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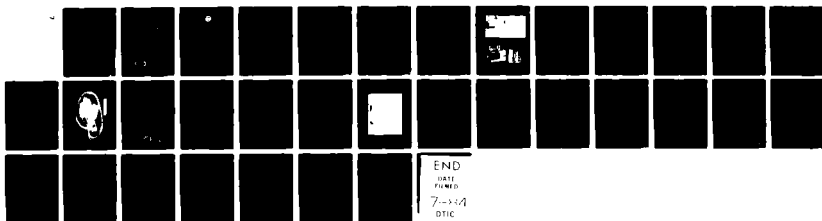
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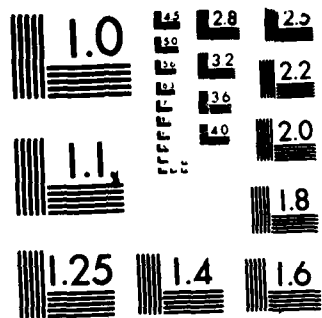
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Technical Document 690

HP-85/MINI-RANGER NAVIGATION SYSTEM

R. Uhrich
M. McCord

April 1984
Final Report

Prepared for
Navy Engineering Logistics Office
Code 01

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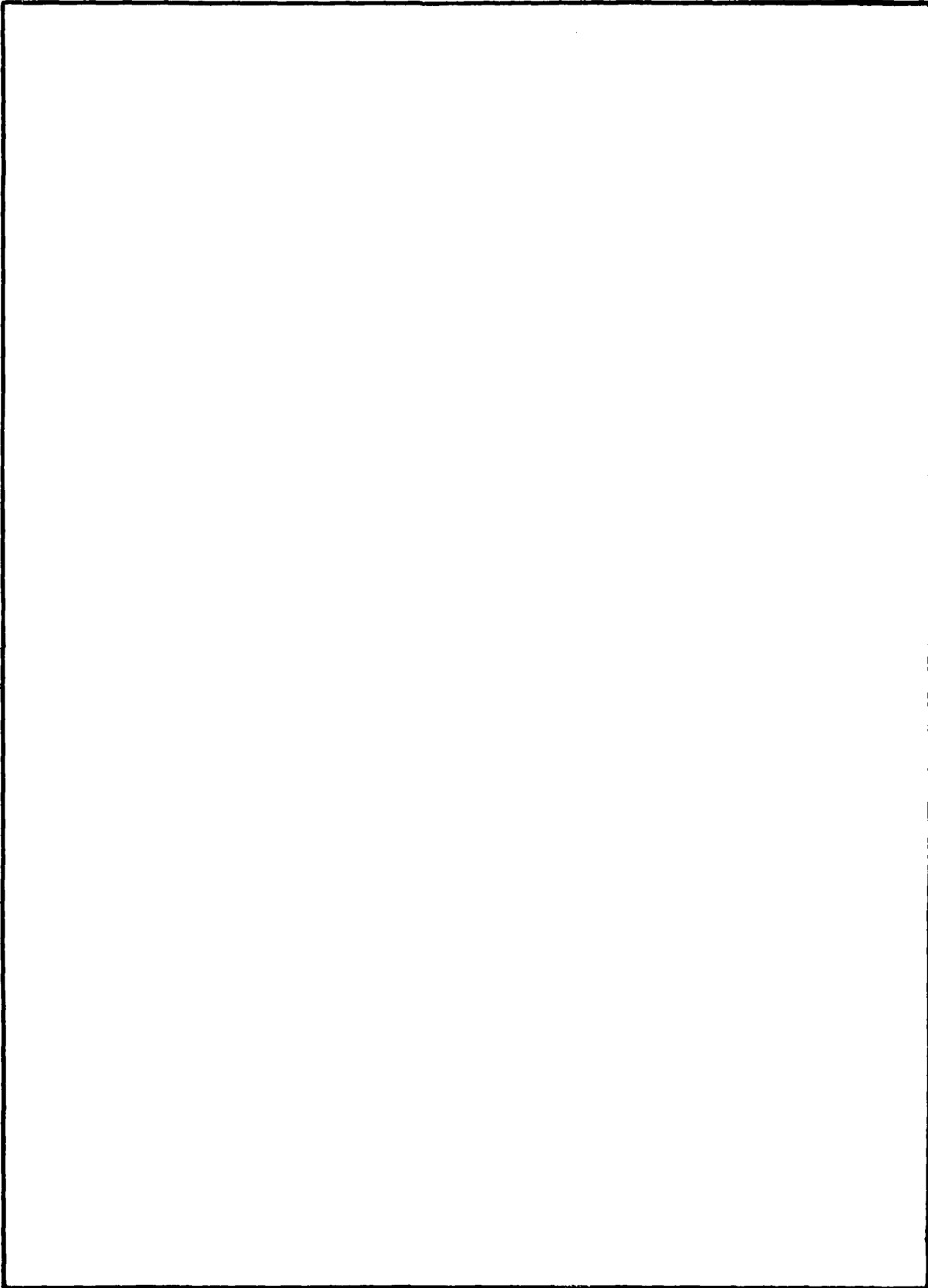
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INTRODUCTION

BACKGROUND

As our undersea capabilities at NOSC have grown, so has the need for accurate surface navigation. With advancements in manned and unmanned vehicles, saturation diving, and search techniques, we have more frequently needed to know where our ships and boats are and where they have been. Radio, satellite, and inertial navigation systems are all available, but none combines reasonable accuracy with reasonable cost, ease of operation, and transportability.

On the other hand, operations often can or must take place near land, making line-of-sight shore based assistance possible. In our R&D efforts, we have used established radar and optical facilities and, when necessary, placed our own surveyors on shore with transits or laser range finders. We have also used radar transponders on the shore and interrogated them from the ship to determine their ranges. This type of navigation system requires no shore support personnel and provides real-time data directly to the ship.

The Motorola Mini-Ranger is one of several commercially available radar transponder ranging systems. The ranges of two transponders are displayed at regular intervals. Ship's position can be plotted manually on a chart using a compass and scale. If the positions of the shore stations are known in some coordinate system, the ship's location can be calculated and plotted to a more accurate scale. This has been done using either a hand-held programmable calculator and a sheet of grid paper, or a desk top calculator with a plotter. However, even with the plotter, the process of manual data entry is tedious.

SYSTEM

The availability of general purpose personal computers has made it possible for us to assemble our own portable automated navigation system. A Hewlett-Packard computer has been interfaced with a Mini-Ranger and a plotter. This system is shown in Figure 1. Mechanical modifications consisted of soldering three connectors on a standard interface module. The computer program involved significant development, but now is a readily available tool (see Appendix A). Once the system is set up and operating, all control is via labeled, dedicated buttons on the computer keyboard. The process of data taking and plotting is completely automatic.

COORDINATES

In a Lambert conformal map, a sector of the earth's surface is projected onto a conical surface coaxial with the earth and intersecting it along two lines of parallel. When the conical surface is unwrapped and laid flat, lines of parallel become arcs and meridians become radii. Because the meridians are shortened slightly by projection as straight lines onto the cone, the unwrapped arcs are also shortened. The result is a conformal mapping: angles between lines on the earth's surface measure correctly on a Lambert chart. This feature makes the Lambert projection ideal for navigation by bearings to radio beacons. It is widely used for long-distance travel by air or water.

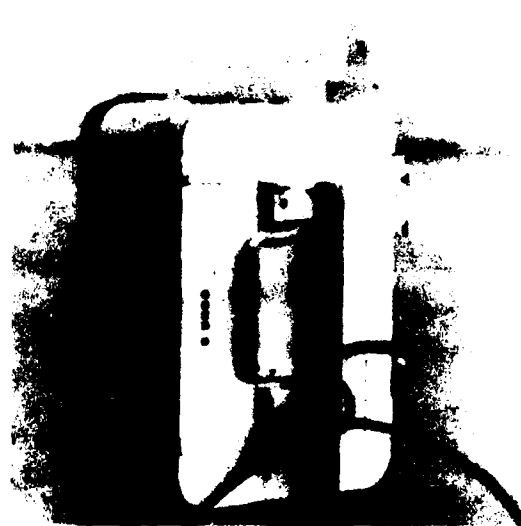
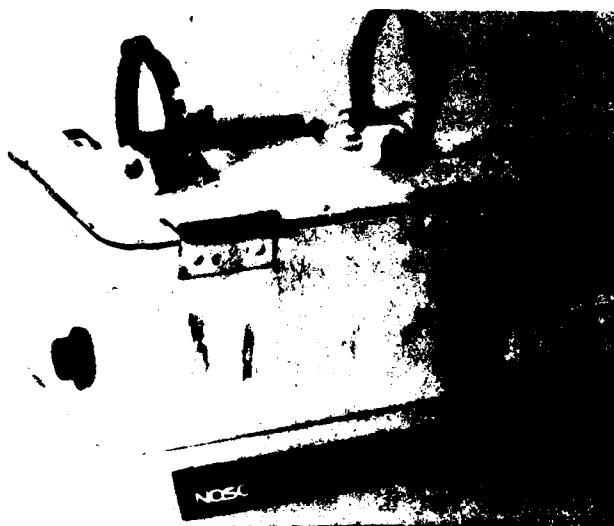


Figure 1. HP-85/Mini-Ranger navigation system.

The United States Coast and Geodetic Survey provides convenient local reference systems by defining standard zones within each state and providing surveyed locations. In California there are seven zones, each with its own Lambert projection and an arbitrary distant reference point for an origin. Locations within a zone are specified within a fraction of a foot by east and north coordinates measured on a square grid placed upon the Lambert projection. The linear distortion of the method is negligible, but the local north Lambert departs slightly from geographic north. Thus, an adjustment is necessary for north referenced angles. By locating our microwave transponders at two surveyed locations and making the local angular correction, we can define ship's position as distances "true" east and north.

DATA PLOTS

The primary purpose of the navigation system is to provide a real-time plot of ship's position. This plot is drawn as a sequence of disconnected dots on a piece of paper or chart, or on the computer's CRT. Diverting to the CRT can be used when no record is required, or in the event of a plotter malfunction. The scale and the location on which the plot is based are adjustable by the user. Location is defined as offset in feet east and north from one transponder position to the center of the plot. Besides the default offset, several alternative "sites" are previously defined and available by means of a simple menu. Data taking can be turned on or off at any time without stopping the program. Plots drawn on paper are automatically labeled as to time, date, offset, and scale, and given a site name. An example of a plot is shown in Figure 2.

DATA RECORDS

In addition to the plots, two independent options are provided for preserving data: a printed listing on paper tape, and a recording on magnetic tape. The recording consists of all ranges and time taken. Recording on tape is useful for later analyses or replotting. This capability has also proven valuable when checking out the system for the source of problems, such as determining which transponder is unreliable when the ship is in a certain area.

The printed information includes ship's speed and X-Y position with respect to the present plot location. In addition, the printed record includes changes in offset, labels as "bad data" any sharp changes in velocity, and indicates "no data" if the Mini-Ranger doesn't receive ranges within five seconds. As with plotting, printing can be diverted to the CRT or back to paper at any time. A sample of a data listing is given in Figure 3.

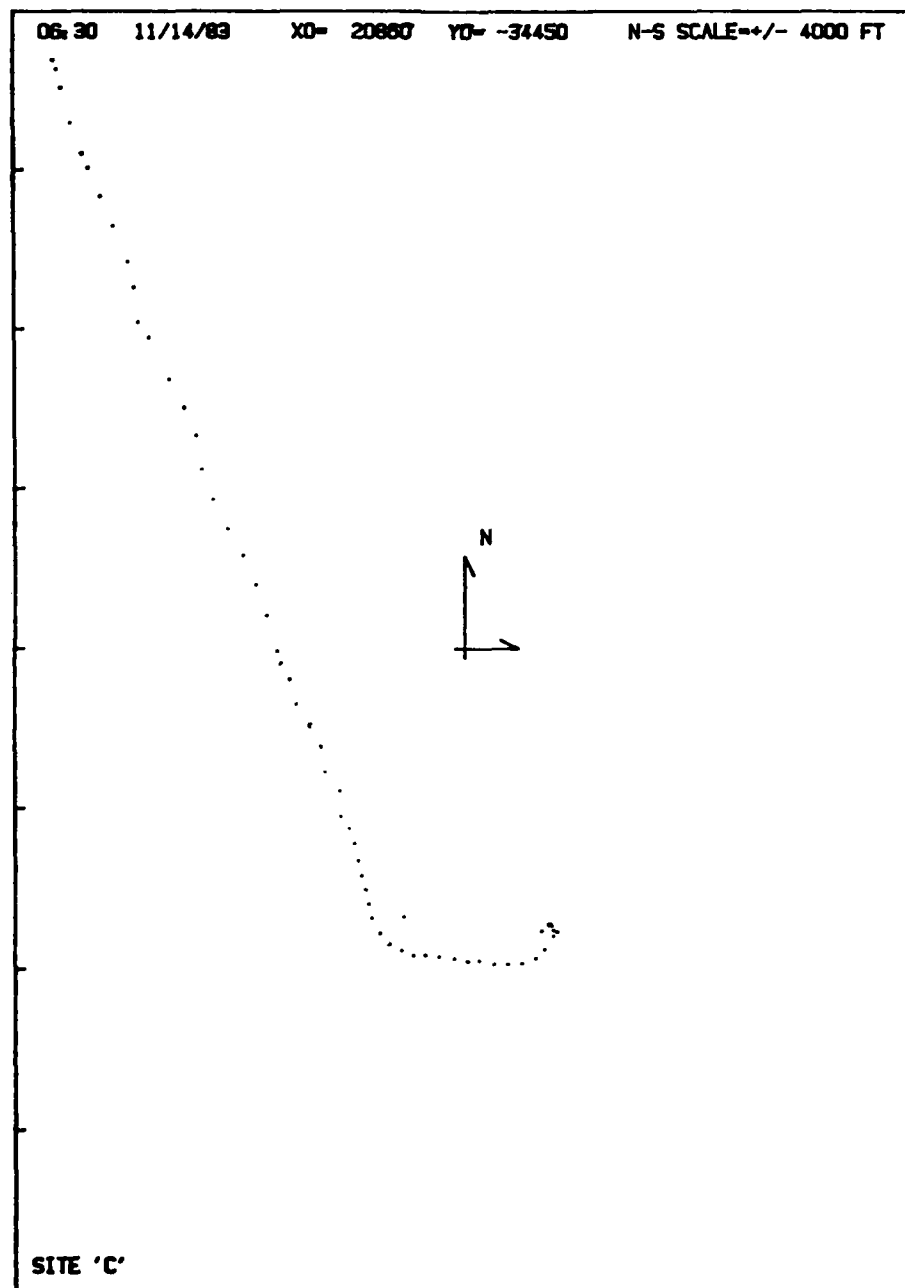


Figure 2. Data plot example.

<u>11/14/83</u>	<u>06:31</u>	
<u>06:44:15</u>	R1= 12052, R2=	5650YDS
V= 7.0KTS, X=	-2514Y=	3297FT
<u>06:44:32</u>	R1= 12120, R2=	5653YDS
V= 7.1KTS, X=	-2443Y=	3102FT
<u>06:44:40</u>	R1= 12152, R2=	5653YDS
V= 7.0KTS, X=	-2404Y=	3013FT
<u>06:44:57</u>	R1= 12218, R2=	5652YDS
V= 7.0KTS, X=	-2322Y=	2832FT
<u>06:45:15</u>	P1= 12285, R2=	5653YDS
V= 7.0KTS, X=	-2241Y=	2647FT
<u>06:45:32</u>	R1= 12365, R2=	5657YDS
V= 7.3KTS, X=	-2149Y=	2422FT
<u>06:45:49</u>	R1= 12418, R2=	5669YDS
V= 6.9KTS, X=	-2110Y=	2261FT
<u>06:46:06</u>	R1= 12485, R2=	5693YDS
V= 7.0KTS, X=	-2083Y=	2044FT
<u>06:46:24</u>	P1= 12525, R2=	5687YDS
V= 6.4KTS, X=	-2013Y=	1946FT
<u>06:46:41</u>	R1= 12621, R2=	5690YDS
V= 7.0KTS, X=	-1886Y=	1686FT
<u>06:46:58</u>	R1= 12689, R2=	5691YDS
V= 6.7KTS, X=	-1792Y=	1506FT
<u>06:47:16</u>	R1= 12752, R2=	5696YDS
V= 6.9KTS, X=	-1712Y=	1333FT
<u>06:47:33</u>	R1= 12819, R2=	5721YDS
V= 6.9KTS, X=	-1677Y=	1121FT
<u>06:47:50</u>	R1= 12885, R2=	5732YDS
V= 7.5KTS, X=	-1605Y=	934FT
<u>06:48:07</u>	R1= 12955, R2=	5737YDS
V= 6.9KTS, X=	-1510Y=	747FT

Figure 3. Sample data listing.

HARDWARE DESCRIPTION

Figure 4 is a block diagram of the HP-85/Mini-Ranger Navigation System hardware configuration. A brief description of each of the components is given in the following paragraphs. Detailed descriptions and other information for individual components may be obtained from the appropriate listings in the Bibliography section of this report.

MINI-RANGER

The Mini-Ranger III System (MRS) is a pulse radar-based position determining system that accurately determines the range of a mobile vehicle from two known geographical locations. The MRS consists of a range console, a receiver-transmitter station or interrogator with interconnecting cable, and two remotely located transponders. The range console and receiver-transmitter are located on the ship and the transponders are located at predetermined reference points. The range console alternately interrogates each reference station via the receiver-transmitter. The elapsed time between the transmitted pulse and the reception of the transponder's reply pulse is used by the range console to determine the range to each reference station. The ranges are displayed as individual six digit numbers on the range console (channel A and channel B range displays). The displayed range values, together with the known locations of the reference stations, can then be used to obtain the position of the ship.

On the rear of the range console are three input/output connectors (J2, J4 and J5) which allow the MRS to interface with an external ancillary device. Connectors J4 and J5 output the two range values displayed on the front panel. Channel A range data is output through J5 and channel B range data is output through J4. Each range value is output as 24 parallel lines (six decimal digits, four bits each) of 1248 positive true BCD data. Also available on J4 and J5 are two output flag signals. In the MRS version used by this system, the two output flag signals are combined into one. This is referred to as FLGA&B which is true only after both channels are updated.

Available on connector J2 is an external sync control input. This input allows an external device to trigger the interrogation sequence which results in the MRS outputting new range data. The external sync input is TTL compatible and negative-edge triggered. When operating under the control of the external sync, the internal sample rate oscillator must be inhibited. This is accomplished by rotating the front panel DISPLAY RATE control fully clockwise to the "EXTERNAL" detented position.

COMPUTER

A Hewlett-Packard Model 85 (HP-85) Personal Computer is used for system control, numerical computing, data display, and data recording for the HP-85/Mini-Ranger Navigation System. The HP-85 consists of a typewriter-like full alphanumeric keyboard, 16-line by 32-character CRT screen, magnetic-tape driver unit, 32-character bidirectional thermal printer, 16Kbytes of user read/write memory, and ROM operating system, all combined in one portable package. On the back of the HP-85 are four I/O ports for interfacing external

peripheral devices, and the HP ROM Drawer. The HP-85 accepts programs written in HP BASIC, an extended version of ANSI BASIC.

INTERFACE

The HP-85 and the MRS III are connected via the HP-82941A BCD interface module. The manufacturer supplied BCD interface module cable was cut in the center and equipped with two MS3116F20-41P connectors and one MS3116F14-19 connector as illustrated in Figure 5. The interface wiring diagram is Figure 6. The two MS3116F20-41P connectors, designated as channel A and channel B, are mated with connectors J4 and J5, respectively, on the rear of the MRS III range console. The BCD interface module I/O format is specified by the HP-85/MRS navigation system software, which requires the range data as a single 40-bit positive true BCD word (10-decimal digits, five for each channel). The sixth digit of each channel is not needed for ranges less than 50 miles, so is not used. Channels A and B each contain five BCD data I/O ports, a ground line, and shield wires. Channel A also contains a handshake line, the MRS III FLGA&B, which signifies when data is ready.

The MS3116F20-19P connector, designated the external control connector, is mated with connector J2, located on the rear of the MRS III range console. The external control connector contains a single handshake line which HP refers to as CTLA, and a ground line. CTLA acts as the MRS III external trigger. The CTLA output is negative true; FLGA&B is positive true; and both are leading edge handshaking.

Figure 7 is a simplified timing diagram for the MRS III interface. When it is ready to accept new range data, the HP-85 sets the CTLA line true (low). The MRS III responds by taking the range readings and readying the range data for output, then pulsing FLGA&B true (high). When it detects the FLGA&B pulse, the BCD interface module drives CTLA false once more. The MRS III continues to hold the new range data on line until the HP-85 again requests a range update.

PERIPHERALS

ROM Drawer. The ROM Drawer (Hewlett-Packard part number HP-82936A) plugs into one of the four I/O ports located on the rear of the HP-85. The ROM Drawer contains six rectangular slots that hold any HP Series 80 ROMs. The HP-85/Mini-Ranger Navigation System requires installation of the I/O ROM, Advanced Programming ROM, and Plotter/Printer ROM in the ROM Drawer.

Plotter/Printer ROM. The Plotter/Printer ROM (Hewlett-Packard part number 00085-15002) allows the HP-85 to interface with a graphics plotter and printer.

I/O ROM. The I/O ROM (Hewlett-Packard part number 00085-15003) allows the HP-85 to monitor and control external peripherals via Hewlett-Packard interface modules.

Advanced Programming ROM. The Advanced Programming ROM (Hewlett-Packard part number 00085-15005) increases the number of user available functions, statements and commands of the HP-85. For example, the Advanced Programming

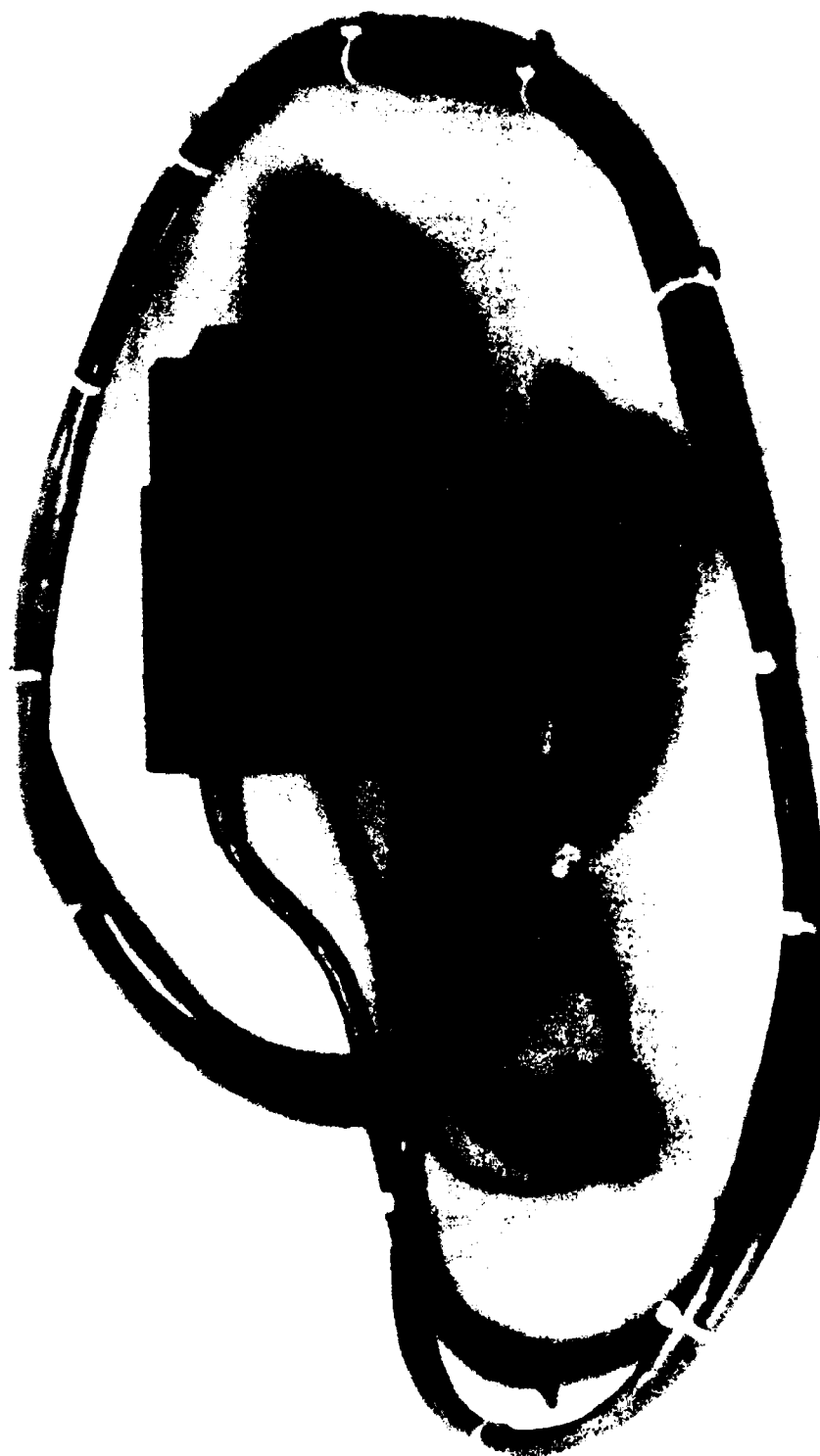


Figure 5. HP-82941A BCD interface module.



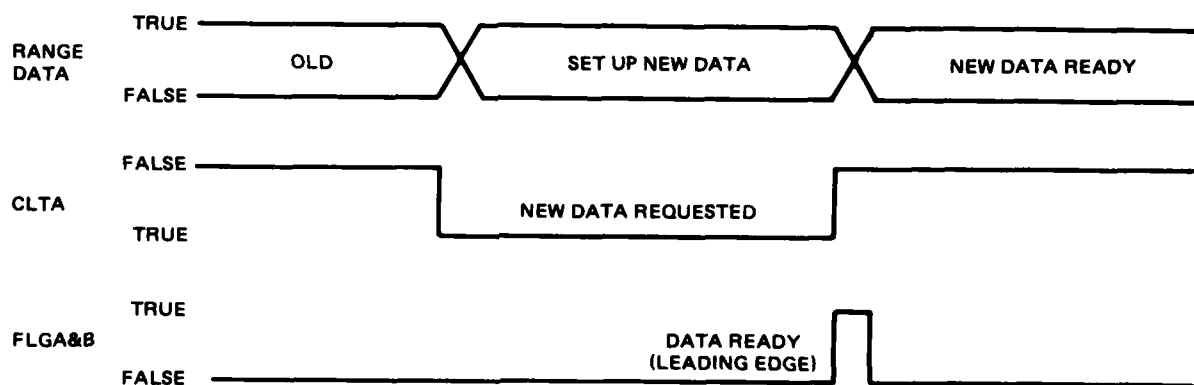


Figure 7. Simplified HP-85/MRS interface timing diagram.

ROM enables the HP-85 to read string information directly from the CRT display, create string variables, and execute subprograms. This ROM is required by the HP-85/Mini-Ranger System for performing certain string handling and time keeping functions.

BCD Interface Module. The BCD interface module allows the HP-85 to interface with peripherals that handle numeric information in binary coded decimal (BCD) form. The BCD interface module is plugged into one of the four I/O ports located on the rear of the HP-85. The BCD interface is used to connect the HP-85 to the Mini-Ranger Display Unit.

HP-IB Interface Module. An HP-IB interface module (Hewlett-Packard part number 82937A) is used to connect the HP-85 to the XY plotter. The HP-IB interface is a bidirectional parallel interface which permits the HP-85 to communicate with external synchronous parallel data communication devices. The HP-IB conforms to IEEE Standard 488-1978. The interface is plugged into one of the four I/O ports located in the rear of the HP-85.

XY Plotter. The XY plotter is a Hewlett-Packard 7225B graphics plotter, or equivalent. The XY plotter is connected to the HP-85 via an HP-IB interface module.

Program Tapes. A program tape (Hewlett-Packard part number 9800A) is a magnetic tape cartridge capable of storing 210Kbytes. Program tapes are used to store and retrieve programs and data via the HP-85 built-in tape drive.

OPERATING THE COMPUTER

GENERAL

The operator of the system is not required to be a computer scientist. Taking data and plotting it is totally automatic. However, the computer must also be told when to start or stop taking data, when to start a new plot, how the area and scale are to be defined, and whether to print and plot on paper or the CRT. This information is requested by self-explanatory prompts or labeled multiple-choice menus. Wherever possible, the required response is the pushing of a single button. Key-masking and error-recovery traps are provided to prevent an inappropriate response from stopping the program. Generally one or two practice sessions are sufficient to train a new operator.

LOADING THE PROGRAM

If the program is stored in a file named "Autost," and if the program tape is in place when power is turned on, it will automatically be loaded into the computer and run. If the program has a different name or the tape is inserted after power is on, the operator must press 'LOAD', type the name in double quotes, press 'END LINE' to load it, and press 'RUN' to start it.

Although the program tape can also be used for storing data, it is safer to keep the write protect tab closed and put data, if desired, on separate tapes. If data is to be recorded on a tape separate from the program, the operator should have a data tape prepared in advance. A new tape must be formatted by inserting it in the computer, typing "ERASETAPE" and pressing 'END LINE'. The write protect tab must be left open on a data tape.

PROGRAM STARTUP

The first time the program is run after power-up, the user is prompted by the CRT to enter the time, then the date. This information sets an internal clock, and all plots and data records will be labeled with this information. If the program is re-run without turning power off, time and date will not be required or requested. The user is always asked whether data is to be recorded. If recording is selected, the user is prompted to insert the tape on which a data file is to be created. This process takes several minutes, but the file will hold about ten hours of continuous data.

NORMAL OPERATION

The program will print time and date, draw a border around the plot, clear the CRT, and present on it the menu of special function keys 'K1' through 'K8'. The menu appears as "key labels," shown in Figure 8. Each label applies to the key directly below; eg., "GRAPH" is 'K5' (shift-'K1') and "PRINT?" is 'K1'. At this time, normal keyboard operation is suspended and only the special keys ('K1'-'K8'), 'KEY LABEL', and 'PAUSE' are functional. This is the standby mode. The options are as follows:

- 'K1'-"PRINT?" changes print output from CRT to paper list, or vice versa. This is an alternate-action switch. When paper lister is active, the label appears underlined; ie., "PRINT?".

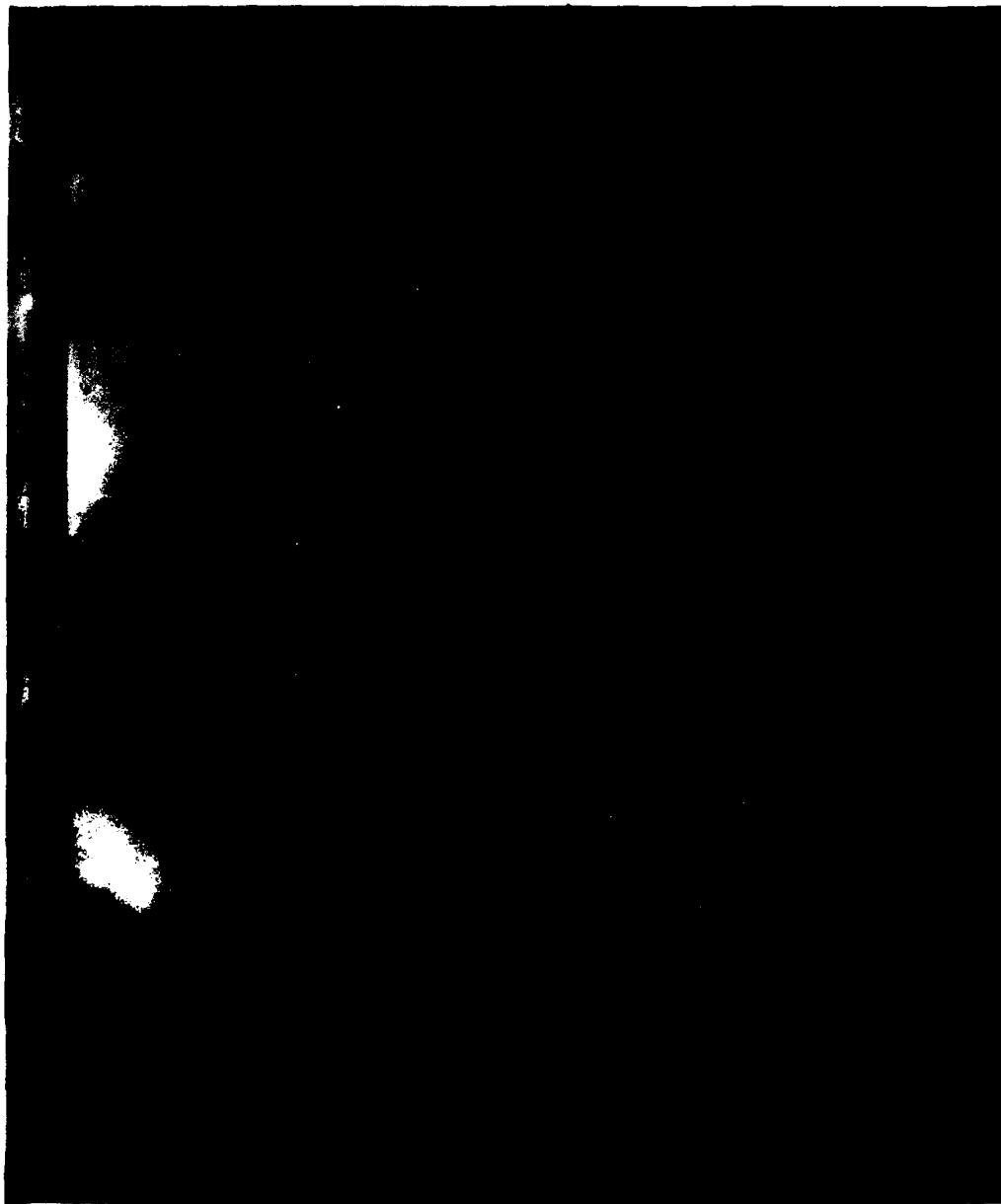


Figure 8. CRT displayed key labels menu.

- 'K2'--"PLOT?" operates in a similar manner with respect to the CRT and plotter. The label appears underlined when the plotter is active.
- 'K3'--"NEWPLOT" presents a sub-menu of predetermined options. Each selection except "OTHER" sets the offsets to a particular site. Some also set the scale; but others give the present scale and the option of changing it. "OTHER" is general purpose. It displays the present offsets and gives the option of changing to any desired location, and then does the same with the scale. If the plotter is active ('K2'), the paper will be framed and labeled with the present time, date, offset, and scale. A north arrow is drawn at the origin and labeled, tick marks are drawn at 1000-ft increments on the left border, and the option name is written in the lower left corner.
- 'K4'--"DATA?" acts like an alternate action switch, starting or terminating data taken by the Mini-Ranger. The incoming data is processed, plotted, printed, and/or recorded, as previously chosen. As with 'K1' and 'K2', the label is underlined when this function is active.
- 'K5'--"GRAPH" is used to cause the CRT to display in graphics mode rather than alphanumeric; ie., if the data is being both plotted and printed on the CRT, this key displays the plot until the next print. "KEY LABEL" switches to print. After each new point, the plot would normally be displayed for five seconds before print is displayed.
- 'K6'--"COPY" does the same as 'K5', then makes a copy of the CRT plot on paper tape.
- 'K7'--"DELAY" displays and permits changes of a built-in delay period between data input loops.
- 'K8'--"MANUAL" allows the user to enter ranges by hand, and the results are plotted as if input from the Mini-Ranger. This might be used to plot a pre-determined spot or in the unlikely event of an interface failure.

Keys 'K1'-'K4' deserve attention in sequence: activate printer, activate plotter, new plot, then turn data on. The upper keys, 'K5'-'K8', will seldom be required.

CUSTOMIZING THE PROGRAM

The HP-85 navigation program is designed to be used for previously planned operations at specific sites. Each application involves the Lambert coordinates and elevations of both transponder sites, the height of the ship's interrogator, a suitable plot scale, and the offsets to the site. It would be very inconvenient for the operator to enter these ten values each time the program is run, especially when the same site is to be used repeatedly. The 'NEWPLOT' menu is designed to allow a site to be totally specified by as little as one key entry. To implement this feature, and minimize the requirements upon the on-site operator, it is necessary that the program be modified in advance to suit the application.

The program is written in HP BASIC, and can be easily modified by anyone with a knowledge of programming fundamentals. Specific instructions are given in the last section of Appendix B.

SUMMARY

The HP-85/Mini-Ranger Navigation System consists of a general purpose personal computer and an off-the-shelf radar ranging device combined into an automatic and portable system for navigation near the shore. This system provides a real-time plot of ship's position relative to fixed transponders. Time and position data can also be printed on paper or saved on magnetic tape. The computer program can be modified for any specific geographic location making the system a readily transportable tool.

APPENDIX A: PROGRAM LISTING

```

100 REM *LAST UPDATE: 11 OCT 83*
110 REM ***'VANILLA' VERSION***
120 REM **USER MUST REDEFINE**
130 REM **VALUES FROM 275-365**
140 REM *AND PROCEDURE AT 2400*
190 ENABLE KBD 255-16 ! LOCKOUT
200 PLOTTER IS 1 @ PRINTER IS 1
205 DIM L$(25) ! PLOT LABELS
210 OPTION BASE 0 @ DIM V(3,5)
220 GCLEAR @ CLEAR @ DEG
225 F0=0 ! CW FROM BASELINE
230 F1=0 ! PRINT FLAG OFF
240 F2=0 ! PLOT FLAG OFF
250 F3=0 ! RECORD FLAG OFF
260 F4=0 ! DATA FLAG OFF
270 D=7000 ! DELAY PERIOD
275 ! *****
280 S0=2000 ! SCALE #
290 X0=1500 @ Y0=-100 ! OFFSET#
300 E1=1290051 ! E-LAM STA1 #
310 N1=317610.8 ! N-LAM STA1 #
320 Z1=377.31 ! ELEV STA1 #
330 E2=1291054.83 ! E-LAM STA2#
340 N2=319580.22 ! N-LAM STA2 #
350 Z2=45.25 ! ELEV STA2 #
360 Z=15 ! ELEV SHIP'S ANT. #
365 ! *****
370 H1=(Z1-Z)^2 @ H2=(Z2-Z)^2
380 B=SQR((E1-E2)^2+(N1-N2)^2)
390 IF E1=E2 AND N1=N2 THEN A=0
    ELSE A=ATN2(E2-E1,N2-N1)
400 A=A+ATN((E1-2000000)/(322712
    67.72-N1))
410 IF A>180 THEN A=A-360
411 IF A<=-180 THEN A=A+360
415 IF X0=0 AND Y0=0 THEN A0=180
    ELSE A0=ATN2(X0,Y0)
418 IF A0<A THEN F0=1 ELSE F0=0
420 IF DATE<>0 THEN GOTO 500
425 ! ----ENTER TIME,DATE---
430 DISP "WHAT TIME IS IT(HR,MIN
    ,SEC)";@ BEEP
440 INPUT H,M,S
450 SETTIME H*3600+M*60+S,0
460 DISP "WHAT'S THE DATE(MO,DA,
    YR)";@ BEEP
470 INPUT D1,D2,D3
480 D1=D1*1000+D2*10+FP(D3/10)*1
    0
490 SETTIME TIME,D1
500 D1=IP(DATE/1000)
510 D2=IP((DATE/1000-D1)*100)
520 D3=FP(DATE/10)*10+80
525 DISP @ DISP @ DISP "PRESS 'E
    ND LINE'; OR"
530 DISP "TYPE 'Y' TO RECORD DAT
    A ON TAPE";@ BEEP @ INPUT F$
540 IF F$<>"Y" THEN 650
544 REM
550 ! ----CREATE DATA FILE---
560 F3=1 ! (TAPE FLAG ON)
570 CLEAR @ CAT @ DISP
575 ON ERROR GOTO 580
580 DISP "WHEN DATA TAPE IS INSE
    RTED, HIT 'END LINE'";@ BEEP
590 INPUT F$
600 F$=HMS$(TIME)
610 F$=F$(1,5)
620 CREATE F$,200,256
625 OFF ERROR
630 ASSIGN# 1,TO F$
640 PRINT# 1 ; TIME,DATE
650 PRINT USING 660 ; D1,D2,D3,H
    MS$(TIME)
660 IMAGE DD,"/",ZZ,"/",DD,7X,5A
670 PRINT @ WAIT 1000
680 ON ERROR GOTO 720 ! TESTING
690 RESET 3 ! BCD INTERFACE = 3
700 CONTROL 3,3 ; 10,0,0,0 ! SIN
    GLE CHANL/TEN DIGITS
710 CONTROL 3,7 ; 48 ! POS TRUE/
    LDN EDGE
720 OFF ERROR @ FRAME
730 SCALE -S0,S0,-(S0/RATIO),S0/
    RATIO
740 MOVE S0,S0/RATIO
750 ON KEY# 1,"PPINT?" GOSUB 860
760 ON KEY# 2,"PLOT?" GOSUB 920
770 ON KEY# 3,"NEWPLOT" GOSUB 24
    00
780 ON KEY# 4,"DATA?" GOTO 1280
790 ON KEY# 5,"GPAPH" GOSUB 980
800 ON KEY# 6,"COPY" GOSUB 1000
810 ON KEY# 7,"DELAY" GOSUB 2310
820 ON KEY# 8,"MANUAL" GOSUB 206
    0
830 CLEAR @ KEY LABEL
840 GOTO 840 ! WAIT HERE FOREVER
850 ! =====
860 ! =====1.PRINT?=====
870 IF F1=0 THEN GOTO 900
880 ON KEY# 1,"PRINT?" GOSUB 860
    @ F1=0 @ KEY LABEL
890 PRINTER IS 1 @ RETURN
900 ON KEY# 1,HGL$("PRINT?") GOS
    UB 860 @ F1=1 @ KEY LABEL
910 PRINTER IS 2 @ PRINT HGL$("
    ")
915 PRINT USING 660 ; D1,D2,D3,H
    MS$(TIME) @ PRINT @ RETURN
920 ! =====2.PLOT?=====
930 IF F2=0 THEN GOTO 960
940 ON KEY# 2,"PLOT?" GOSUB 920
    @ F2=0 @ KEY LABEL

```

```

950 PLOTTER IS 1 @ FRAME
955 SCALE -S0,S0,-(S0/RATIO),S0/
    RATIO @ MOVE S0,S0/RATIO @ R
    ETURN
960 ON KEY# 2,HGL$("PLOT?") GOSU
    B 920 @ F2=1 @ KEY LABEL
970 PLOTTER IS 705 @ FRAME
975 SCALE -S0,S0,-(S0/RATIO),S0/
    RATIO @ MOVE S0,S0/RATIO @ R
    ETURN
980 ! =====5.GRAPH=====
990 GRAPH @ RETURN
1000 ! =====6.COPY=====
1010 GRAPH @ COPY @ RETURN
1020 ! =====NEW OFFSETS=====
1030 CLEAR @ ON ERROR GOTO 1080
1035 DISP "OLD X0=";X0
1040 DISP "OLD Y0=";Y0
1045 DISP @ DISP "PRESS 'END LIN
    E', OR"
1050 DISP "ENTER NEW OFFSETS(X0,
    Y0)";@ BEEP
1055 INPUT X0,Y0
1060 PRINT "X0=";X0
1065 PRINT "Y0=";Y0
1070 IF X0=0 AND Y0=0 THEN A0=18
    @ ELSE A0=ATN2(X0,Y0)
1075 IF A0<A THEN F0=1 ELSE F0=0
1080 OFF ERROR @ RETURN
1085 RETURN
1100 ! =====NEW SCALE=====
1105 CLEAR @ ON ERROR GOTO 1135
1110 DISP "SCALE=+/-";S0
1115 DISP @ DISP "PRESS 'END LIN
    E', OR"
1125 DISP "ENTER NEW VERTICAL SC
    ALE";@ BEEP @ INPUT S0
1130 SCALE -S0,S0,-(S0/RATIO),S0
    /RATIO
1135 OFF ERROR @ RETURN
1140 ! =====SETUP PLOTTER=====
1150 GCLEAR
1160 FRAME @ SETGU @ MOVE 3,3
1170 LDIR 90
1180 LABEL USING 1190 ; HMS$(TIM
    E),D1,D2,D3,X0,Y0,S0
1190 IMAGE 5A,3X,DD,"/",ZZ,"/",D
    D,5X,"X0=",7D,3X,"Y0=",7D,5
    X,"N-S SCALE=+/-",5D," FT"
1200 MOVE 50*RATIO,50
1210 RPLOT 0,-1 @ RPLOT 0,6 @ RP
    LOT -1,4 @ PENUP
1220 RPLOT 1,0 @ RPLOT -10,0 @ R
    PLOT -8,1 @ PENUP
1230 MOVE 58,52 @ LABEL "N"
1235 MOVE 100*RATIO-2,2 @ LABEL
    L$
1240 SCALE -S0,S0,-(S0/RATIO),S0
    /RATIO
1245 XAXIS -(S0/RATIO),1000

```

```

1250 MOVE S0,S0/RATIO
1255 CLEAR @ KEY LABEL @ RETURN
1260 ! =====TAPE ERROR=====
1265 OFF ERROR @ F3=0 ! OFF
1270 BEEP @ BEEP @ PRINT @ PRINT
    HGL$("DATA FILE FULL; REST
    ART PROGRAM!") @ BEEP @ BEE
    P @ PRINT
1275 RETURN
1280 ! =====4.DATA?=====
1290 IF F4=0 THEN GOTO 1320
1300 ON KEY# 4,"DATA?" GOTO 1280
    @ F4=0
1310 MOVE S0,S0/RATIO @ GOTO 830
1320 ON KEY# 4,HGL$("DATA?") GOT
    O 1280 @ F4=1 @ KEY LABEL
1340 PRINT USING 1350 ; HGL$("DA
    TA ON"),HMS$(TIME),D1,D2,D3
1350 IMAGE 7A," AT ",5A," OF ",D
    D,"/",ZZ,"/",DD
1360 PRINT
1370 FOR I=1 TO 3 @ FOR J=1 TO 5
1380 V(I,J)=0 @ NEXT J @ NEXT I
1390 V=0 @ K=0 @ F5=0
1400 SET TIMEOUT 3;5000
1410 ON TIMEOUT 3 GOTO 1855
1420 ENTER 303 ; R
1430 T=TIME
1440 BEEP
1450 R=ABS(R)
1460 ON ERROR GOSUB 1260
1470 IF F3=1 THEN PRINT# 1 ; T,R
1480 OFF ERROR
1490 R1=IP(R/100000)
1500 R2=R-R1*100000
1510 R1=3*R1 @ R2=3*R2
1520 Y3=(R1^2-R2^2+B^2+H2-H1)/(2
    *B)
1530 X3=R1^2-Y3^2-H1
1540 IF X3<0 THEN GOTO 1925
1550 X3=SQR(X3)
1555 IF F0=1 THEN X3=-X3
1560 X4=X3*COS(A)+Y3*SIN(A)
1570 Y4=-(X3*SIN(A))+Y3*COS(A)
1580 X=X4-X0
1590 Y=Y4-Y0
1600 PLOT -Y,X
1610 MOVE S0,S0/RATIO
1615 ! ----VELOCITY----
1620 IF K=0 THEN GOTO 1780
1630 V1=SQR((X-X6)^2+(Y-Y6)^2)/(
    T-T6) @ V1=V1/1.69
1640 IF F5=1 THEN GOTO 1680
1650 FOR I=1 TO 3 @ FOR J=1 TO 4
1660 V(I,J)=V(I,J+1)
1670 NEXT J @ NEXT I
1680 V(1,5)=X-X6 @ V(2,5)=Y-Y6
1690 V(3,5)=T-T6
1700 FOR I=1 TO 3 @ V(I,0)=0

```

```

1710 FOR J=1 TO 5
1720 V(I,0)=V(I,0)+V(I,J)
1730 NEXT J @ NEXT I
1740 V=SQR(V(1,0)^2+V(2,0)^2)/V(
3,0) @ V=V/1.69
1760 IF ABS(V-V1)>3 THEN GOTO 19
25
1765 ! ----GOOD DATA----
1770 F5=0 ! ERROR FLAG OFF
1780 PRINT USING 1790 ; HGL$(HMS
$(T)),R1/3,R2/3
1790 IMAGE 8A,"";"R1=",6D,"R2=
",6D,"YDS"
1800 PRINT USING 1810 ; V,X,Y
1810 IMAGE "V=",2D,D,"KTS,X=",7D
,"Y=",7D,"FT"
1820 PRINT
1830 X6=X @ Y6=Y @ T6=T @ K=K+1
1840 WAIT D
1850 GOTO 1400
1855 ! ----NO DATA----
1860 PRINT HGL$(HMS$(TIME));"; N
O DATA!"
1870 PRINT
1880 IF F3=1 THEN PRINT# 1 ; TIM
E,0
1890 BEEP 1000,100
1900 OFF TIMEOUT 3
1910 ABORTIO 3
1920 GOTO 1400
1925 ! ----BAD DATA----
1926 F5=1 ! ERROR FLAG ON
1930 PRINT HGL$(HMS$(T));"; BAD
DATA:"
1940 PRINT " (R1=";R1/3;"R2="
;R2/3;"YDS)"
1950 PRINT
1960 IF K>3 THEN GOTO 1400 ELSE
GOTO 1370 ! RESTART DATA?
2060 ! =====8. MANUAL DATA=====
2070 CLEAR @ ON ERROR GOTO 2290
2080 DISP @ DISP "PRESS 'END LIN
E'; OR"
2090 DISP "ENTER RANGES(R1,R2)";
HGL$("YDS");@ BEEP
2100 INPUT R1,R2
2110 R1=3*R1 @ R2=3*R2
2120 Y3=(R1^2-R2^2+B^2+H2-H1)/(2
*B)
2130 X3=R1^2-Y3^2-H1
2140 IF X3<0 THEN DISP HGL$("OUT
OF RANGE") @ DISP @ GOTO 2
080
2150 X3=SQR(X3)
2155 IF F0=1 THEN X3=-X3
2160 X8=X3*COS(A)+Y3*SIN(A)
2170 X=X8-X0
2180 Y8=-(X3*SIN(A))+Y3*COS(A)
2190 Y=Y8-Y0
2200 PRINT "DIST.E.OF STA1=";X8;
"FT"

```

```

2210 PRINT "DIST.N.OF STA1=";Y8
2220 PRINT "X=";X
2230 PRINT "Y=";Y @ PRINT
2240 SCALE -S0,S0,-(S0/RATIO),S0
/RATIO
2250 PLOT -Y,X
2260 IF F2=0 THEN GRAPH @ WAIT 5
000
2270 MOVE S0,S0/RATIO
2280 GOTO 2080
2290 OFF ERROR
2300 CLEAR @ KEY LABEL @ RETURN
2310 ! =====7. NEW DELAY=====
2320 ON ERROR GOTO 2380
2330 DISP "CURRENT DELAY TIME=";
D/1000;"SECONDS"
2340 DISP @ DISP "PRESS 'END LIN
E'; OR"
2350 DISP "ENTER NEW DELAY";@ BE
EP
2360 INPUT D
2370 D=D*1000
2380 OFF ERROR
2390 CLEAR @ KEY LABEL @ RETURN
2400 ! *****3. NEW PLOT*****
2410 CLEAR
2420 DISP " 1. SITE 'A';FIXED SC
ALE"
2430 DISP " 2. SITE 'A';VARIABLE
SCALE"
2440 DISP " 3. OTHER"
2500 ON ERROR GOTO 2540
2510 DISP @ DISP "PRESS 'END LIN
E'; OR"
2520 DISP "ENTER NUMBER OF SITE"
;@ BEEP @ INPUT N
2530 ON N GOSUB 2555,2655,2755
2540 OFF ERROR
2550 CLEAR @ KEY LABEL @ RETURN
2555 ! ----OPTION 1-----
2560 OFF ERROR @ L$="SITE 'A';FI
XED SCALE"
2565 X0=1500 @ Y0=-100 @ S0=2000
2570 GOSUB 1140 ! SETUP PLOTTER
2580 RETURN
2655 ! ----OPTION 2-----
2660 OFF ERROR @ L$="SITE 'A';VA
R. SCALE"
2665 X0=1500 @ Y0=-100
2670 GOSUB 1100 ! NEW SCALE?
2680 GOSUB 1140 ! SETUP PLOTTER
2690 RETURN
2755 ! ----OPTION 3-----
2760 OFF ERROR @ L$="USER DEFINE
D"
2770 GOSUB 1020 ! NEW OFFSET?
2780 GOSUB 1100 ! NEW SCALE?
2790 GOSUB 1140 ! SETUP PLOTTER
2800 RETURN

```

APPENDIX B: PROGRAM DESCRIPTION

In the following description, it is intended that Appendix A and Table B1 be consulted upon references to line numbers and variable names, respectively.

STARTUP SEQUENCE

The first executable step, 190, disables all but the special function keys ('K1'-'K8' and 'KEY LABEL') and 'PAUSE' during normal operation. While awaiting input, the HP-85 again enables the keyboard. Both the printer and plotter are diverted to the CRT for startup. This also prevents an error if the plotter is not connected. A string is DIMensioned for labels on plots, and a velocity array, V(3,5), is DIMensioned to start with element V(0,0). Both the graphics and text screens are cleared, and trig functions are set to operate in DEgrees. All flags are set to default (off or 0).

A startup scale (S0) and offset (X0,Y0) are set, as are the Lambert coordinates and the elevations of both transponder locations (E1,N1,Z1; E2,N2,Z2), and the ship's receiver/transmitter elevation (Z). All these assignments must be changed for the specific application. The location designated by subscript '1' will be the origin; i.e., the point from which offsets are defined. This will conventionally (but not necessarily) be the more southern transponder location.

The baseline distance between transponders (B) is calculated, and so is the angle of that line (A), clockwise from north. That angle is then corrected to true north, in the range $-180^\circ < A < 180^\circ$. (Note that this correction, line 400, is specifically for California's Zone Six of the State Plane Coordinate System.) The angle from the E1,N1 origin to plotter offset origin (A0) is also found, and a flag (F0) is set to '1' if $A0 < A$. This flag determines which solution of the two possible for intersecting radii is selected by the program. A0 is recalculated and F0 reset, if necessary, whenever X0 and Y0 are redefined during an operation.

If the SETTIME function, line 420, has not been used, the operator's first prompt, accompanied by a BEEP, is to input the time of day. The operator is then prompted for the date. The decade is assumed to be the 1980's. SETTIME is then called to store this information in the HP-85's internal clock. If the program is rerun without power being interrupted, this information will be intact and the time setting procedure will be skipped.

Whether or not time and date are requested, the user is always prompted, line 530, to specify whether data is to be saved on magnetic tape. If he responds with 'Y' he is shown the catalog of the tape, if any, in the computer, and prompted to press the 'END LINE' key when a data tape has been inserted. This allows him to switch tapes if the program tape is nearly full or if he wishes to keep data and programs separately. If a formatted tape with sufficient room is present when 'END LINE' is pressed, a data file consisting of 200 256-byte records will be created and named with the present time (e.g., "09:00"). If no tape is present, if the tape is not formatted, or if there are not that many contiguous records, the tape insertion prompt will be repeated. (Note that CREATE takes several minutes for such a large file.)

The first two data bytes stored in any newly created file are the internal values of TIME and DATE.

The time and date are briefly displayed, and a frame is drawn on the CRT to remind the user that both printed and plotted information will be directed to the CRT, unless specified otherwise. Buffer #3 is then set up for inputting 10-digit BCD numbers from the Mini-Ranger; but an error trap around that process at line 680 permits the program to be demonstrated without the BCD interface in place. The scale of the graphics CRT is set to ±50 in the north-south direction, and the 'pen' is moved out of the way. (Note that the display is rotated: north is to the left. This is rotated back on COPY, and also makes north 'up' on standard 8-1/2 by 11 plotting paper.)

Lines 750 through 820 define the labels to represent special keys 'K1' through 'K8'. Lines 750 through 820 also tell where program execution is to be transferred when each is pressed. All except 'K4' initiate subroutines, thus can be executed while 'K4' is 'on' and data is being taken. However, they cannot be used when the program is awaiting input from the keyboard. Next, the alphanumeric display is cleared, and the key labels displayed. At line 840, the program enters an infinite loop. Setup is completed, and keys 'K1' through 'K8' are awaited.

NUMBERED PROCEDURES

The numbered procedures, those directly called by the specially labeled keys 'K1'-'K8', do not appear in sequence in the program listing; yet, except for the minor procedures to be discussed in the final section, each is completely independent. Therefore, the numbered procedures will be discussed in numerical order.

'K1'-"PRINT?" (Printer On/Off), Line 860

'K1' interrupts program execution to change the output of PRINTed information from the CRT to the printer, or vice versa. If the print flag (F1) is '0' or off, as on startup, then the label for key #1 is redefined to highlight (ie., underline) the word "PRINT?," the flag is set to '1', and the new key labels called. Then line 910 activates the printer and outputs an underline. The next line prints date and time, and returns to the interrupted program location.

If the print flag was on when 'K1' was pressed, line 880 redefines the label to remove the highlight, the flag is turned off, and the new key labels called. The printer is set to device '1', the CRT, and the RETURN is executed.

'K2'-"PLOT?" (Plotter On/Off), Line 920

'K2' interrupts program execution to change the output of plotted information from the CRT to the plotter, or vice versa. If the plot flag (F2) is '0', or off, then the label for key #2 is redefined to highlight "PLOT?," the flag is turned on, the new key labels are called, and the plotter is activated. If the flag is on, then the label highlight is removed, the flag is turned off, the labels are called, and the plotter is set to device '1', the CRT. In either case, a frame is drawn on the active device, a new SCALE

is done, the pen homed, and RETURN executed. The rescale is necessary whenever the plotting device is redefined or it will default to standard graphics units and scale. The pen motion is physically necessary for viewing the plotter, and serves as a PENUP on the graphics CRT.

'K3'--"NEWPLOT?" (Begin New Plot), Line 2400

"NEWPLOT" is to be used whenever a new sheet of plotting paper is put in the plotter or whenever the graphics CRT is to be cleared. This should be done before data is first turned on, each time scale or offset are changed, and whenever the plot becomes too crowded with data. This procedure can be called during data taking. It only interrupts the process temporarily.

Pressing 'K3' results in a menu of numbered options being displayed. This menu should be customized for the actual site. The selections given here are meant only as illustrations of the capabilities available through the subroutines "NEW OFFSETS" (line 1020), "NEW SCALE" (line 1100), and "SET UP PLOTTER" (line 1140). These subroutines will be described in detail in the section "MISCELLANEOUS SUBROUTINES" on page 25.

The sample menu shows three options. All use "SET UP PLOTTER" and label the plot. However, the first contains a previously selected scale and offset (no options), the second has a previously selected offset with a scale option, and the third has both options. The format of choice '1' should be used for repeated operations at a known site. Choice '2' format allows a large scale for approaching such a site or detailed scale for use during critical maneuvers. Choice '3' should always be available as general purpose tool. The error trap at line 2500 causes an 'END LINE' or any invalid choice to result in a RETURN, aborting the "NEWPLOT" procedure. (Similar traps within each option subroutine allow the use of 'END LINE' to leave the respective option unchanged.)

'K4'--"DATA?" (Data-Taking On/Off), Line 1280

The purpose of the system is to take data and plot it. 'K4' turns this process on and off. This is the heart of the program, and the most complicated part. This procedure is a GOTO, and should only be turned on from the loop at line 840 to which it returns when turned off. It can be turned off only by being called from within itself. (All other numbered procedures are GOSUBs, and can be called from within the loop or while taking data.)

If the data flag (F4) is on, line 1300 merely removes the label highlight, turns the flag off, and homes the pen. The new labels are displayed and the infinite loop is re-entered. If the flag is off when 'K4' is pressed, the procedure is more complicated as the following paragraphs will show.

If the data flag is off, line 1320 highlights the label, turns the flag on, and displays the labels. The time and date of data startup is PRINTed to whichever device is the currently active printer. Lines 1370 through 1390 are a startup sequence wherein the velocity array (V(3,5)), the scaler velocity (V), the data count (K), and the error flag (F5) are all zeroed.

Line 1400 begins the main data loop. A timer is started for device '3', the Mini-Ranger. If no data is received within five seconds, control passes

to line 1855. In that case a message is printed, a '0' is sent to tape if a data file is active, and the loop is restarted. Line 1420 waits for data and assigns it to a variable (R). The time is stored (T), and a BEEP signifies successful data entry. The negative sign of the data, an interface artifact, is discarded. If the tape flag (F3) is on, the time and data are stored on magnetic tape. A tape error calls the subroutine at line 1260 which turns the tape flag off and prints a noisy warning that no more data can be recorded.

The upper five digits of the data are stored as range from the origin transponder (R1) and the lower five as the other (R2). Both are converted from yards to feet. Line 1520 finds the position component which lies along the baseline (Y3). (This is done by projecting both radii into a horizontal plane and applying the law of cosines.) Then the square of the horizontal perpendicular component (X3) is found. If square is negative, signifying a geometric impossibility, execution is redirected to line 1925. Otherwise, the root is taken and given a negative sign if the origin flag (F0) is on (implying the solution on the counter-clockwise side of the baseline angle from true north). The coordinates (X3,Y3) are rotated to true north (X4,Y4), translated to the plotter origin (X,Y), plotted by line 1600, and the pen is homed. (As previously stated, the plot is rotated. Thus, the command is "PLOT -Y,X" instead of "PLOT X,Y".)

Lines 1615 through 1760 deal with velocity (V1), a smoothed velocity average (V), and throwing out points which depart radically from the average. The discarded points are plotted; they are merely excluded from the calculation of the average, and marked as "BAD DATA" on the printout. The average consists of the vector sum of the last four good points divided by the total time elapsed between them.

The first point after a data startup must be assumed good, since no average yet exists; so line 1620 GOTOs 1765, skipping the velocity section entirely. There the error flag is set to off; and the time, ranges in yards, average velocity (which is zero the first time), and coordinates (X,Y) in feet from the present plotter origin (X0,Y0), are all printed. The present coordinates and time are stored (X6,Y6, and T6), the data count (K) is incremented, a WAIT executed, and the data loop repeated at line 1400.

On successive passes, line 1630 calculates the latest velocity and converts it to knots. If the last point was good (F5=0 in line 1640) column elements two through five of rows one through three are all moved down one. This wipes out all three column ones. Lines 1680 and 1690 pack column five of rows one through three with the latest delta-X, delta-Y, and delta-T, respectively. So under normal circumstances, columns one through four hold "good" updated information, but column five holds new and untested values at this point. Lines 1700 through 1730 then fill the zeroth column of each row with the sum of columns one through five; i.e., V(1,0) contains the cumulative delta-X of the last five points, V(2,0) contains the cumulative delta-Y, and V(3,0) the delta-T. From these values a tentative average velocity is found, and a comparison is made with the latest instantaneous velocity. If the difference is less than three knots, the latest data point is considered good and treated as described in the previous paragraph.

On bad data, execution skips to line 1925. The error flag is set so the columns of the velocity array will not be moved down again on the next pass,

and the ranges in yards are printed with the label "BAD DATA". The data count is not incremented, and the loop repeats. But if any bad data appears on startup, before the velocity array is filled (i.e., before K=4), then startup is re-initiated at line 1370. This test, performed by line 1960, prevents erratic starting data from creating an array which causes all true data to be rejected.

'K5'--"GRAPH" (CRT to Graphics Mode), Line 980

This key merely changes the CRT to display the graphics mode. Conversely, 'KEY LABEL' switches to alphanumeric mode. These options might be useful when both printing and plotting are diverted to the CRT. Whenever new data is printed, the screen reverts to alphanumeric. (Note that the standard 'GRAPH' key is disabled, along with the keyboard, by line 190.)

'K6'--"COPY" (Copy Graphics Mode on Printer), Line 1000

'K6' causes the Graphics screen to be COPIed on paper. Like 'K5', this is provided because the standard key is disabled.

'K7'--"DELAY" (Set New Delay), Line 2310

This key enables the user to change the length of the WAIT between good data points at line 1840. The WAIT is in addition to normal processing time which is about four seconds. As with other inputs, the present value is displayed and 'END LINE' leaves it unchanged.

'K8'--"MANUAL" (Manual Data Entry), Line 2060

The capability for manual data entry is provided mainly as a diagnostic tool but might be useful for locating a site from a chart. It can be called even during automatic data entry.

The user is prompted to enter two ranges in yards, or to hit 'END LINE' to end manual mode. The ranges are much like automatic data but no velocities are calculated and nothing is recorded on tape. An "OUT OF RANGE" message is displayed for ranges which are not possible within the defined transponder geometry. Good data is plotted, and the coordinates are printed, both absolute (distance east and north of reference transponder) and relative to present plotter origin. If plotting is being diverted to the CRT, line 2260 causes a five second WAIT in graphics mode for viewing the newly plotted point (if it's on scale). The procedure then loops back to prompt for 'END LINE' or more data.

MISCELLANEOUS SUBROUTINES

There are also four short subroutines which are not directly accessible using the special function keys. The first three to be described are called from the "NEWPLOT" subroutine 'K3'.

"New Offsets," Line 1020

This subroutine is used to reset the geographic center of the plot by designating new values (X0,Y0) for its offset in feet east and north from the

reference transponder site. The present values are displayed, and the user is prompted to enter new values or press 'END LINE' to leave them unchanged. New values are printed on the paper listing if the printer is active or on the CRT. Lines 1070 and 1075 determine on which side of the baseline is the new origin. FO is set accordingly. All succeeding data points will be assumed on that side, too.

"New Scale," Line 1100

The scale (S0) is the distance in feet represented by the space from the center to the north or south end of the plot. The present value is given, and a new value or 'END LINE' is requested. 'END LINE' leaves the scale unchanged. A new scale is made active by SCALE in line 1130.

"Set Up Plotter," Line 1140

This subroutine is intended mainly for identifying paper plots for future reference. A frame is drawn at line 1160, and the time, date, offset, and scale are written across the north end of the plot. When plotting is diverted to the CRT, the labeling will not appear. Lines 1200 through 1230 draw a small compass arrow indicating true north, and label it with an "N". This is to alleviate confusion over the fact that both the CRT and plotter actually show plots rotated 90°. The plot is then labeled in the lower left corner with the site description (L\$) set by the menu choice in 'K3'. Line 1240 resets SCALE (this is actually redundant, since the previous procedure also does this, but it is retained for modularity). Line 1245 puts tick marks at 1000-ft spacing, starting at the north end, down the west side of the plot. This is to serve as a guide for scaling.

"Tape Error," Line 1260

This subroutine will only be called if the error trap at line 1460 is sprung by an attempt to write data on tape. This will happen if the data file has become full. In that case a warning is printed to rerun the program, but data plotting continues with the tape flag (F3) off.

TAILORING THE PROGRAM

Customizing consists of setting the values of the constants E1, N1, Z1, E2, N2, Z2, and Z between lines 275 and 365, and the variables X0, Y0, S0, and L\$ everywhere they occur. The numeric variables are set on lines 280 and 290, and on lines 2565 and 2665 of 'NEWPLOT'. (They are also set in 'NEW OFFSETS' and 'NEW SCALE' as INPUTs so these subroutines need not be modified.) The string variable L\$, which becomes the label on a new plot, is set on lines 2560, 2660, and 2760. If the site is not within California's Zone Six, which extends from Orange County south, then line 400 must also be changed (see Reference 1).

For optimum user convenience, the 'NEWPLOT' menu (lines 2420 through 2440) can be changed to more appropriately describe each particular site. The menu is not restricted to three items. Several specific sites can be described by their offsets and incorporated as separate menu items, either with

fixed scales as in the example menu item 1, or with the rescale option of item 2. The ON...GOTO statement of line 2530 can be extended to include many such additional subroutines.

TABLE B1. LIST OF VARIABLES

NAME:	TYPE:	DESCRIPTION:
A	CONSTANT	ANGLE FROM TRUE NORTH CLOCKWISE TO BASELINE (DEG)
A0	VARIABLE	ANGLE FROM TRUE NORTH CLOCKWISE TO PLOT ORIGIN (DEG)
B	CONSTANT	BASELINE DISTANCE BETWEEN TRANSPONDERS (FT)
D	VARIABLE	DELAY PERIOD AFTER GOOD DATA (MSEC)
D1	VARIABLE	MONTH or DATE
D2	CONSTANT	DAY
D3	CONSTANT	YEAR
E1	CONSTANT	EAST LAMBERT COORD. OF TRANSPONDER STATION 1 (FT)
E2	CONSTANT	EAST LAMBERT COORD. OF TRANSPONDER STATION 2 (FT)
F\$[]	STRING	INPUT or FILE NAME
F0	FLAG	AO<A?
F1	FLAG	PRINTER ON?
F2	FLAG	PLOTTER ON?
F3	FLAG	RECORDER ON?
F4	FLAG	DATA ON?
F5	FLAG	ERROR ON LAST DATA?
H	VARIABLE	HOURL
H1	CONSTANT	(Z1-Z)^2
H2	CONSTANT	(Z2-Z)^2
I	VARIABLE	LOOP COUNTER
J	VARIABLE	LOOP COUNTER
K	VARIABLE	DATA COUNT
LS[]	STRING	LABEL FOR PLOT
M	VARIABLE	MINUTE
N	VARIABLE	INPUT MENU ITEM
N1	CONSTANT	NORTH LAMBERT COORD. OF TRANSPONDER STATION 1 (FT)
N2	CONSTANT	NORTH LAMBERT COORD. OF TRANSPONDER STATION 2 (FT)
R	VARIABLE	RAW DATA VARIABLE CONTAINING RANGE INFORMATION
R1	VARIABLE	RANGE FROM STATION 1 (YDS or FT)
R2	VARIABLE	RANGE FROM STATION 2 (YDS or FT)
S	VARIABLE	SECOND
T	VARIABLE	TIME (SEC)
T6	VARIABLE	LAST TIME (SEC)
V	VARIABLE	AVERAGE VELOCITY (FT/SEC or KT)
V1	VARIABLE	INSTANT. VELOCITY (FT/SEC or KT)
V()	ARRAY	VELOCITY HISTORY
X	VARIABLE	DISTANCE EAST OF PLOT ORIGIN (FT)
X0	VARIABLE	EAST OFFSET OF PLOT ORIGIN FROM STATION 1 (FT)
X3	VARIABLE	DISTANCE ALONG BASELINE FROM STATION 1 (FT)
X4	VARIABLE	DISTANCE EAST OF STATION 1 (FT)
X6	VARIABLE	LAST X (FT)
X8	VARIABLE	X4 FOR MANUAL DATA (FT)
Y	VARIABLE	DISTANCE NORTH OF PLOT ORIGIN (FT)
Y0	VARIABLE	NORTH OFFSET OF PLOT ORIGIN FROM STATION 1 (FT)
Y3	VARIABLE	DISTANCE FROM BASELINE (FT)
Y4	VARIABLE	DISTANCE NORTH OF STATION 1 (FT)
Y6	VARIABLE	LAST Y (FT)
Y8	VARIABLE	Y4 FOR MANUAL DATA (FT)
Z	CONSTANT	ALTITUDE OF SHIP'S RECEIVE/TRANSMIT UNIT
Z1	CONSTANT	ALTITUDE OF STATION 1
Z2	CONSTANT	ALTITUDE OF STATION 2

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