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A PHOTOGRAPHIC METHOD FOR ASSESSMENT OF BOMBING RESULTS

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RADIATION LABORATORY
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A PHOTOGRAPHIC METHOD FOR ASSESSMENT OF BOMBING RESULTS

ABSTRACT

A means for testing the accuracy of a bombsight without dropping bombs is provided by photographing the test airplane from the ground with a special vertical phototheodolite. The design of the phototheodolite employs a standard 16 mm movie camera which photographs through a set of wire cross hairs held vertically above the camera. In analyzing the results azimuth errors are measured directly on the enlarged 16 mm frame while range errors are computed from the reading of a clock which is photographed along with the airplane and cross hairs. The accuracy of the vertical phototheodolite is indicated by errors in azimuth of not more than .75 mils and errors in range of about five feet plus .75 mils for an airplane moving at 180 miles per hour.

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Title page
8 numbered pages

A PHOTOGRAPHIC METHOD FOR ASSESSMENT OF BOMBING RESULTS

GENERAL REQUIREMENTS

The particular bombing device to be tested in this case was a radar bombsight, the APA-5, installed in a B-24. It was desired to test the accuracy of the bombsight at various altitudes between 500 and 15,000 feet without dropping bombs. This required a method which would provide data from which the distance from the target to the imaginary impact point could be found.

PHOTOGRAPHY FROM THE GROUND

The method selected as the one best suited to testing of the APA-5 employs special equipment which photographs the airplane from the target point as it passes over the point, suitably recording data from which the location of the impact point can be computed.

The major advantage of this method is the accuracy obtainable which is considerably better than that of other methods, such as radar tracking, or photography from the airplane. (Radar tracking is not very satisfactory for handling runs at the lowest altitude of these tests, 500 feet.)

Another advantage is the relative simplicity of the equipment. No special optical systems are required, a standard camera is used, and the most delicate adjustment required is easily accomplished with the aid of a plumb bob. The equipment required is approximately equivalent in weight and bulk to the radio receiver and transmitter which are used in conjunction with it.

The ground photography method has some definite limitations, the most fundamental of which is its dependance on the conditions of photographic visibility. Another limitation is imposed by the angle of view of the camera and lens employed which prevents measuring errors greater than a certain value. This angle can be increased by using a different lens-camera combination but may sacrifice other desirable features. A third limitation is the inability to handle numerous airplanes over the same target as might be required at a training field.

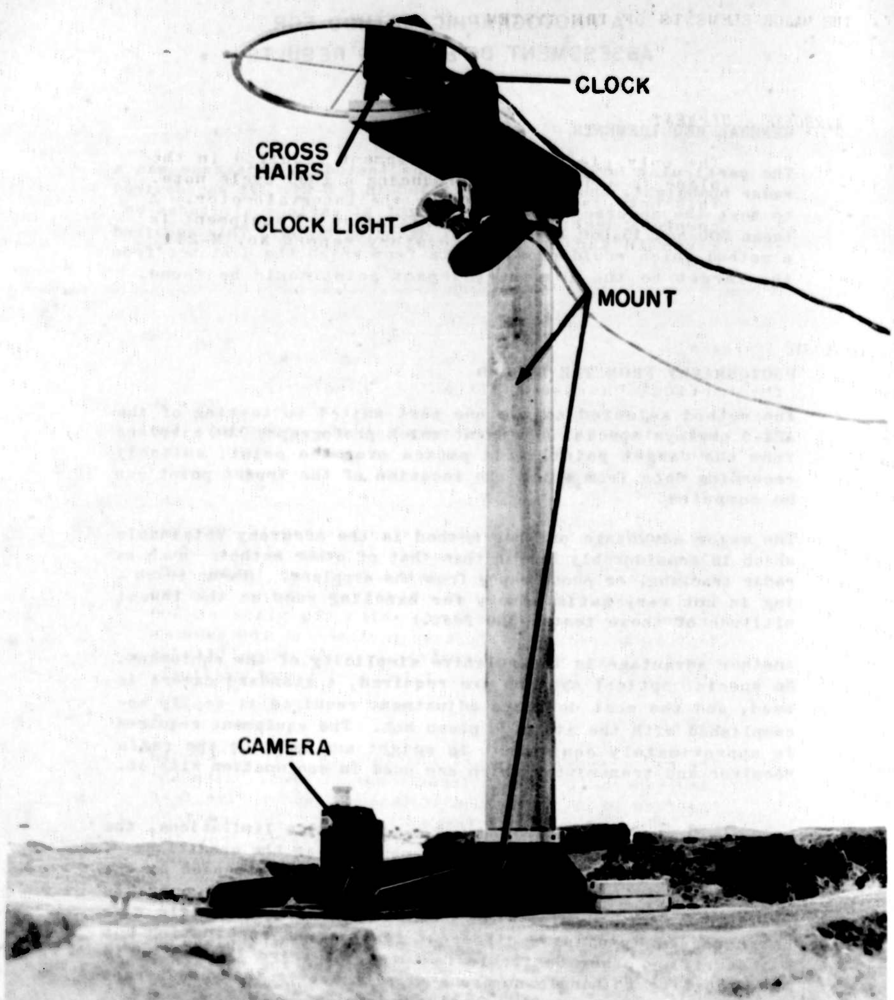

FIGURE I
THE VERTICAL THEODOLITE

THE MAJOR ELEMENTS OF THE SYSTEM

AIRBORNE EQUIPMENT

The only piece of test equipment required in the plane is a device for producing a 1000 cycle note. This note is turned off by the intervalometer. A complete description of this piece of equipment is given in Radiation Laboratory report No. M-241.

GROUND EQUIPMENT

The Vertical Phototheodolite (see Figure 1).

This piece of equipment consists of, or employs the following parts:

The Camera

The particular camera used is an Eastman 16 mm magazine loading Ciné. It was felt desirable to use a movie camera in order to have pictures taken sufficiently often so that no extrapolation between frames would be necessary. With the plane at 500 feet it is necessary to take pictures at the camera's maximum rate of 64 frames per second. At altitudes of 5,000 feet and over the film speed is not critical.

Lenses Used

The major requirement of the lens is that it should simultaneously keep in focus a set of cross hairs and the face of a clock at a distance of about five feet and an airplane at a large distance. The one inch lens with which the camera is ordinarily provided meets this requirement adequately up to about 10,000 feet, providing a fast film is used so that stops no larger than f/16 need be employed. At an altitude of 15,000 feet it is necessary to use a 2-inch lens in order to be able to locate the image of the plane on the 16 mm frame. This necessitates moving the clock further from the camera in order to keep the face in focus.

Film

A special Eastman film known as Shell Burst Pan was found to give the best results, although Super XX is nearly as good. Shell Burst Pan is designed to provide maximum contrast between blue sky and a black object, therefore the bottom of the test plane was painted black. The problem of proper exposure is made less critical by the fact that a silhouette only is required for the image of the airplane.

Cross Hairs and Mount

The cross hairs are of piano wire strung in an aluminum ring which can be rotated in azimuth if desired. The rotation feature was not found to be especially useful. The mount, which holds the cross hairs at about 54 inches above the camera lens, should be sufficiently rigid to prevent a relative lateral motion of more than 1/16 of an inch (approximately .75 mils) between cross hairs and lens due to wind or other factors. The mount illustrated in Figure 1 exceeds this requirement.

Clock

The clock used is a precision electric clock made by Standard Electric Time Products Company with a sweep second dial capable of being read to 1/100 of a second. It is operated from a crystal controlled power supply in order to prevent error from fluctuations in the commercial power supply.

Clock Control Circuit

It is necessary to start the clock at the instant of bomb release and this is accomplished by transmitting a 1000 cycle note over the standard communication facilities of the plane. The note is turned on prior to bomb release, and turned off at the release point. Cessation of the note trips a clock-starting circuit.

Clock Illumination

This is accomplished by using a 300-watt reflector spotlight controlled by a variac. It was found necessary to make lengthy calibration tables of exposure versus light voltage and this system of illumination is rather unsatisfactory in general.

Vertical Sight

It is desirable to have some very simple form of vertical sight to indicate to the operator when the plane enters the field of the camera.

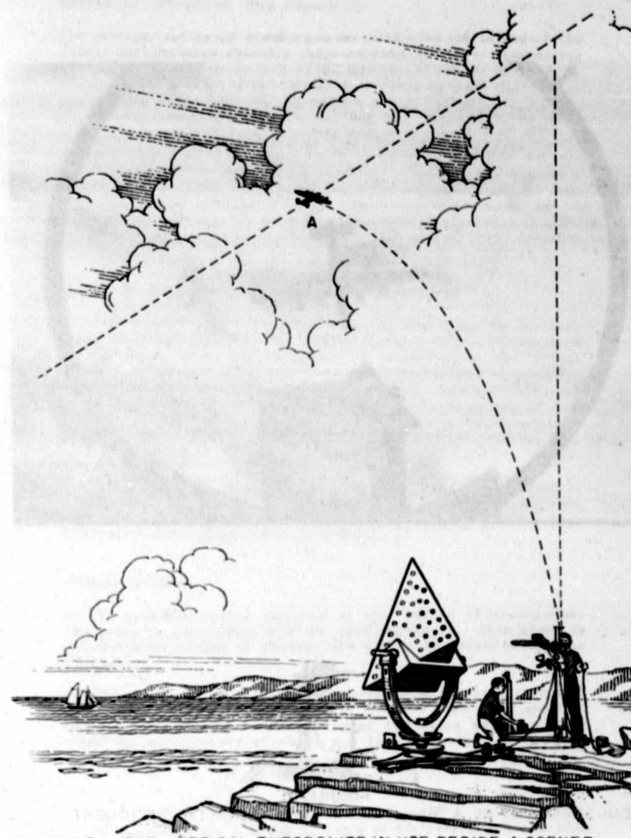

FIGURE 2 - THE VERTICAL THEODOLITE IN USE BESIDE A CORNER REFLECTOR WHICH SERVES AS THE TARGET.

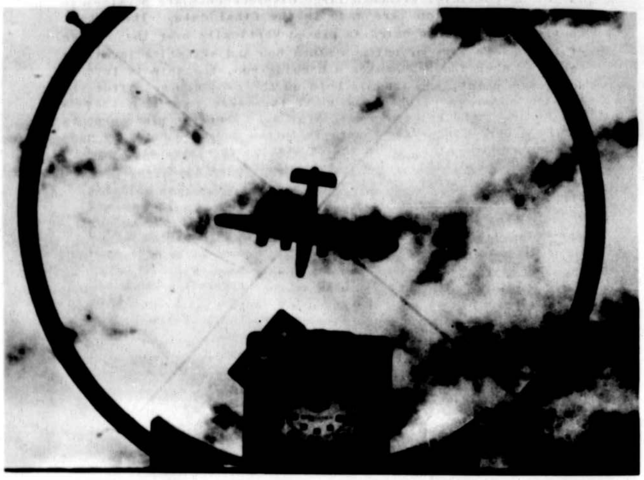

FIGURE 3
ENLARGEMENT OF A 16mm FRAME AIRPLANE ALTITUDE 1000FT.

METHOD OF OPERATION (See Figure 2)

The phototheodolite is usually set up as near to the center of the target as possible, although large displacements are permissable provided corrections are made in the final data. The intersection of the cross hairs is placed vertically over the center of the camera lens by using a plumb bob and adjusting levelling screws. When the B-24 makes a bombing run, the ship is left on automatic pilot, and thus is held on the same course, after the release point is reached and until it passes over the target. (In Figure 2 the release point is at A.) When the plane appears in the camera finder the camera is turned on and a movie is made which shows the airplane, a set of stationary cross hairs, and a clock which had already been started automatically by a signal from the plane at the release point. An actual frame from the film is shown in Figure 3.

METHOD OF ANALYZING PHOTOGRAPHS (See Figure 3)

When an analysis of the photos is made, the frame is selected which shows the plane* at its closest approach to the intersection of the cross hairs, and the number of seconds since the release point is then read from the clock. The difference between the clock reading and the time of fall of the bomb multiplied by the ground speed of the plane gives the distance, in range, of the point of impact from the target, assuming that the bomb would have remained directly under the plane as it fell. Further corrections for trail and cross trail may be made.

The azimuth error is determined by measuring the distance of closest approach of the airplane's course to the intersection of cross hairs on the film and converting to the actual distance expressed either in feet or in mils.

SOURCES OF ERROR

Of the possible errors involved in this method of assessment, one group is associated with the test equipment. This group is divided into errors of timing, and errors in establishing the vertical.

Careful tests of the clock and its associated circuits show that the probable overall timing error is not more than ± .02 seconds. For an airplane (or bomb) moving at 180 miles per hour this means an uncertainty of about ± 5 feet in range.

** The center of the bomb bay is taken as the reference point for measuring distances.*

Errors in establishing the vertical depend on the care with which the intersection of cross hairs is placed over the center of the camera lens and the certainty with which this relation is maintained. By using a plumb bob the lateral displacement between these two points can be made to be less than 1/16 of an inch. This means that the vertical is established with a radial error of not more than ± .75 mils. Any errors due to non-rigidity of the cross hair mount are smaller than 1/32 of an inch.

The second group of errors is related to the accuracy with which the plane follows the same course after the release point as before. This error is not clearly known. The most definite statement that can be made about it is that on the basis of the bombing tests which have been made with this system it appears that the probable deviation of the plane from its course is little, if any, greater than the probable deviation of the bomb from its predicted course.

November 29, 1945 George F. Wheeler

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