# ASTRO*CARD
# *USER MANUAL*

A guide, with examples, to the use and operation of ASTRO*CARD.


Developed and copyrighted by:

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# ASTRO*CARD USER MANUAL

## NOTES



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Should the user have questions concerning ASTRO*CARD, please write or call:

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Our staff is available to answer questions about ASTRO*CARD's use, application and results. We cannot, however, make ourselves available by phone to answer questions about HP-48 operations, nor programming. Consult the calculator's owner's manual or contact your HP dealer for assistance.

**Revised 1/16/92**

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# INTRODUCTION

ASTRO*CARD is designed primarily to collect sun- and Polaris field observation data (times and circle readings) and to compute an accurate astronomic azimuth to the backsight point while the instrument is on-site without inputting ephemeris data. For normal celestial observation procedures, the sequence of prompts and inputs is easy to follow, somewhat self-explanatory, and requires little study and training. ASTRO*CARD, however, is very versatile, containing many options which include: conversion to state plane grid azimuth; altitude and azimuth of a celestial body; generation of ephemeris data for any date (for verification purposes); manual entry of time and date to compute azimuths from previous observation data; observations on stars other than the sun and Polaris; and other features. A more detailed study of this manual may be necessary to execute these options.

When first learning to use ASTRO*CARD it is recommended the next section on operation be read to obtain an overview for later reference. Next review the section on examples and work <u>all</u> of the examples in the order given, even though the user may, for example, be primarily interested in sun observations. There may well be an illustration in the Polaris example that the user can apply to sun observations and vice versa.

Only ASTRO*CARD user instructions are contained in this manual. If information on field procedures and techniques for the hour angle method of celestial observations is desired, reference should be made to an edition of the *Celestial Observation Handbook and Ephemeris*, published by the Lietz/Sokkia Company, or *Practical Surveying Guide to Celestial Observations*, published by P.O.B. Publishing Company. (Either can be ordered through the Elgin, Knowles & Senne, Inc. Rolla office.)

The internal ephemeris generation routine contained in ASTRO*CARD is designed for the years 1965 through 2010. Any ephemeris data errors during this design period will be insignificant when compared with expected accuracies of the input field data (see Appendix F).

For those interested in transferring ASTRO*CARD input data files to the PC, via the HP interface kit, to be run. by the firm's ASTRO*DISK software, program ASTRO48 is available from Elgin, Knowles & Senne, Inc. for $45.00. This program makes the necessary conversions from ASTRO*CARD to ASTRO*DISK data files.

# OPERATION

ASTRO*CARD is a Read Only Memory (ROM) module and contains all of the routines necessary for its operation. Execution of these routines will create objects (variable names, directories, etc.) in main memory. If the card is removed, many of these objects will remain; however, the routines cannot be executed without ASTRO*CARD in place.

Make sure the calculator is off and insert ASTRO*CARD in either port with the finger grip facing toward the back. Turn the calculator on and press the following keys (the white menu keys are shown as being underlined):

[ ↱ ] [ HOME ]

[ VAR ]

<u>ASTVA</u>

* [ ↰ ] [ LIBRARY ]

<u>ASTRO</u>

This places the calculator in the ASTVAR1 subdirectory where the ASTRO*CARD routines can be executed. These routines are displayed in the menu with various layers being viewed by pressing [ NXT ] or [ ↰ ] [ PREV ].

The first time ASTRO*CARD is used in a calculator or the first time it is used after all memory has been cleared, the following initialization procedure should be performed. This creates variables that are required in a few of the routines. Initialization can be performed by executing the following (calculator must be in the ASTRVAR1 subdirectory):

* This is for the HP48SX calculator.
For the HP48GX use:-

[ ↱ ] [LIBRARY]

| DISPLAY | ENTRY | KEY STROKE |
|---|---|---|
| | | LCML |
| :LONG. CM: | 90* | ▼ |
| :LAM:. CONST: | 0* | ENTER |
| | | ASTRO |
| :SUN=0, POL=1, ST=2: | 2 | ▼ |
| :TMO=0, SGL=1, EPH=2: | 2 | ENTER |
| :TABLE=1, COORD.=0: | 1 | ENTER |
| :STAR NUMBER: | 1* | ENTER |
| :DATE M.DY: | 1.011992* | ▼ |
| :UT@SW=0: | 0* | ENTER |
| GHA: 97.54502<br>DECL: 29.03022<br>SD: 0.00000<br>SID.TIME: 6.39385 | (Ephemeris data for star Alpheratz is displayed.) | |

*These values are arbitrary. The purpose here is only to create variables.

If ENTER is accidently pressed before all data in a given menu has been entered, a syntax error will result. However, this can be ignored and any remaining data should be entered.

Each ASTRO*CARD routine is briefly explained below. For a detailed use of each, refer to the section on examples. All input/output is in the format of: D.MMSSss (angles), HH.MMSSss (time), MM.DDYYYY (date).

LCML

Entering longitude of the central meridian and Lambert convergence factor for a state plane coordinate zone. These constants remain in memory until changed. Constants for each state and zone are listed in Appendix A.

ASTRO

This is the main routine in ASTRO*CARD designed for data collection and calculation of astronomic and grid azimuth. It contains several options such as: type of celestial body (sun, Polaris or other star) and multiple foresight (MFS) or single foresight (SFS) observation procedures. When using the routine's TM option (time and date of a pointing taken directly from the 48SX) it is necessary that 48SX clock be accurately set (see Appendix B). Times of pointings (CLOCK displayed) are obtained by quickly pressing and releasing the ENTER key. The clock can be bypassed for manual entry of time and date by setting flag 4. When using the MFS option an azimuth for each pointing on the celestial body is computed and displayed. The maximum number of pointings is 10. For the SFS option an azimuth for each pointing is computed and the azimuth for each pair (D&R) is averaged and displayed. This option is designed for a maximum of 20 pointings (10 positions on the circle). Any number of pointings can be taken, computed and displayed; however, the averaging routine (SEQ) can average only the last 10 azimuths displayed.

LTLN

For editing/changing stored values of latitude and longitude. North latitude is positive, south negative. West longitude is positive, east negative. After executing this section, azimuths can be recomputed.

M.DY

For editing/changing stored values of date and beginning stopwatch time (if flag 4 is set). After executing this section, azimuths can be recomputed.

BSFS

For entry of a new backsight, foresight and stopwatch time (single observation/pointing only). Azimuth is automatically recomputed.

RUNA

For recomputing azimuth. (SNG option only.)

MFS

In the TMO option using either the MFS or SFS options this sends program to the field data portion (prompt for NO. OF POINTINGS). Used primarily when taking an additional set of data at the same instrument location.

DUMP

Provides a data "dump" or listing. All of the data can be viewed by using the arrow up key.

CMPT

Recomputes azimuths from the stored data (MFS and SFS options). It would normally be used after some data has been edited. (See LTLN and M.DY above and Appendix C.)

AZLT

Relist azimuths which have been previously computed for an observation set.

SEQ

This routine is for averaging the listed azimuths. To average the desired azimuths key a decimal point followed by the listed azimuth numbers. For the number 10, enter a minus sign. As an example, to average azimuths 1, 3, 4 and 6, key .1346. To average azimuths 1, 4, 5, 7, 9 and 10, key .14579-.

GAZ

If not already displayed, this routine will list the averaged astronomic azimuth and grid azimuth.

RA

For editing star coordinates of celestial bodies other than the sun and Polaris. Coordinate values prompted for are: Right Ascension (RA), Declination (DEC), Proper Motion in Right Ascension (PMA) and Proper Motion in Declination (PMD).

SAVE

For saving (storing) sets of field data which can be recalled and computed or printed at a later time. Key in an alpha character file name.

GETD

For recalling field data that has been previously stored.

STRN

For changing a star number. See Appendix H for star numbers.

CORRT

For adding corrections in seconds, tenths and hundreths of a second (S.ss) to the 48SX clock. Used in conjunction with the TM and CLOK routines.

TM

Pressing this key will take a time from the 48SX clock and put it in the display. Used with a time signal (e.g. WWV) to determine any necessary correction to the 48SX clock. See Appendix B.

CLOK

Similar to TM above except pressing this key puts the program in an ASTRO routine for CLOCK and FS. This allows the ENTER key, rather than a menu key, to be used to synchronize the clock. Flag 4 must be cleared to use this routine. See Appendix B.

SDC

For editing/changing the sun's semidiameter code. 1 is for pointings on the sun's left edge, 0 for sun's center and -1 for sun's right edge. In the northern hemisphere at latitudes above $23.5^{O}$N the left edge is the trailing edge.

NOTE: To abort a menu operation press ATTN ATTN

# EXAMPLE EXECUTIONS

By use of some example executions, this section illustrates the application of ASTRO*CARD. This module is so versatile that all of its variations would be impractical to list. All major options are illustrated, complete with example field data and keystrokes.

For all examples set flag 4 so the given times and dates can be manually entered. If set, flags are displayed in the top line of the display. To set flag 4 perform the following steps:

4 [α] [α] SF

[ ENTER ]

Flag 5 is the printer flag. When set, output is sent to the infrared printer and in some cases not displayed. It may also delay calculation time. If flag 5 is displayed (set), it should be cleared before executing the examples.

5 [α] [α] CF

[ ENTER ]

To execute the routines in ASTRO*CARD, the calculator must be in the ASTVAR1 subdirectory. If not in this subdirectory (ASTVAR1 displayed), perform the following steps:

[↱] [ HOME ]

[ VAR ]

ASTVA

[↰] [ LIBRARY ]

ASTRO

The ASTRO menus should now be displayed.

It is important that the initialization procedure as described in the previous section be performed before executing the examples, particularly those involved with storing field data.

Situation 1. Sun observation at a point of known (predetermined) latitude and longitude. Stopwatch used for time of pointings. Multiple foresights on the sun's left edge. Azimuth computed on site with conversion to state plane grid (Arkansas North). For field notes, see Figure 1. Use SUN/TMO/MFS options. Menu keys are shown as underlined.

| DISPLAY | ENTRY/(REMARKS) | KEY STROKE |
|---|---|---|
| | | LCML |
| :LONG. CM: | 92 (Longitude of central meridian, Arkansas North zone. See Appendix A.) | ▼ |
| :LAM. CONST: | .581899 (Lambert convergence factor. See Appendix A.) | ENTER |
| | | ASTRO |
| :SUN=0, POL=1, ST=2: | 0 | ▼ |
| :TMO=0, SGL=1, EPH=2: | 0 | ENTER |
| :MFS=0, SFS=1: | 0 | ENTER |
| :LAT: | 36.0400 | ▼ |
| :LONG: | 94.1008 | ENTER |
| :SD (1, 0, -1): | 1 (Enter 1 for sun's left edge, 0 for sun's center, -1 for sun's right edge.) | ENTER |
| :NO. OF POINTINGS: | 6 (Total number of pointings on the celestial body. Must be a multiple of 2.) | ENTER |
| :DATE M.DY: | 6.081992 (Greenwich date.) | ▼ |
| :UT@SW=0: | 13.34016 (UT time when stopwatch was started.) | ENTER |
| :BSD: | 0 (Circle reading on BS with telescope direct.) | ENTER |
| :SW: | 0.12157 (Stopwatch reading in H.MMSSs of first pointing.) | ENTER |
| :FS: | 351.1315 (Circle reading in D.MMSS of first pointing on sun.) | ENTER |
| :SW: | 0.12488 (Stopwatch for second pointing.) | ENTER |
| :FS: | 351.1740 (Circle reading of second pointing.) | ENTER |
| :SW: | 0.13109 | ENTER |

| | | |
|---|---|---|
| :FS: | 351.2130 | ENTER |
| REVERSE | (Prompt to reverse telescope.) | |
| :SW: | 0.15421 | ENTER |
| :FS: | 171.4005 | ENTER |
| :SW: | 0.16029 | ENTER |
| :FS: | 171.4245 | ENTER |
| :SW: | 0.16312 | ENTER |
| :FS: | 171.4630 | ENTER |
| :BSR: | 180.0005 (Circle reading on BS with telescope reversed.) | ENTER |
| | (Calculator will take several seconds to generate ephemeris data and compute an azimuth for each pointing.) | |
| 6 AZML: 91.22421<br>5 AZML: 91.22383<br>4 AZML: 91.21427<br>3 AZML: 91.23082<br>2 AZML: 91.23129<br>1 AZML: 91.23122 | (Azimuths for the last 4 pointings are displayed. Use the ▲ key to view the first two pointings. Note: the azimuth on line 6 is the azimuth for the first pointing, line 5 for the second, etc. If the ▲ key is used to view azimuths, press ATTN to have cursor exit listing.) | |
| | | ←┐ CONT |
| :SEQUENCE ↑. : | .1256 (This is the averaging routine. Third Azimuth, line 4, is bad. Throw this plus an azimuth reversed out, e.g. fourth azimuth, line 3. Key in the azimuth line numbers preceded by a decimal point.) | ENTER |
| AZML: 91.22564<br>GRID: 92.38398<br>H: 31.55094<br>Z: 83.28125 | (The average astronomic azimuth to BS is line 4. Grid azimuth is line 3. Altitude corrected for parallax and refraction is line 2. Azimuth to sun is line 1. H and Z are computed to the sun's center at the UT time of the last pointing. All values in D.MMSSs.) | |
| | (Assume it is desired to compute an average of lines 1, 3, 5 and 6 for comparison purposes.) | |

| | | |
|---|---|---|
| | | <u>SEQ</u> |
| :SEQUENCE ↑.: | .1356 | ENTER |
| AZML: 91.22552<br>GRID: 92.38387<br>H: 31.55094<br>Z: 83.28125 | | |
| | (At this point input data could be stored in a file. It can also be viewed and manually recorded with the DUMP routine.) | |
| | | <u>DUMP</u> |
| "SUN"<br>6.081992<br>M.DY<br>"(PRESS CONT)" | | ↵ CONT |
| LON: 94.10080<br>SD.CODE: 1.00000<br>LCM: 92.00000<br>L: 0.58190 | (The remaining data can be viewed by pressing the ▲ key. To exit viewing press the ATTN key.) | |

## SUN OBSERVATION

| POINTING | TELE. | STOPWATCH TIME | CIRCLE READING |
|---|---|---|---|
| MCS | D | | 0-00-00 |
| þ | D | 0:12:15.7 | 351-13-15 |
| p | D | 0:12:48.8 | 351-17-40 |
| þ | D | 0:13:10.9 | 351-21-30 |
| b | R | 0:15:42.1 | 171-40-20 |
| b | R | 0:16:02.9 | 171-42-45 |
| p | R | 0:16:31.2 | 171-46-30 |
| MCS | R | | 180-00-05 |

## SUN OBSERVATION

LIETZ SET 3 — MON. am

OBJECTIVE FILTER — JUNE 8, 1992

CLEAR, CALM

DRK, RE

LATITUDE = 36°04'00" N

LONGITUDE = 94°10'08" W

UTC = 13:34:02 (BY WWV)

DUT = -0.4 sec. (estimate for example)

UT1 = 13:34:01.6

STOPWATCH = 0:00:00.0

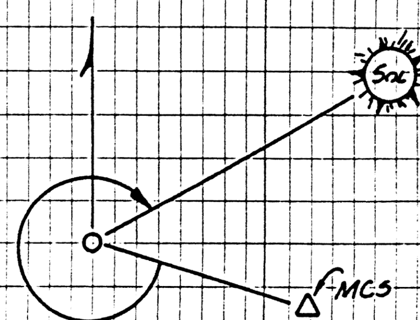


**FIGURE 1**

**Sun Observation Field Notes for Situation 1.**

Situation 2. Same as Situation 1. except latitude and longitude of station unknown at time of observation. Data to be stored in field, recalled in office, latitude and longitude entered and calculations performed. (Note: Grid conversion constants remain in storage until changed.) Printing field data and calculated results are illustrated.

| DISPLAY | ENTRY/(REMARKS) | KEY STROKES |
|---|---|---|
| | | ASTRO |
| :SUN=0, POL=1, ST=2:<br>:TMO=0, SGL=1, EPH=2: | 0<br>0 | ▼<br>ENTER |
| :MFS=0, SFS=1: | 0 | ENTER |
| :LAT:<br>:LONG: | 0<br>0 | ▼<br>ENTER |
| :SD (1, 0, -1): | 1 | ENTER |
| :NO. OF POINTINGS: | 6 | ENTER |
| :DATE M.DY:<br>UT@SW=0: | 6.081992<br>13.34016 | ▼<br>ENTER |
| :BSD: | 0 | ENTER |
| :SW: | 0.12157 | ENTER |
| :FS: | 351.1315 | ENTER |
| :SW: | 0.12488 | ENTER |
| :FS: | 351.1740 | ENTER |
| :SW: | 0.13109 | ENTER |
| :FS: | 351.2130 | ENTER |
| :SW: | 0.15421 | ENTER |
| :FS: | 171.4005 | ENTER |
| :SW: | 0.16029 | ENTER |
| :FS: | 171.4245 | ENTER |
| :SW: | 0.16312 | ENTER |
| :FS: | 171.4630 | ENTER |
| :BSR: | 180.0005 | ENTER |

| | | |
|---|---|---|
| 4: AZML: 321.05023<br>3: AZML: 320.10274<br>2: AZML: 320.02545<br>1: AZML: 319.52327 | (These azimuths are incorrect due to unknown latitude and longitude. This unnecessary calculation can be terminated by pressing the ATTN key.) | |
| | (Store data in file SUN1.) | |
| | | NXT<br>NXT<br><u>SAVE</u> |
| :FL NAME?: | αα SUN1 | ENTER |
| | (In the office, latitude and longitude are scaled as $36^{o}04'00"$ and $94^{o}10'08"$.) | |
| | | <u>GETD</u> |
| :FL NAME?: | αα SUN1 | ENTER |
| | | NXT<br>NXT<br><u>LTLN</u> |
| :LAT:<br>:LONG: | 36.04<br>94.1008 | ▼<br>ENTER |
| | (Recompute azimuths.) | NXT<br><u>CMPT</u> |
| 6 AZML: 91.22421<br>5 AZML: 91.22382<br>4 AZML: 91.21427<br>3 AZML: 91.23082<br>2 AZML: 91.23129<br>1 AZML: 91.23122 | (Only lines 4 thru 1 displayed.) | |
| | | ↰ CONT |
| :SEQUENCE ↑.: | .1256 | ENTER |
| AZML: 91.22564<br>GRID: 92.38398<br>H: 31.55094<br>Z: 83.28125 | | |
| | (To print out field data and results, set flag 5.) | |
| | 5αα SF | ENTER |

| | | |
|---|---|---|
| | | <u>DUMP</u> |
| | (Field data is printed.) | |
| | | <u>AZLT</u> |
| | (List of azimuths are printed.) | |
| :SEQUENCE 4.: | .1256 | ENTER |
| | (Computed results are printed.) | |
| | (After printing, flag 5 should be cleared.) | |
| | 5 $\alpha\alpha$ CF | ENTER |

<u>Situation 3.</u> Polaris observation at point of known (predetermined) latitude and longitude. UTC time of pointings recorded. Single foresights, 3 positions on the circle (6 pointings on Polaris). Two methods of observations shown: SFS procedure as shown in Figure 2 field notes; and, MFS procedure which is not illustrated with a set of field notes. Azimuth computed on site with conversion to grid (Missouri Central). Precompute zenith angle for 9:00 pm and 9:30 pm CDT.

To precompute zenith angle to Polaris, first convert local time to UTC. Then use POL/SGL options.

7:00 pm CDT May 7 = $0^{hr}$ UTC May 8

9:00 pm and 9:30 pm CDT = $2^{hr}$ and $2^{hr}30^{m}$ UTC May 8

| DISPLAY | ENTRY/(REMARKS) | KEY STROKE |
|---|---|---|
| | | <u>ASTRO</u> |
| :SUN=0, POL=1, ST=2: | 1 | ▼ |
| :TMO=0, SGL=1, EPH=2: | 1 | ENTER |
| :LAT: | 37.5723 | ▼ |
| :LONG: | 91.4635 | ENTER |
| :DATE M.DY: | 5.081992 | ▼ |
| :UT@SW=0: | 0 | ENTER |
| :BS: | 0 | ▼ |
| :FS: | 0 | ▼ |
| :SW: | 2 | ENTER |
| AZML: 359.14389 | (Azimuth to Polaris. Neglect GRID | |
| GRID: 359.06505 | since Missouri constants not entered. | |
| H: 37.29332 | H is vertical angle corrected for | |
| Z: -0.45211 | refraction. To obtain zenith angle | |
| | subtract H from 90°. Zenith angle = 52°30'27") | |
| | | <u>BSFS</u> |
| :BS: | 0 | ▼ |
| :FS: | 0 | ▼ |
| :SW: | 2.30 | ENTER |
| AZML: 359.19510 | | |
| GRID: 359.12026 | | |
| H: 37.25076 | (Zenith angle = 52°34'52") | |
| Z: -0.40090 | | |

Observations:

| DISPLAY | ENTRY/(REMARKS) | KEY STROKE |
|---|---|---|
| | | LCML |
| :LONG. CM: | 92.30 | ▼ |
| :LAM. CONST: | 0 (Enter zero for all Mercator Projection.) | ENTER |
| | | ASTRO |
| :SUN=0, POL=1, ST=2: | 1 | ▼ |
| :TMO=0, SGL=1, EPH=2: | 0 | ENTER |
| :MFS=0, SFS=1: | 1 | ENTER |
| :LAT: | 37.5723 | ▼ |
| :LONG: | 91.4635 | ENTER |
| :NO. OF POINTINGS: | 6 (Total number of pointings on the celestial body. Must be a multiple of 2.) | ENTER |
| :DATE M.DY: | 5.081992 | ▼ |
| :UT@SW=0: | 0 (Enter zero since times are UT.) | ENTER |
| :BSD: | 0.0008 | ENTER |
| :SW: | 2.16215 | ENTER |
| :FS: | 94.5038 | ENTER |
| :SW: | 2.19361 | ENTER |
| :FS: | 274.5114 | ENTER |
| :BSR: | 180.0003 | ENTER |
| :BSD | 60.0321 | ENTER |
| :SW: | 2.28110 | ENTER |
| :FS: | 154.5600 | ENTER |
| :SW: | 2.30154 | ENTER |
| :FS: | 334.5626 | ENTER |
| :BSR: | 240.0318 | ENTER |
| :BSD: | 120.0644 | ENTER |

| | | |
|---|---|---|
| :SW: | 2.41576 | ENTER |
| :FS: | 215.0156 | ENTER |
| :SW: | 2.44189 | ENTER |
| :FS: | 35.0226 | ENTER |
| :BSR: | 300.0640 | ENTER |
| AZML: 264.26503<br>AZML: 264.26489<br>AZML: 264.26518 | (The average of D&R for each set is listed.) | ↵ CONT |
| :SEQUENCE ↓.: | .123 | ENTER |
| AZML: 264.26503<br>GRID: 264.00081<br>H: 37.23127<br>Z: -0.37254 | | |
| | (To take another observation at same location, use MFS routine.) | NXT<br>MFS |
| :NO. OF POINTINGS: | 6 | ENTER |
| :DATE M.DY:<br>:UT@SW=0: | 5.081992<br>0 | ▼<br>ENTER |
| :BSD: | 0.0012 | ENTER |
| :SW: | 3.02168 | ENTER |
| :FS: | 94.5932 | ENTER |
| :SW: | 3.04217 | ENTER |
| :FS: | 274.5959 | ENTER |
| :BSR: | 180.0008 | ENTER |
| :BSD: | 60.0329 | ENTER |
| :SW: | 3.09282 | ENTER |
| :FS: | 155.0417 | ENTER |
| :SW: | 3.11216 | ENTER |
| :FS: | 335.0444 | ENTER |
| :BSR: | 240.0326 | ENTER |
| :BSD: | 120.0651 | ENTER |

| | | |
|---|---|---|
| :SW: | 3.20563 | ENTER |
| :FS: | 215.1011 | ENTER |
| :SW: | 3.22427 | ENTER |
| :FS: | 35.1035 | ENTER |
| :BSR: | 300.0646 | ENTER |
| AZML: 264.26494<br>AZML: 264.26515<br>AZML: 264.26477 | | ←┐ CONT |
| :SEQUENCE ↑. : | .123 | ENTER |
| AZML: 264.26495<br>GRID: 264.00073<br>H: 37.18466<br>Z: -0.29261 | | |

POLARIS OBSERVATION

| SET | POINTING | TELE. | | |
|---|---|---|---|---|
| 1 | AM1 | D | | 0-00-08 |
| | * | D | 2:16:21.5 | 94-50-38 |
| | * | R | 2:19:36.1 | 274-51-14 |
| | AM1 | R | | 180-00-03 |
| 2 | AM1 | D | | 60-03-21 |
| | * | D | 2:28:11.0 | 154-56-00 |
| | * | R | 2:30:15.4 | 334-56-26 |
| | AM1 | R | | 240-03-18 |
| 3 | AM1 | D | | 120-06-44 |
| | * | D | 2:41:57.6 | 215-01-56 |
| | * | R | 2:44:18.9 | 35-02-26 |
| | AM1 | R | | 300-06-40 |

POLARIS OBSERVATION

LIETZ TM1A 03892

THUR. NITE
MAY 7, 1992
CLEAR, COOL
JHS, RE

LATITUDE = 37°57'23" N
LONGITUDE = 91°46'35" W

HP-48SX CLOCK SET WITH WWV AT 1:56:00 UTC MAY 8

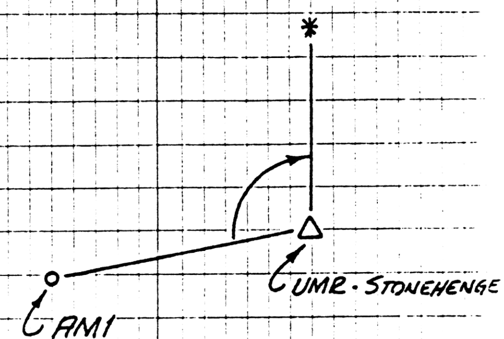


**FIGURE 2**

**Polaris Observation Field Notes for Situation 3.**

Situation 4. Observation on star Antares (star number 21, see Appendix H) at point of known latitude and longitude. For field notes, see Figure 3. Multiple foresight with UT1 times recorded. (Note: Missouri Central constants have remained in memory.)

| DISPLAY | ENTRY/(REMARKS) | KEY STROKE |
|---|---|---|
| | | ASTRO |
| :SUN=0, POL=1, ST=2:<br>:TMO=0, SGL=1, EPH=2: | 2<br>0 | ▼<br>ENTER |
| :MFS=0, SFS=1: | 0 | ENTER |
| :TABLE=1, COORD.=0: | 1 (For stars listed in Appendix H, use the TABLE option.) | ENTER |
| :STAR NUMBER: | 21 (From Appendix H.) | ENTER |
| :LAT:<br>:LONG: | 37.56084<br>91.46051 | ▼<br>ENTER |
| :NO. OF POINTINGS: | 6 | ENTER |
| :DATE M.DY:<br>:UT@SW=0: | 7.011992<br>0 | ▼<br>ENTER |
| :BSD: | 0.0008 | ENTER |
| :SW: | 2.12231 | ENTER |
| :FS: | 61.0434 | ENTER |
| :SW: | 2.14481 | ENTER |
| :FS: | 61.3650 | ENTER |
| :SW: | 2.18016 | ENTER |
| :FS: | 62.2020 | ENTER |
| :SW: | 2.20257 | ENTER |
| :FS: | 242.5239 | ENTER |
| :SW: | 2.23426 | ENTER |
| :FS: | 243.3730 | ENTER |
| :SW: | 2.25387 | ENTER |
| :FS: | 244.0351 | ENTER |

| | | |
|---|---|---|
| :BSR: | 180.0003 | ENTER |
| 6 AZML: 93.33135<br>5 AZML: 93.33195<br>4 AZML: 93.33151<br>3 AZML: 93.33216<br>2 AZML: 93.33097<br>1 AZML: 93.33158 | (Use the ▲ key to view all six azimuths.) | ATTN<br>↵ CONT |
| :SEQUENCE ↓.: | .123456 | ENTER |
| AZML: 93.33159<br>GRID: 93.06160<br>H: 22.06201<br>Z: 157.37038 | | |

It should be noted again that in all of the above examples, flag 4 was set in order to bypass the clock. This causes the TMO routines to prompt for date (M.DY), UT time when stopwatch was started (UT@SW=0) and stopwatch time of pointing (SW). If it is desired to use ASTRO*CARD in the field as a data collector, including date and time, flag 4 must be cleared. Date and beginning stopwatch time will not be prompted for (date taken from clock) and CLOCK will display in lieu of SW. At the instant of pointing (with CLOCK displayed) quickly press and release the ENTER key. This will retrieve time of pointing from the internal clock. It is extremely important that the internal date has been correctly set and the clock has been accurately synchronized to UT. (See Appendix B.) If it is felt that a time of pointing was incorrectly made, at the prompt for FS enter a minus one (-1). The program will back up one step and allow the retaking of the pointing.

STAR OBSERVATION (ANTARES)

| POINTING | TELE. | UT1, JULY 1 | CIRCLE READ. |
|---|---|---|---|
| MK | D | | 0-00-08 |
| * | D | 2:12:23.1 | 61-04-34 |
| * | D | 2:14:48.1 | 61-36-50 |
| * | D | 2:18:01.6 | 62-20-20 |
| * | R | 2:20:25.7 | 242-52-39 |
| * | R | 2:23:42.6 | 243-37-30 |
| * | R | 2:25:38.7 | 244-03-51 |
| MK | R | | 180-00-03 |

STAR OBSERVATION (ANTARES)

LIETZ TM1A
03892

TUE. NITE
JUNE 30, 1992
CLEAR, WARM
JHS, PE

LATITUDE = 37°56'08."4 N
LONGITUDE = 91°46'05."1 W

HP-48SX CLOCK SET WITH WWV
AT 1:45:00 UTC JULY 1
CORRECTED FOR DUT = -0.ˢ4

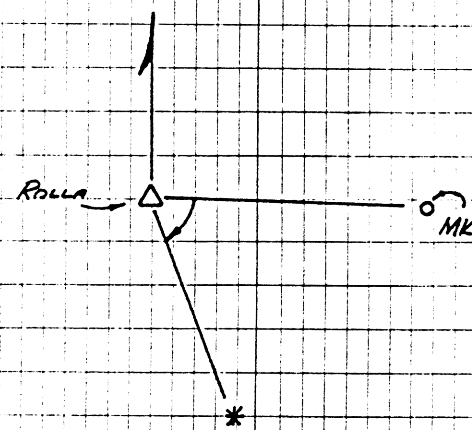


**FIGURE 3**

**Star Observation Field Notes for Situation 4.**

# APPENDIX A

## STATE PLANE COORDINATE CONSTANTS

Values are for both NAD27 and NAD83 Datums, unless noted separately.

| STATE | ZONE | LONGITUDE CENTRAL MERIDIAN | LAMBERT CONSTANT |
|---|---|---|---|
| Alabama | | | |
| | East | 85°50'00" | 0 |
| | West | 87°30'00" | 0 |
| Alaska | | | |
| | 2 | 142°00'00" | 0 |
| | 3 | 146°00'00" | 0 |
| | 4 | 150°00'00" | 0 |
| | 5 | 154°00'00" | 0 |
| | 6 | 158°00'00" | 0 |
| | 7 | 162°00'00" | 0 |
| | 8 | 166°00'00" | 0 |
| | 9 | 170°00'00" | 0 |
| | 10 | 176°00'00" | 0.796922 |
| Arizona | | | |
| | East | 110°10'00" | 0 |
| | Central | 111°55'00" | 0 |
| | West | 113°45'00" | 0 |
| Arkansas | | | |
| | North | 92°00'00" | 0.581899 |
| | South | 92°00'00" | 0.559691 |
| California | | | |
| | I | 122°00'00" | 0.653884 |
| | II | 122°00'00" | 0.630468 |
| | III | 120°30'00" | 0.612232 |
| | IV | 119°00'00" | 0.596587 |
| | V | 118°00'00" | 0.570012 |
| | VI | 116°15'00" | 0.549518 |
| | VII (1927) | 118°20'00" | 0.561243 |
| Colorado | | | |
| | North | 105°30'00" | 0.646133 |
| | Central | 105°30'00" | 0.630690 |
| | South | 105°30'00" | 0.613378 |
| Connecticut | | 72°45'00" | 0.663059 |
| Delaware | | 75°25'00" | 0 |

| STATE | ZONE | LONGITUDE CENTRAL MERIDIAN | LAMBERT CONSTANT |
|---|---|---|---|
| Florida | | | |
| | North | 84°30'00" | 0.502526 |
| | East | 81°00'00" | 0 |
| | West | 82°00'00" | 0 |
| Georgia | | | |
| | East | 82°10'00" | 0 |
| | West | 84°10'00" | 0 |
| Hawaii | | | |
| | 1 | 155°30'00" | 0 |
| | 2 | 156°40'00" | 0 |
| | 3 | 158°00'00" | 0 |
| | 4 | 159°30'00" | 0 |
| | 5 | 160°10'00" | 0 |
| Idaho | | | |
| | East | 112°10'00" | 0 |
| | Central | 114°00'00" | 0 |
| | West | 115°45'00" | 0 |
| Illinois | | | |
| | East | 88°20'00" | 0 |
| | West | 90°10'00" | 0 |
| Indiana | | | |
| | East | 85°40'00" | 0 |
| | West | 87°05'00" | 0 |
| Iowa | | | |
| | North | 93°30'00" | 0.677745 |
| | South | 93°30'00" | 0.658701 |
| Kansas | | | |
| | North | 98°00'00" | 0.632715 |
| | South | 98°30'00" | 0.614528 |
| Kentucky | | | |
| | North | 84°15'00" | 0.622067 |
| | South | 85°45'00" | 0.606462 |
| Louisiana | | | |
| | North | 92°30'00" | 0.528701 |
| | South | 91°20'00" | 0.500013 |
| | Offshore | 91°20'00" | 0.454007 |
| Maine | | | |
| | East | 68°30'00" | 0 |
| | West | 70°10'00" | 0 |

| STATE | ZONE | LONGITUDE CENTRAL MERIDIAN | LAMBERT CONSTANT |
|---|---|---|---|
| Maryland | | 77°00'00" | 0.627634 |
| Massachusetts | | | |
| | Mainland | 71°30'00" | 0.671729 |
| | Island | 70°30'00" | 0.661095 |
| Michigan (1964) | | | |
| | North | 87°00'00" | 0.722790 |
| | Central | 84°20'00" | 0.706407 |
| | South | 84°20'00" | 0.680529 |
| Michigan (1934) | | | |
| | East | 83°40'00" | 0 |
| | Central | 85°45'00" | 0 |
| | West | 88°45'00" | 0 |
| Michigan (1983) | | | |
| | Central | 84°22'00" | 0.706407 |
| | South | 84°22'00" | 0.680529 |
| Minnesota | | | |
| | North | 93°06'00" | 0.741220 |
| | Central | 94°15'00" | 0.723388 |
| | South | 94°00'00" | 0.700928 |
| Mississippi | | | |
| | East | 88°50'00" | 0 |
| | West | 90°20'00" | 0 |
| Missouri | | | |
| | East | 90°30'00" | 0 |
| | Central | 92°30'00" | 0 |
| | West | 94°30'00" | 0 |
| Montana (1927) | | | |
| | North | 109°30'00" | 0.746452 |
| | Central | 109°30'00" | 0.733354 |
| | South | 109°30'00" | 0.714901 |
| Montana (1983) | | | |
| | Single Zone | 109°30'00" | 0.731504 |
| Nebraska (1927) | | | |
| | North | 100°00'00" | 0.673451 |
| | South | 99°30'00" | 0.656076 |
| Nebraska (1983) | | | |
| | Single Zone | 100°00'00" | 0.662697 |

| STATE | ZONE | LONGITUDE CENTRAL MERIDIAN | LAMBERT CONSTANT |
|---|---|---|---|
| Nevada | | | |
| | East | 115°35'00" | 0 |
| | Central | 116°40'00" | 0 |
| | West | 118°35'00" | 0 |
| New Hampshire | | 71°40'00" | 0 |
| New Jersey (1927) | | 74°40'00" | 0 |
| New Jersey (1983) | | 74°30'00" | 0 |
| New Mexico | | | |
| | East | 104°20'00" | 0 |
| | Central | 106°15'00" | 0 |
| | West | 107°50'00" | 0 |
| New York (1927) | | | |
| | East | 74°20'00" | 0 |
| | Central | 76°35'00" | 0 |
| | West | 78°35'00" | 0 |
| | Long Island | 74°00'00" | 0.654082 |
| New York (1983) | | | |
| | East | 74°30'00" | 0 |
| North Carolina | | 79°00'00" | 0.577171 |
| North Dakota | | | |
| | North | 100°30'00" | 0.744133 |
| | South | 100°30'00" | 0.729383 |
| Ohio | | | |
| | North | 82°30'00" | 0.656950 |
| | South | 82°30'00" | 0.634520 |
| Oklahoma | | | |
| | North | 98°00'00" | 0.590147 |
| | South | 98°00'00" | 0.567617 |
| Oregon | | | |
| | North | 120°30'00" | 0.709186 |
| | South | 120°30'00" | 0.684147 |
| Pennsylvania | | | |
| | North | 77°45'00" | 0.661540 |
| | South | 77°45'00" | 0.648793 |
| Rhode Island | | 71°30'00" | 0 |

| STATE | ZONE | LONGITUDE CENTRAL MERIDIAN | LAMBERT CONSTANT |
|---|---|---|---|
| South Carolina (1927) | | | |
| | North | 81°00'00" | 0.564497 |
| | South | 81°00'00" | 0.544652 |
| South Carolina (1983) | | | |
| | Single Zone | 81°00'00" | 0.554399 |
| South Dakota | | | |
| | North | 100°00'00" | 0.707738 |
| | South | 100°20'00" | 0.689852 |
| Tennessee | | 86°00'00" | 0.585440 |
| Texas (1927) | | | |
| | North | 101°30'00" | 0.579536 |
| | North Central | 97°30'00" | 0.545394 |
| | Central | 100°20'00" | 0.515059 |
| | South Central | 99°00'00" | 0.489913 |
| | South | 98°30'00" | 0.454007 |
| Texas (1983) | | | |
| | North Central | 98°30'00" | 0.545394 |
| Utah | | | |
| | North | 111°30'00" | 0.659355 |
| | Central | 111°30'00" | 0.640579 |
| | South | 111°30'00" | 0.612687 |
| Vermont | | 72°30'00" | 0 |
| Virginia | | | |
| | North | 78°30'00" | 0.624118 |
| | South | 78°30'00" | 0.606925 |
| Washington | | | |
| | North | 120°50'00" | 0.744520 |
| | South | 120°30'00" | 0.726396 |
| West Virginia | | | |
| | North | 79°30'00" | 0.637773 |
| | South | 81°00'00" | 0.618195 |
| Wisconsin | | | |
| | North | 90°00'00" | 0.721371 |
| | Central | 90°00'00" | 0.705577 |
| | South | 90°00'00" | 0.687103 |

| STATE | ZONE | LONGITUDE CENTRAL MERIDIAN | LAMBERT CONSTANT |
|---|---|---|---|
| Wyoming | | | |
| | East | 105°10'00" | 0 |
| | East Central | 107°20'00" | 0 |
| | West Central | 108°45'00" | 0 |
| | West | 110°05'00" | 0 |
| Puerto Rico | | 66°26'00" | 0.312888 |
| St. Croix | | 66°26'00" | 0.312888 |
| Virgin Islands | | 66°20'00" | 0.312888 |

# APPENDIX B

## SETTING TIME AND DATE

To take full advantage of the routines in ASTRO*CARD, the HP 48SX clock should be accurately set to Universal Time (UT1) and Date (time and date at Greenwich). An accurate Coordinated Universal Time (UTC) signal can be received from station WWV or some other time station (e.g. WWVH or CHU). UT1 is obtained by adding a correction (DUT) to UTC (UT1 = UTC + DUT). This DUT correction, which at present changes by 0.1 seconds approximately every two months, is obtained from the time signal by counting the number of double ticks following the minute tone. Each double tick represents a tenth of a second and is positive for the first seven seconds (ticks). Beginning with the ninth second, each double tick represents a negative tenth of a second correction. While this correction will not exceed 0.7 seconds, it is easy to apply and may significantly increase the accuracy of computed azimuths.

In the United States (including Alaska and Hawaii), Greenwich and local date will be the same from early morning until at least local noon. Apply the following rules for any location world wide. For the western hemisphere, if UTC is greater than local time (Daylight or Standard), Greenwich date is the same as local date. If UTC is less than local time, Greenwich date is local date plus one day. For the eastern hemisphere, if UTC is less than local time (24 hour basis), Greenwich date is the same as local date. If UTC is greater than local time, Greenwich date is local date minus one day.

To set the approximate UT1 time and date in the HP 48SX clock, enter the 48SX TIME menu (see page 41 of the 48SX Owner's Manual, Volume 1). While listening to the WWV time signal, key in the UTC (HH.MM) for the next full minute, and on the minute tone press and quickly release the ->TIM menu key. This should result in the clock being set to within approximately one second of UTC. Next key in the correct Greenwich date (MM.DDYYYY) and press the ->DAT menu key. Note that both the time and date display formats may be toggled using the 12/24 and M/D keys. Although not necessary, a continuous display of the clock can be obtained by entering the 48SX MODES menu and turning CLK on or by setting flag -40.

When making observations on celestial bodies other than those close to the celestial poles (e.g. Polaris), it is extremely important to obtain accurate time of pointings. The 48SX TIME menu contains routines for adjusting the clock; however, accuracy is limited to about one second and they do not take into account any possible calculation and/or user lag when executing programs in ASTRO*CARD. Consequently, three routines (TM, CLOK, and CORRT) have been included in ASTRO*CARD for accurately adjusting or synchronizing the clock to UT1.

ASTRO routines TM and CLOK are designed to determine any systematic difference between the WWV time signal and the internal 48SX clock. Either or both of these routines can be used depending on the preference of the user. TM has the advantage of displaying both time and date while CLOK uses the same key and program steps as an actual celestial observation in ASTRO. Using either of these routines is similar to taking stopwatch split times on WWV ticks (full seconds) to determine any error in starting the stopwatch.

Quickly pressing and releasing the TM menu key will place the 48SX clock time (at the instant the key was released) in register line 1 and the date in register line 2. Using this routine consists of quickly pressing/releasing the TM key on a WWV tick (full second) and observing any systematic difference between the time displayed in line 1 and a full second. This should be repeated several times to verify a consistent difference. It should also be performed on a known time, e.g. a minute tone or known number of ticks past the tone, to check for a full number of seconds difference. Any systematic difference should be noted for use in the CORRT routine below to adjust the clock.

To use the CLOK routine flag 4 must be clear. This flag causes the ASTRO programs to take time from the internal clock rather than prompting for time. When the CLOK menu key is pressed, this routine "borrows" program steps prompting for a pointing (CLOCK and FS) as if an actual celestial observation was being made. With the prompt of CLOCK displayed, quickly press and release the ENTER key on a WWV tick just as if the user was making a pointing on a celestial body. At the FS prompt enter any value (e.g. 0). Time from the internal clock will be displayed in register line 2. Repeat this several times and compare the display with a full second as explained in the TM routine above.

ASTRO routine CORRT is used to correct the clock by any systematic time difference determined from using the TM or CLOK routines above. CORRT differs from the 48SX TIME routine in that seconds, tenths and hundreths of seconds can be easily corrected for. To use this routine press the CORRT menu key and enter the correction in seconds, tenths and hundreths of seconds (S.ss). The correction will be positive if the displayed time in TM or CLOK was less than WWV and negative if more.

Using TM/CLOK and CORRT should be repeated until the clock appears to be accurately set to WWV (UTC). CORRT can then be executed to apply the DUT correction to set the clock to UT1.

Depending on environmental conditions and the clock's accuracy, the TM/CLOK and CORRT routines should be performed shortly before a set of celestial observations.

# APPENDIX C

## EDITING INPUT DATA ARRAY [ OBS ]

If after running ASTRO, it appears some of the input field data is in error, it can be easily checked using matrix writer to view and edit the input data array [OBS] which contains all of the foresight angles and pointing times. To do this for the MFS option proceed as follows:

1. Set decimal fix at 5.

2. Type ['] [α ] [α ] OBS [α ] ↱ [RCL] or press the menu key under [OBS]. This will put [OBS] on the stack.

3. Press ▼ , this puts [OBS] in the matrix writer mode. Now use the cursor keys to move around the matrix. Note that the current value is displayed at the bottom. The matrix has two columns which read from bottom up. The first column contains foresights and the second, times. Press cursor keys to move to number to be changed.

4. Press [EDIT] (left menu key). This will permit editing the number at the bottom. Now edit the number using the cursor, number and delete keys; then press [ENTER]. The old number in the matrix should now be replaced by the new one. All data contained in [OBS] is in d.ms and h.ms.

5. The next step is to store the revised array into data file [OBS]. To do this, press [ENTER] ['] [α] [α] OBS [α ] ▶ [STO].

6. For the MFS option BSD and BSR are stored separately. To edit these variables enter the new value (in degrees) on the stack, type ['] [α ] [α] BSD (or BSR) [α] ▶ and press [STO]. Check the value by pressing the menu key under BSD (or BSR), or by typing ['] [α] [α] BSD [α ] ↱ [RCL] etc.

7. To edit field data for SFS proceed as above but note that in this case BSD and BSR are contained within the array which is composed of one row per set, each row reading from right to left and from the bottom up. For example, six pointings would be in the following format:

   (position 3) BSR FSR SW FSD SW BSD
   (position 2) BSR FSR SW FSD SW BSD
   (position 1) BSR FSR SW FSD SW BSD

   Additional note: The array OBS is contained in the directory ASTVAR1 which contains all of the variables for ASTRO*CARD. This is analogous to the storage registers in the HP41 calculator. Since there can be 48 variables shown in ASTVAR1 it is desirable to have those that need to be accessed, on the first menu row. To place a variable in this row first purge the variable by pressing key ['], and then the menu key under the variable name. Next press ↰ [PURGE] and the variable should be deleted. If others are to be moved forward, repeat the procedure. After they have been purged, run ASTRO*CARD with an observation containing those terms and they will appear in the first menu row.

It is desirable to have BSD, OBS and BSR up front so that they can be quickly found for editing.

# APPENDIX D

## LIST OF USEFUL VARIABLES IN DIRECTORY ASTVAR1

| | |
|---|---|
| BS | Backsight for single observation (degrees) |
| FS | Foresight for single observation (degrees) |
| BSD | BSD for MFS (degrees) |
| BSR | BSR for MFS (degrees) |
| OBS | Array of pointings for MFS & SFS (d.ms & h.ms) |
| CM | Longitude of central meridian (degrees) |
| LC | Lambert constant "L" |
| MDY | Month,day,year (M.DY) |
| SO | UT@SW=0 (hours) |
| SW | Stopwatch or UT1 (hours) |
| UT | SO+SW=UT1 (hours) |
| SD | Semidiameter of Sun (degrees) |
| SDC | Sun's semidiameter code |
| L1 | Latitude (+N,-S), (degrees) |
| L2 | Longitude (+W,-E), (degrees) |
| NP | Number of pointings, MFS & SFS |
| $\alpha$ | Apparent right ascension of star (degrees) |
| $\delta$ | Apparent declination of star (degrees) |
| RA0 | Right ascension of star, epoch J2000.0, FK5 (hours) |
| DL0 | Declination of star, epoch J2000.0, FK5 (degrees) |
| PMA | Star proper motion in RA (hours/century) |
| PMD | Star proper motion in decl. (degrees/century) |
| SN | Star number |
| LHA | Local hour angle |
| GHA | Greenwich hour angle (degrees) |
| H | Computed vertical angle to body, not corrected for refraction or parallax (degrees) |
| Z | Direction of body from north (+E,-W), (degrees) |

# APPENDIX E

## USER FLAGS (SET)

| | |
|---|---|
| 1 | Sun |
| 2 | Polaris |
| 3 | Star |
| 4 | Manual time/date input |
| 5 | Print |
| 6 | MFS |
| 6 & 7 | SFS |
| 8 | Single observation |
| 9 | Ephemeris |
| 10 | Used |

Note: Flags 1 through 3 and 6 through 10 are cleared each time ASTRO is executed.
Flag numbers 1 through 5 are visible in HP48 annunciator window.

## USEFUL SYSTEM FLAGS (SET)

| | |
|---|---|
| -37 | Double space printing for IR printer |
| -40 | Displays date and clock in HP48 window |
| -57 | Beep suppressed |

# APPENDIX F

## ACCURACIES

The design period for non-ephemeris routines in ASTRO is from the year 1965 through 2010. While the program will generate ephemeris data outside of this period, the accuracies stated below do not apply.

### SUN

Maximum error in GHA is 2.2 arc-seconds and 90% of the time error is less than 1.0 arc-seconds.

Maximum error in declination is 1.4 arc-seconds and 90% of the time error is less than 1.0 arc-seconds.

The above errors result in a maximum error in azimuth of 3.3 arc-seconds (90% of the time less than 1.5 arc-seconds) when the sun's altitude is at 40 degrees. Error decreases as altitude of sun decreases.

### POLARIS

Maximum error is azimuth is 0.6 arc-seconds for observations made at $60^{o}$N latitude. Maximum error is 0.4 arc-seconds at $40^{o}$N latitude.

# APPENDIX G

## HP48 (ASTRO*CARD) INPUT TO PC (ASTRO*DISK) INPUT

ASTRO48 is a program to convert input data generated by ASTRO*CARD using the HP48SX calculator for use by ASTRO*DISK on PC computers. Basically, observations are made using ASTRO*CARD inserted in the HP48SX in which the input data for either MFS or SFS options have been saved using the SAVE menu command. This file is then transferred to the PC via the serial interface cable and kit sold by HP for the HP48. The transfer is made by invoking KERMIT which is included with the kit. Once the file is in the PC it can then be converted to an ASTRO*DISK input data file by running ASTRO48. The program permits a choice of input data files depending which of three versions of ASTRO*DISK will be used to run the data. The three versions are ASTRO*DISK27/ASTRO*DISK83, ASTRO*DISK34, and ASTRO*DISK. Each of these requires a slightly different format for input data. The transfer works only for the MFS and SFS options.

ASTRO48 can be obtained from the Rolla, Missouri office of Elgin, Knowles & Senne, Inc. for $45.00.

# APPENDIX H

## STAR NUMBERS

| No. | Star Name | Mag. | No. | Star Name | Mag. |
|---|---|---|---|---|---|
| 1 | A Andromedae (Alpheratz) | 2.2 | 33 | 01 Eridani (Acamar) | 3.4 |
| 2 | B Hydri (SAO 255670) | 2.9 | 34 | A Ceti (Menkar) | 2.8 |
| 3 | B Ceti (Diphda) | 2.2 | 35 | A Persi (Mirfak) | 1.9 |
| 4 | A Ursa Minoris (Polaris) | 2.1 | 36 | G Orionis (Bellatrix) | 1.7 |
| 5 | A Arietis (Hamal) | 2.2 | 37 | B Tauri (Elnath) | 1.8 |
| 6 | A Tauri (Aldebaran) | 1.1 | 38 | E Orionis (Alnilam) | 1.8 |
| 7 | B Orionis (Rigel) | 0.3 | 39 | E Camelopardalis (Adhara) | 1.6 |
| 8 | A Aurigae (Capella) | 0.2 | 40 | E Carinae (Avior) | 1.7 |
| 9 | A Orionis (Betelgeuse) | 0.5v | 41 | L Velorum (Suhail) | 2.2 |
| 10 | A Carinae (Canopus) | -0.9 | 42 | B Carinae (Miaplacidus) | 1.8 |
| 11 | A Canis Majoris (Sirius) | -1.6 | 43 | A Ursae Majoris (Dubhe) | 2.0 |
| 12 | A Canis Minoris (Procyon) | 0.5 | 44 | G Corvi (Gienah) | 2.8 |
| 13 | B Geminorum (Pollux) | 1.2 | 45 | A1 Crucis (Acrux) | 1.6 |
| 14 | A Hydrae (Alphard) | 2.2 | 46 | G Crucis (Gacrux) | 1.6 |
| 15 | A Leonis (Regulus) | 1.3 | 47 | E Ursae Majoris (Alioth) | 1.7 |
| 16 | B Leonis (Denebola) | 2.2 | 48 | Eta Ursae Majoris(Alkaid) | 1.9 |
| 17 | A Virginis (Spica) | 1.2 | 49 | B Centauri (Hadar) | 0.9 |
| 18 | 0 Centauri (Menkent) | 2.3 | 50 | A Centauri (Rigel Kentar) | 0.3 |
| 19 | A Bootis (Arcturus) | 0.2 | 51 | A2 Librae (Zubenelgenubi) | 2.9 |
| 20 | A Coronae Borealis(Alphecca) | 2.3 | 52 | B Ursae Minoris (Kochab) | 2.2 |
| 21 | A Scorpii (Antares) | 1.2 | 53 | A Trianguli Austr.(Atria) | 1.9 |
| 22 | A Ophiuchi (Rasalhague) | 2.1 | 54 | Eta Ophiuchi (Sabik) | 2.4 |
| 23 | A Lyrae (Vega) | 0.1 | 55 | L Scorpii (Shaula) | 1.7 |
| 24 | S Sagittarii (Nunki) | 2.1 | 56 | G Draconis (Eltanin) | 2.4 |
| 25 | A Aquilae (Altair) | 0.9 | 57 | E Sagittarii (Kaus Austr) | 2.0 |
| 26 | E Pegasi (Enif) | 2.5 | 58 | A Pavonis (Peacock) | 2.1 |
| 27 | A Piscis Australis(Fomalhaut) | 1.3 | 59 | A Cygni (Deneb) | 1.3 |
| 28 | A Pegasi (Markab) | 2.6 | 60 | A Gruis (Al Na'ir) | 2.2 |
| 29 | S Octantis (S. pole) | 5.5 | 61 | B Crucis (Mimosa) | 1.5 |
| 30 | A Phoenicis (Ankaa) | 2.4 | 62 | G2 Velorum (Al Suhai) | 1.9 |
| 31 | A Cassiopeiae (Schedar) | 2.5 | 63 | G Geminorum (Alhena) | 1.9 |
| 32 | A Eridani (Achernar) | 0.6 | | | |

NOTES: Above table includes all of the 57 standard navigational stars.
Sirius and procyon are both binary systems whose positions, without proper correction may be in error 0.8 arc seconds by the year 1994.
Betelgeuse varies in magnitude from 0.1 to 1.2 (brightness).
Beta Hydri is a south circumpolar star.
Sigma Octantis is the south polar star.

Star name (Greek letter) prefixes: A = Alpha, B = Beta, E = Epsilon, G = Gamma, L = Lambda, S = Sigma, 0 = Theta.

# APPENDIX I

## ELGIN, KNOWLES & SENNE, INC.; THE FIRM AND THE PARTNERS

Elgin, Knowles & Senne, Inc. offers surveying consulting services for a broad spectrum of topics within the field of surveying. Previous projects and current products include: Authors of the *Celestial Observation Handbook and Ephemeris* (The Lietz Company) and *Practical Surveying Guide to Celestial Observations* (P.O.B. Publishing Company); developers of ASTRO*ROM2, ASTRO*CARD and ASTRO*DISK, internal ephemeris programs for astronomic azimuth observations for the HP-41, HP-48SX and IBM PC/compatibles respectively; producers of "Sun Observations for Astronomic Azimuth," a 4-1/2 hour videotape on sun observations; authors of programs used in software packages; surveying experts in the case Arkansas v. Mississippi (85 L.Ed.2d 400); surveying consultants on matters of litigation including surveyor's liability, accident site surveys, disputed boundaries and software copyright infringement; lecturers on celestial observations, legal aspects of boundary surveying, least squares adjustment. Drs. Elgin and Knowles are the coauthors of *Legal Principles of Boundary Location for Arkansas* (Landmark Enterprises, 1983).

Dr. Dick Elgin, a second-generation surveyor, was raised in his father's surveying business in Rolla, Missouri. He received the degrees B.S. and M.S. in Civil Engineering from the University of Missouri-Rolla (UMR). After working in private surveying practice for several years he attended the University of Arkansas and received the degree Doctor of Philosophy. Formerly an Assistant Professor of Civil Engineering at UMR, he now owns the family business. Dr. Elgin is a past president of the Missouri Association of Registered Land Surveyors (MARLS). He was named the 1983 Young Engineer of the Year by the Missouri Society of Professional Engineers. Dr. Elgin is a member of ACSM, NSPS, NSPE, MSPE, MARLS, Chi Epsilon, Tau Beta Pi and the Rolla Rotary Club. He is an avid collector of early American surveying equipment and Land Rovers.

Dr. David Knowles received the degrees B.S. and M.S. in Civil Engineering from Georgia Tech. He received the degree Doctor of Philosophy from the University of Texas. He taught surveying and conducted surveying instrument research at Texas A & M University. Presently he is Professor of Civil Engineering at the University of Arkansas. Dr. Knowles is a past president of the Arkansas Association of Registered Land Surveyors (AARLS). He has served as an NSPS Area Director, and is a recipient of the Arkansas Surveyor of the Year. While serving as its Editor, the AARLS magazine, *HI's and PI's* received the ACSM Excellence in Journalism Award. Dr. Knowles is a Fellow Member of ACSM, and a member of NSPS, ASPS and ASCE. He is an avid fisherman.

Professor Emeritus Joseph Senne recently retired from being Professor and Chairman of the Department of Civil Engineering, University of Missouri-Rolla (UMR), formerly the Missouri School of Mines (MSM). He received the degrees B.S.C.E. from Washington University (St. Louis), M.S.C.E. from MSM, and Ph.D. from Iowa State. With a wide academic and consulting background in engineering, surveying, orbital mechanics and astronomy, a few of his more interesting surveying/astronomy consulting projects have included:

Consultant to establish precise astronomic coordinates for the Feather Ridge Observatory, consultant in orbital mechanics to develop tracking programs for communication satellites, and consultant on precision alignment of magnet units for a 95 meter radius proton synchrotron. Dr. Senne is the vice president of the International Occultation Timing Association which is involved in precise timing of lunar total and grazing occultations of stars, planets and asteroids. (This work is done in cooperation with the U.S. Naval Observatory.) Author of numerous papers, Dr. Senne is a member of ASPRS, ASCE, ASEE, NSPE, MSPE, The Society of Sigma Xi, Chi Epsilon, Tau Beta Pi, Phi Kappa Phi and American Men of Science. He is a computer "bug."

The trio received the prestigious 1990 ACSM "Presidential Award."