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Aerial Reconnaissance and Photogrammetry with Small Cameras

The equipment and procedures for producing photography suitable for aerial reconnaissance utilizing small cameras are described.

Abstract: *A method is described whereby 35- and 70-mm cameras, a new film, a simple lightweight mount, and a minimally modified light aircraft can be used to achieve large camera results, inexpensively, in the acquisition of black-and-white aerial reconnaissance photography.*

Introduction

This paper describes a procedure which makes it practical for individuals, agencies, or small business firms interested in aerial reconnaissance to produce photographs at minimum cost with off-the-counter equipment.

Our developmental project began during November 1971 and was completed in August 1974. Individuals and firms that cooperated were—Michael Ferguson, Big Sky Maintenance, Logan Field, Billings, Montana; James Osman, Christian, Spring, Sielback & Associates, Billings, Montana; Sylvan Kasper, Kaspers Photo, Billings, Montana; Harold Holden and Arnold Weichert, H & W Company, St. Johnsbury, Vermont; Ernst Wildi, Paillard, Inc., Linden, New Jersey; Bob Riggs, Riggs Camera, Miles City, Montana; and Ralph Compton, Registered Professional Engineer 3088E. Miles City, Montana.

During the latter 1960s and early 1970s, Floyd F. Sabins, Jr. of Chevron Oil Field Research published results demonstrating the possibilities of small camera aerial photography[5], as did Ulliman, *et al.*[6], Marlar and Rinker[3], Fisher and Steever[2], and possibly others.

Three previous attempts to adapt a small camera to aerial reconnaissance were made by the author in 1939, 1942, and 1947. These attempts were successful in establishing starting points for flight lines with 9-by-9-inch mapping cameras, but otherwise useless as suitable film and processing were not available at that time to produce the results necessary for precise work. However, the advent of improved Hasselblad 500 EL/M and MK 70 cameras in the 1960s and the development of H & W film and processing have now made it possible and practical to use a small off-the-counter camera for aerial reconnaissance. A serviceable mount and procedure, as described herein, complete the system.

It is my belief that the people currently developing the small aerial camera, processing, and mapping procedure will have an impact on aerial mapping comparable to that which the people who first used 35mm cameras for press work had on photo journalism.

Equipment

A prime necessity is a camera with approximately the same coverage as a 9-by-9inch mapping camera equipped with an 8 1/4-inch lens. The Hasselblad 500 EL/M camera

with the 55-by-55mm format equipped with the Zeiss Distagon 50mm lens, is capable of producing excellent reconnaissance photography and will meet this specification. The camera should be equipped with two A12 magazines for 120 film; one 70mm magazine for black and white, color, and infrared film; and three filters, one haze, one red, and one yellow. The Hasselblad MK 70 with 53-by-53mm format, equipped with the Zeiss Biogon 60mm lens and 70 exposure 70mm magazine, is a photogrammetric camera capable of producing superior results. As with all photogrammetric cameras, a calibration report accompanies this camera. When equipment comparable to a 9-by-9-inch camera equipped with a 6-inch lens is desired, a modified Hasselblad Super-Wide camera equipped with a Biogon 38mm lens has proven to be an acceptable solution.

An aircraft capable of maintaining a mapping speed of 120 mph at 10,000 feet and accommodating a camera hole of 12 inches should be easily available. The 182 Cessna has been found satisfactory. A 12-inch camera hole can be installed on either side of the ship behind the pilot or copilot without altering the air frame or changing the position of control cables or wiring, and without need for a special kit. Cost of installation of the camera hole at the present time should be approximately four hundred dollars.

A camera mount, adapting a small camera to the aircraft for reconnaissance and photogrammetry, is required. The mounts we are using at this time are designed and fabricated in our shop in Miles City, Montana. The mounts incorporate all standard features used in mapping procedure: gimbal and level for correcting tip and tilt; shock mounting for the unit; drift indicator and prisms for forward vision; view finder and stop watch for timing intervals and correcting for crab; light meter; and linkage to provide for coupling the reconnaissance camera with an auxiliary 35mm camera so that 35mm photography can be provided together with 70mm reconnaissance. The Leica Mda equipped with either the Summicron 35- or 50-mm lens has proved reliable for this purpose, as has the TOPCON Super DM camera equipped with a TOPCOR 50mm lens. The mount will also accommodate the Hasselblad MK70 Photogrammetric camera or either of the other Hasselblad cameras mentioned above. All equipment is assembled in a unit 15-by-16-by-7 inches and mounted over a 12-inch camera hole. A slide in the lower portion of the mounts closes the camera hole during takeoff, landing, and when the units are not in use. The entire units, as shown in Figures 1 and 2, with cameras installed, weigh approximately 28 pounds.

The black-and-white film producing by far the best results with the process being described is H & W Control VTE Pan film with an ASA speed of 80, processed in H & W developer. A normal exposure for this film, at an elevation of 10,000 feet on a clear day during mapping season, is about f:5.6 at 1/500. This film has extremely fine grain and good contrast. High quality 24-by-24 inch mylars can be made from the 55-by-55mm negatives.

Processing the film is inexpensive and easy as the H & W black and white film, Kodak CPS type S color negative film in 120, 220, or 70mm sizes and all 35mm film can be processed in quick fill Nikor tanks. 70mm bulk film can be cut to 24 exposure lengths and threaded on 100-inch X-ray reels that have been cut down to fit the 220 Nikor tank.

Projection printing is used in all cases with the process being described, as the 9-by-9 inch format is the smallest print in general use in aerial photography. Printing can be done with the D-2V or D-2VXL Omega enlargers. These enlargers have 45-inch and 57-inch cantilevered girders, respectively, and should be used only with their best lens. It is also necessary to have the enlarger equipped with the Hasselblad lens flange so the Zeiss lens for the Hasselblad can be used in the enlarger. The

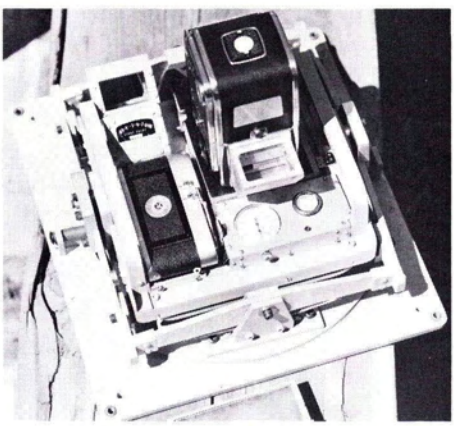

FIG. 1. Camera mount designed and fabricated by the author, May 1972. Hasselblad EL/M camera mounted, with a Leica MDa camera also mounted in front of the light meter. A timer and a level are in the panel in front of the Hasselblad. A prism and plexiglas plate with drift and interval lines have been fabricated to replace the conventional Hasselblad viewfinder hood.

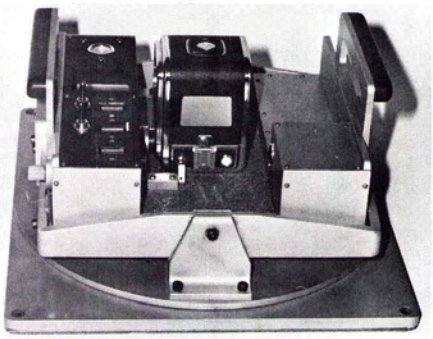

FIG. 2. Modified and improved mount, assembled September 1975, as currently designed, fabricated, and sold to custom order by the author.

negative carrier for the 55-by-55mm negatives will have to be enlarged so the edges of the negative are visible on the print. This alteration is necessary because the distance across the negative is used, in some cases, to determine measurements on the ground. A contact printer can be used as a light box so the negative can be centered in the carrier. The enlarger should also be equipped with a 30-by-30-inch piece of 1/4-inch plate glass and sponge rubber when the enlarger is to be used as a large contact printer for making contact prints of mylars. The 80mm Zeiss Planar is useful as an enlarger lens for making mylar contact prints. The 120mm Zeiss S-Planar is an excellent enlarger lens for printing 9-by-9s or 10-by-10s. The 120mm Zeiss S-Planar equipped with the Hasselblad quick-focusing handle #2 and mounted in the enlarger will provide the unit with auxiliary helical focusing.

We have found the best stock to use for prints to be Kodak 1594 for most 9-by-9s and 10-by-10s when it is necessary to assemble photo indexes. Kodagraph Super-K Projection Paper KP5 can be used for high contrast prints as it produces excellent results when used with H & W negatives. Kodagraph Projection Film 2921 can be used when diazo or blue print copies are to be made. Kodak Dektol can be used as developer for both the papers and the film.

A 4-by-8-foot table equipped with a drafting arm is necessary to lay out a small photo index. Suitable sizes of 1/4-inch masonite and drawing paper are needed for backing. The prints can be mounted with 3M photo spray adhesive.

The photo index can be copied using the Hasselblad camera with the 120mm Zeiss S-Planar lens, using H & W Control film and H & W developer. Line copies can also be made on H & W Control film, using Kodak D-19 developer.

PROCEDURE

Using the previously described equipment, the following procedure will produce very good reconnaissance photography.

It is first necessary to find the coverage of your camera from a given elevation, which can be accomplished as follows. Make five targets on mat white paper stock. Crosses on the targets should be made with dull black tape or spray paint, 1/10 inch with 6-inch arms. Lay the targets out in a line at points 25 feet apart. (A hangar wall may be a good place to attach the targets as it should be level, straight, and stable, well over the necessary 100 feet needed, and in the sun and well lighted.) The targets should be the same distance off the ground as the camera will be when mounted on a tripod. From the center target run a chain 100 feet perpendicular to the line of the targets. Use two 100-feet chains to make any necessary corrections to the perpendicular line, using the 25-foot targets as guides. Set the camera over the 100-foot mark on the perpendicular line with the diaphragm ring over the 100-foot mark using a plumb bob to insure that the camera is properly located. Using a roll of 120 H & W film, exposing only in bright sunlight, use four exposures: 1/500 at *f*:4, *f*:5.6, *f*:8, and *f*:11. These exposures should be made with the self timer on the lens to avoid vibration. Develop the film in Kodak D-19 for five minutes at 68°F. The result should be four very high contrast negatives with excellent resolution. Start printing with either the *f*:5.6 or *f*:8 negative by projecting the image on a white card and enlarging the image to a point where the outside targets are 25 inches apart. Use the 40 scale on an engineer's rule and the scale will read 100: each of the gradations on the scale will indicate 1/10 of a foot and will have the same dimensions as the width of the lines on the projected image of the target arms. Cut a strip of Kodagraph Projection Film 2921, approximately 30 inches long and 4 inches wide, and place under the enlarger. Expose at *f*:11 for four seconds and develop in Dektol 1-2 for 90 seconds. This may not be the correct exposure for all equipment but will serve as a guide. Use stop, hypo, clearing agent, and wash and dry as film instructions indicate. Coverage of the lens can now be measured. The Zeiss Distagon 50mm lens should cover about 108 feet at 100 feet. The constant for the lens can now be determined so that the prescribed elevation of the air-

craft over the project can be calculated. The results of a check on the Zeiss Distagon 50mm lens tested and used by the author were as follows: the coverage across the center of the negative where the line of targets was located was 107.3 feet and where the perpendicular distance from the center target to the camera was 100 feet 100 ÷ 107.3 = 93.196, indicated the constant for this particular Distagon lens to be 93.196.

From this information a flight plan for a project can be assembled. For example, the project described by the flight report shown in Figure 3 called for an index assembled from 10-by-10-inch prints scaled 1" = 800'. A stereo pair of prints for the project scaled 1" = 800', with attached contact prints is shown in Figure 4. Individual prints from the project were to be 20-by-20 inches and scaled 1" = 400'. At this scale the 55-by-55mm negative should cover an area of 8,000-by-8,000 feet. An enlarged portion of the stereo pair is shown in Figure 5.

Using the constant 93.196 × 8,000 feet produces 7,455 feet, the elevation over the terrain the aircraft should maintain. Average elevation above sea level of the terrain in

AERIAL SURVEY, INC. 93.196 × 8000' = 74550 + 2700 = 10,155'

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MILES CITY, MONTANA 59301

TELEPHONE 406-232-4226
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6 SEC. INTERVAL FOR 2640'
18 SEC. 60% OVERLAP

PHOTOGRAPHIC FLIGHT REPORT

Date 8/6/74

93.196

PLANE	C-182 3387F	CAMERA	500ELM
PILOT	LYMAN CHOATE	LENS	50mm DISTAGON
PHOTOGRAPHER	BILL WOODCOCK	FILM & FILTER	H&W - HAZE

WORK PERFORMED

ROLL NO.	FLIGHT NO.	DIRECTION OF FLIGHT	START TIME	START EXP. NO.	STOP EXP. NO.	STOP TIME	ACTUAL ALTITUDE
1	B1 ①	W	10:50	1	12	—	SEA LEVEL 2700'
2	B1A ①	W	—	1	12	—	7453
3	B2 ②	W	—	1	12	—	10,155'
4	B3 ③	W	—	1	12	—	
5	B4 ④	W	—	1	9	—	
5	B5 ⑥	W	—	10	12	11:30	

TAKE OFF	10:15-10:50 FROM GLASSCOCK	CONTRACTING PARTY	PAUL BIEGALKE
START PHOTO	10:50 AM	LOCATION	HORTON, MONTANA
STOP PHOTO	11:30 AM	SCALE	1"=800' ON 10"×10" PRINTS
LAND	11:30AM-12:00NOON TO ALLEN	SHUTTER SPEED & STOP	1/500 - f5.6

FIG. 3. Flight report dated August 6, 1974, made while the prototype unit was being used to record a $42,000 fire damage to range and grasslands owned by Paul Biegalke near Horton, Montana. Also taken the same day were photographs of a 12 section wheat farm (Glasscock), 25 miles of highway (Allen), and some incidental oblique photography. Total flying time on the date was 3.6 hours. All of the photos taken were acceptable and no reflights were necessary.

this case was 2,700 feet. The 7,455 feet + 2,700 feet gives 10,155 feet, the reading given the pilot of the aircraft so that he could correct for temperature and pressure to obtain a true elevation for the project flight lines. Flight lines were spaced one mile apart so sidelap would be approximately 2,700 feet. It was the pilot's responsibility to fly the aircraft over the flight lines indicated on the flight map, at 10,155 feet and at 120 mph in a stable position. (The 120mph was established because at that speed the aircraft in use produced the least engine vibration and airframe resonance.)

The forward overlap on each print must be about 60 percent so that good stereo coverage can be maintained. Control of this factor, and correction for tip, tilt, and crab, is the photographer's responsibility. A preliminary indication of what the necessary interval between exposures should be to maintain a 60 percent overlap can be determined before a flight is attempted. If the aircraft is travelling at 120 mph, the speed over the ground is 176fps. The useable print or distance between exposures is 40 per cent of 8,000 feet or 3,200 feet. This 3,200 feet ÷ 176 fps = 18.18 seconds, the interval between exposures. This 18 second interval is only a starting approximation, of course, as subsequent corrections for windage have to be made with the drift indicator and the view finder. When flight lines have been drawn on the flight map, the starting points and number of exposures in each flight line can be determined, making it possible to calculate in advance the amount of film needed and the point at which magazines are to be changed or loaded. The photographic flight can now be made on any clear, sunny day between 10:00 am and 3:00 pm during the mapping season. Exposure with H & W film should be at f:5.6 at about 1/500 and with a haze filter, which is necessary not only to eliminate haze but also to protect the lens. The filter will probably collect some oil after a photographic flight. A damaged filter can be replaced for under $30; replacement of a damaged lens will cost nearly $1,000. As another precaution, after setting the lens at infinity, place some masking tape around the focusing ring to prevent it from rotating out of the infinity setting. This simple expedient has been found necessary by a number of people who used this equipment for aerial work.

If possible, good ground control over the area to be photographed should be established. Without it the project is dependent on the calculated height of the aircraft over the project and the pilot's ability to correct

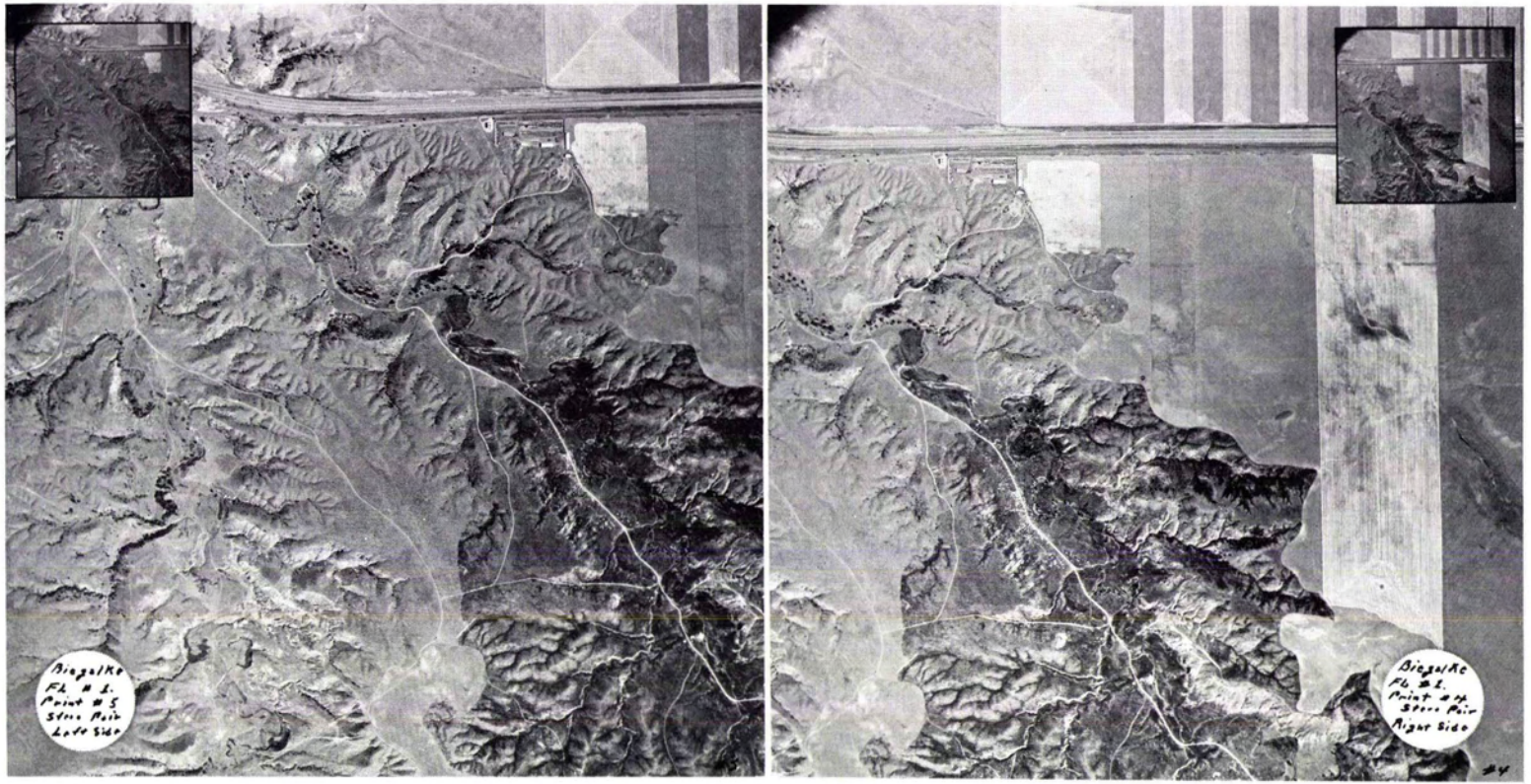

FIG. 4. A stereo pair of prints from stations #4 and #5 of flight line #1 of the flight over the Biegalke fire shown reported in Figure 3. The prints are scaled 1" = 800' and enlarged 4.62 diameters from the negative. Original contact prints of the two negatives are mounted in the upper outside corners of the enlargements. These prints were used separately to indicate where the fire started. (Reduced 0.42 × for publication.)

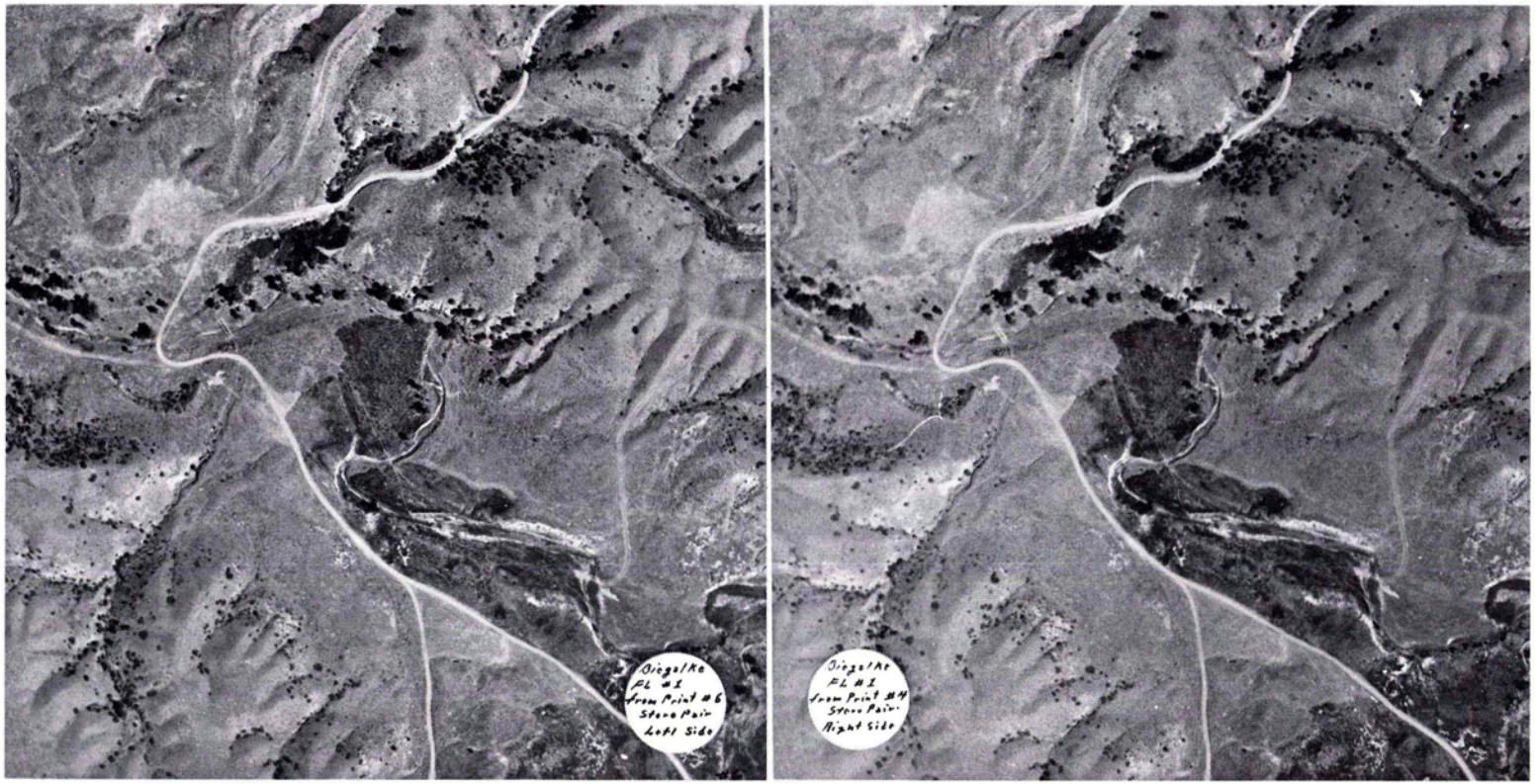

FIG. 5. The stereo pair shown in Figure 4 enlarged to 17.3 diameters to determine the exact point at which the Biegalke fire started. (Reduced 0.42× for publication.)

for temperature and pressure. Most areas will have some known distance that can be identified from the air or on the photograph. If possible, place targets over the controls. At the scale mentioned in this paper, white crosses, made from building covering, with arms 10 feet long and 24 inches wide and weighted in the center with a tire, are easily identified on a photograph.

Film should be processed as soon as possible, using the procedure for developing H & W film indicated by the factory. The negatives will look thin: that is their normal appearance. If a good control is included in the project, print the negative with the control first. Using an 80 scale over the ground control, the correction can be read directly in feet on a 10-by-10 enlargement. If the flight altitude was correct, the print will be 10-by-10 inches. Whatever the size of the print, the scaled width in feet can be multiplied by the constant to determine the altitude of the aircraft over the project. If there is no ground control, it has to be assumed that the flight altitude calculated by the pilot was correct.

Print the 10-by-10s on Kodak Kind 1594 paper, using the process recommended by Eastman, and lay out the photographs on a table suitable for the size of the index. During the printing process, a soft lead pencil can be used to identify the prints. After processing, the lead will wash off and the white lettering will remain on the print for identification.

To prepare for final assembly of the index, cut a piece of 1/4-inch masonite slightly larger than indicated by the roughly assembled index. Cover the masonite with drawing paper cemented down with 3M photo mount adhesive. Lay out a base line and control lines and points on the drawing paper with a K & E drafting machine and place the first flight line over the proper controls so that any necessary corrections can be made. Some distortion due to differences in elevation and to photographs which were taken when the camera was not level at the time of exposure will be encountered. The index can now be assembled. The drafting machine can be used to line up the prints as they are mounted. Before each print is attached to the backing, the corners should be marked with a pencil because the photo mount adhesive will hold the prints firmly in place after 40 seconds. Pencil lines can be erased later and the identification needed can be placed on the index after it has been cleaned (Figures 6 and 7).

Copies of the index can now be made with the Hasselblad equipped with the 120mm S-Planar, using 120 H & W film and four copy lights. If continuous tone prints are to

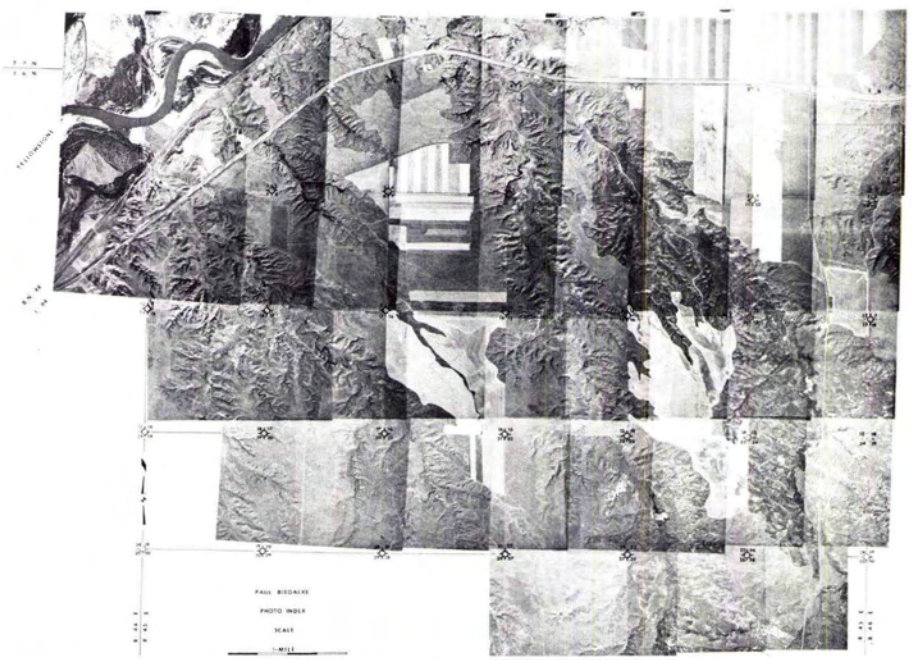

FIG. 6. Final assembled photo index of the Biegalke fire, scaled 1" = 800', with pertinent information added, ready for copying by the method described (below).

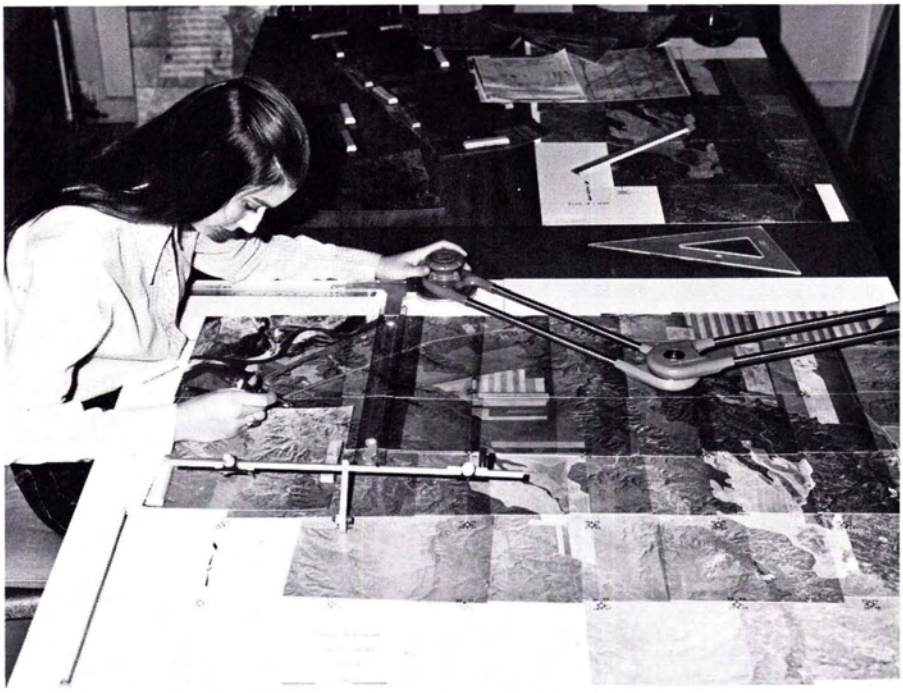

FIG. 7. A second map of the same project, but scaled 8" = 5,280' as used by SCS offices, being assembled by the method described (above).

be made, use H & W Developer, and if line copies are to be made, use Kodak D-19 Developer. The photo index must be vertical and the camera leveled when the copies are made. Where high contrast line copies are to be made or continuous tone copies of high contrast are desired, it is advisable to use Kodagraph Super-K Projection Paper KP5. If normal contrast is desired, use Kodak Kind 1594 Paper.

Information on the photo index or on the prints can be transferred to a map or other media by using tracing paper and sketching the information on the paper or by using a pantograph (Figure 8).

When it is necessary to make a number of prints from one negative for use in the field, a useful method is to project the negative on Kodagraph Projection Film 2921 at whatever scale is to be used and develop in a solution of Dektol 1-2 for 90 seconds. After processing, map information can be drawn on the positive and blue prints or diazo prints can be made from the positive.

CONCLUSION

The author hopes that this paper will be both useful and encouraging to people interested in doing their own aerial photography. The equipment described is relatively inexpensive and the procedure outlined is not only simple, but almost infallible.

Anyone wishing to pursue the subject further should acquire Volume I and II of the Third Edition of the *Manual of Photogrammetry*, published in 1966 by the American Society of Photogrammetry, which was itself established in 1934. During the past 40 years, since the founding of the Society, equipment for aerial photography has been refined and the latest films, papers, developers, and equipment are far superior to those in use when the industry was in its infancy. The basic processes, however, are much the same as they were when the industry was born.

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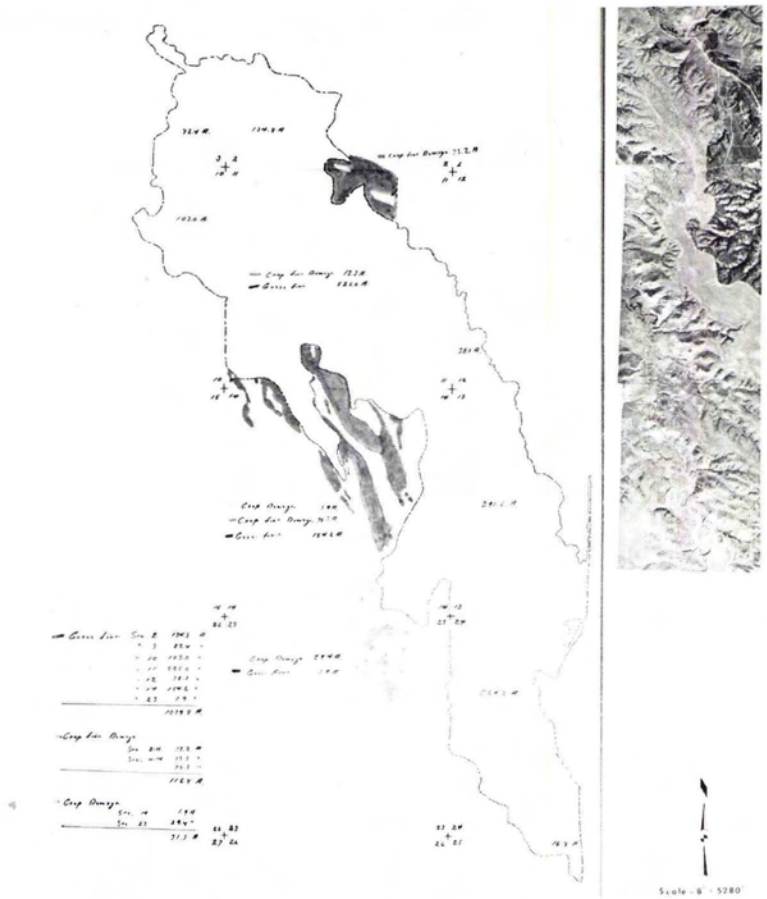

FIG. 8. Tracing from the map scaled 8" = 5,280' indicating the location and area damaged by the Biegalke fire. The field acreages correspond to current SCS aerial survey maps. A grid and planimeter were used for final measurement of the fire damage, thereby completing the project and fulfilling the contract.

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Proceedings of the Commission IV Symposium (September 1974)

Publication of the reports presented during the Paris symposium arranged by Commission IV of the International Society for Photogrammetry (September 1974) has just been completed. They form three special issues of the *Bulletin de la Société Française de Photogrammétrie*. These three issues can be ordered from the Secretariat of the Société Française de Photogrammétrie, 2 Avenue Pasteur, F-94160 Saint-Mandé (France) at a cost of 70 French Francs (postage included).