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UTILIZATION OF A PHOTOGRAMMETRIC FACILITY (PF) IN HUMAN ENGINEERING LABORATORIES BATTALION ARTILLERY TEST NUMBER TWO (HELBAT II)

by

1LT Richard E. Schneck

August 1971

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
FORT BELVOIR, VIRGINIA

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The high visibility given the concept, equipment, and operations of the Photogrammetric Facility (PF) during HELBAT II resulted in subjective evaluation at all levels of command which was significant in the general acceptance of the PF's potential for military support. Sufficient data for numerical analysis were gathered only for Forward Observer and target positioning exercises, but other potential applications were examined. Test data indicate a 30% improvement in the capability to locate Forward Observers as compared with the doctrinal map-spot techniques, but a degradation in the ability to position targets was noted.

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Project 4A662707D853

August 1971

Distributed by

The Commanding Officer
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Prepared by

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Surveying and Geodesy Division

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FOREWORD

This report was prepared under the authority of Project 4A662707D853, Mapping and Geodesy.

The report was prepared by 1LT Richard E. Schneck, Research and Development Coordinator, assigned to the Surveying and Geodesy Division, under the direction of Mr. Melvin Crowell, Jr., Chairman, ETL STANO Working Group, and under the general direction of Mr. Gilbert G. Lorenz, Technical Director, Engineer Topographic Laboratories, U. S. Army Topographic Command, Fort Belvoir, Virginia.

Testing activities reported in this document were coordinated with Mr. Gary L. Horley, Aberdeen Research and Development Center (ARDC), Human Engineering Laboratories (HEL), Aberdeen Proving Ground, Maryland.

During the conduct of HELBAT II, the equipment system was operated by SP5 Warren E. Smith and SP4 Alan F. Chamberlain, 30th Engineer Battalion, Base Topo, LTC J. R. Lund, Commanding.

Configuration and acquisition of the system equipment were accomplished primarily through the efforts of Mr. F. R. Norvelle, a member of the STANO Working Group, Engineer Topographic Laboratories (ETL).

Personnel using the graphic materials during the conduct of the HELBAT II Tests were provided by the First Armored Division Artillery, Colonel R. G. Trefry, Commanding.

SUMMARY

This report covers tests of the capability of photogrammetric equipment and techniques to provide positional data required by Field Artillery operations. Commercial-grade photogrammetric equipment was assembled and installed by the U. S. Army Engineer Topographic Laboratories and was operated by enlisted personnel from the 30th Engineer Battalion (BT). The test was designed and implemented by the Human Engineering Laboratories, Aberdeen Research and Development Center, in concert with an organizational readiness training test involving the First Armored Division Artillery at Fort Hood, Texas, during February 1971. Results of the total testing effort, Human Engineering Laboratories Battalion Artillery Test Number Two (HELBAT II), are reported in a separate document by the Human Engineering Laboratories, Aberdeen, Maryland.

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I. INTRODUCTION

1. **Purpose.** This report examines the results of the utilization of a Photogrammetric Facility (PF) supplied by the U. S. Army Engineer Topographic Laboratories (ETL) for the Human Engineering Laboratories Battalion Artillery Test Number Two (HELBAT II) which was conducted at Fort Hood, Texas, during February 1971. The primary purpose of ETL's participation in HELBAT II was to determine whether photogrammetric techniques and equipment could be effectively used to improve the positioning capabilities of the Field Artillery.

2. **Background.** The U. S. Army Topographic Command (TOPOCOM), in the course of meeting the mission to provide positional and other topographic support to the Field Army, has become involved in the creation of new concepts for the generation of modern topographic materials. The new concepts permit a time-phased topographic readiness capability according to world-wide threat analyses and base-plant production capacity. Implementation of these concepts is predicated upon the availability and processing of select imagery, known as data base materials, used in CONUS based facilities.

a. **Photogrammetric Facility Concept.** It occurred to TOPOCOM that there was an opportunity to exploit these same data base materials and related base plant operational technology for direct application to Field Army requirements. The generalized concept is contained in ETL Technical Report 56-TR, "Photogrammetric Applications to Field Artillery," by Messrs. Eugene P. Griffin, Donald R. Barnes, and James E. Stillwell, dated March 1970. The theme of this concept stresses the points that data-base materials, available by virtue of the TOPOCOM mapping missions, can be made available to Field Army users; that data-base materials can be used in the field employing standard photogrammetric techniques developed in conjunction with base plant production procedures; that commercial-grade photogrammetric equipments are available and suitable for accommodating the data-base materials; that the data-base materials are of such scale and resolution characteristics that when used with the commercial equipment and standard photogrammetric techniques an entire Division area of responsibility can be attended in a single "model" setup; that present CONARC training exists for teaching the skills necessary to operate the photogrammetric equipment and, in fact, is employed in the standard training of Engineer Topo Units; that the state of commercial-grade mini-computers is such as to enable a reasonable dimensional configuration, memory size, and operating speed compatible with Field Army operational objectives; and that such data-base materials, photogrammetric equipment, computers, techniques, and operator skills can be used in a system to provide positional and other topographic information to meet many of the accuracy and response-time needs in support of Field Army operational concepts. The concept has appeal and near-time operational availability because of its innovative characteristics; i.e., it exploits current and planned data-base materials, existing technology, commercially available components, existing MOS skills, and existing Field Army sensor and communications facilities and applies these without modification to achieve entirely different objectives in addition to basic justification for the above.

b. **Concept Development and Testing.** In August 1970, ETL, the research and development activity of TOPOCOM, formed a Working Group to provide centralized control of all research and development efforts associated with Surveillance, Target Acquisition, and Night Observation (STANO). One concept which appeared to have considerable potential in this area was the PF concept. Activities of the Working Group as well as TOPOCOM briefings and demonstrations surfaced the concept for consideration by Army requirements and force structuring agencies. In this context, the Army Research Office acted as broker by way of introducing the concept as a candidate for evaluation during tests being conducted by HEL, ARDC, Aberdeen Proving Ground, Maryland, in February 1971, at Fort Hood, Texas. The Human Engineering Laboratories Battalion Artillery Test (HELBAT I) took place at Fort Hood in 1970. The purpose of HELBAT I was to determine the capability of a Battalion of M-109, self-propelled 155-mm howitzers to deliver accurate mass fire without adjustment. One of the objectives was to determine what portion of the total system error was human error and to isolate that error in each of the functional sections of the fire-delivery operations. The tests concluded that a significant portion of the errors was associated with Forward Observer (FO) operations; i.e., the FO's ability to locate his position (by conventional map-spot techniques) and his ability to measure range and azimuth to a target (by conventional map and compass and range estimation techniques). (See Technical Memorandum 24-70, "Human Engineering Laboratories Battalion Artillery Test," by Messrs. Horley and Giordano, dated September 1970.) It was recommended that additional tests (HELBAT II) be undertaken . . . "to examine equipment and procedural methods for Forward Observers that would improve the FO's ability to locate himself . . .". HELBAT II was conducted in February 1971 at Fort Hood with the First Armored Division Artillery acting as the Test Unit. As in HELBAT I, M-109 self-propelled 155-mm howitzers were employed for all firing, and standard Field Artillery procedures were used for Artillery surveys, Fire Direction Center operations, and Firing Battery activities. Forward Observers were divided into three types depending on the equipment and techniques they were to use. "Conventional" Forward Observers had a 1/50,000 scale line map and an M-2 compass to use for positioning themselves and all targets. "Laser" Forward Observers employed a Laser Rangefinder and special techniques to determine their own locations and target locations. "Super Laser" Observers were issued a Gyro-Azimuth Device in addition to a Laser Rangefinder. Super Laser and Laser Forward Observers also estimated their locations and target locations for all missions using a map and compass. Each of the four Battalions tested was in the field about 2½ days, and the Forward Observers moved to new positions three times during this period.

Through collaboration between HEL and ETL, a PF was subjected to evaluation during HELBAT II for its potential Field Artillery applications and, specifically, for its potential to reduce the errors in the FO's ability to locate himself, thereby improving the effectiveness of Artillery fire.

II. INVESTIGATION

3. **Test Site.** HELBAT II was conducted on the firing range at Fort Hood, Texas. All firing during the test was conducted in the western half of the range with the FO's occupying observation posts located on hills surrounding the Impact Zone. The total area of operations covered approximately 10 by 14 kilometers. The PF was positioned on Manning Mountain at the western edge of the Impact Zone.

All accuracy analyses for HELBAT II operations were based upon fourth-order Artillery surveys.

4. **Equipment Description.** The PF was comprised of non-militarized, commercially available components consisting of a 525 Balplex Stereoplotter interfaced with a digitizing system sold commercially by Keuffel and Esser Company (K&E) under the tradename "Traverscan" System. The "Traverscan" System consists of a Bendix Data Grid, a Nova Computer with accompanying software, and a Teletypewriter (Fig. 1). The system was installed in an M-109 Van (Fig. 2). Inside dimensions of the van are approximately 10 by 7 by 6.5 feet.

a. **525 Balplex Stereoplotter.** The Balplex Stereoplotter consists of three precision projectors, a support bar and frame, a tracing surface, and a tracing table. The instrument occupies an area approximately 56 by 42 inches and is less than 70 inches in height.

The Balplex Stereoplotter is designed for map compilation using overlapping aerial photographs taken with a 6-inch focal length, cartographic camera having a 9 by 9 inch format. These photographs must be reduced to 110 by 110 millimeters and printed on glass plates by a special printer. A plate-centering device is used to position the glass plates within their holders before the plates and holders are put into the projectors. The projectors each have six degrees of freedom, or modes of movement, which enable the operator to orient the projectors so that they have the same relative position with respect to each other and the plotter table that the aerial camera had with

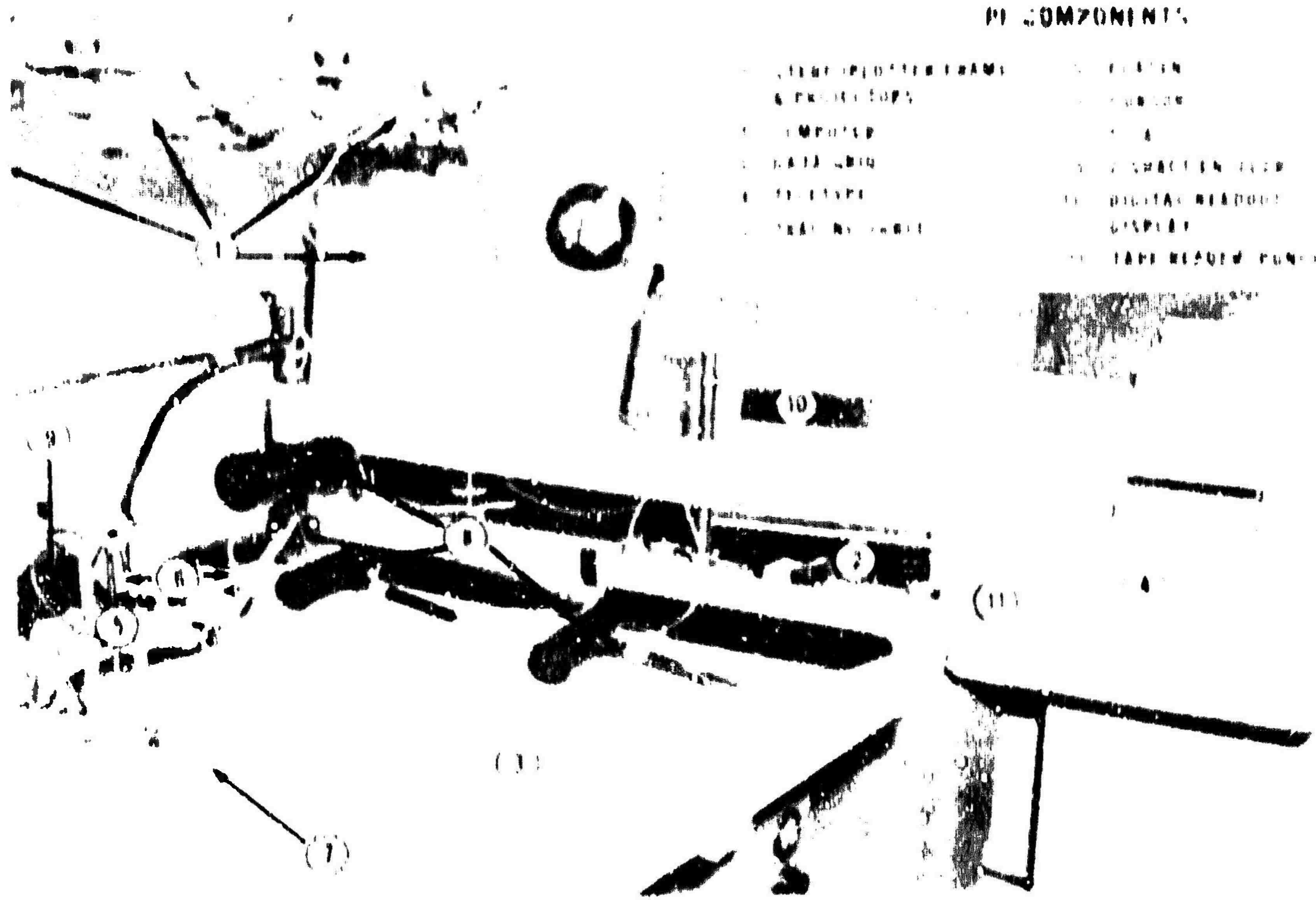


Fig. 1. Photogrammetric facility components.

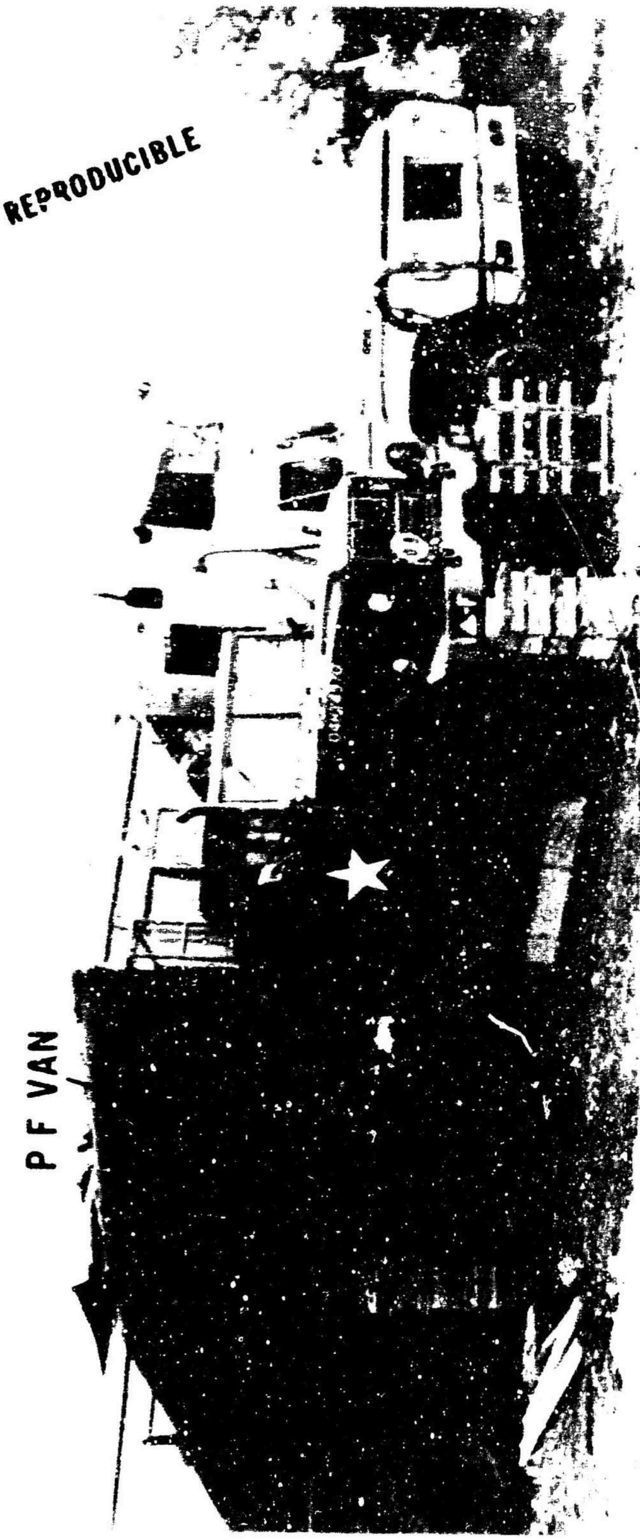


Fig. 2. PF field setup.

respect to the ground when the photographs were taken. The projected imagery from the overlapping photographs can then form a 3-dimensional stereomodel of the original photographs.

The operator achieves a stereo view of the terrain photographed by using a special viewing system called the Stereo Image Alternator (SIA). The effect of the SIA is to permit only one eye to see an image from only one projector at any instant. This is accomplished by using synchronous motors to rotate slotted cylinders. By alternating the images viewed in this manner, the operator is provided a stereoscopic view of the terrain photographed.

The operator uses a tracing table for making 3-dimensional measurements in the stereomodel. The table contains a horizontal surface (platen) on which the projected imagery is viewed and which has at its center a small hole that is illuminated from below to serve as a reference dot for measuring the stereomodel. The reference dot can be moved horizontally by moving the entire tracing table, and the dot can be moved vertically by means of a knob on the back of the tracing table which causes the platen to be raised or lowered. Horizontal positions can be recorded on the tracing surface by means of a pencil lead which is located directly below the reference dot.

b. **Traverscan System.** The Traverscan System consists of a Bendix Data Grid, a Nova Computer, a Teletypewriter, and accompanying software. It is, for the most part, mechanically independent of the stereoplotter. There are two items which are attached directly to the tracing table. One is a Z-shaft encoder which measures the elevation of the tracing table platen. This value corresponds directly to sea level elevations in the stereomodel. The other item is a cursor which is mounted at the base of the tracing table and is centered on the reference-light dot on the platen. This cursor emits an oscillating signal which is picked up by the Bendix Data Grid.

The Bendix Data Grid is used to replace the conventional table-top surface of the stereoplotter, and its function is to sense horizontal coordinates taken from the stereoplotter. As the cursor, which is mounted on the tracing table, moves across the top of the tracing surface, the signal which it is emitting is picked up by a matrix of wires which is embedded in the Data Grid. The position of the cursor with respect to the Data Grid is digitized to a precision of 0.001 inch, and these values correspond to horizontal positions in the terrain model.

The X, Y, and Z digitized signals are supplied to a Nova Computer which provides a 2-dimensional rotation, a translation, and a scaling operation to express Data Grid coordinates from the Stereomodel in terms of UTM coordinates and sea level elevations. The software also provides a polar mode of operation where the operator can determine the range and azimuth between any two points in the stereomodel.

The Teletypewriter will print out all resultant data, and, if desired, it will punch out all data on paper tape. These data are also displayed on a digital read-out device. The teletype is also used to enter into the computer data which determines the rotation, translation, and scaling that the computer is to perform. The Nova Computer has a nonvolatile memory; but, should the need arise, it can be reprogrammed using punched tape read by the Teletypewriter.

The equipment requires about 30 square feet of floor space and about 6 feet of headroom. The total weight of all of the equipment is approximately 600 pounds.

The equipment was operated using military, 10-kw generators or a truck-mounted, 6-KW commercial generator. The equipment requires about 4 KW of power for normal operation.

5. **Data Base.** The term "Data Base" is used to define the topographic materials and data that are needed for the operation of the PF. In the case of HELBAT II, the Data Base consisted of "Giant Scale" photographic coverage of Fort Hood, Texas, and the ground coordinates of points required to establish the stereomodels in the Balplex Stereoplotter. Copies of the original photography were made by the Topographic Production Center (TPC) of TOPOCOM on glass plates suitable for use with the stereoplotter. Three plates were required because the HELBAT II area fell in the center of one photograph and, therefore, on the edge of two stereomodels.

It was originally planned that the TPC would establish the ground control needed to orient the stereomodels in the plotter. In this process, TPC marked and measured the photographic images of survey control points that could be identified on the photographs and also other points for which ground coordinates were desired. These data were used in a block triangulation computation to determine the UTM coordinates and elevations of well-defined terrain features throughout an area covered by six Giant Scale photographs. The initial results of the triangulation were not as accurate as could normally be expected and were, therefore, not used. The data from later triangulation attempts proved more accurate but were not available prior to HELBAT II.

Only two stereomodels were required to cover the HELBAT II area; and normally, survey control in the vicinity could be used for orienting the stereomodels in the Balplex stereoplotter. Stereomodels formed in the Balplex using Giant Scale photographs are, however, at a small viewing scale; and positive identification of survey control points is very difficult. Also, the control at Fort Hood is primarily concentrated along the southern boundary of the reservation and, therefore, is not adequately dispersed to be suitable for model orientation in a second-order stereoplotter such as the Balplex.

As an expedient, it was decided to triangulate the necessary control data using the AS-11A stereoplotter. The AS-11A is a first-order instrument and it has a zoom optical system which permits large scale viewing to aid in the point identification process. The two stereomodels that covered the HELBAT II test area were oriented in the instrument to survey control points that could be identified on the photographs; and with this accomplished, the instrumental coordinates of other well-defined and well-dispersed terrain features (road intersections primarily) were read and recorded. The instrumental coordinates of the survey control points were compared with their known values to determine the transformation required to convert instrument coordinates to UTM values. This transformation was then applied to the other unknown points (15 in all) to determine their UTM coordinates. These data were used during HELBAT II to control the stereomodels in the Balplex Stereoplotter.

6. **Graphic Materials.** The graphic materials used in HELBAT II represented a hasty design of a graphic aid for use in conjunction with the PF. These graphic materials, called Photopacs, were prepared from the same aerial photography (data base) used to make the glass plates for the Balplex projectors. Each Photopac consisted of 21 photographs, one film overlay, and a cover sheet. There was one index photograph of about 1/60,000 scale which included all the forward observer positions and the target area. The index photograph was covered by a 4-centimeter grid which had its lines running approximately North-South and East-West. Each grid square had a letter designation on the film overlay (Fig. 3). For each of the labeled grid squares on the index photograph, there was an enlargement of about 1/16,000 scale. These enlargements also had a 4-centimeter grid on them with the North-South lines designated by a number (1, 2, 3 . . . , etc.) and the East-West lines designated by a letter (A, B, C . . . , etc.) (Fig. 4). The 4-centimeter grid size was chosen because it is the standard size grid for a 1/25,000 scale map, and this made it possible to use standard map coordinate scales for determining coordinates. One sample point is indicated on Figs. 3 and 4. The resulting product was a small book of photographs. The photographs were on a substance called Chronapaque—a tough, film-based type of printing paper. Each page was 10 by 10 inches, and the book was approximately ¼-inch thick Chronapaque was used rather than regular photographic printing paper because of the extremes of weather and the hard usage the photographs would probably be exposed to.

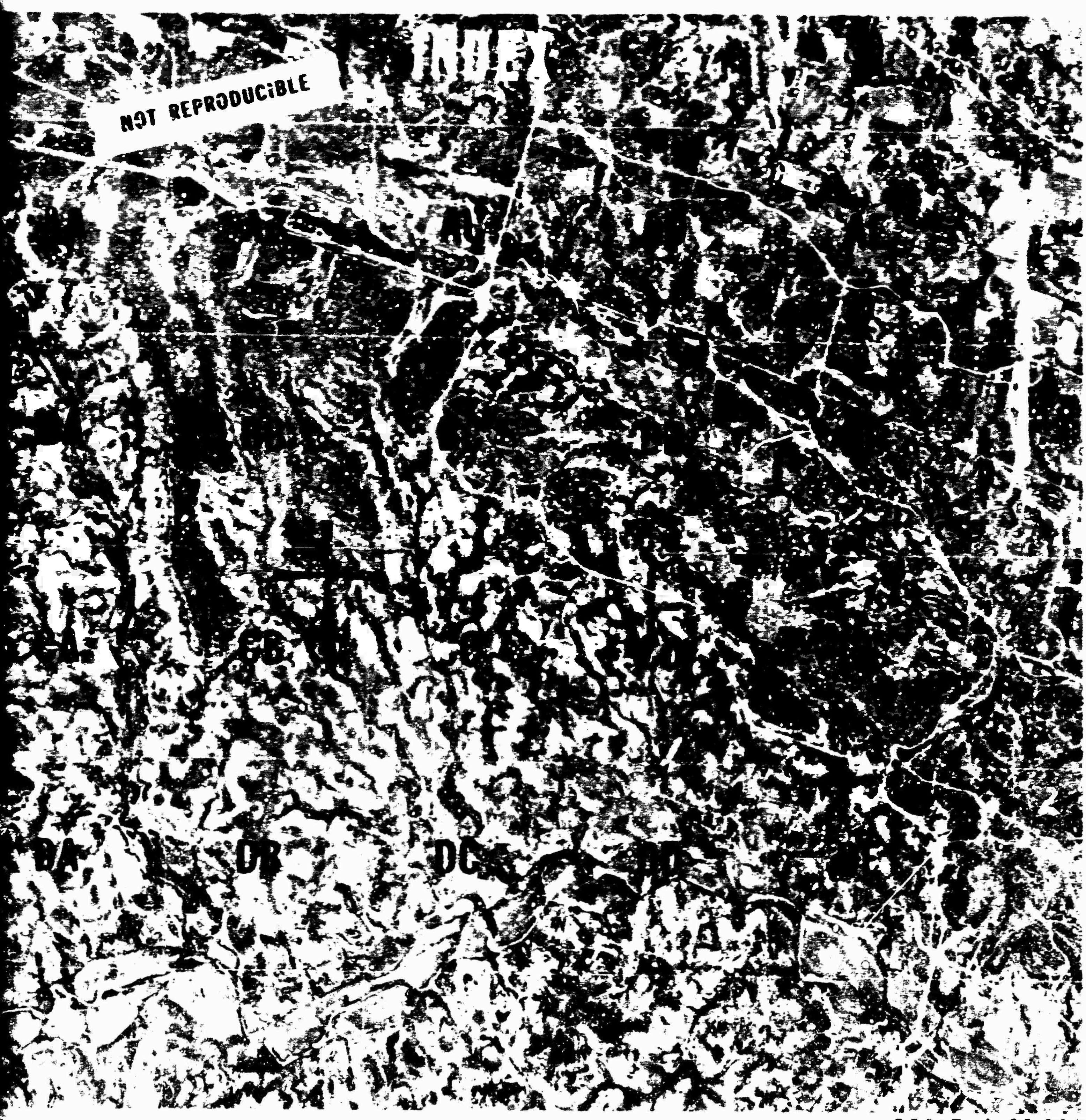
7. **Training.** Two different types of training were required for the HELBAT II operations. The first type of training was that which was provided for the men who were to actually operate the PF during HELBAT II, and the other type was given to the Forward Observers who were to provide input data to the PF through the use of the Photopac.

a. **PF Operators.** The men who were to operate the PF during the test were able to spend about 6½ days actually working with the equipment at Fort Belvoir before

A

Fig. 3. Photopac index photograph.

B



SCALE: 1/60,000

Fig. 3. Photopac index photograph.

A

NOT REPRODUCIBLE

CB

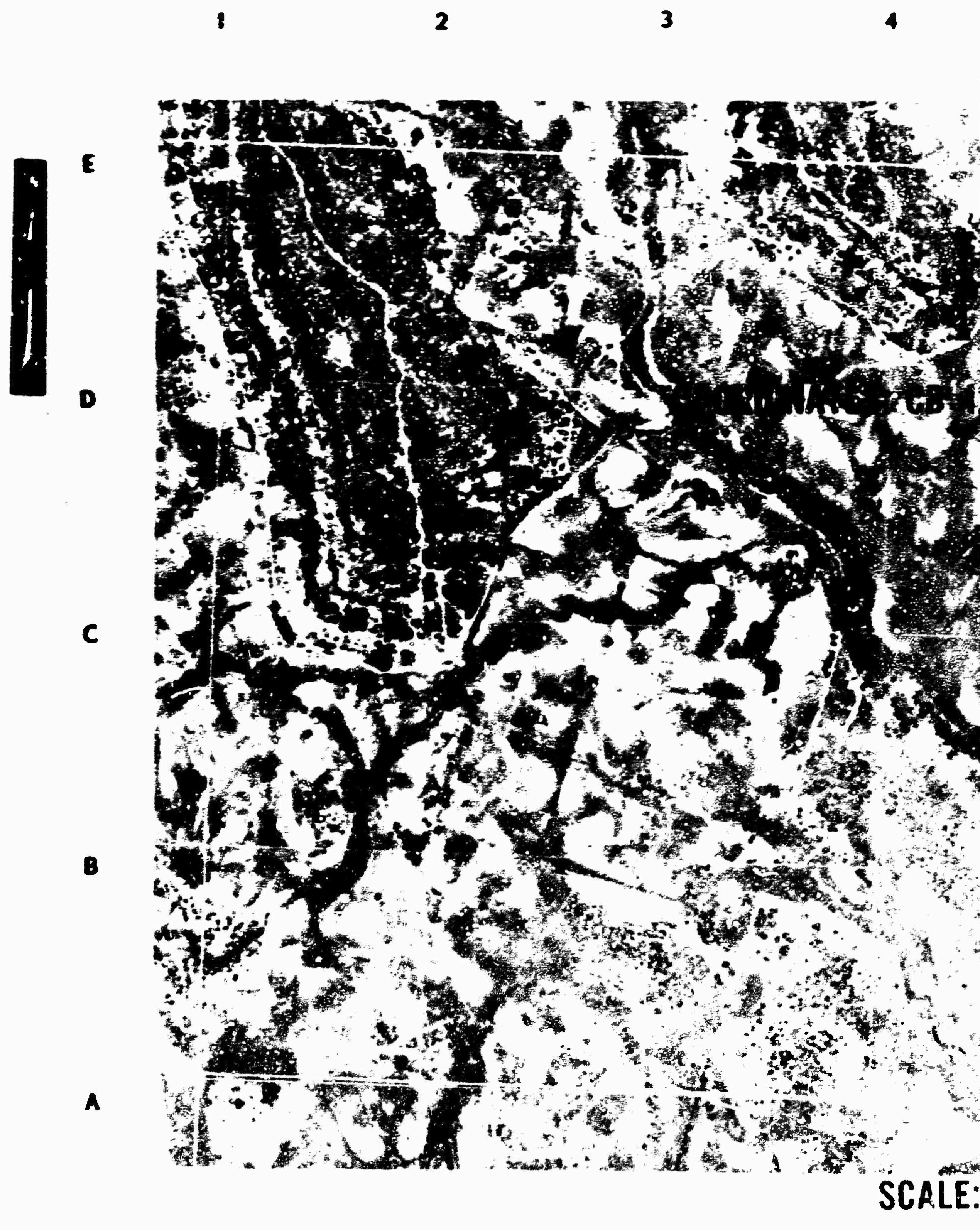


Fig. 4. Photopac enlargement.

C B

B

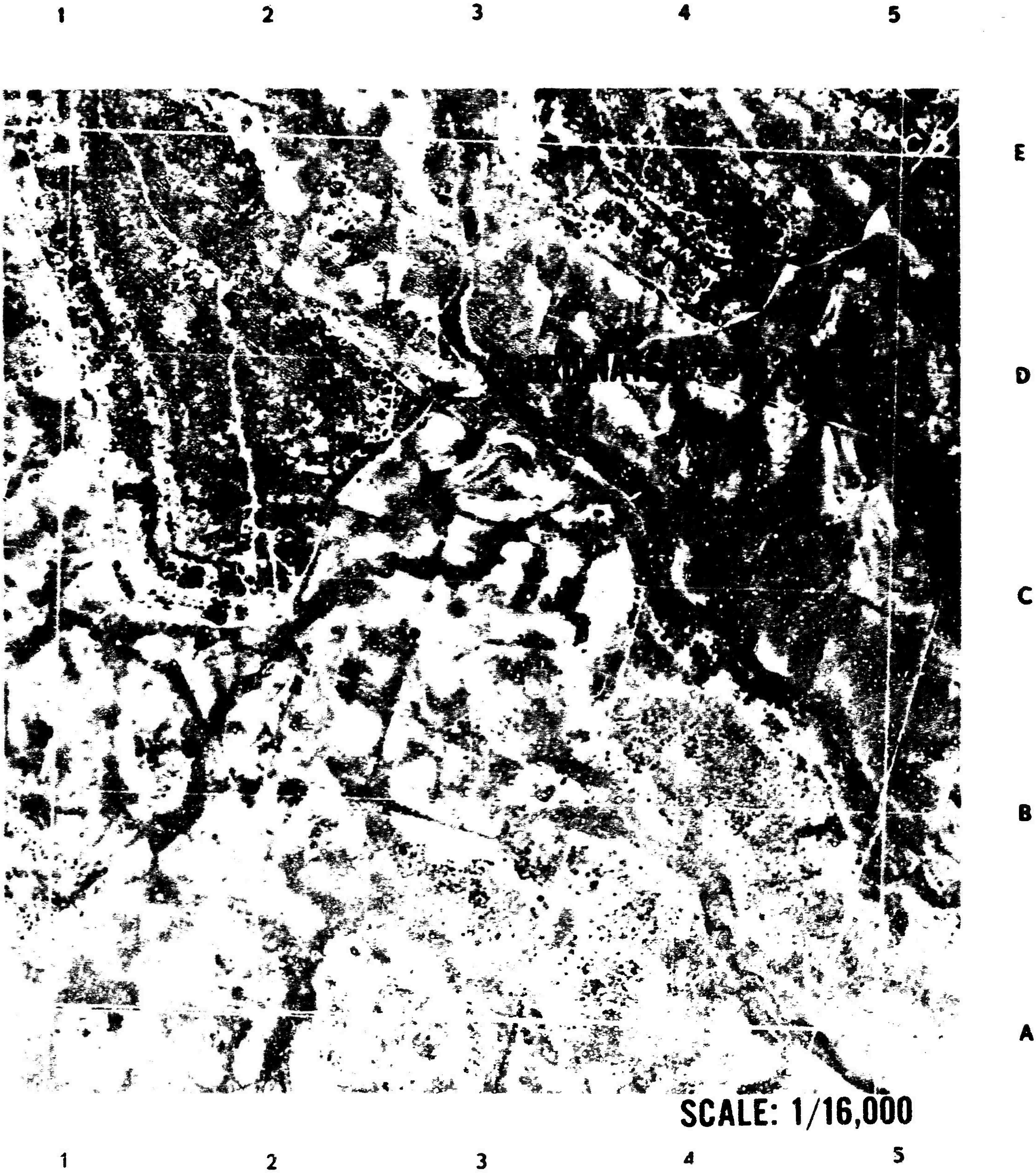


Fig. 4. Photopac enlargement.

it was shipped to Fort Hood. Four enlisted men from the 30th Engineer Battalion (Base Topo) arrived at ETL on 11 January 1971 to begin training on the PF. All of these men had previous military training and experience with stereoplotting techniques and equipment. Their initial training consisted of a general introduction to the PF concept, HELBAT II, and related background information. Their work on the actual equipment was also preceded by some training in radio procedures and familiarization with the Photopac.

The training on the PF equipment covered all phases of the operation including setting up and orientation of the stereomodel, entering computer control values for the model, and reading in computer program tapes. Several days were spent practicing the image matching technique and becoming generally familiar with the area covered by the stereomodel. The procedure used during this period was similar to that which was expected to be used during the actual test. One man would choose any point in one of the enlargements in the Photopac and scale off its coordinates. These coordinates were then told to the other man who replotted the points in their own Photopacs. After plotting the points on their photos, the men went to the stereomodel and determined the coordinates of the point which they had plotted. These UTM coordinates and the visual location of the points were then compared to the location as determined by the person who originally picked the point.

At the end of the training period, two of the four men who had been trained were selected to actually participate in HELBAT II at Fort Hood.

b. **Forward Observer Training.** The FO's received different amounts of training depending on whether they were "Conventional" FO's, "Laser" FO's or "Super Laser" FO's. The "Conventional" FO's were those who had only a 1/50,000 scale topographic line map and an M-2 Compass to use for determining locations. The "Laser" FO's used a Laser Rangefinder along with their map and compass. The "Super Laser" FO's had an ARK-1 Gyrocompass as well as a Laser Rangefinder, map, and compass. The "Conventional" FO's were inadvertently excluded from about 3/4 of the training given to the other FO's because they did not need to receive any special training from the HEL personnel before the test.

The Laser and Super Laser FO's received a total of about 1 hour of training. This was split into three sessions. The first session, which lasted about ½-hour, consisted of an introduction to the PF concept, the equipment, and the associated graphic aids. The Super and Laser FO's were shown the PF equipment, and the procedure for its use was explained to them. They were told how to extract coordinates from the Photopacs and how to use the stereograms which they had been given. Photopacs, coordinate scales, grease pencils, stereograms, and glasses were issued to the Super and Laser FO's during this period.

The second training period, which lasted about 15 minutes, also included only the Super and Laser FO's. It consisted, primarily, of a check to see if they understood how to scale coordinates from the photographs in the Photopac.

The third training session lasted about 15 minutes and included all of the FO's from each Battalion. One of these sessions was conducted for each Battalion's FO's just before they moved out to their observation posts. This period constituted the only training received by the Conventional FO's, and it was during this session that they saw the Photopac and the stereogram for the first time. This was primarily a general review of the procedure for scaling coordinates from the Photopacs.

8. **Operational Procedures.** The PF was employed principally for determining observation posts and target coordinates; but the determination of Battery Centers through the use of Polaroid photographs taken from a helicopter and the image-match technique and setting up check-points for use with the Improved Position Locator (IPL) were also examined.

a. **Observation Post and Target Location.** The operational procedure which was employed to determine Forward Observer/Observation Post Locations or target locations was essentially the same. The procedure was as follows:

(1) Forward observer plotted his position or target position on what he believed was the correct enlargement in his Photopac.

(2) Forward Observer then scaled off the photo coordinates of the point plotted as his position or target position using normal procedure for determining map coordinates by measuring first the Easting and then the Northing.

(3) HELBAT controller then recorded the photo coordinates on the data card for that mission.

(4) Data cards were collected when controllers came in from the field and the photo data was copied.

(5) Points were then plotted in Photopacs at the PF.

(6) Using an image matching technique, point in photograph image was found in stereomodel.

(7) Computer then gave printout of UTM coordinates and elevation of point.

This procedure was repeated for each data sample which was recorded.

b. **Location of Battery Centers.** Another procedure which was tried was to use the image-match technique in conjunction with Polaroid photographs taken from a helicopter to locate battery centers. The procedure was as follows:

(1) A Polaroid picture was taken of a Firing Battery from a helicopter at an altitude of approximately 500 feet and an angle of 45 to 60 degrees from the vertical.

(2) The prints were returned to the PF.

(3) The approximate Battery location was found in the stereomodel and the location of the Battery Center was estimated.

(4) A computer printout of the UTM coordinates and the elevation of the estimated Battery Center were obtained.

c. **IPL Checkpoints.** Several checkpoints were established along an Improved Position Locator (IPL) route as references in an attempt to evaluate the effect of varying types of terrain on the accuracy of the IPL. These checkpoints could be expected to be accurate within 20 meters.

III. DISCUSSION

9. **General.** The principal benefit resulting from utilization of the PF in HELBAT II came in the form of exposure of the system and concept to a large number of Field Artillery personnel. In general, the visitors to the PF during HELBAT II were very enthusiastic about its potential applications. This interest was expressed by men at all levels of command, and the primary point of discussion was not whether a capability such as that demonstrated by the PF should be made available to the Field Artillery, but rather, the organizational level at which this capability should be deployed.

As a test for the PF concept and equipment, HELBAT II was of somewhat less value because the PF was considered for HELBAT II only a short time before the test. Because of this, the PF had to be accommodated in an established Test Plan. Consequently, the PF was not an integral part of HELBAT II but was given a role for subjective evaluation rather than a rigorous operational test. Data for the PF was gathered primarily on a noninterference basis, which meant that at some times the FO's were able to take their time and do a careful job and at other times they had to rush so that they could start planning their next mission. The near total lack of training of some FO's in the utilization of aerial photographs with the point designation coordinates in conjunction with the pressure to work rapidly undoubtedly compromised performance. One result of the general lack of emphasis on the PF during the training period preceding the test was that many of the FO's seemed to feel that the PF and their data for it was the least important part of their involvement in HELBAT II.

10. Data Analysis. HELBAT II produced the first data which can be used to evaluate the PF's potential applications within the Field Artillery. There were two types of missions for which sufficient data were collected for numerical analysis: (1) where the FO determined his own locations using the Photopac; and (2) where the FO determined target locations in the same manner. Although these exercises did require use of the image-matching technique by the PF operators, the primary result was an indication of the capability of the FO to use aerial photographs (Photopacs) to determine locations in the field. Because the primary emphasis in these Forward Observer missions was on the FO's capability to determine locations using aerial photographic imagery, an attempt was made to determine whether any of the resulting errors were caused by carelessness in scaling and recording coordinates or other human errors rather than an inability to accurately pinpoint a location within the imagery.

a. Analysis Procedure. The same general procedure was used in the evaluation of data for both Forward Observer and target location missions. As was previously mentioned, the photo coordinates which the FO's had recorded in the field were taken to the PF, and UTM coordinates were determined through the image-match process and the computer readout. These UTM coordinates of observation posts and targets were then compared with fourth-order artillery surveys which had been run to all observation posts and targets. The survey data was used as the basis for all error analyses. The variations in Easting and Northing were converted to radial errors, and then individual standard deviations were calculated using all of the data for each of the two types of missions. Those data samples which were found to be greater than three times the standard deviation were considered to be outliers and were excluded from the calculation of the mean radial error and the RMS.

b. Forward Observer Location. The forward observer location errors of the FO location missions are as follows:

Number of Missions	37
S. D. (All)	119m

3 Samples > 3 x S. D.

MEAN RADIAL ERROR	RMS
67m	93m

The data from four missions were discounted because they were proven to contain errors which resulted from carelessness in scaling and recording coordinates rather than from an inability to determine the O.P. location on the photograph. In three cases, these errors were the product of a combination of carelessness and the configuration of one enlargement in the Photopac. Three of the data samples, found to be greater than three times the standard deviation, were considered outliers and were not used to calculate the mean radial error and the RMS. These three data samples constituted approximately 8% of the total data. Figure 5 shows the distribution of radial errors from the Forward Observer location missions.

c. **Target Location.** The results of the target location missions are as follows:

Number of Missions	210
S. D. (All)	647m

15 Samples > 3 x S. D.

MEAN RADIAL ERROR	RMS
604m	786m

All of the data were assumed to be valid, because it was impossible to determine conclusively whether any were compromised purely through improper scaling techniques.

Fifteen data samples, or about 7% of the total, were found to exceed three times the standard deviation and were considered outliers. The distribution of the radial errors is shown in Fig. 6.

d. **Battery Center Location.** Only a small amount of data were collected on the process of determining the coordinates of firing battery centers by using Polaroid snapshots of the batteries taken from helicopters. The only results obtained were arrived at while the computer was inoperable; and, even then, only two exercises were performed.

11. **Test Results.** Utilization of the PF in HELBAT II yielded what should be considered indications rather than conclusive results. The basis for this statement is discussed in paragraph 9.

a. **Equipment.** Considering that the equipment which comprised the PF was commercial, off-the-shelf equipment, it performed quite well during HELBAT II. ETL originally stated that the equipment would require environmental control (65° to 75° F temperature and 35 to 55% humidity) when operating, but it was soon discovered that these constraints could not be met at Fort Hood during the test. The temperature in

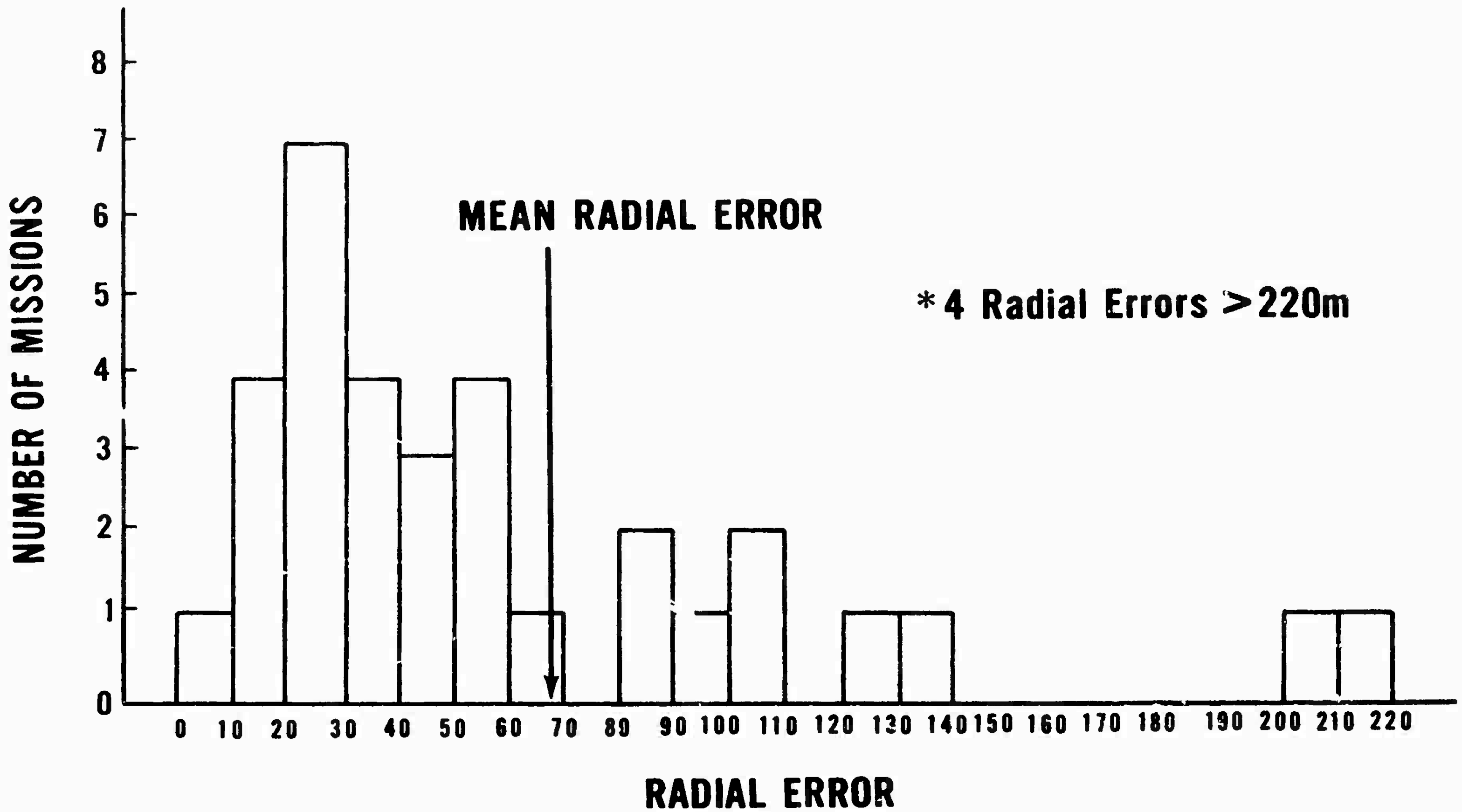


Fig. 5. Forward Observer Location Errors.

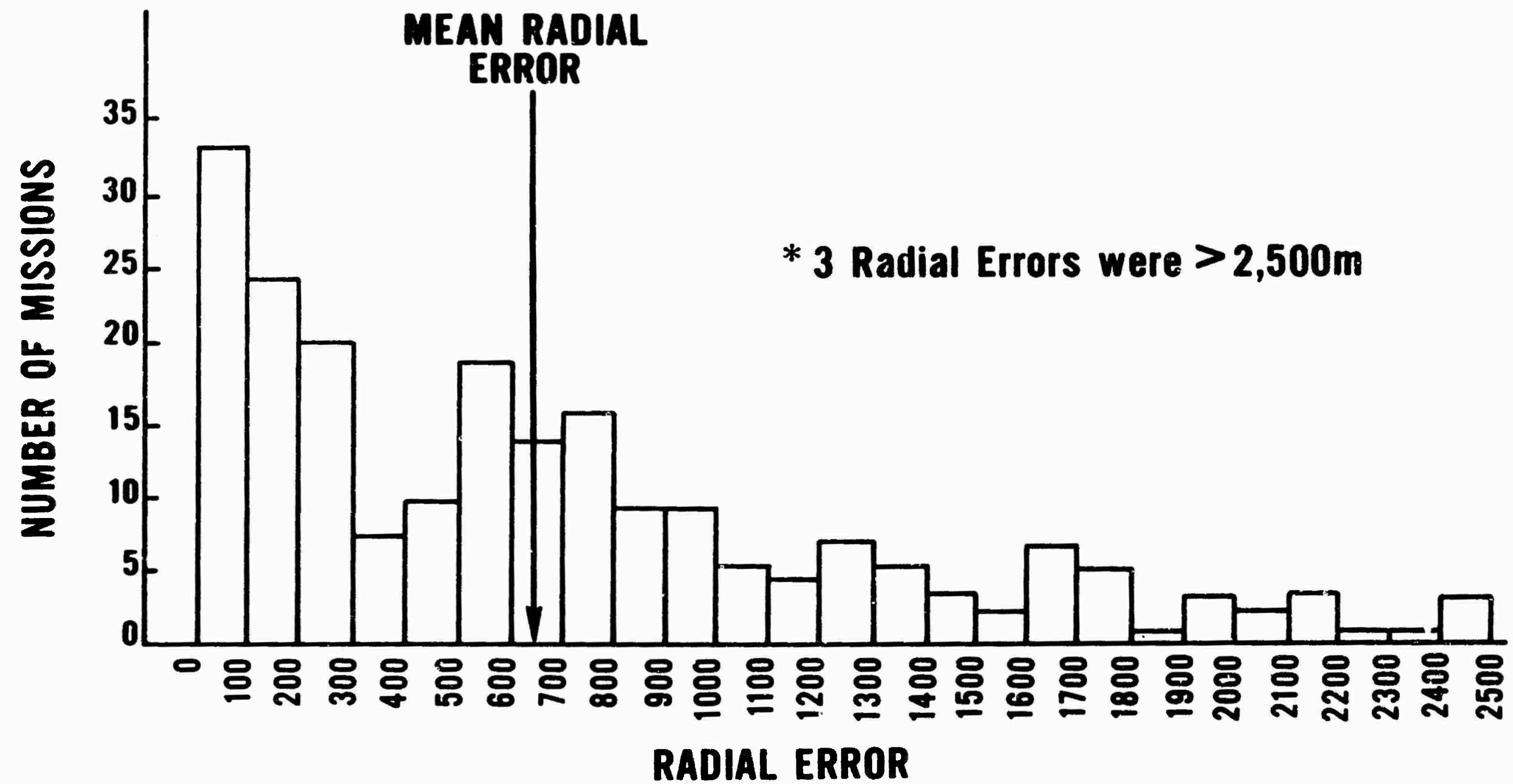


Fig. 6. Target Location Errors.

the PF Van ranged from about 45° to 95° F, and the humidity varied by about 50%. The Balplex Stereoplotter and the SIA functioned perfectly at all times, but operating difficulties were experienced with the Traverscan System at both temperature extremes. Humidity variations did not seem to affect the equipment. Dust was also abundant, but it was not possible to determine if it affected the equipment.

The equipment was subjected to several power losses and at least one series of surges as a result of generator operator error. The computer apparently had a partial memory loss as a result of one generator stoppage, but the program tapes were read-in after several attempts and the system resumed normal operation. The power supplied to the equipment ranged from about 10? volts to 120 volts. It was discovered that the computer would not function properly at less than 109 to 110 volts.

The PF Van and equipment were moved several times while at Fort Hood. Each move called for partial disassembly (removing the projectors from the frame) and bracing of all equipment which required about 30 minutes to complete. Several hours were required to reset the Stereomodel and resume operation after moving. The time required for setting up the model would have been greatly reduced if the new computer program which would eliminate the need for scaling the Stereomodel had been received.

A serious computer malfunction occurred three days before the test was scheduled to end. A technical representative from Keuffel and Esser (K&E) came to Fort Hood to correct the problem. This malfunction may have resulted from the operating conditions, but this assumption cannot be stated definitely at this time.

The Stereoplotting Equipment functioned perfectly during the entire test. Before HELBAT II, there was some question about how well the delicate projectors would stand up to dust, extreme temperature and humidity variations, and movement in a military vehicle. The results were very encouraging, and even the constant flow of visitors in and out of the PF Van and the rocking of the Van by the wind which was expected to cause problems in keeping the projectors aligned had negligible effect.

Detailed tests of the accuracy of ground (UTM) coordinates determined by the PF were not possible, although some survey control which could be identified by personnel stationed at Fort Hood was compared to the listed survey coordinates. The coordinates as determined by the PF varied from the survey data by about 6 to 12 m in Easting and Northing.

The experience gained from participation in HELBAT II led to the conclusion that several equipment modifications would help to improve the overall efficiency and effectiveness of the PF. Some of the suggested changes are:

(1) Ruggedized teletype

(2) Continuous visual coordinate readout

(3) Better balance for the tracing table and a larger platen

(4) Heater/air conditioner to stabilize environmental conditions

(5) Method of permanently fastening Bendix Data Grid to Stereoplotter frame.

b. **Graphic Materials.** One area in which HELBAT II was expected to shed some light was the capability of people without any photo interpretation (PI) experience to make effective use of aerial photography in the field. Most of the people who were exposed to the Photopacs during HELBAT II had no previous experience with aerial photography. Their degree of success in using the Photopac seemed to depend more on attitude and the desire or lack of desire to perform well than on any other factor. That the Photopacs could be used successfully was first demonstrated by personnel from HEL prior to this start of HELBAT II. It was necessary for the HEL people to determine the best routes to all of the OP's to be used during the test, and they soon discovered that the 1/50,000 scale line maps which they first tried to use were of little help. After being given Photopacs, these men, none of whom had previous PI experience, were able to find every OP without difficulty. On the other hand, there were several cases where the FO's made gross positioning errors simply through carelessness. In one instance, the FO held the Photopac upside down while measuring coordinates thus introducing approximately a 650 m error in both Easting and Northing (each grid square on the enlargements was approximately 650 x 650 m). In at least three other cases, FO's correctly identified their positions on the index photograph but then scaled off coordinates for a different ground feature on the enlargement because in their haste they chose a prominent feature which happened to be in the center of the enlargement rather than their actual position which was up in one corner. (See point indicated in Figs. 3 and 4.)

In general, the design of the HELBAT II Photopac was somewhat less than ideal. The primary problem was that the small area covered by an individual enlargement seemed to confuse some of the users. This was particularly true for target location missions because there were relatively few features in the impact area which an FO could use to help orient the photographs. Also, the loss of resolution which resulted from the 10X enlargement of the original photography to the 1/16,000 scale used for the enlargements caused some difficulty for the inexperienced users. HELBAT II indicated that in future experiments it might be wise to test graphics which are printed on a larger size base material to include a larger area and are printed at a slightly smaller scale (say 1/25,000) to improve resolution.

c. **Operational Procedures.** Since HELBAT II provided the first field test of the PF concept, there were no established operational procedures to follow. These procedures were, therefore, established and revised as the test progressed. It became evident that the primary problem with respect to the operational setup in HELBAT II stemmed from the absence of direct communication between the FO's and the PF. This situation made it difficult to evaluate the responsiveness of the PF to incoming data. Those data which were relayed back to the PF by the Div Arty umpires at the OP's were frequently different than the corresponding information on the HELBAT data cards. Another benefit which direct communciation with the FO's would have produced became apparent when the photo coordinate data were being processed at the PF. In many cases, the coordinates which an FO had given as being those of his own position were found to be in error as soon as they were located in the Stereomodel. They were obviously in error because the points were located either in such a low position that they would not be chosen as observation posts or else they were in such a position that the observer could not possibly see the area of interest which he had been assigned. Had direct contact been established, the FO's could have been told to check and/or correct their location estimate.

HELBAT II experience provided a basis from which techniques and procedures can be developed for future tests.

d. **Potential Applications.** Quite a few possible applications for the PF concept have become evident as a result of its development and exposure. Those which became most obvious during HELBAT II include the following:

(1) **Forward Observer/Observation Post and Target Location.** Use of the PF in conjunction with graphics given to the Forward Observer has shown definite promise, and it is felt that a man with some photo interpretation training or experience could use aerial photograph imagery to even greater advantage. The table shows a comparison of the mean radial errors achieved during HELBAT II by Forward Observers using 1/50,000 scale line maps alone and the Photopac in conjunction with the PF.

Comparison of Mean Radial Errors

	Photopac/PF	Line Map (1/50,000)
F. O. Location	67m	97m
Target Location	604m	479m

The poor results in the target location missions using the Photopac are difficult to evaluate. Much of the error probably was caused by the difficulty of working with the small area covered by the enlargements, but other factors were also involved. The first two Battalions tested had a target location RMS of 463 m, but the introduction of data from the last two Battalions resulted in a total RMS of 786 m for the four Battalions. Aside from some inclement weather conditions which the final Battalion was exposed to, there is no apparent reason for the extreme degradation of accuracy. More testing, particularly with other types of graphics, is required to determine the value of aerial photographic products in the field.

(2) **Battery Center Location.** The feasibility of using reconnaissance photography of emplaced firing batteries to determine battery centers was demonstrated during HELBAT II. The photography used was taken by a Polaroid camera in a helicopter. The photography was difficult to use because of the poor resolution and the oblique nature of the photography necessitated by the small field of view of the camera. Nevertheless, in those instances where it was attempted, location of the area in the Stereomodel was achieved. With higher quality, wide angle lens cameras and panelled points, this procedure could probably be accomplished very satisfactorily.

(3) **Establishing Reference Points.** Reference points for use with the Laser Resection techniques or techniques using Lasers and Azimuth Determining Instruments can be established by the PF. Although the PF was not used to establish reference points for use in these procedures during HELBAT II, the techniques proved to be very accurate for determining FO locations when reference points established by fourth-order Artillery Survey methods were used.

(4) **IPL Checkpoints.** The accuracy and range of the IPL can easily be complemented by the PF. Any point which can be identified in the Stereomodel and on the ground can be used as an initialization or check point for the IPL.

(5) **Terrain Analyses.** The Stereomodel can be used to perform general terrain analyses, route reconnaissance, situation studies, etc., since all information in the aerial photograph imagery is viewed in three dimensions.

(6) Unit Boundaries, No-Fire Lines, etc., can be established and the coordinates of their boundaries determined with the PF.

These are just the principal Field Artillery applications which were discussed during HELBAT II and by no means do they represent all of the potential applications for PF-type equipment.

IV. CONCLUSIONS

12. Conclusions. It is concluded that:

a. The experience of HELBAT II has reinforced the belief that photogrammetric equipment and techniques can be used in the field to help provide solutions to many Field Artillery survey/positioning problems as well as to provide a source of terrain information to be used in making command decisions.

b. By subjective analyses, the capabilities offered by deployment of a Type PF go beyond Field Artillery positional needs and, in fact, have appliation to many Field Army operational needs.

c. Analyses of test results and operating procedures indicate that for future testing, improvements can be made with regard to the data base materials, the PF hardware and software components, and the associated graphic materials which should result in enhanced capability and utility.

d. Personnel with no experience in using aerial photographs should at least be given some familiarization in photo interpretation techniques before being expected to make use of them in the field.