*The Taking of Helicopter Photography for Use in Photogrammetric Research and Training**

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ABSTRACT: *For certain types of photogrammetric research and training it is desirable to obtain either still or motion picture photography from low altitudes and from precisely situated camera stations. When attempting to obtain such photography from fixed wing aircraft, their relatively high rate of travel and limited maneuverability pose serious problems in (1) framing the target properly, (2) photographing it from the correct camera stations, (3) minimizing image blur and (4) obtaining sufficient overlap to permit either stereoscopic or motion picture viewing of the photo images. Examples of both still and motion picture photography are presented in which these problems have been overcome through employment of a helicopter as the aerial camera platform. Means of installing and operating aerial cameras in helicopters also are illustrated.*

INTRODUCTION

MOST of the work reported upon in this paper was performed in cooperation with personnel of the United States Naval Air Station at Oakland, California. The valuable assistance rendered by that group is hereby gratefully acknowledged. All of the photography was obtained on an "incident-to-training" basis by personnel, including the author, who had had little or no experience in the taking of helicopter photography. Nevertheless, satisfactory results were obtained quite consistently. While this indicates a general usability of the methods employed, it is quite probable that numerous improvements in these methods can be developed through additional experience in this relatively new field and through discussions on uses of the helicopter.

In attempting to illustrate briefly some of the important uses which can be made of helicopter photography in photogrammetric research and training, and the means of taking such photography, only two specific examples will be discussed: a *research* project dealing with the aerial photo assessment of cereal crop diseases; and a *training* project involving the preparation of a motion picture entitled "Introduction to Photo Interpretation." Emphasis will be placed on the special types of still and motion picture photography required for these two projects and the extent to which the use of helicopters permitted such photography to be obtained. Little will be said about the interpretation of the photography itself. This constitutes the subject matter of other papers and does not fall within the purview of this discussion.

EQUIPMENT EMPLOYED

Two types of helicopters were employed in these tests: (1) the Hiller, Model HTE-2, having a single main rotor assembly as shown in Figure 1; and (2) the Piasecki, Model HUP-2, having two main rotor assemblies, as shown in Figure 2. Both types proved to have satisfactory flight characteristics for obtaining the necessary aerial photography, although excessive aircraft vibration at times made it difficult to obtain sharp pictures. In obtaining photography of the types here discussed, the excellent visibility afforded both the pilot and photographer from a helicopter and the relative freedom from aircraft obstructions when taking oblique and vertical photos proved to be important

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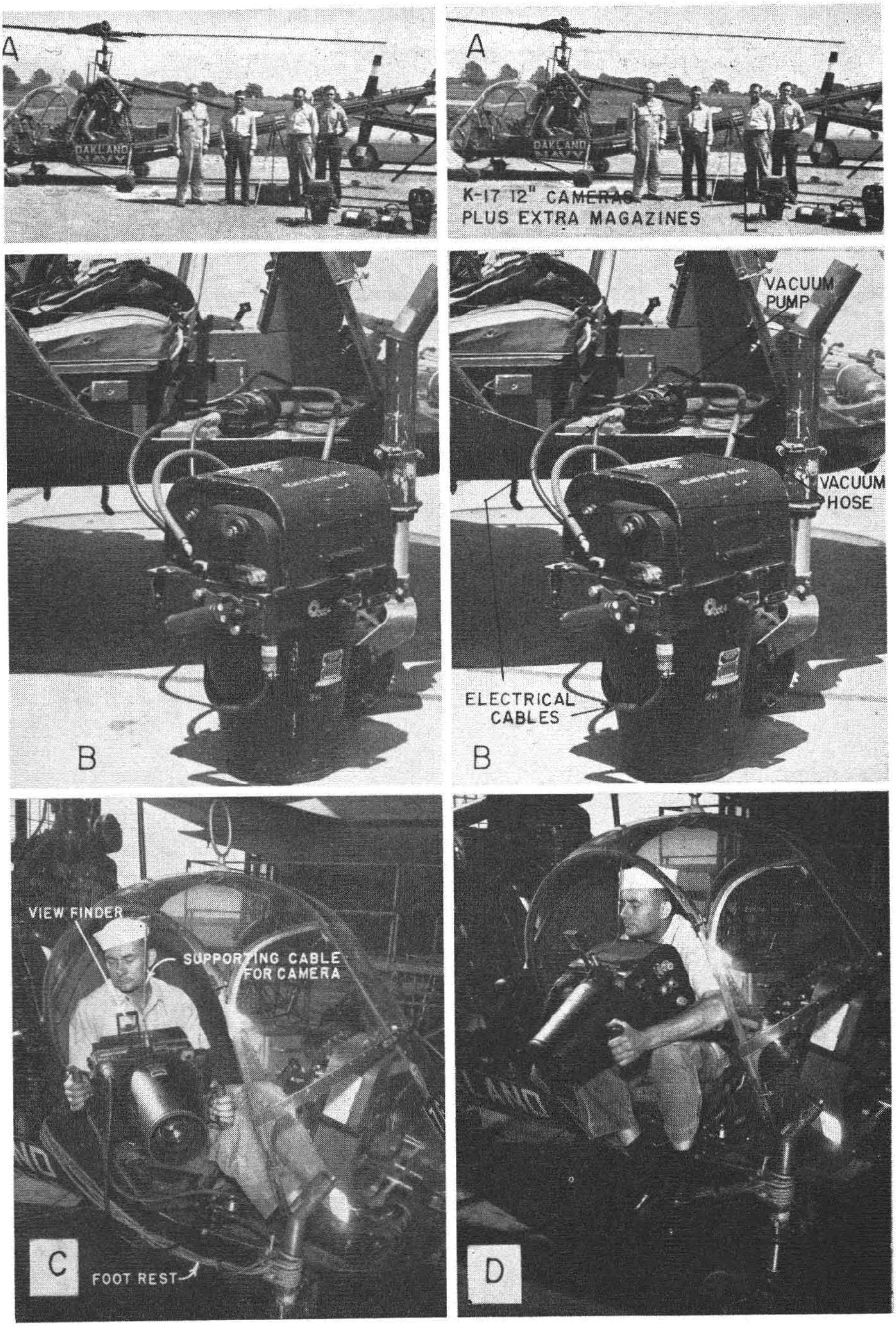

FIG. 1.—A. Stereogram of Hiller helicopter, model HTE-2, and photographic equipment used in taking still photography. Tail assembly of second helicopter is partially visible at right edge of stereogram. B. Stereogram on K-17 12″ camera showing electrical and vacuum connections to helicopter. C. Attitude of photographer during approach to target. Note that weight of camera is supported by a thin cable. D. Attitude of photographer while photographing the target. Entire weight of camera is now being supported by photographer. Note use of viewfinder and footrest.

FIG. 2.—Stereograms of Piasecki helicopter, model HUP-2, and photographic equipment used in taking motion picture photography. Note use of goggles, intercommunication equipment, and "pistol grip" handle on movie camera, as discussed in text.

factors favoring the use of helicopters over conventional fixed-wing aircraft.

The K-17 aerial camera, with 12-inch focal length, was used in taking still photography; the Cine-Special 16 mm. motion picture camera, with focal lengths of 25 and 63 mm., was used for taking motion picture photography. Installation of a special vacuum pump (Figure 1B) proved necessary when taking still photography in order to suck the film flat against the camera platen at the instant of exposure. No problems were encountered, however, in fitting the electrical cables of the camera to the electrical system of the helicopter (Figure 1B).

The weight of the loaded K-17 camera was so great that a photographer experienced difficulty in hand-holding it for long periods of time. Nevertheless, it was considered desirable to obtain hand-held photography in order to minimize image blur due to aircraft vibration. Therefore, a flexible supporting cable was used as shown in Figure 1C, so that the camera could be suspended from the helicopter frame during each approach run on the target. This permitted the photographer to rest between runs and even during a run except when actually taking pictures. At the instant of photography, however, none of the camera's weight was supported by this cable; instead the photographer supported it entirely, as shown in Figure 1D, thereby minimizing image blur due to vibration.

A rope sling was improvised to serve as a footrest for the photographer. Both the pilot and the photographer were equipped with conventional safety belts and with intercommunication equipment. The latter proved to be essential in implementing teamwork during a photographic run.

Goggles were consistently needed in taking motion picture photography, because prolonged exposure of the photographer to the airstream caused his eyes to water and impaired his vision. In some instances goggles also were required for the taking of still photography.

The motion picture camera was hand-held by the photographer by means of a wooden handle, (Figure 2) in order to minimize the amount of vibration transmitted from aircraft to camera. However, this did not completely eliminate the rhythmic undulations caused by the helicopter's rotary blades, which tended to produce an unpleasant image movement when the motion pictures were projected.*

Aerial Photo Assessment of Cereal Crop Diseases

This work was performed under sponsorship of the National Research Council Committee on Plant and Crop Ecology, Division of Biology and Agriculture. Among the many agencies which actively participated in the project are: (1) the University of California (Departments of Agronomy, Forestry and Electrical Engineering); (2) the National Bureau of Standards (under a U. S. Air Force, WADC contract for research in spectrophotometry); and (3) the Office of Naval Research. Special acknowledgement for the growing of cereal crops and for the manipulation of diseases on them is given to Mr. Coit A. Suneson, Research Agronomist of the Field Crops Research Branch, U. S. Department of Agriculture, assigned to the Agronomy Department of the University of California.

A primary objective of this research was to determine the extent to which aerial photography could be used in detecting the presence, and determining the severity, of certain cereal crop diseases, such as Black Stem Rust and Yellow Dwarf Virus, on oats and wheat. While much of the aerial photography obtained in support of this project was flown at high altitudes from fixed wing aircraft, it was considered probable that certain kinds of information relative to the cereal crop diseases could best be obtained from low-altitude stereoscopic photography, either vertical or oblique. When attempting to obtain such photography from fixed wing aircraft, it was found that their relatively high rate of travel and limited maneuverability posed serious problems in (1) framing the target properly, (2) photographing it from the correct camera stations, (3) minimizing image blur and (4) obtaining sufficient overlap to permit stereoscopic or motion picture viewing of the photo images. In addition, the restricted visibility from most fixed wing aircraft made it difficult to navigate accurately at low altitudes and to obtain photography in which the appearance of wings or other aircraft parts did not obscure important ground detail. Each of these problems was satisfactorily overcome through employment of a helicopter as the aerial camera platform.

Since one important aspect of this study was to determine the photographic film-filter combination best suited to the assessment of cereal crop diseases, it was quite important that comparable photography of the test area be taken with each combination. It was not feasible to make multiple camera installations in the helicopter; a separate photographic run was required for each film-filter combination. Therefore such factors as flight altitude, overlap, photographic scale, and degree of obliquity of the camera had to be carefully controlled on successive runs over the target if valid comparisons were to be made among the various film-filter combinations being tested. Furthermore it was quite important that, on successive dates during the development of each disease, comparable photography be obtained as regards each of the above factors. The extent to which use of a helicopter permitted the photographer to fulfill these many requirements is indicated in Figure 3. It should be emphasized that this illustration shows only the photography obtained from three camera stations; furthermore the photography shown is for only one date, for only two of the film-filter combinations tested, and for only one disease, namely Black Stem Rust on oats and wheat. However, the examples presented in Figure 3 are considered representative of the more than 10,000 photos taken in support of this project.

Maneuverability of the helicopter was a factor of such importance in obtaining this photograpny that it can scarcely be overemphasized. Specifically: (1) when taking oblique photos of a rectangular test area from all four sides (to determine the best photographic angle, with respect to the sun, for detecting diseased areas), the ability to make right angle turns in the helicopter permitted such photography to be taken in one continuous circuit rather than in four separate passes; (2) the ability to reduce the forward rate of travel of the helicopter resulted in its advancing only a short distance during the period required for camera recycling; this permitted the photographer to obtain a sufficiently short

* For the description of a special camera mount designed to overcome this difficulty, see a U. S. Navy publication entitled "Aerial Motion Picture Coverage by Helicopter" (NavAer 10-IRB-522).

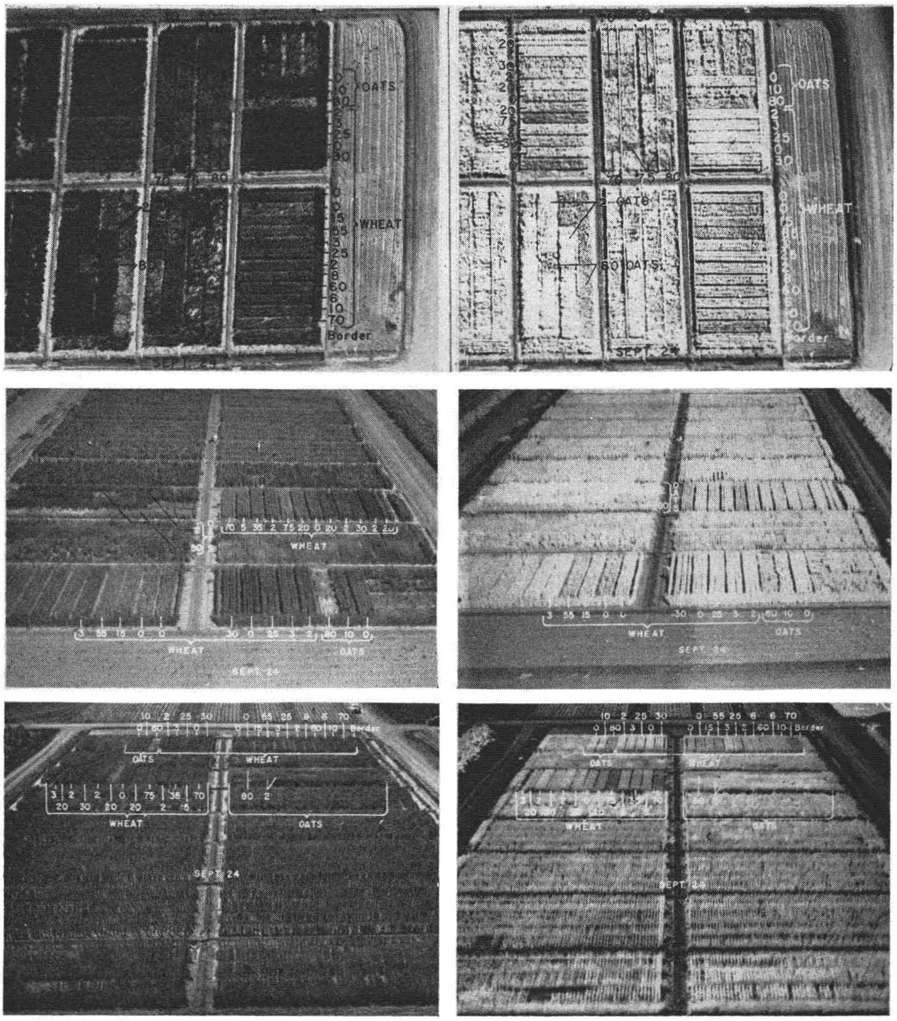

FIG. 3.—Matched sets of still photographs taken from the Hiller helicopter of a cereal crop nursery at Davis, California. All photos in left column were taken with panchromatic film and 25A filter. All photos in right column were taken with infrared film and 89A filter. Figures pertain to severity, in per cent, of black stem rust on oats and wheat. Camera stations were (from top to bottom) directly above the nursery, at south edge of nursery, and at north edge of nursery, respectively. Note that camera stations and angles of photography are sufficiently comparable in left and right columns to permit valid conclusions as to relative merits of the two film-filter combinations for disease assessment.

air base between successive exposures, so that the resulting prints could be viewed stereoscopically, despite the nearness of the camera stations to the target area; (3) the ability of the helicopter to climb or descend vertically, and in small increments, permitted accurate control of the altitude of photography; and (4) the ability of the helicopter to land and to take off from the road beside the test plots facilitated the changing of film magazines—an important requirement since, as previously stated, it was not feasible to make multiple camera installations in the helicopter. As a result of these factors, it was possible to obtain, in a period of less than one hour, all the photo coverage required on one particular date for a test plot such as that shown in Figure 3. If an appreciably longer period of time had been required, variations in sun altitude and light intensity would have been sufficiently great to invalidate photo image comparisons among the various film-filter combinations.

Preparation of a Training Film Entitled "Introduction to Photo Interpretation"

This film is being produced under sponsorship of the Pan American Institute of Geography and History of which the United States and other American Republics are members. It is intended for use by all the American governments in teaching the techniques of aerial photo interpretation to selected personnel.

One of the basic problems which a student encounters when learning to interpret aerial photos results from the fact that objects present a much different aspect or appearance to him in aerial views than in the ground views with which he is more familiar. Often those features which are most conspicuous from the ground view, such as the steeple of a church or the waterfall in a stream, are surprisingly inconspicuous when viewed from the air. Conversely, certain features which are rarely noticed on the ground, such as roof patterns and shadow details, may be surprisingly conspicuous and of great diagnostic value in the aerial view. It seemed that this important point should be well illustrated in an introductory training film on photo interpretation. In order to accomplish this effectively, there was need for some means by which the motion picture camera, while photographing a suitable object such as the aforementioned church or waterfall, (Figure 4) could be transported through an arc extending from a point on the ground near the object, to a point vertically above the object. If the photographer could then keep his motion picture camera trained continuously on the object while describing the arc, the resulting motion picture would illustrate the gradual change in appearance of the object during the transition from ground view, through aerial oblique views, to the truly vertical view commonly encountered when interpreting aerial photographs.

The potential value of this type of presentation in a motion picture was first demonstrated in each of two ways: (1) by selecting several small items of office equipment, sticking them vertically into a piece of fiberboard and photographing them with a motion picture camera while it was being panned from horizontal to vertical, using two legs of the camera tripod for a fulcrum (three frames from this scene are shown in the left column of Figure 4); and (2) by selecting a physiographic feature, such as the waterfall shown in Figure 4, which was so situated with respect to the surrounding topography that it could be photographed both horizontally and obliquely from selected vantage points on the ground, and vertically from a conventional fixed wing aircraft. Except in such special cases, however, the desired photography could not be obtained when employing only conventional means of photography.

Although some difficulties were encountered when attempting to describe the necessary arcuate flight path with a helicopter, while taking motion pictures from it, generally satisfactory results were obtained as indicated by photos in the two right hand columns of Figure 4.

Since Figure 4 shows, for each of the targets, only three frames clipped from the motion picture—a ground view, an oblique view and a vertical view—the concept of a gradual transition in object appearance, which can be so effectively illustrated in motion pictures, can only be deduced from a study of this figure.

Among the problems encountered, and solutions devised, while taking this motion picture photography are the following:

(1) When "panning" up and over a target in a helicopter there is a strong tendency to rotate the camera about its optical axis, as this facilitates keeping the target centered in the field of view. However, any such rotation obviously will detract from the effectiveness of the photography when it is projected, and therefore must be avoided. Usually the best results will be obtained by keeping one side of the camera in a vertical plane parallel to the main axis of the helicopter throughout the entire photographic run, rotating it about an imaginary axis perpendicular to this plane to the extent required for keeping the target centered in the field of view throughout the entire run. This is quite feasible provided that all portions of the arcuate flight path described by the helicopter fall approximately in a vertical plane that includes the target to be photographed.

(2) When attempting to obtain large scale motion picture photography of the

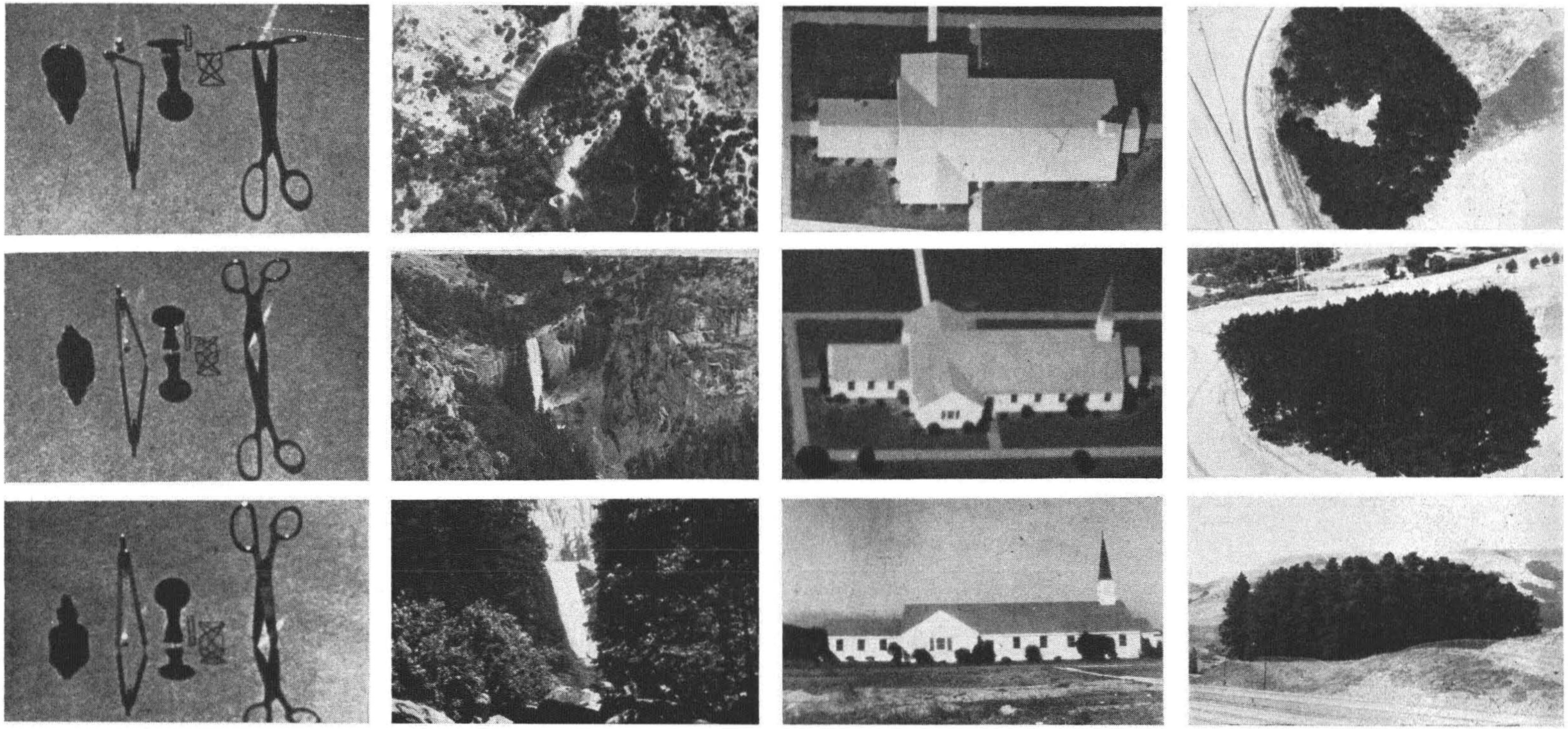

FIG. 4.—Matched sets of motion picture photographs of (left to right) standard items of office equipment; a waterfall and lake; a church; and a stand of timber which has a large hole in the crown canopy. Photos in the two right-hand columns were taken with a Piasecki helicopter as shown in Fig. 2. Such photos particularly when shown in motion picture form, enable the beginning photo interpreter to visualize how objects which he is accustomed to viewing on the ground (bottom row) should look in the aerial oblique (middle row) and vertical views (top row). For further explanation, see text.

target from a helicopter several interrelated factors are involved: if flying speeds greater than about 40 miles per hour are employed while flying close to the target, the motion picture tends to appear discontinuous or "jumpy" because of insufficient overlap between successive exposures; if the forward rate of travel of the helicopter falls below about 30 miles per hour, increased aircraft vibration coupled with a more erratic flight path, results in poor image quality particularly when flying close to the target; and if a lens of long focal length is used (to permit the desired scale of photography to be obtained at a greater distance from the target) vibrations and other sources of unsteadiness of the camera are greatly magnified in the projected image. In the work here reported upon, by far the most satisfactory remedy to this multifaceted problem resulted from employment of (a) high camera speeds (64 frames per second instead of the conventional 16 to 24); (b) short focal lengths, to minimize unsteadiness of the image; and (c) flying speeds as high as 30 to 40 miles per hour, even when flying within 200 to 300 feet of the target.

(3) When flying close to the ground over dry terrain, the strong downdraft of air beneath the helicopter's rotary blades tended to create such a dust-storm that it was virtually impossible to take good photography; for the same reason the photographing of cereal crops from very low altitudes sometimes resulted in images which could not be fused stereoscopically because the foliage was buffeted from one position to another during the interval between successive exposures, thereby producing large parallactic distortions. At altitudes of greater than 50 feet, however, neither of these factors proved troublesome.

In the interest of brevity, only passing mention can be made of certain other valuable uses of the helicopter in preparing this training film. The ideal way for a beginner to learn photo interpretation after having familiarized himself with the aerial view, as described above, is to study the aerial photos of a great many suitable areas and then to occupy these same areas on the ground, so that he may check the accuracy of his interpretations. In attempting to simulate this procedure as closely as possible in a training film, the helicopter is useful, first in making a low altitude reconnaissance for the purpose of selecting suitable areas, then in photographing such areas with a motion picture camera from the most favorable aerial vantage points, and finally in permitting the photographer to land at or near the selected areas so that he may examine each area carefully on the ground, prepare pertinent and accurate narrations for this portion of the film, and take supplementary motion pictures on the ground, as required to illustrate certain essential points. By this means the motion picture viewers, without leaving the comfort of their theatre seats, can in effect be conducted on an extensive photo interpretation field trip to a wide variety of carefully selected areas, however remote, by an expert who has thoroughly familiarized himself with each area through actual ground observation.

In illustrating certain aspects of photo interpretation it is desirable to show how an analysis of the motion of objects during the interval between successive exposures can be exploited by the photo interpreter. Whether it be an analysis of the flow of traffic in a congested area, or the acceleration rate and ultimate speed of a naval vessel under full power, if aerial photos are used in the analysis, then aerial motion pictures are an excellent means for explaining the techniques. Obviously the helicopter proves useful in the making of these scenes because its ability to hover or advance slowly provides the photographer with precisely the desired vantage points from which to take his motion pictures of the moving objects.

While many other important uses of the helicopter in taking either still or motion picture photography might be discussed, it is considered appropriate to devote the remainder of this brief paper to a discussion of some limitations of the helicopter in this regard: Much of the photography desired should be taken at altitudes of from 50 to 500 feet. This corresponds closely to the altitudinal range considered most hazardous by helicopter pilots since it is too low to permit any emergency landing by means of autorotation in the event of engine failure and it is too high to permit any beneficial use of the "aircushion" created by the strong downdraft of air from the rotary wings. For these reasons some pilots are unwilling to hover or even to fly at speeds as low as 30 to 40 miles per hour while operating within this altitudinal range. Accordingly the photographer may be limited as to the types of photography he can obtain.

With amazingly high frequency the shadow of the helicopter tends to appear within the area to be photographed. Perhaps this should not be too surprising, after all, when it is considered that the best illumination of an area usually exists when the sun is at the photographers' back; this is the very condition under which the helicopter's shadow is most apt to fall within the area to be photographed. Because of the relatively low altitudes at which most helicopter photography is flown, the shadow tends to occupy a very large portion of the area to be photographed and therefore is much more conspicuous than on conventional, high altitude photography. On motion picture photography, the shadow of a helicopter fluttering across the area of interest, with its wings rotating at an observable rate, can be especially distracting. While this difficulty is by no means insurmountable, the limitations imposed by it should be clearly recognized.

The carrying capacity of most present-day helicopters is too little to permit the desired flexibility of operations on certain aerial photographic missions. For example, in the project involving assessment of cereal crop diseases, it was necessary to transport the extra film magazines and several gallons of high test aviation gasoline to the target area by automobile rather than in the helicopter itself, because of both weight and volume limitations of the helicopter.

Still another limitation which is somewhat corollary to the above is that the performance characteristics of a helicopter flying at slow speeds, or hovering, are greatly dependent upon air density. In the projects that have just been described this imposed limitations in two respects: (a) it was not possible to obtain helicopter photography of all the desired terrain features in the Sierra because some of them were situated at such high elevations that there was insufficient air density to support helicopter flight; (b) even at the low elevations (less than 100 feet above sea level) at which the test plots of cereal crops were grown, helicopter performance was so reduced on very hot days that several "involuntary landings" were made. Although there fortunately was no damage to personnel or equipment, these landings were indeed so involuntary as to be termed "crashes" by most observers unfamiliar with the more technical terminology.

In summary, then, it may be said that the helicopter has proved to be an exceedingly valuable platform from which to take aerial photography of the types herein described, but its versatility, great though it is, still is limited by its performance characteristics. While rotary-winged aircraft can perform certain types of photo reconnaissance missions that fixed-winged aircraft cannot perform, the converse is also true. Accordingly the relation between these two types of aircraft for photo reconnaissance purposes should be recognized as being mutually complementary rather than being competitive.