can use the same photography in planning logging chances and roads needed for timber extraction. The forest manager and administrator can further utilize this photography to divide the forest property into compartments consistent with desired intensity of management.

In all of the above fields, conventional black-and-white photography has been use-

ABSTRACT: *Aerial color photography offers greater possibilities to forestry than the conventional black-and-white photography. The representation of a wide range of colors distinct in hue, value and chroma and the excellent reproduction of the subdued hues are of utmost importance in the distinction between tree species, understory vegetation, and soil types. The color negative process offers excellent possibilities for additional color correction in the positive transparency in order to produce the optimum color contrast wanted for special purposes of photo interpretation. The fine grain of the color transparency, coupled with its range of colors, will allow it to serve a greater multiplicity of photogrammetric and photo interpretive purposes than can possibly be served by any one type of black-and-white photography.*

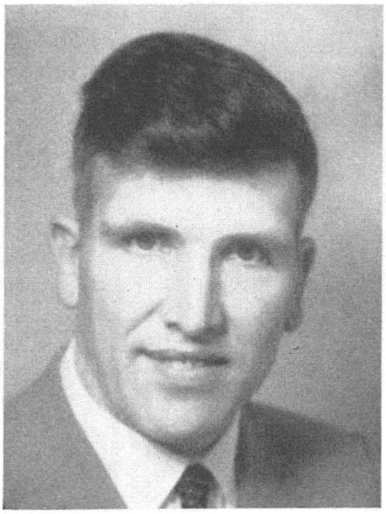
Corrective filters are recommended to reduce color distortion. It is concluded from film-filter experiments that color quality is adversely affected by haze and by increased flying altitude. The most natural color balance is achieved on clear mornings without a haze filter at flying altitudes of 1,500 to 2,000 ft., or with a filter #1A at flying altitudes of about 5,000 ft. Low-altitude photography at scales of 1:8,000 to 1:12,000 has the greatest value for intensive management purposes. Foliage coloration has been found to be of great importance for identification of tree species. Spring and fall color photography has been advantageously applied to hardwood species particularly. The demand is growing for more accurate and speedier methods of obtaining mensurational and silvicultural details of large tracts of forest land, and color photography will be increasingly used.

fully applied. Color photography, only recently introduced, has proved by its unique qualities to be of superior value in such fields as photo interpretation, mensuration, reconnaissance, and management planning. A single color transparency will serve a multiplicity of photogrammetric and photo interpretive purposes better than a single black-and-white photograph.

Since World War II, aerial color film quality has been improved constantly in its color fidelity, color balance, sensitivity, and fineness of grain. This becomes immediately evident when one inspects color photographs taken in 1948 and compares them with photographs taken 10 years later. Color films commonly used in aerial photography in the United States and Canada are Kodak Ektachrome Aero, Kodak Ektachrome Camouflage Detection, Kodak Aero Ektacolor, Anscochrome, and Super Anscochrome. The Kodak color files have a sensitivity rating of 40 ASA, Anscochrome film is rated at 64 ASA, and Super Anscochrome film is rated at 100 ASA. Occasionally, Kodachrome film, with the relatively slow film-speed of 10 ASA, is used in aerial photography; but it is less suitable than faster films. European color films used in aerial photography include Agfacolor, Gevacolor and Ferranicolor. Practically all utilize the color reversal principle. The color negative films most commonly used are Ektacolor and Agfacolor.

Color photography has inherent advantages over black-and-white, particularly in applications where photo interpretation is dependent upon true color rendition. In black-and-white photography, the limitation inherent in reproduction of only monochromatic, gray tones can be only partly overcome by specific film-filter combinations that increase tonal contrast between tree species. Even with this increased tonal contrast, the final result will be registered in the relatively limited range of black, gray, and white tones of which the human eye can distinguish only about 100 to 300. It is possible to make accurate distinctions between about 200,000 colors on the basis of hue, value and chroma. By hue is meant the specific wave-length pattern of a color; value is the brightness, or degree of blackness/whiteness; and chroma is the brilliance, or color saturation.

Color transparencies are susceptible to damage from heat and excessive humidity. To avoid fading of the dyes, transparencies must be stored in a dark, cool, fairly dry place (temperature 60 to 70°F. and relative humidity of 40 to 60%). Condensation on the trans-



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parency may encourage fungus growth on the gelatine layers, causing serious color deterioration and rendering the transparency useless. For field work, the color transparency can be best protected with a thin acrylic plastic spray, or it can be enclosed between plexiglass or inserted in a clear plastic envelope. This will protect the transparency against damage. Annotations can be made on the plastic cover. Since the most valuable color information is contained only in the original transparency, great care must be taken in storing and handling these originals.

Special equipment is needed for viewing color transparencies. This creates problems in field work. A split or slotted light table can be used advantageously to receive the overlapping edges of transparencies viewed in stereo (Avery 1958). There is available a Swedish stereoscope that provides a special tongue-shaped leg support for receiving these overlapping corners (Simonsson 1957). A simple, portable light table has been constructed for field use by Wear & Dilworth (1955). Modern light tables that provide uniform lighting are available for office work. Other instruments like the Diachromoscope and the Minythoscope (O'Neill & Nagel 1952, 1957) provide for viewing transparencies under variable light conditions and magnification. Changes in light quality and intensity can bring otherwise imperceptible color graduations to perceptible contrast. Colored fluorescent light, neon light, or tungsten light can be used in conjunction with filters to create any desirable light quality. A new lighting system developed by the Westinghouse Electric Corporation consists of electro-luminescent plates coated with a fluorescent compound, which at a potential of 600 volts can be excited to various light intensities (Ivey 1957). Called rayescent lamps. the electro-luminescent plates produce a desirable soft, uniform light. They are available in a number of colors.

Color photography has proved useful in detecting and locating diseased and insect-infested trees. This requires accurate distinctions between minute foliage color differences. Sharp image resolution is also required. Large-scale color photography in particular (scales from 1:500 to 1:7,920) has proved to be superior to black-and-white photography for detecting infested trees. The excellent research work and applications of R. C. Heller and his associates bear witness to this advanced perfection of photo techniques and equipment used in color photo interpretation.

Identification of tree species, forest and other vegetation types based upon color differences offers great possibilities. With black-and-white photography such a distinction is often exceedingly difficult and time-consuming. Modern color films are capable of rendering even faint hues, making formerly dubious identifications reliable and efficient. Some examples from the inspected photography may illustrate this point.

(1) Ektachrome photography at a scale of 1:3,960 illustrating upland oak forest near Brevard, N. C. shows a faint but clear bluish-green hue outlining the distribution of Rhododendron and Mountain Laurel brush cover. This hue is invisible on black-and-white photography taken at the same time and of identical scale. (Photography of March 21, 1957, courtesy of Beltsville Forest Insect Laboratory, Beltsville, Md.)

(2) Anscochrome photography at scales of 1:900 to 1:1,000 of open fields in Tishomingo County, Miss. show the patch distribution of tiny weed communities among the crop plants as a light greenish hue contrasting against the mottled redbrown soil. This clear distinction between weed community and soil mottling is lost in the corresponding black-and-white photography. (Photography of March 1957, courtesy of the Southern Forest Experiment Station, New Orleans, La.)

(3) Ektachrome photography at a scale of 1:8,000 of virgin Douglas fir forest in the Cascades of Oregon shows the initial yellowish green discolorations in Douglas fir crowns that are signs of incipient beetle-attack. This color differentiation cannot be interpreted from corresponding black-and-white photography. (Photography of summer 1954, courtesy of the Pacific Northwest Forest & Range Experiment Station, Portland, Oregon.)

(4) Both Ektachrome photography at a scale of 1:3,960 from near Brevard, N. C. (Photography of October 10, 1955, courtesy of the Beltsville Forest Insect Laboratory) and the author's own Kodachrome photography at a scale of 1:5,720 from Auburn, Ala. show the great potentialites for identification of hardwood species by means of fall coloration. Hardwoods reach their peak of fall coloration gradually, often markedly changing their foliage color over a period of weeks.

(5) Anscochrome photography at scales of 1:1,100 to 1:2,200 of a pine forest in Tishomingo County, Miss. makes possible distinguishing between shortleaf pine and loblolly pine. With black-and-white photography, this distinction is very difficult, if not impossible. (Photography of March 1957, courtesy of the Southern Forest Experiment Station, New Orleans, La.)

Changes in foliage reflectivity with seasons can be advantageously used for distinction between tree species. Locally, these changes have to be field-checked first. Also, comparison of photographs taken with a few weeks separation may prove to be very helpful. Late fall photography will probably differentiate best the pines and hardwoods, because of the sharp color contrast between the yellow foliage of most hardwoods and the dark green needles of the pines. Since published data on foliage reflectivity are available for only a very limited number of tree species, more detailed investigations are needed. The differences in reflectivity between certain wave lengths can be used to distinguish between species, even on black-and-white photographs.

Based on the author's experience, there seems to be little advantage for color in using summer photography for species or forest type identifications. The most profitable use of color is to be expected from spring, fall, or winter photography. In addition to hue, color brilliance, or chroma, shows promise as a distinctive criterion. However, chroma differences can be accurately detected only under light conditions of controlled, and variable, color and intensity. Generally, it is thought that foliage reflectivity depends largely upon leaf size and texture of leaf surface. However, little research as been conducted in this direction. It is safe to state that the full potential value of color as a means for species distinction has not yet been fully investigated.

Aerial color photography generally requires use of correcting filters. The primary function of a filter is to improve the color balance by affording selective control of the wavelength admitted to the sensitized emulsion layers. Two types of filters have been recommended, HF-filters and EF-filters. HF-filters are used for haze correction. If the photographs are taken from high altitude, a bluish cast (haze) will interfere with the color balance. This haze is caused by the light-squattering effect of moisture and dust particles. An orange or yellow filter will usually compensate for the predominance of blue color that results from haze, but at a loss in the rendition of the yellow chroma. Film color balance differs from emulsion to emulsion. The EF-filters are used to compensate for differences in color balance between film lots. The proper EF-filter is generally specified by the film manufacturer; or it may be determined by personal experience and experimentation.

Extensive film-filter tests have not been conducted in forest photography. The Beltsville Forest Insect Laboratory made a preliminary test in February 1958 with Anscochrome film, exposed and developed for 64 ASA. The film-filter test included photographs with no filter and with filters #1A, #81A, and #2B. The following general conclusions were made for the existing photographic and weather conditions:

(1) With increased flying altitude and without a filter, there is a definite bluish overtone that is not objectional if the transparency is correctly exposed. In practice, the overtone seems to disappear when the transparency is inspected under 4× magnification.

(2) The Wratten filter #81A compensates for haze at normal flying altitudes. Unfortunately, at altitudes below 4,000 ft., the result is a transparency with a distinct yellowish overcast. This constitutes a practical impairment of color balance.

(3) The Wratten filter #1A seems to render the most desirable contrast between green shades of different tree species at all elevations.

(4) Ektachrome and Anscochrome photography without any filter has a tendency to give warmer, more yellowish colors in the green foliage when taken at low altitudes at a scale of 1:7,920 or larger. Photography at higher altitudes is distinctly more blue in color. However, with the fast Super Anscochrome taken at very low altitudes (scale of 1:500 or 1:7,920), no appreciable increase in the yellows has been noted.

It is recognized that these are only preliminary results. Additional experiments with over-exposure or under-exposure and with forced color development should be undertaken for different regions and seasons. It may be noted that different photointerpreters evaluate color distinctions quite differently. Some persons are more or less color-blind to specific differences in yellows and greens.

In spite of the advantages noted, foresters have been hesitant to accept aerial color photography as a good substitute for black-and-white photography. Their reluctance is based upon several reasons:

(1) Color photography is expensive. Wear & Dilworth (1955) reported a 20% higher direct cost for color photography than for similar black-and-white photography. Heller *et al.* (1959) reported a 11 to 12% cost increase for color at scales of 1:3,960, 1:7,920, and 1:15,840. Others have indicated a 25 to 30% cost increase. This increase in cost may eventually be reduced to about 7 to 10% with increasing use of and demand for aerial color photography.

(2) Black-and-white film can be manufactured with both stable and uniform characteristics. At present color film is still far from uniform. Color balance and quality are the result of a complex interaction between the three emulsion layers that differ slightly from one lot to another. Film manufacturers generally recommend specific corrective filters for achieving the best possible color balance. Variability of film emulsions is one of the main reasons why aerial color photography has achieved varying degrees of success or failure.

(3) The dyes used in color photography are the best available, but their color permanence cannot be warranted. This serious disadvantage limits the application of color photography. However, the newer dyes have better color

stability than the old. No appreciable discoloration has been noticed by the author in photographs taken in 1958 and reinspected in 1959. If color transparencies are properly processed and stored, good color rendition can be expected for at least 10 to 15 years.

(4) Due to unwanted light absorption in the dye layers, exact color rendition is never achieved. In fact, there is little spectrophotometric resemblance between the color reproduced on the transparency and the actual color photographed. Despite this imperfection, a visually satisfactory color reproduction is achieved. However, serious difficulties are experienced in making duplicate transparencies or prints. Color errors of the original transparency may be compounded in the process of duplication. However, with proper exposure and filters, carefully determined by intensive experimentation, almost identical copies of color transparencies can be obtained. Opaque color prints are never expected to equal transparencies in quality. Inherent in the printing process are reductions in fineness of grain and brightness of color and chroma.

(5) Color films are generally considered to be much slower than comparable black-and-white films, particularly if they have to be exposed with correcting filters. However, the fast Super Anscochrome (rating 100 ASA) is comparable to most black-and-white aero films.

The advantages for using aerial color photography definitely outweigh the disadvantages. Its increased application can be predicted for the following reasons:

(1) Color film is capable of depicting a wide range of colors, offering unique possibilities for the identification of minor vegetation, tree species, soil types, and plant diseases and insect infestations.

(2) Color differences can be picked with relative ease. When aerial color photography is used, there is always a significant increase in accuracy and rapidity of interpretation of infested (discolored) trees as compared with the corresponding black-and-white photography (Wear & Lauterbach 1955, Wear & Dilworth 1955, Heller *et al.* 1952, 1955, 1959).

(3) Color transparencies viewed under transmitted light offer excellent color distinction. Optimal color contrast can be artificially created by means of special viewing equipment that facilitates and increases color contrast and image magnification. This increases rapidity as well as accuracy of interpretation.

(4) In the color reversal process, there is an opportunity for visual inspection before the second exposure. Tonal corrections can be made by means of filters during exposure for the positive transparencies of different color quality and balance can be printed from a single color negative. Home-processing makes feasible determining best exposure and color development procedure for distinction of local forest types.

(5) Modern color film has a relatively fine grain. Therefore, color transparencies can be examined under 4× magnification without serious loss of detail. Indeed, inspection with the Old Delft magnifying stereoscope under optimal conditions of controlled light hue and intensity will reveal many details that escaped discernment in previous 2× magnification viewing. The possibility of inspecting color photographs at such magnifications, without impairment of color quality or interpretation accuracy, implied that scales of 1:7,920 to 1:12,000 will serve the multiple purposes of mapping, mensuration, interpretation, and reconnaissance. Therefore, large-scale photography is not generally needed. In detailed inventories for diseased or beetle-killed trees, photography at scales of 1:3,960 to 1:1,800 is highly desirable. Tests carried out for fineness of grain and over-all photo quality on color transparencies and on black-and-white transparencies have not revealed any significant differences that might affect the general photogrammetric use of color photography (Ottoson 1956).

Experience and tests have indicated that aerial color photography should be advocated for forestry applications in a number of fields. However, its use in fall and spring seasons has been limited; further research and applications are suggested. It is expected that increased application of aerial color photography will decrease the present costs and will lead to further perfection of film, equipment, and techniques.

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*Color and Infrared Experimental Photography for Coastal Mapping**

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ABSTRACT: *Color, infrared and panchromatic aerial photography of shoal areas have been obtained for comparative studies for applications to coastal mapping. The general idea was originally to continue to use conventional panchromatic photographs for mapping, and also to use the other types in an auxiliary interpretative manner in order to assist the identification of the waterline and significant navigational features. One possible application of color photography is for determining relative depths, not replacing the hydrographic survey, but isolating shallow areas which may require a dense hydrographic study, and assisting in the planning of wire-drag operations. Special devices and techniques are discussed, including the problem of obtaining aerial photographs at a specific stage of the tide, and the possible adaptation of stereoscopic instruments.*

INTRODUCTION

THE nautical chart comprises one of the principal products of the Coast and Geodetic Survey. Published at scales ranging from 1:5,000 to 1:80,000, this chart shows several items which are particularly significant in this discussion, namely: (1) the shoreline; (2) the specific latitude-longitude location of each printed depth or sounding; (3) the depths of the water at each location; and (4) the implication that the bottom has a constant slope between adjacent sounding figures. Mapping topographic features near the shore, although an important item of the chart from the standpoint of photogrammetry, is not included in this discussion.

I will describe briefly how these chart data are ordinarily and currently obtained in order

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