Technical Note 2-77

FOUR SURVEY-TYPE PROGRAMS FOR USE WITH A PROGRAMMABLE POCKET CALCULATOR (HP-65)

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March 1977

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Four programs for use with an HP-65 programmable pocket calculator are presented. The programs perform survey-type computations: Program 1 computes grid coordinates of an unknown point (a target or the point-of-impact of a round) based on the intersection of all pairs of azimuth rays from three known observation points to the unknown point; Program 2 is similar to Program 1 but uses only two observation points and computes grid coordinates to a higher degree of accuracy than Program 1; Program 3 computes grid coordinates of an unknown point given distance, azimuth and slant angle to a known point—data which can be obtained using a laser range finder on a mount which provides a readout of azimuth and slant angle; Program 4

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computes range and azimuth from point A to point B, two known points. The programs were designed to provide an in-the-field data processing capability for experimenters conducting mortar and artillery indirect fire experiments, but can assist Army survey teams in preparing "Trig." lists of target grid coordinates in an impact area, or in providing flash support to mortar or artillery units undergoing training tests. As formatted, the programs can be used only with one calculator, the HP-65. With suitable modifications, other calculators might accept the programs, and programs similar in nature to these might find application by other users.

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FOUR SURVEY-TYPE PROGRAMS FOR USE WITH A

PROGRAMMABLE POCKET CALCULATOR (HP-65)

INTRODUCTION

The programs described in this report were developed in January 1975 for use in the HEL Mortar System Test (HELMST) (1) to provide a data processing capability under certain stringent conditions. First, we wanted to compute quickly and easily grid coordinates of mortar round points-of-impact using flash data, grid coordinates of an unknown point using range and azimuth from a known point, and the distance and azimuth between two known points; as well as perform simple arithmetic computations. Second, we wanted to perform the computations at various areas within the test site where there were no telephone lines and no reliable source of AC power. Third, the device on which the computations would be performed had to be readily transportable so that computations could be performed both on-site during the day and at quarters in the evening.

Meeting these requirements dictated a small, lightweight, battery operated, programmable calculator with a non-destructable memory. Although many calculators could meet most of the requirements, all but one forgot the programs typed into memory as soon as the on-off switch was turned off. Only the newly introduced (February 1974) HP-65 calculator could fulfill all of the requirements.[a] This hand-held calculator contains a small built-in magnetic tape recorder which allows programs to be stored on a small magnetic card for later use.

In addition to use in HELMST, these programs were used extensively during the more recent HELBAT 5 (3) and HELBAT 6 (4), and will most likely be used in future indirect fire experiments conducted by the U. S. Army Human Engineering Laboratory (HEL). Hopefully, the programs will enjoy use by other experimenters concerned with indirect fire; but, their use is not solely restricted to this role. They can greatly assist Army survey teams in preparing "Trig Lists" of target locations in an impact area or in providing "flash" support to artillery and mortar units undergoing training tests.

To provide an understanding of how and why these programs should be used by survey teams for the above purpose requires a description of the survey team's methods for acquiring and processing the data. The following also describes what is meant by "flash data" and the type of problem the first two of the four programs are designed to handle.

[a]Subsequent to the introduction of the HP-65, a calculator with similar characteristics, the SR-52, was developed by Texas Instruments. Working independently of HEL, International Laser Systems developed programs similar to those described here for use on the SR-52 (5). Most likely, other (and perhaps more powerful) pocket calculators will be developed which could accept these programs with some modification.

The grid locations of unknown points in an impact area, such as a target and fall-of-shot point-of-impact, are typically measured using flash techniques whereby an aiming circle (or other azimuth measuring device) and a trained operator are positioned at a number of observation points, and azimuths to the target or round impact are obtained. Azimuths are usually measured with respect to grid north or other suitable reference point when determining target locations, and with respect to the target for fall of shot (unless there is no real target or the target's center is not easily discerned). Flash triangulation is illustrated in Figure 1.

For fall of shot, the azimuth data are relayed to a control center and plotted. The center of the polygon formed by the intersection of all pairs of azimuth rays from the observation positions (OPs) is determined graphically and used as an estimate of the actual location of the point of impact. The accuracy of the grid coordinates and, therefore target miss distance, obtained in this manner are to a large degree dependent on the size of the plotting board, the size of the azimuth scale, and the sharpness of the data recorder and his pencil.

Target locations are computed more precisely than fall of shot; Trig lists usually show target grid coordinates measured to the nearest centimeter. Although quite precise, the accuracy of the grid coordinates is often questionable. In a number of HEL artillery field experiments for which survey teams measured target location prior to the experiment, subsequent data analysis revealed survey errors in meters, tens of meters and hundreds of meters. In HELMST, a preliminary and a final list of target coordinates were provided by a survey team. Target coordinates on both lists were precise to the nearest centimeter, but for almost all targets the coordinates differed between lists by at least a few meters. Azimuth measurements from OPs, obtained by test controllers (and using programs 1 and 2) provided a third and still different set of coordinates which we believe to be the more reliable (accurate and precise) estimate of the true target locations.

The inaccuracy of the survey team data arises in part from the archaic "brute-force" computational techniques used by the survey teams, where precision is governed by the number of decimal places in a trigonometric table, and accuracy is an unknown quantity which depends on the human computer's ability to perform lengthy manual computations. Obviously, survey teams could benefit from the introduction of more modern computational methods—which would not only provide more accurate data, but might ultimately result in a net savings in man-hours per calculation, which would in turn more than pay for the acquisition of modern computational devices.

PROGRAMMING THE CALCULATOR

Implementing the following programs requires that the user have only a basic understanding of the HP-65 calculator. We will only provide information necessary to input, store and use the program. A more complete description of the calculator and its usage is contained in the "Owners Handbook" (2).

The calculator keyboard and display are shown in Figure 2. The top row of keys are used to divide a stored program into special subroutines (or functions) such that depressing either of keys A through E initiates the portion of the program defined by that key; which we will refer to as "stored under label A through E."

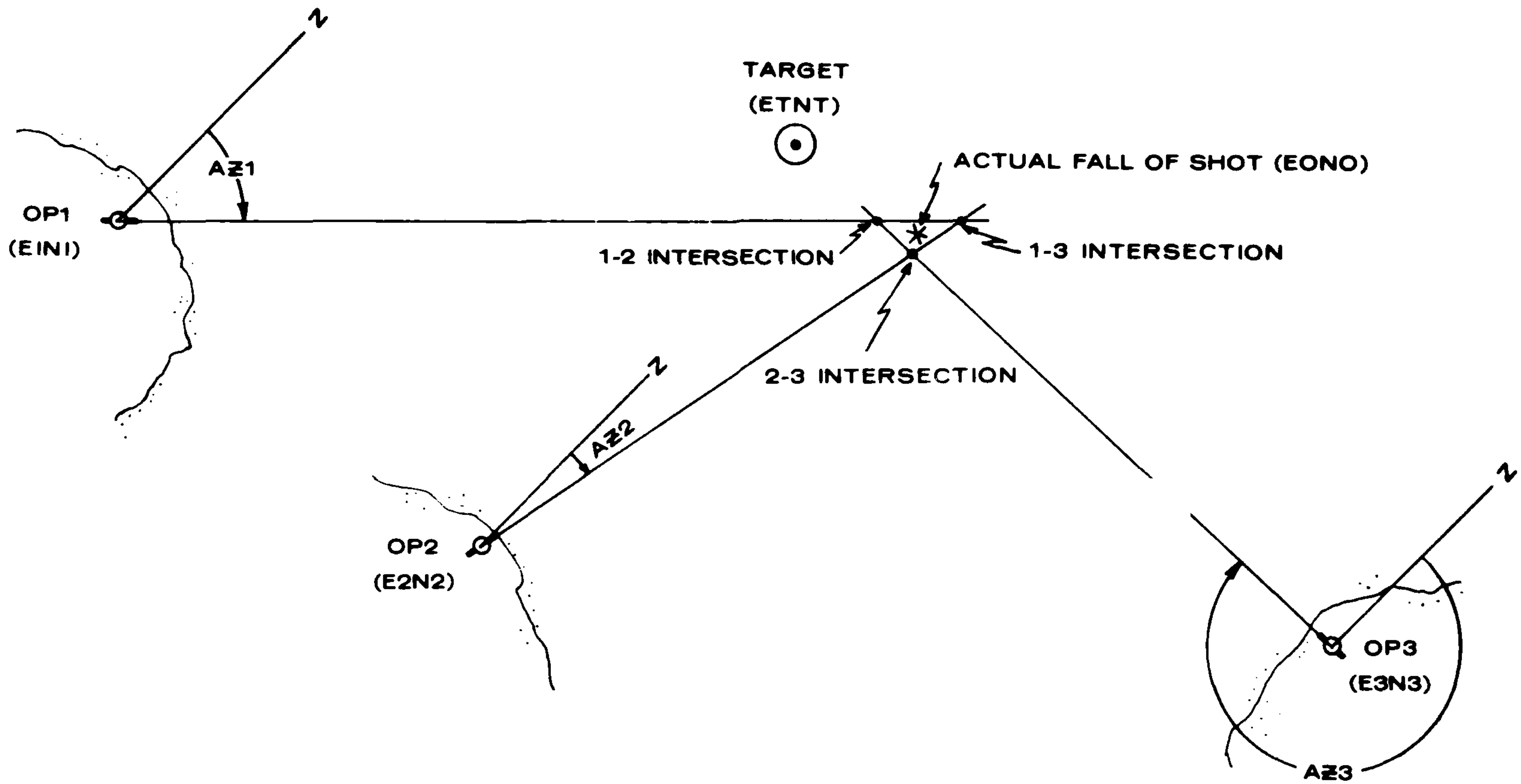

Figure 1. Flash triangulation.

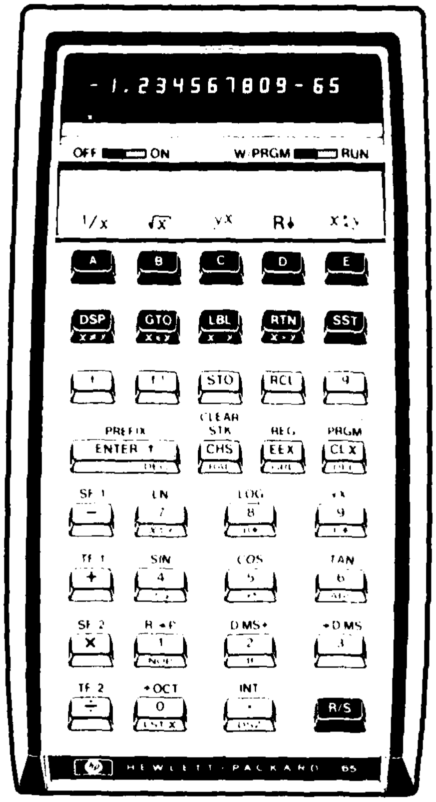

Figure 2. HP-65 calculator keyboard and display.

Some of the lower row keys are imprinted with either numbers, letters or symbols on the forward slope of the keys or above the keys as well as directly on the keys. Thus, each key can be defined up to three ways. The keys are "normally" defined by the label imprinted directly on the key. Depressing either "f" or "f^{-1}" activates the function indicated by the label above the key (or redefines the key) and depressing "g" activates the function shown on the forward slope of the key.

When operating the calculator in the run mode, the display shows data input on the keyboard and the results of computations. When in the write or program mode ("W/PRGM") the display shows codes which identify buttons. Pressing keys labeled "0" through "9" results in a display of "01" through "09." The code for each of the other keys identifies the row and column in which the key is located. For example, "SST" is located in row 2, column 5, and when pressed, the display reads "25."

To program the calculator, turn the off-on switch to "on" and the W/PRGM-Run switch to "W/PRGM." The display will show 00 00, which indicates "top of memory" (where the blank space between the two sets of zeros indicates a blank space in the display). When any individual key is pressed, the two zeros on the right are replaced by the appropriate key code and the left-most zeros are replaced by blanks; e.g., depressing "5" results in "05" in the display and depressing "+" results in "61" in the display. Two key strokes are combined into one display (and one programming step) when depressing either "STO" (33) or "RCL" (34) followed by "1" through "8," or "g" (35) followed by "0,1,7,8,DSP,GTO,LBL, or RTN"; e.g., "g" followed by "9" is displayed as "35 09."

Program 1 (Figure 3) will be used as an example in the following description of how to program the calculator:

The "program forms" (Figures 3, 5, 7 and 8) have three columns labeled "key entry," "code shown" and "comments," the meanings of which are self explanatory (and the first two of which were previously described). The first two key entries in Figure 3 "LBL," "C," define the portion of the program, or function, stored under this label. This function terminates at the thirteenth step from the bottom of the page, after which Label A is defined. Pressing any one of the keys A through E causes that portion of the stored program to run. Use of these keys in a stored program are described for each of the programs.

To input and store the program, set the two switches to "On" and "W/PRGM" respectively, and then to clear memory, press "f" (31) and "PRGM" (00 00); the latter being the label above the "CLX" button. Next, type in the key entries shown in the program, starting with the upper left and ending with the bottom right key entry shown on the program form, while observing and comparing the code shown in the display with that shown in column two of the program form.

If a single button push error is made, the entry can be deleted and replaced with the correct entry by pressing "g" (35), "DEL" (00 00), followed by the correct button.

After entering all steps of the program, the stored program should be checked for correctness. To do this, set the W/PRGM-Run switch to "RUN," press "RTN" and set the switch back to "W/PRGM." This sets the "program pointer" to the first step of the program; for Program 1, the display should read "23." Pressing "SST" moves the pointer down one step and changes the display accordingly; e.g., pressing "SST" once causes the display to read "13," the second step of the program. Continue pressing "SST" and compare each new display with the code shown in the program form. A mismatch between the two indicates a programming error. Depending on the type of error, the error can be corrected in one of three ways. First, you can clear the entire program—by clearing the memory as previously described—and then start over from the beginning. Second, a button-push error can be changed as previously described so long as the pointer is at the error (and the display is showing the code identified with the error). If the pointer has been advanced beyond the error, it should be returned to the beginning of the program and stepped through until it reaches the step which is to be corrected. Third, if one or more program steps were not input to the programs, they can be inserted by placing the program pointer to the step preceding the one(s) which were not input to the program and then pressing the desired buttons. For example, if step 9, "X" (71) was not input to the program, return the pointer to step 8, "RCL 4" (34 04) and press "X" (71). This step will now be inserted in the program between "RCL 4" and "-."

After verifying the program stored in memory, the program should now be stored on a magnetic card. To do this, enter (an unsecured) card into the lower slot on the right side of the calculator. The small motor drive will pick up the card and drive it through the slot on the left side of the calculator. Next, by clipping off the upper left edge of the card, the program on the card cannot be erased or written over and is therefore "secured." Now the calculator can be turned off.

To input and run a program stored on a magnetic card, set the W/PRGM-Run switch to "RUN" and insert the magnetic card into the lower right slot of the calculator. When the card exists from the left, place the card in the upper right-hand slot of the calculator so as to cover the labels above keys A through E. The program is now ready to run.

The labels on each program card should be identified as shown in Figures 3, 5, 7 and 8 to differentiate between programs and to assist the operator when running a program.

MATHEMATICAL SUBROUTINES

Mathematical subroutines used in all of the programs fall into two categories: angular conversion and azimuth ray intersection. Referring to the appropriate program forms (Figures 3, 5, 7 and 8) will assist the reader in understanding how the subroutines are used in each program.

Angular Conversion

Use of built-in calculator functions in the programs—which are rectangular to polar conversion (f, R→P), polar to rectangular conversion (f^{-1}, R→P), and tangent (f, Tan)—require an angular conversion. Whereas angular data input to or output from these functions are in cartesian degrees, the programs require that all angular data be in artillery mils. The conversion is accomplished in two steps: first, a magnitude conversion, and second, a reference point conversion.

Cartesian degrees are measured counterclockwise from grid east and there are 360 degrees to a full circle. Artillery mils, on the other hand, are measured clockwise from grid north and there are 6400 mils to a full circle. The following relationship is used to convert from one system to the other in magnitude only: mils x 9 ÷ 160 = degrees.

When correcting slant range for slant angle under label C in Program 4 using the polar to rectangular conversion, the magnitude conversion from mils to degrees is all that is required.

A change in reference point is required when computing the easting and northing component of range and azimuth under label B in Program 4. This is done by subtracting 90 degrees from the above answer ((mils x 9 ÷ 160) - 90).

when computing the azimuth from A to B in Program 3, the angle in mils obtained from the rectangular to polar conversion under label C is converted to mils under label D. For this conversion, we first change the point of reference (450 - degrees = W). Next, to ensure the final answer is less than 6400 mils we subtract 360 degrees from W, if W is greater than 360. Finally, W is converted to mils in magnitude, where degrees X 160 ÷ 9 = mils.

When computing the slope of the azimuth rays in both Program 1 (under label A) and Program 2 (under label E), mils are converted to degrees in magnitude before obtaining the tangent of the angle. The required 90-degree reference point conversion is accomplished by obtaining the inverse of the tangent (g, 1/x), which is the cotangent.

Azimuth Ray Intersection

In computing the point of intersection for each pair of azimuth rays in Programs 1 and 2, the line from each of two OPs to the unknown point is expressed in the slope intercept form and then solved for the intercept.

The lines from the OPs are:

(1) M1 (X1-X0) = Y1 - Y0, for OP1, and

(2) M2 (X2-X0) = Y2 - Y0, for OP2

In these equations we define the following:

M1, M2 = the slope of the line from OP1 and OP2, respectively.

X1, Y1; X2, Y2 = the coordinates of OP1 and OP2, respectively.

X0, Y0 = the coordinates of the intercept, the unknown point.

Subtracting 2 from 1 above, we obtain

(3) M1X1 - M2X0 - M2X2 + M2X0 = Y1-Y2.

Substituting B1 = Y1-M1X1 in 3 and solving for X0 we obtain

(4) X0 = (B1-Y2 + M2X2) / (M2-M1), where all quantities on the right side are known. After solving for X0, we substitute the answer into 1 and solve for Y0, where

(5) Y0 = B1 + M1X0.

PROGRAM 1—FLASH TRIANGULATION USING THREE OPs

Program 1 computes the three sets of grid coordinates of an unknown point as determined from the intersection of an azimuth ray from each of three known OPs to the unknown point. The grid coordinates determined from the 1-2, 1-3 and 2-3 intersections (computed in the order shown) must be recorded manually by the operator and subsequently averaged. This can be done using the mathematical functions provided by the calculator (add and divide) without disturbing the program. The program listing is shown in Figure 3.

The program can accept only five digits each for easting and northing of an OP (because of program step limitations). In preparing data for entry into the program, all grid coordinates must be rounded off to the nearest meter and only the last five digits to the left of the decimal point of each coordinate retained.

The truncation procedure poses no problem so long as all of the OPs have identical sixth digits (to the left of the decimal point) in easting and identical sixth digits in northing. If not, the coordinate(s) must be adjusted to avoid erroneous answers. The adjustment is easily accomplished by adding (or subtracting) multiples of 10,000 to either easting or northing (or both) of all OPs so as to arrive at identical sixth digits. However, whatever number is added must be subtracted from the resultant answers (or vice versa).

When performing a series of computations involving three OPs, the grid coordinates of the OPs need be stored (in registers one through three) only for the initial computation. The three storage registers are undisturbed during any program computations.

Keyboard computations can be performed at the completion of any data entry (i.e., at the completion of either of steps one through six) and intermediate answers stored in any register not previously used to store data (where there is a one-to-one correspondence between data entry steps and storage register numbers).

After a complete program computation (i.e., after computing all three intersections), intermediate answers for keyboard computations can be stored in any register except registers one through three.

Because grid coordinates are rounded off to the nearest meter, answers should be recorded only to the nearest meter. Therefore, after entering the grid coordinates the operator should set the display accordingly; i.e., DSP.0. If it is necessary to check the stored grid coordinates, the operator should reset the display to five decimal places (DSP.5) in order to view the stored northing coordinate.

If computations involving four OPs are desired, the computations can be performed using a procedure similar to the one described under Program 2 for three OPs. However, this involves much "data juggling" and therefore a high probability for operator error.

A sample data sheet for this program, which was developed for use in HELMST, is shown in Figure 4. For that experiment, angular data to fall-of-shot was measured in mils deviation (abbreviated DEV. in Figure 4) referenced to the target. Therefore, deviation and target azimuth had to be added together to obtain azimuth to the point-of-impact (AZ. to RD. in Figure 4) before entering these data in the program.

HP-65 Program Form

Program #1 Flash Triangulation Using Azimuth from Three OPs

KEY ENTRY	CODE SHOWN	COMMENTS
LBL	23	Computes 1-2 (and 2-3)
C	13	Intersection
RCL 1	3401	E1.N1
B	12	Extract N1
RCL 1	3401	E1.N1
f	31	
INT	83	Take Integer Part, E1
RCL 4	3404	M1
X	71	
-	51	N1-(M1XE1) = B1
STO 7	3307	
RCL 2	3402	E2.N2
B	12	Extract N2
-	51	B1-N2 = J
RCL 5	3405	M2
RCL 2	3402	E2.N2
f	31	
INT	83	Take Integer Part, E2
X	71	
+	61	E2 x M2 + J = k
RCL 5	3405	M2
RCL 4	3404	M1
-	51	
÷	81	k ÷ (M2-M1) = E_0
R/S	84	**Stop/Disp E_0**
RCL 4	3404	**M1**
X	71	**M1XE0 = L**
RCL 7	3407	**B1**
+	61	**L + B1 = NO**
STO 8	3308	
f	31	If registers 3 & 1 and
TF1	61	4 & 6 switched, then
g 1	3501	**restore them to**
E	15	original condition
f-1	32	
SF1	51	Set flag 1 to "off"
RCL 8	3408	NO
RTN	24	Stop/Disp NO
LBL	23	Converts artillery azi-
A	11	muth to cartesian deg.
9	9	
X	71	
1	01	
6	06	
0	00	
÷	81	Convert **mils** to degrees
f	31	
TAN	06	Slope (Az reference)
g	35	
1/x	04	Slope (M1)

KEY ENTRY	CODE SHOWN	COMMENTS
RTN	24	
LBL	23	
B	12	Extracts N from E.N
f-1	32	Decimal Part of E.N.
INT	83	N x 10^{-5}
EEX	43	
5	05	
X	71	Convert to N
RTN	24	
LBL	23	
D	14	Computes 1-3 Intersection
RCL 7	3407	B1
RCL 3	3403	E3.N3
B	12	Extract N3
-	51	B1-N3 = J
RCL 6	3406	M3
RCL 3	3403	E3.N3
f	31	
INT	83	Take Integer Part, E3
X	71	
+	61	E3 x M3 + J = k
RCL 6	3406	M3
RCL 4	3404	M1
-	51	
÷	81	k ÷ (M3 - M1) = E0
R/S	84	Stop/Disp E0
RCL 4	3404	M1
X	71	M1XE0 = L
RCL 7	3407	B1
+	61	L + B1 = NO
RTN	24	RTN/Disp NO
LBL	23	Sets C to compute
E	15	2-3 intersection
RCL 1	3401	E1.N1 (OP1)
RCL 3	3403	E3.N3 (OP3)
STO 1	3301	
g 8	3508	(R↓) Switch Locations
STO 3	3303	of OP1 and OP3
RCL 4	3404	M1
RCL 6	3406	M3
STO 4	3304	
g 8	3508	(R↓) Switch locations
STO 6	3306	of M1 and M3
f	31	
SF1	51	Set test flag to "on"
2	02	
3	03	
RTN	24	RTN Disp "23"
g 1	3501	(NOP)
g 1	3501	(NOP)

REGISTERS

Register	Contents
R1	E1.N1
R2	E2.N2
R3	E3.N3
R4	M1
R5	M2
R6	M3
R7	Current y intercept
R8	No
R9	

LABELS

Label	Use
A	₥ → Deg.
B	
C	1-2 Int
D	1-3 Int
E	2-3 Int
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	

FLAGS

Flag	Use
1	Yes
2	

Figure 3 Program 1 Listing

PLATOON ____________

REP ____________

MISSION ____________

TARGET ____________

MORTAR ____________

ADJ/FFE ____________

PAGE ______ OF ______

OP NO.	HP-65		IMPACT		INTERSECTIONS	
	E	N	E	N	E	N
MAP GRID COORD.						
HP OP COORD.						
HP OP NO.	STO (1)		STO (2)		STO (3)	
OP AZIMUTH TO TARGET →		STO(4)		STO(5)		STO(6)
ROUND NUMBER	DEV.	AZ.TO RD.	DEV.	AZ.TO RD.	DEV.	AZ.TO RD.

	INTERSECTIONS			
	1-2	1-3	2-3	MEAN
E				
N				
E				
N				
E				
N				
E				
N				
E				
N				
E				
N				
E				
N				

Figure 4. Sample data sheet for Program I

PROGRAM 1–OPERATOR INSTRUCTIONS

PURPOSE: Calculate the grid coordinates of an unknown point (or target) as determined by the intersections of the OP-target lines. Since there are three OP's, the program gives grid coordinates for three intersections. These intersections are the 1-2, 1-3, and 2-3 intersections where the numbers given are the numbers of the OP's. If there are more than three OP's, all intersections can be determined by taking all combinations of OP's three at a time.

GIVEN: (1) The 10-place grid coordinates of three OP's.

(2) The azimuth (in mils from north) to a target from each OP.

METHOD: Ten-place grid coordinates must be used to enter OP location. The OP coordinates must be entered exactly as follows:

EEEEE.NNNNN

where EEEEE is the 5-digit easting grid coordinate and NNNNN is the 5-digit northing grid coordinate of the OP.

Note: Do not use exactly 3200 mils as an azimuth from any OP. If 3200 mils is given, add a small amount to the angle–for example, use 3200.01.

Arbitrarily assign numbers 1 through 3 to the OP's.

Place W/PRGM - RUN switch in RUN position

Load Program 1

Press DSP

Press . (decimal point)

Press 5

Step 1: Key in the coordinates of OP 1:

EEEEE.NNNNN Press STO; press 1

Step 2: Key in the coordinates of OP 2:

EEEEE.NNNNN Press STO; press 2

Step 3: Key in the coordinates of OP 3:

EEEEE.NNNNN Press STO; press 3

Step 4: Key in azimuth in mils from OP 1 to target:

mils Press A; press STO; press 4

Step 5: Key in azimuth in mils from OP 2 to target:

mils Press A; press STO; press 5

Step 6: Key in azimuth in mils from OP 3 to target:

mils Press A; press STO; press 6

Step 7: To get grid coordinates of 1-2 intersection:

Press C This gives easting coordinate

Press R/S This gives northing coordinate

Step 8: To get grid coordinates 1-3 intersection:

Press D This gives easting coordinate

Press R/S This gives northing coordinate

Step 9: To get grid coordinates of 2-3 intersection:

Press E

Press C This gives easting coordinate

Press R/S This gives northing coordinate

EXAMPLE

STEP	ENTRY	OPERATION	RESULTING DISPLAY
1	35000.51000	Press STO	35000.51000
		Press 1	35000.51000
2	39000.51000	Press STO	39000.51000
		Press 2	39000.51000
3	37000.57000	Press STO	37000.57000
		Press 3	37000.57000
4	800	Press A	1.00000
		Press STO	1.00000
		Press 4	1.00000
5	5600	Press A	-1.00000
		Press STO	-1.00000
		Press 5	-1.00000
6	3200.1	Press A	10185.89254
		Press STO	10185.89254
		Press 6	10185.89254
7		Press C	37000.00000
		Press R/S	53000.00000
8		Press D	36999.60726
		Press R/S	52999.60726
9		Press E	23.00000
		Press C	36999.60734
		Press R/S	53000.40000

PROGRAM 2–FLASH TRIANGULATION USING TWO OPs

Program 2, which is a modification of Program 1, provides a higher degree of accuracy in computing the grid coordinates of an unknown point than that provided by Program 1. This is done by allowing up to 10 digits each for easting and northing of the OPs as compared to five digits allowed in Program 1. However, in order to obtain the increased accuracy, the program is limited to only two OPs so as not to exceed the available storage registers or the allowable programming steps. The program listing is shown in Figure 5.

Because of the larger number of allowable digits for entry of OP grid coordinates, the need to re-reference grid coordinates, which can arise when using Program 1, is avoided in this program.

Although the program can accept data from only two OPs at a time, multiple intersections for azimuth rays from more than two OPs–for example OPs A, B, and C–can be obtained using the following procedure which minimizes the number of Key-strokes. First, input A and B data and compute the 1-2 intersection. Second, input C data using label B and compute the 1-3 intersection. Third, input B data under label A and compute the 2-3 intersection. Unfortunately, this same sequence must be followed for each new "unknown point."

HP-65 Program Form

Program #2 **Flash Triangulation Using Azimuths from Two OPs**

KEY ENTRY	CODE SHOWN	COMMENTS
LBL	23	
A	11	Stores E1 and N1
STO 3	3303	N1
g 8	3508	(R↓)
STO 1	3301	E1
1	01	
3	03	
RTN	24	RTN/Disp "13"
LBL	23	
B	12	Stores E2 and N2
STO 6	3306	N2
g 8	3508	(R↓)
STO 2	3302	E2
2	02	
6	06	
RTN	24	RTN/Disp "26"
LBL	23	Computes grid coord of
C	13	unknown point
E	15	Convert AZ2 to M2
STO 5	3305	AZ1
g 8	3508	(R↓)
E	15	Convert AZ1 to M1
STO 4	3304	AZ2
RCL 3	3403	N1
RCL 1	3401	E1
RCL 4	3404	M1
x	71	
-	51	N1 - (E1 x M1) = B1
STO 7	3307	
RCL 6	3406	N2
-	51	B1 - N2 = J
RCL 5	3405	M2
RCL 2	3402	E2
x	71	
+	61	E2 x M2 + J = k
RCL 5	3405	M2
RCL 4	3404	M1
-	51	
÷	81	k ÷ (M2 - M1) = E0
R/S	84	Stop/Disp E0
RCL 4	3404	M1
x	71	M1XE0 = L
RCL 7	3407	B1
+	61	L + B1 = N0
RTN	24	Return/Disp N0
LBL	23	Converts Artillery Azi-
E	15	muth to cartesian deg.
9	09	
x	71	
1	01	

KEY ENTRY	CODE SHOWN	COMMENTS
6	06	
0	00	Convert Mils to degrees
÷	81	in magnitude only
f	31	
TAN	06	Slope(w/AZ reference)
9	35	
1/x	04	Slope (m)
RTN	24	
g 1	3501	(NOP)

REGISTERS	
R_1	E1
R_2	E2
R_3	N1
R_4	AZ1
R_5	AZ2
R_6	N2
R_7	Current Y Intercept
R_8	
R_9	

LABELS	
A	E1↑N1
B	E2↑N2
C	AZ1↑AZ2
D	
E	m → Deg.
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	

FLAGS	
1	
2	

Figure 5. Program 2 listing.

PROGRAM 2–OPERATOR INSTRUCTIONS AND SAMPLE PROBLEM

PURPOSE: To find the grid coordinates of an unknown point (or target).

GIVEN: Grid coordinates of 2 OP's and the azimuth in mils from each point to the unknown point.

METHOD: Same as Program 1 except only 2 OP's are used and their grid coordinates can have up to 10 digits each for easting and northing.

Place W/PRGM - RUN switch in RUN position.

Load Program 2

Step 1: Enter easting coordinate of OP 1

Press ENTER ↑

Step 2: Enter northing coordinate of OP 1

Press A

Step 3: Enter easting coordinate of OP 2

Press ENTER ↑

Step 4: Enter northing coordinate of OP2

Press B

Step 5: Enter azimuth in mils from OP 1 to target

Press ENTER ↑

Step 6: Enter azimuth in mils from OP 2 to target

Press C

Display shows easting coordinate of target

Step 7: Press R/S

Display shows northing coordinates of target

EXAMPLE

STEP	ENTRY	OPERATION	RESULTING DISPLAY
1	35000.1	Press ENTER ↑	35000.1
2	51000.1	Press A	13.
3	39000	Press ENTER ↑	39000.
4	51000	Press B	26.
5	800	Press ENTER ↑	800.
6	5600	Press C	37000.
7		Press R/S	53000.

PROGRAM 3–LOCATING AN UNKNOWN POINT USING LASER RANGE FINDER (LRF) DATA

Program 3 was designed for use in field experiments which examined procedures whereby a forward observer adjusts rounds onto a target using a LRF on a mount which provides a readout of azimuth and (possibly) slant angle. Input data to the program are the known location of an OP and the following data for an unknown point: slant range measured with the LRF, azimuth, and as an operator option, slant angle. Using these data, the program computes the grid location of the unknown point (see Figure 6).

The unknown point can be either the target, or the point of impact of a round. If the location of the OP is unknown, it can be determined using this program if a known point is available. For this condition, the OP is the unknown point and all measured angles are back-angles.

The program can be used in conjunction with Program 1 in that entry of Program 3 into memory does not disturb the three registers which contain grid coordinates of OPs used in Program 1. If an operator, having performed computations using Program 1, desires to use Program 3, he need only insert the program into memory and can either recall one of the three OPs stored when using Program 1 or input the coordinates of any other OP as an entry for Program 4 computations. When finished with these computations, he can re-insert Program 1 into memory and not have to re-enter the three OP grid coordinates.

Because the range finding precision of a LRF is usually less than one meter (display limited), there is no need to enter grid coordinates to an accuracy greater than one meter. However, if high accuracy is desired, the program can be suitably modified to accept a maximum of 10 digits for both easting and northing of the known point as is done in Program 2.

Experience has shown that typical observer to target ranges are so large in comparison to elevation differences between target and OP that slant angle range corrections are usually unnecessary. Because of this, and to minimize the number of operator key strokes, the program provides the option of either correcting slant range for slant angle or not correcting for slant angle. When preparing to perform a series of computations from an OP, the observer should select a representative target with respect to slant angle and perform an initial set of computations to determine whether or not future computations require slant angle corrections.

In making this determination, the operator would first compute the location of the unknown point without correcting for slant angle (press "B"). He would record these coordinates, recompute coordinates corrected for slant angle (input slant angle, press "C") and compare the two sets of coordinates. If, based on a predetermined error criterion, it is determined that slant angle corrections are required for subsequent computations, the operator bypasses "B" and "C" and uses "E," which requires that both azimuth and slant angle be input. If subsequent slant angle corrections are not required, the operator uses "B " which does not require slant angle as an input.

The program listing is shown in Figure 7.

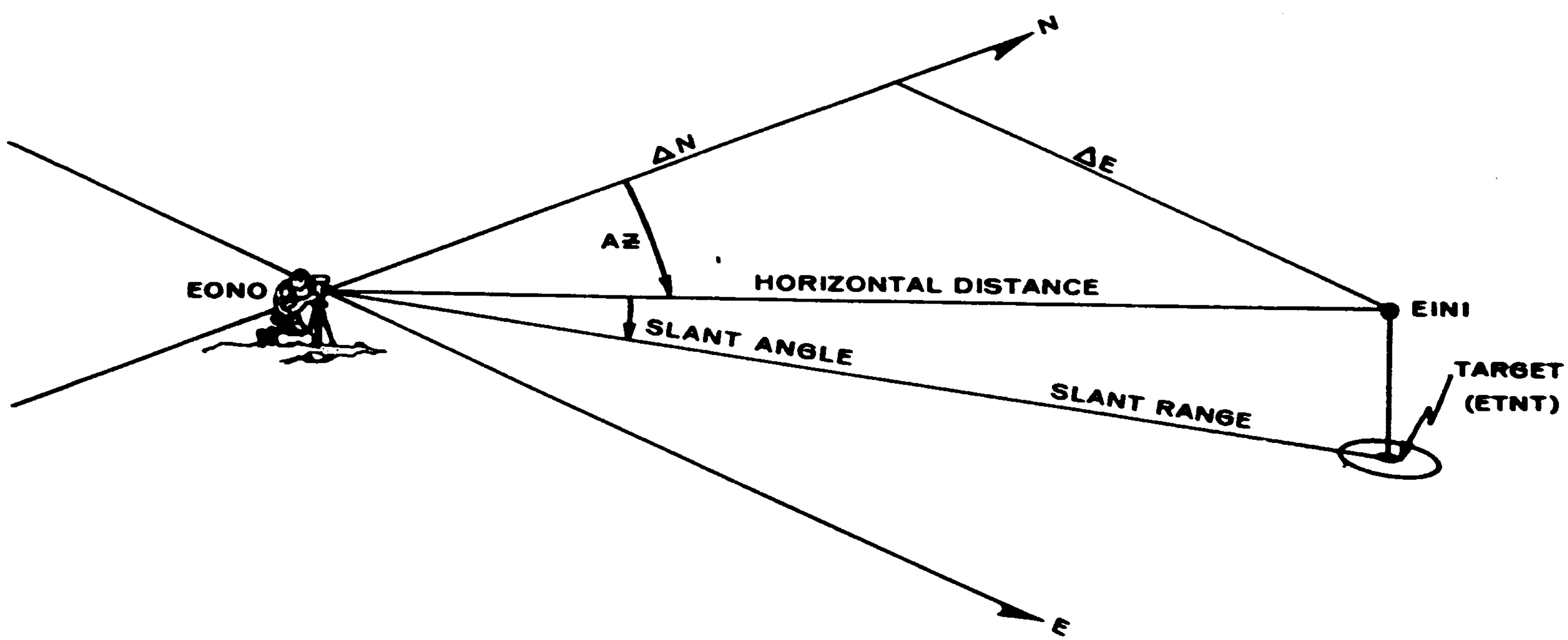

Figure 6. Locating unknown point with a LRF.

HP-65 Program Form

Program #3 **Locate Unknown Point Given Distance, Azimuth (and Slant Angle) from Known Point**

KEY ENTRY	CODE SHOWN	COMMENTS
LBL	23	Computes grid coord of
B	12	unknown point
STO 7	3307	**Range**
g 8	3508	(R↓) Roll Az into x
ENTER	41	register and into y
ENTER	41	register and into z reg.
9	9	
X	71	
1	01	
6	06	
0	00	Convert mils to degrees
÷	81	in magnitude only
4	04	
5	05	
0	00	
g 7	3507	(x ⇄ y) Refer degrees
-	51	to cartesian system
RCL 7	3407	Range
f-1	32	Polar to rect coord,
R→P	01	reference 0,0; Eo,No
RCL 8	3408	E1.N1
f	31	
INT	83	Take Integer Part, E1
+	61	E0 + E1 = E2
R/S	84	STOP/DISP E2
g 8	3508	(R↓)
RCL 8	3408	E1.N1
f-1	32	Decimal part of E1.N1,
INT	83	N1 x 10^{-5}
EEX	43	
5	05	
X	71	Convert to N1
+	61	N0 + N1 = N2
RTN	24	RTN/DISP N2
LBL	23	
A	11	Stores E1.N1
STO 8	3308	E1.N1
RTN	24	RTN/DISP E1.N1
LBL	23	Corrects range for
C	13	non-zero vert. angle
g 7	3507	(x ⇄ y)
CLX	44	
g 8	3508	(R↓) Vert. Angle into x
9	09	**reg., 0,0 into T reg.**
X	71	
1	01	
6	06	
0	00	Convert mils to degrees
÷	81	in magnitude only
RCL 7	3407	Range
f-1	32	Polar to rect. coord.,
R→P	01	reference 0,0, Eo No
g 7	3507	(x ⇄ y) Corrected range
g 8	3508	(R↓) in x reg.
GTO	22	
B	12	Execute B
LBL	23	
E	15	
g 8	3508	(R↓) Rng in x register
STO 7	3307	
g 9	3509	(R↑) Vert angle in x register
GTO	22	
C	13	Execute C
g 1	3501	(NOP)

REGISTERS
R
R
R
R
R
R
R Range
R8 E1.N1
R9

LABELS	
A	E.N
B	AZ↑RG
C	Vert. ∠
D	
E	AZ↑RG↑∠
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	

FLAGS	
1	
2	

Figure 7. Program 3 listing.

PROGRAM 3--OPERATOR INSTRUCTIONS AND SAMPLE PROBLEM

PURPOSE: To find the grid coordinates of a target if the distance, azimuth and vertical angle from a known OP are measured.

If the above data are measured from an unknown point to a known point, the unknown point can be determined by referring angular data to the known point; i.e., convert azimuth to back azimuth by adding or subtracting 3200 mils so as to obtain a back-azimuth less than 6400 mils.

OPTION 1: Given: Grid coordinates of the OP,

Azimuth to the target,

Distance to the target.

OPTION 2: Given: All of the above, plus

Slant angle, and

It is desired to correct coordinates obtained in Option 1 for slant angle and compare answers.

OPTION 3: Given: Grid coordinates of the OP,

Azimuth to the target,

Distance to the target,

Slant angle, and

It is desired to compute directly grid coordinates corrected for slant angle.

Place W/PRGM - RUN switch in RUN position

Load Program 1

OPTION 1: Press DSP

Press . (decimal point)

Press 5

Step 1: Enter grid coordinates of OP in 10-digit coordinates

EEEEE.NNNNN Press A

Step 2: Enter direction from OP to target in mils

mils Press ENTER ↑

Step 3: Enter range from OP to target in meters

range — Press B

The number which appears after B is pressed is the easting coordinate of the target, using a zero vertical angle.

Step 4: Press R/S. The resulting number is the northing coordinate of the target, using a zero vertical angle.

OPTION 2: To correct coordinates when vertical angle is not zero (after running Option 1).

Step 5: Enter vertical angle in mils — Press C

The resulting number is the easting coordinate of the target corrected for a non-zero vertical angle.

Step 6: Press R/S. The resulting number is the northing coordinate of the target corrected for a non-zero vertical angle.

OPTION 3:

Press DSP

Press . (decimal point)

Press 5

Step 1: Enter grid coordinates of OP in 10-digit coordinates

EEEEE.NNNNN — Press A

Step 2: Enter azimuth from OP to target in mils

Azimuth — Press ENTER↑

Step 3: Enter range from OP to target in meters

Range — Press B Enter ↑

Step 4: Enter vertical angle in mils

Vertical Angle — Press E

The resulting number is the easting coordinate of the target corrected for a non-zero vertical angle.

Step 5: Press R/S. The resulting number is the northing coordinate of the target corrected for a non-zero vertical target.

EXAMPLE-OPTION 1

STEP	ENTRY	OPERATION	RESULTING DISPLAY
1	35000.51000	Press A	35000.51000
2	800	Press ENTER ↑	800.00000
3	2800	Press B	36979.89899
4		Press R/S	52979.89899

EXAMPLE-OPTION 2
(After Running Option 1)

STEP	ENTRY	OPERATION	RESULTING DISPLAY
5	120	Press C	36966.17523
6		Press R/S	52966.17523

EXAMPLE-OPTION 3

STEP	ENTRY	OPERATION	RESULTING DISPLAY
1	35000.51000	Press A	35000.51000
2	800	Press ENTER ↑	800.00000
3	2800	Press ENTER ↑	2800.00000
4	120	Press R/S	52966.17523

PROGRAM 4–RANGE AND AZIMUTH BETWEEN TWO KNOWN POINTS

Program 4 computes azimuth and range between two known points. Although the azimuth computed is from point A to point B (the first and second OPs, respectively, for which data are entered), the azimuth from point B to point A can be obtained by adding or subtracting 3200 mils to the answer so as to obtain an azimuth less than 6400 mils.

The number of decimal places displayed in the answers are pre-set in the program to "0" for azimuth and "1" for range (DSP . X). However, they can be easily changed to reflect any desired precision., where "X" above can range from 0 to 9.

Upon entry of grid coordinates for OP A and OP B, the display indicates "12" and "45," respectively. This is done to indicate completion of the required entry and to indicate the registers in which the grid coordinates are stored.

Upon completion of computations for A to B range and azimuth, similar data for another OP, C, can be obtained with respect to either A or B by entering only the new set of grid coordinates. For example, upon completion of A to B computations, if A to C range and azimuth are desired, the grid coordinates for C are entered using "label B." Re-entry of coordinates for A is not required as they are already stored in the appropriate registers, 1 and 2, for computations performed when label C is depressed.

The program listing is shown in Figure 8.

HP-65 Program Form

Program #4 Range and Azimuth from Point A to Point B

KEY ENTRY	CODE SHOWN	COMMENTS
LBL	23	Computes A to B
C	13	Range (and angle)
DSP	21	
•	83	
1	01	Set decimal to 1- place
RCL 5	3405	N B
RCL 2	3402	N A
-	51	NB-NA = J
RCL 4	3404	EB
RCL 1	3401	EA
-	51	EB-EA = R
f	31	Compute A to B distance
R→P	01	and angle (degrees)
RTN	24	RTN/DISP Distance
LBL	23	Stores Point "A"
A	11	grid coord.
STO 2	3302	NA
g 8	3508	(R↓)
STO 1	3301	EA
DSP	21	
•	83	Set decimal to 0- places
0	00	
1	01	
2	02	
RTN	24	RTN/DISP "12"
LBL	23	Stores point "B" grid coord
B	12	
STO 5	3305	NB
g 8	3508	(R↓)
STO 4	3304	EB
DSP	21	
•	83	
0	00	Set decimal to 0- places
4	04	
5	05	
RTN	24	RTN/DISP "45"
LBL	23	
D	14	Computes Azimuth (A to B)
C	13	Compute (RNG and) angle
DSP	21	
•	83	
0	00	Set decimal to 0- places
CLX	44	clear "range"
4	04	
5	05	
0	00	
g 7	3507	(x⇄y)
-	51	450 - angle = W
3	03	
6	06	

KEY ENTRY	CODE SHOWN	COMMENTS
0	00	
g GTO	3522	(x ≤ y)
-	51	
ENTER↑	41	
g 7	3507	(x⇄y) W < 360
1	01	
6	06	
0	00	
x	71	
9	09	
÷	81	W x 160 ÷ 9 = Az
RTN	24	RTN/DISP. Az
g 1	3501	(NOP)

REGISTERS	
R_1	E1
R_2	N1
R_3	
R_4	E2
R_5	N2
R_6	
R_7	
R_8	
R_9	360

LABELS	
A	E1↑N1
B	E2↑N2
C	RNG
D	A to B
E	
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	

FLAGS	
1	
2	

TO RECORD PROGRAM INSERT MAGNETIC CARD WITH SWITCH SET AT W/PRGM

Figure 8. Program 4 listing.

PROGRAM 4–OPERATOR INSTRUCTIONS AND SAMPLE PROBLEM

PURPOSE: To find the range and azimuth from point A to point B.

GIVEN: Grid coordinates of point A and point B.

METHOD: The grid coordinates of point A are entered, followed by grid coordinates of point B.

Output is range in meters from A to B and azimuth from A to B in mils.

Place W/PRGM - RUN switch in RUN position.

Load Program 4

Step 1: Enter easting coordinate for point A

Press ENTER ↑

Step 2: Enter northing coordinate for point A

Press A

Step 3: Enter easting coordinate for point B

Press ENTER ↑

Step 4: Enter northing coordinate for point B

Press B

Step 5: To get range from A to B in meters

Press C

Step 6: To get azimuth from A to B in mils

Press D

EXAMPLE:

STEP	ENTRY	OPERATION	RESULTING DISPLAY
1	35000	Press ENTER ↑	35000.
2	51000	Press A	12.
3	37000	Press ENTER ↑	37000.
4	53000	Press B	45
5		Press C	2828.4
6		Press D	800.

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