

HEWLETT-PACKARD

HP-67/HP-97

Navigation Pac I



CAUTION

It is highly recommended that conventional navigational tables and tools be taken on cruises along with the HP-67/97 and Navigation Pac 1 as insurance against calculator failure or battery discharge.

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INTRODUCTION

This Navigation Pac is a collection of programs deemed most useful to navigators. The programs are intended to answer the questions: "Where am I?", "Which way should I go?", and "How far is it?".

The first four programs are used to answer questions relating to the distance and direction between two points. These programs compute great-circle and rhumb line courses and distances, give estimated time of arrival, and serve as a real-time dead reckoner.

The next seven programs are an integrated set of celestial and bearing fix programs to answer "Where am I?". One program aids the navigator by helping to plan the morning or evening star sights. An almanac interpolator makes it easy to compute sextant height and azimuth for any tabulated body using a current Nautical Almanac. The other almanac programs can be used to compute the position of the Sun, Polaris, or any of the other 57 navigational stars without reference to a published almanac. Two programs compute lines of position from bearings on known objects or from horizontal sextant angles between them. The final program computes the intersection of any two lines (actually circles) of position from the almanac programs or from the bearing or angle programs.

The remaining three programs demonstrate how the calculator can be used in special situations to answer the same three basic questions asked by navigators.

Many navigators have discussed their wants and needs with the Corvallis Division Applications Engineers. Several of them deserve special recognition. Our thanks for ideas, programs, and criticism go to Mr. Alan S. Bagley of Hewlett-Packard; Wing Commander Basil D'Oliveira, R.A.F. (Ret.); Captain Kenneth R. Orcutt of Matson Lines; Mr. Mortimer Rogoff, author of *Calculator Navigation*; and Captain Henry H. Shufeldt, USNR (Ret.).

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A WORD ABOUT PROGRAM USAGE

This application pac has been designed for both the HP-97 Programmable Printing Calculator and the HP-67 Programmable Pocket Calculator. The most significant difference between the HP-67 and the HP-97 calculators is the printing capability of the HP-97. The two calculators also differ in a few minor ways. The purpose of this section is to discuss the ways that the programs in this pac are affected by the difference in the two machines and to suggest how you can make optimal use of your machine, be it an HP-67 or an HP-97.

Many of the computed results in this pac are output by PRINT statements; on the HP-97 these results will be output on the printer. On the HP-67 each PRINT command will be interpreted as a PAUSE: the program will halt, display the result for about five seconds, then continue execution. The term "PRINT/PAUSE" is used to describe this output condition.

If you own an HP-67, you may want more time to copy down the number displayed by a PRINT/PAUSE. All you need to do is press any key on the keyboard. If the command being executed is PRINTx (eight rapid blinks of the decimal point), pressing a key will cause the program to halt. Execution of the halted program may be re-initiated by pressing **R/S**.

HP-97 users may also want to keep a permanent record of the values input to a certain program. A convenient way to do this is to set the Print Mode switch to NORMAL before running the program. In this mode all input values and their corresponding user-definable keys will be listed on the printer, thus providing a record of the entire operation of the program.

Another area that could reflect differences between the HP-67 and the HP-97 is in the keystroke solutions to example problems. It is sometimes necessary in these solutions to include operations that involve prefix keys, namely, **f** on the HP-97 and **f**, **g**, and **h** on the HP-67. For example, the operation 10^x is performed on the HP-97 as **f** 10^x and on the HP-67 as **g** 10^x . In such cases, the keystroke solution omits the prefix key and indicates only the operation (as here, 10^x). As you work through the example problems, take care to press the appropriate prefix keys (if any) for your calculator.

Also in keystroke solutions, those values that are output by the PRINT command will be followed by three asterisks (**).

Certain notational conventions were adopted for use in this pac. The notation "degrees, minutes, and tenths" is never used—mental translation is necessary when keying in values from *The Nautical Almanac*. The sign convention used is that north latitude and west longitude are positive numbers. Altitude intercepts "Away" are positive.

SYMBOLS AND UNITS USED IN THIS PAC

SYMBOL	MEANING
α (alpha)	Greenwich Hour Angle (even though used normally for Right Ascension)
Δ (capital delta)	Difference in (e.g. Δt means "time difference")
δ (delta)	Declination
λ (lambda)	Longitude
a	Altitude intercept
B	Bearing
C, C_c , C_m	Course, Compass course, Course to mark
CMG	Course made good
D	Day
D, DIST	Distance
D, Dev.	Deviation
D.d	Degrees and tenths
D.M	Degrees and minutes
D.MS	Degrees, minutes, and seconds
Dr	Drift
GHA	Greenwich Hour Angle
GMT	Greenwich Mean Time
H	Height (a vertical distance)
H_c	Computed height (an angle)
H_o	Observed height
HE	Height of eye
h_s	Sextant height (an angle)
L	Latitude
LHA	Local Hour Angle
M	Month
R	Range
S	Speed
Sa	Apparent speed
St	Set
SD	Semidiameter
SHA	Sidereal Hour Angle
t	Time, meridian angle
V, Var	Variation
Y	Year
Z_n	Azimuth from North

MAGNETIC CARD SYMBOLS AND CONVENTIONS

SYMBOL OR CONVENTION	INDICATED MEANING
White mnemonic: x A	White mnemonics are associated with the user-definable key they are above when the card is inserted in the calculator's window slot. In this case the value of x could be input by keying it in and pressing A .
Gold mnemonic: y x E	Gold mnemonics are similar to white mnemonics except that the gold f key must be pressed before the user-definable key. In this case y could be input by pressing f E .
x↑y A	↑ is the symbol for ENTER . In this case ENTER is used to separate the input variables x and y. To input both x and y you would key in x, press ENTER , key in y and press A .
x A	The box around the variable x indicates input by pressing STO A .
(x) A	Parentheses indicate an option. In this case, x is not a required input but could be input in special cases.
→x A	→ is the symbol for calculate. This indicates that you may calculate x by pressing key A .
→x, y, z A	This indicates that x, y, and z are calculated by pressing A once. The values would be printed in x, y, z order.
→x; y; z A	The semi-colons indicate that after x has been calculated using A , y and z may be calculated by pressing R/S .
→"x," y A	The quote marks indicate that the x value will be "paused" or held in the display for one second. The pause will be followed by the display of y.
↔ x A	The two-way arrow ↔ indicates that x may be either output or input when the associated user-definable key is pressed. If numeric keys have been pressed between user-definable keys, x is stored. If numeric keys have not been pressed, the program will calculate x.

SYMBOL OR CONVENTION	INDICATED MEANING
P? 	The question mark indicates that this is a mode setting, while the mnemonic indicates the type of mode being set. In this case a print mode is controlled. Mode settings typically have a 1.00 or 0.00 indicator displayed after they are executed. If 1.00 is displayed, the mode is on. If 0.00 is displayed, it is off.
START 	The word START is an example of a command. The start function should be performed to begin or start a program. It is included when initialization is necessary.
DEL 	This special command indicates that the last value or set of values input may be deleted by pressing .
x; ... 	Three dots (...) indicate that additional output follows. See User Instructions for complete description of variables output.
↔ x, y	On input: x ↑ y On output: → x; y

ESTIMATED TIME OF ARRIVAL

ESTIMATED TIME OF ARRIVAL

ZD_a

Dist

Speed

departure D HHMM

arrival D HHMM

This program is an interchangeable solution for the speed, time, and distance problem. The program is written to correct for time zone changes and to account for days as well as hours. The program does not contain a calendar so a ten-day trip begun on the 27th of a month will end on the 37th day of that same month. Simply subtract 28, 29, 30, or 31 as appropriate to get the correct day of the next month.

The data registers are set up so that if the course planning program "Great Circle and Rhumbline Navigation" has just been run, the distance, longitude of departure, and longitude of arrival will not have to be input again.

STEP	INSTRUCTION	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load "Estimated Time of Arrival"			
2	Key in zone descriptions* of			
	Departure point	ZD _d , D.MS	 A	ZD _d
	Arrival point	ZD _a , D.MS	A	ZD _a
3	Key in values for any three of the following quantities:			
	Distance	D, n. mi.	B	D
	Speed	S, knots	C	S
	Departure day and time	D.HHMM	D	GMT _d
	Arrival day and time	D.HHMM	E	GMT _a
4	Compute unknown value for:			
	Distance		B	D, n. mi.
	Speed		C	S, knots
	Departure day and time		D	D.HHMM
	Arrival day and time		E	D.HHMM
	or			

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	First run "Great Circle and Rhumb Line Navigation" to compute distance.			
2	Load "Estimated Time of Arrival"			
3	Continue with step 3 above.			
*	To compute the standard zone description of a place, key in its longitude.	λ , D.MS	F B	ZD

Example 1:

A passage is planned from Los Angeles ($33^{\circ}40'N$, $120^{\circ}10'W$) to Honolulu ($21^{\circ}16'N$, $157^{\circ}50'W$). If it is desired to arrive in Honolulu at noon on the 25th of the month, when should the passage begin? Assume a 17 knot speed-made-good.

Keystrokes:**Outputs:**

Load "Great Circle and Rhumbline Navigation"

33.40 **ENTER** 120.10 **A**

21.16 **ENTER** 157.50 **A B** $\rightarrow$

2124.6341

distance

259.3521

initial course

Load "Estimated Time of Arrival"

8 **A** 10 **A** 17 **C**

25.12 **E D** $\rightarrow$

20.1001

The voyage begins
at 1000 on the 20th.

Example 2:

An engineer wishes to drive the 597 miles from Cupertino, California, to Corvallis, Oregon. He expects to be able to average 50 MPH. What time will he arrive if he leaves Cupertino at 1440 and drives straight through?

Keystrokes:**Outputs:**

Load "Estimated Time of Arrival"

8 **A** 8 **A**

same time zone

597 **B** 50 **C** .1440 **D E** $\rightarrow$

1.0236

He arrives at 0236 the following morning.

GREAT CIRCLE AND RHUMB LINE NAVIGATION

GREAT CIRCLE AND RHUMB LINE NAVIGATION

L₂ + λ_2 -D, H_i- λ

-LIST

This program computes the great-circle distance between two points. It also may be used to produce a list of points on that great circle which are separated by a specified longitude difference. The list of great-circle points is printed along with the rhumb line courses and distances between successive points.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load program			
2	Key in initial and final points			
	Starting latitude	L ₁ , D.MS	ENTER	
	Starting longitude	λ_1 , D.MS	f A	
	Ending latitude	L ₂ , D.MS	ENTER	
	Ending longitude	λ_2 , D.MS	A	
3	Compute distance		B	D, naut. mi.
	and initial heading		R S	H _i , deg.
4	Select a longitude increment			
	(CHS if east)	$\Delta\lambda$, D.MS	C	
5	List great circle points and			
	rhumb lines		D	*
	Note: To compute a one-			
	rhumb line course, let the longi-			
	tude increment equal $\lambda_2 - \lambda_1$		RCL E	
			→HMS	$\Delta\lambda$, D.MS
*	The output is:			
	L ₁			
	λ_1			
	C			
	D			
	L ₁ + ΔL_1			
	$\lambda_1 + \Delta\lambda$			
	C			

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
	D			
	⋮			
	L_2			
	λ_2			
	To compute the highest latitude			
	a great circle route will reach		RCL 0 COS	$\cos L_1$
			RCL 5 SIN	$\sin C$
			X (COS⁻¹)	$L_{\max}$

A passage is planned from Los Angeles (33°45'N, 118°15'W) to Honolulu (21°18'N, 157°52'W). Plan a series of rhumb lines to approximate the great-circle track between the two points. Use a 10° longitude increment.

Keystrokes:**Outputs:**

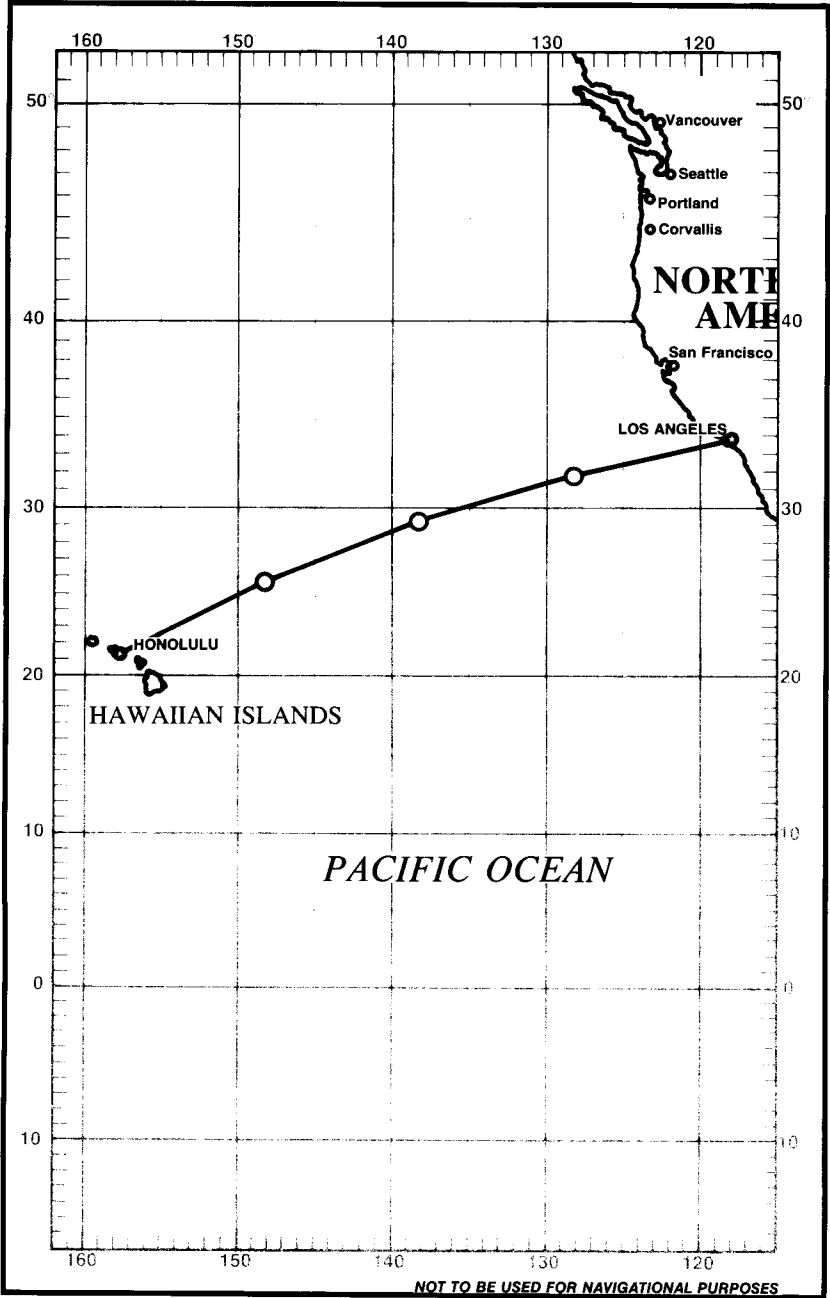
Load "Great Circle and Rhumb Line Navigation"

33.45 **ENTER** 118.15 **f A**

21.18 **ENTER** 157.52 **A B** →

10 **C D** →

2220.4104 *** distance
 260.7546 *** initial course
 33.4500 *** Los Angeles
 118.1500 ***
 258. *** course
 515. *** distance
 31.5756 ***
 128.1500 ***
 253. ***
 541. ***
 29.1721 ***
 138.1500 ***
 248. ***
 575. ***
 25.4037 ***
 148.1500 ***
 244. ***
 591. ***
 21.1800 *** Honolulu
 157.5200 ***



Example:

A well-known amateur navigator sailed from St. George's Harbor, Bermuda, ($32^{\circ}23'N$, $64^{\circ}41'W$), to Horta, Fayal Island, ($38^{\circ}32'N$, $28^{\circ}38'W$). Plot the great-circle track at 5 degree intervals.

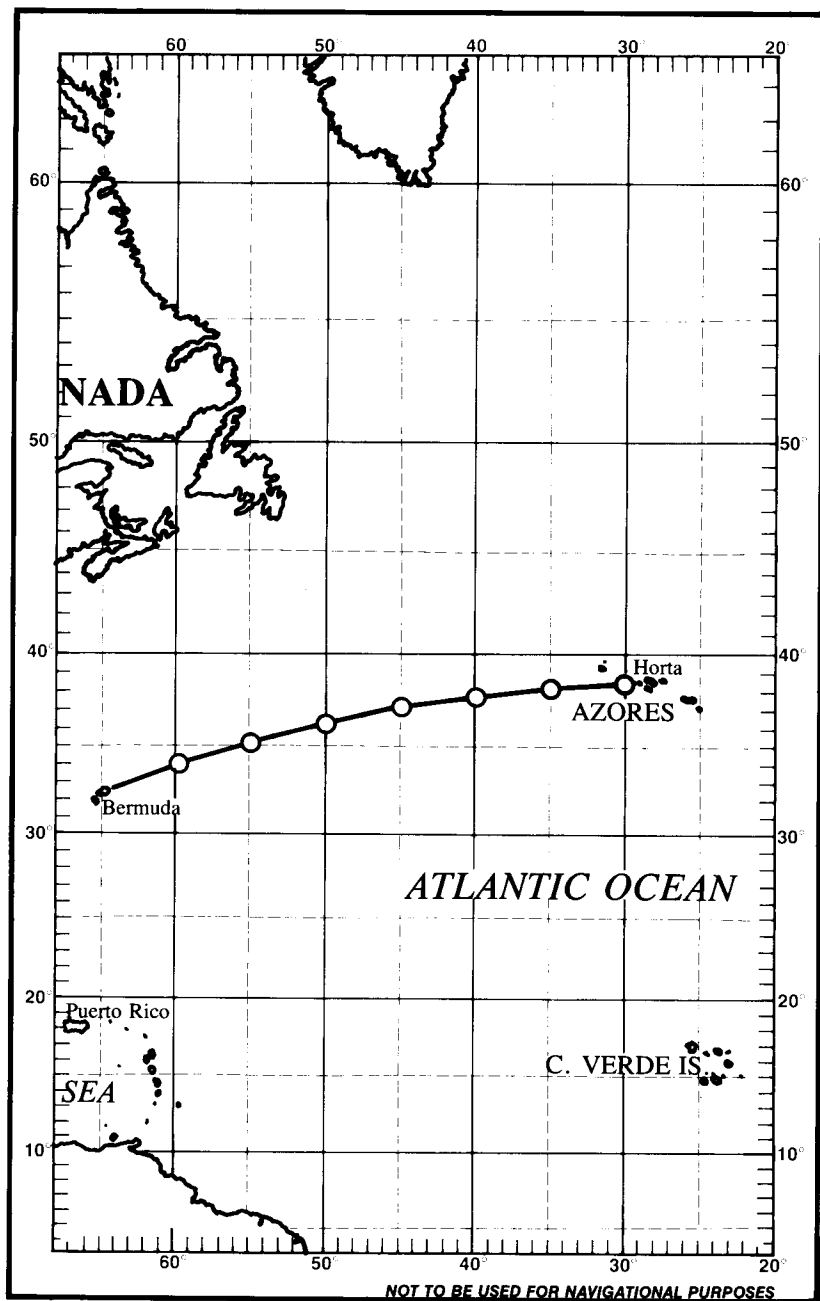
Keystrokes:

32.23 **ENTER** 64.41 **f A**
 38.32 **ENTER** 23.38 **A B** →
 5 **CHS C D** →

Outputs:

1788.1514 *** distance
 67.8537 *** initial C.C. course
 32.2300 *** St. George's
 64.4100 *** Harbor
 69. *** course
 269. *** distance
 33.5820 ***
 59.4100 ***
 72. ***
 260. ***
 35.1831 ***
 54.4100 ***
 75. ***
 252. ***
 36.2410 ***
 49.4100 ***
 78. ***
 246. ***
 37.1550 ***
 44.4100 ***
 81. ***
 241. ***
 37.5359 ***
 39.4100 ***
 84. ***
 237. ***
 38.1859 ***
 34.4100 ***

87. ***
235. ***
38.3105 ***
29.4100 ***
89. ***
49. ***
38.3200 *** Horta
28.3800 ***



Example:

A ship leaves Tokyo ($35^{\circ}40'N$, $139^{\circ}45'E$) bound for Coos Bay, Oregon ($43^{\circ}22'N$, $124^{\circ}13'W$). Plot her position in 20° increments.

Keystrokes:

35.4 **ENTER** 139.45 **CHS** **f**

A 43.22 **ENTER** 124.13

A **B** $\longrightarrow$

20 **CHS** **C** **D** $\longrightarrow$

Outputs:

4213.6169 ***

50.1964 ***

35.4000 *** note the use of a
negative value for
 $\Delta\lambda$

-139.4500 ***

56. ***

1089. ***

45.4247 ***

-159.4500 ***

71. ***

849. ***

50.2423 ***

-179.4500 ***

86. ***

760. ***

51.1631 ***

160.1500 ***

102. ***

788. ***

48.3639 ***

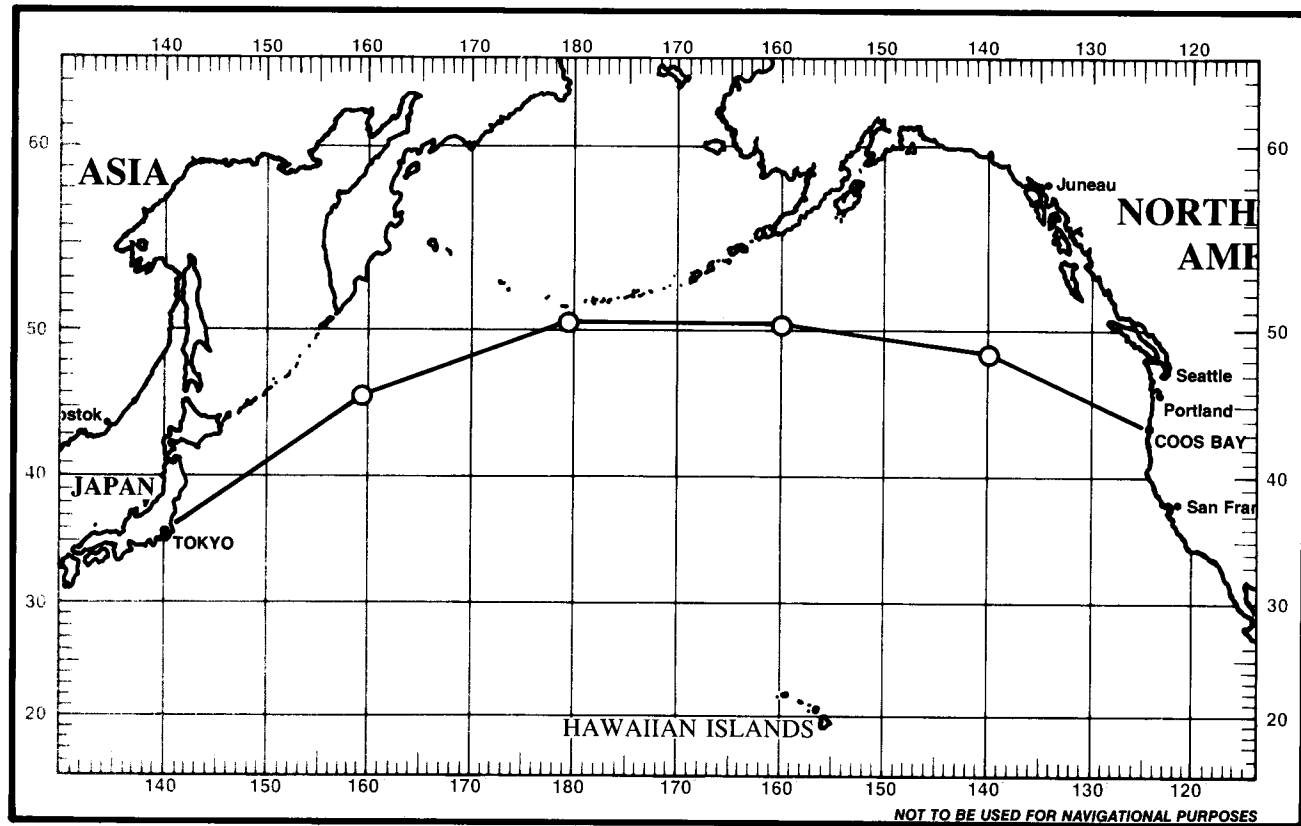
140.1500 ***

115. ***

738. ***

43.2200 ***

124.1300 ***



Example:

A ship is bound from Atico, Peru, ($16^{\circ}14'S$, $73^{\circ}37'W$), to San Antonio, Chile, ($33^{\circ}35'S$, $71^{\circ}38'W$). Print a list of points on the great circle between Atico and San Antonio. Use a $24'$ longitude increment.

Keystrokes:

16.14 **CHS** **ENTER** 73.37 **f** **A**

33.35 **CHS** **ENTER** 71.38

A **B** $\longrightarrow$

.24 **CHS** **C** **D** $\longrightarrow$

Outputs:

```

1046.5098 ***
174.4801 ***
-16.1400 ***
73.3700 ***
174. ***
234. ***
-20.0721 ***
73.1300 ***
174. ***
223. ***
-23.4936 ***
72.4900 ***
174. ***
211. ***
-27.1948 ***
72.2500 ***
174. ***
199. ***
-30.3727 ***
72.0100 ***
174. ***
179. ***
-33.3500 ***
71.3800 ***

```

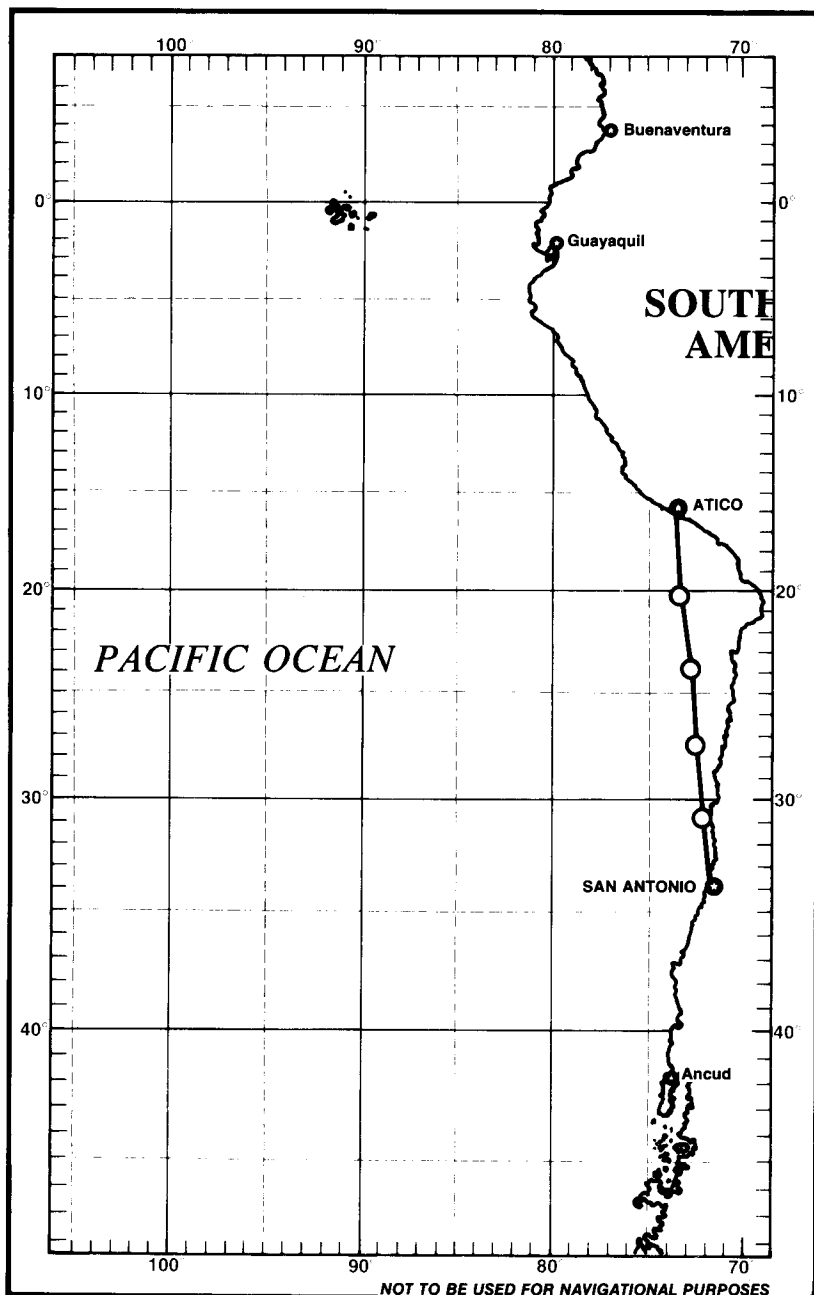
Now compute a single rhumb line course for this passage.

RCL **E** **→HMS** **C** **D** $\longrightarrow$

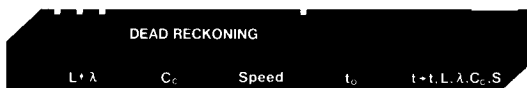
```

-16.1400 ***
73.3700 ***
174. ***
1047. ***
-33.3500 ***
71.3800 ***

```



DEAD RECKONING



This program is fundamentally a program to compute latitude and longitude along a rhumb line course. Inputs are initial position, course, speed, and initial time. When another time is specified, the program updates the latitude and longitude and prints or displays the results depending on whether the print option is selected or not.

A useful feature of this program is that a time difference may be input and the machine will automatically increment the time and compute the corresponding position, continuing until it is stopped. For example, if a time difference of thirty minutes is specified, the vessel's position at thirty-minute intervals will be displayed or printed. If a time difference of approximately 24 seconds is specified, the display* will show the updated position in real time. The items displayed may be replaced by keying in new values while the appropriate item is being displayed. It may be necessary to experiment with your calculator to determine the correct time interval to specify for accurate dead reckoning.

*It is best not to choose the print mode when Δt is so small.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load program			
2	Key in initial position:			
	Latitude	L, D.MS	ENTER +	
	Longitude	λ , D.MS	A	
3	Key in course information			
	Magnetic variation (CHS if West)	Var, deg.	ENTER +	
	Compass deviation (CHS if West)	Dev, deg.	f B	Compass Corr'n
	Compass course	C_c , deg.	B	True Course
4	Key in speed	S, knots	C	
5	Select printing or no printing		f A	1 or 0
	For One Leg At A Time			
6	Key in initial time.	t_0 , H.MS	D	

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
7	Key in next time and compute new position.	Δt , H.MS	E	See note*
8	Modify above inputs as appropriate beginning with step 3.			
	For A Continuous List Of Positions			
6	Key in initial time	t_0 , H.MS	D	
7	Key in time increment	Δt , H.MS	f E	
8	Modify values as appropriate by keying in correct or new values during PAUSE			
	Note: The calculator prints and/or pauses displaying the following:			
	time			
	L			
	λ			
	C			
	S			

Example 1:

A vessel departs at 0900 from $33^{\circ}40'N$, $120^{\circ}10'W$, on course 258 true at 15 knots. Predict her position at 1830.

Keystrokes

33.40 **ENTER** 120.10 **A** 0
ENTER 0 **f** **B** 258 **B** 15
C 9 **D** 18.30 **E** $\longrightarrow$

Outputs

18.3000 *** time
 33.1022 *** $33^{\circ}10'22''$
 122.5660 *** $122^{\circ}57'00''$
 258.0 *** course
 15.0 *** speed

Example 2:

The navigator of the vessel in Example 1 wishes to plot his dead reckoning position for the next hour at 20 minute intervals.

Keystrokes:

.20 **f** **E** →

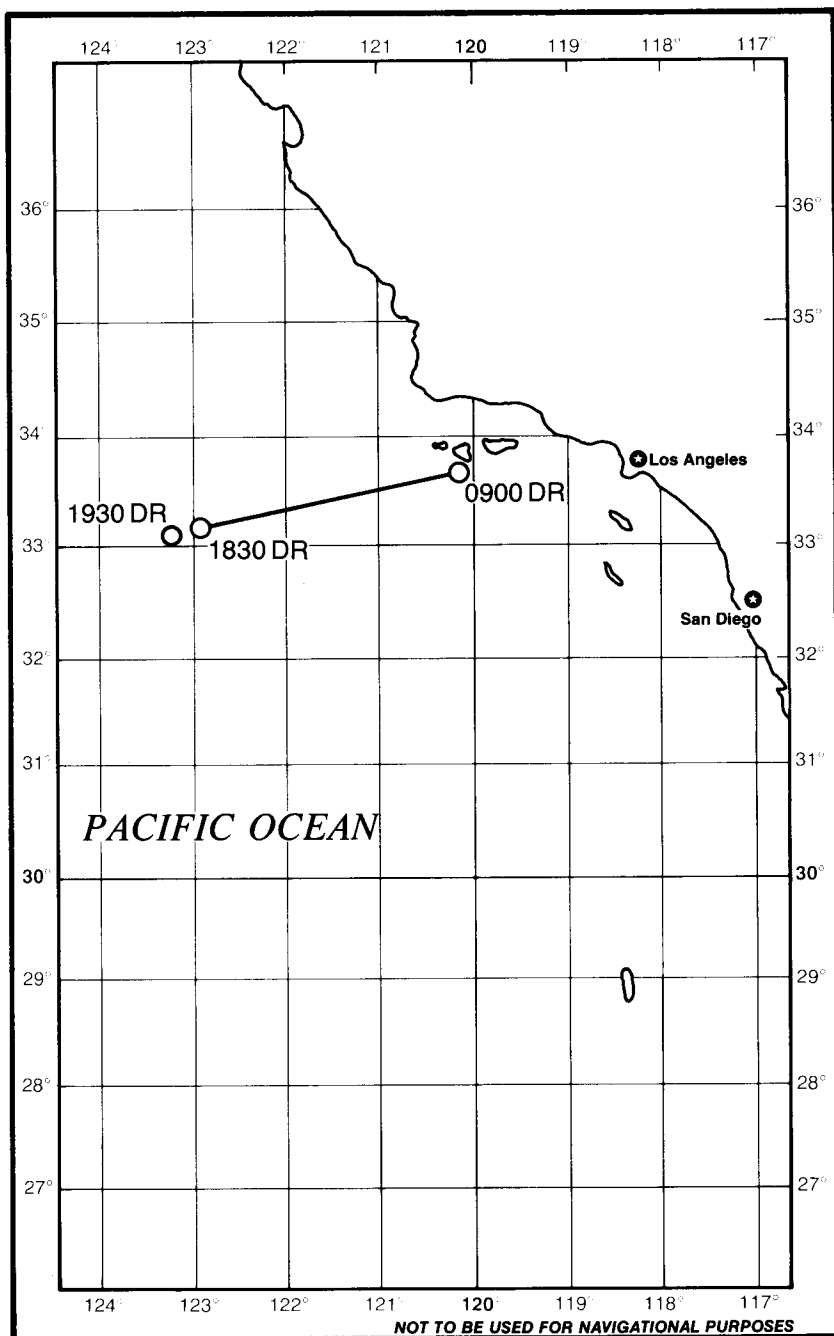
Outputs:

18.5000 ***
 33.0920 ***
 123.0250 ***
 258.0 ***
 15.0 ***

19.1000 ***
 33.0818 ***
 123.0841 ***
 258.0 ***
 15.0 ***

19.3000 ***
 33.0715 ***
 123.1431 ***
 258.0 ***

15.0 *** Press **R/S** to stop
 the list.



Example 3:

On February 10, 1977 at 0300 GMT a ship leaves Tokyo (35°N , $140^{\circ}10'\text{E}$) at 17.8 knots on course 056° true bound for Coos Bay, Oregon ($43^{\circ}22'\text{N}$, $124^{\circ}13'\text{W}$). What DR should her navigator use for a Sun sight at 0700 GMT?

Keystrokes:

35 **ENTER** 140.1 **CHS** **A** 0
ENTER 0 **f** **B** 56 **B** 17.8
C 3 **D** 7 **E** 

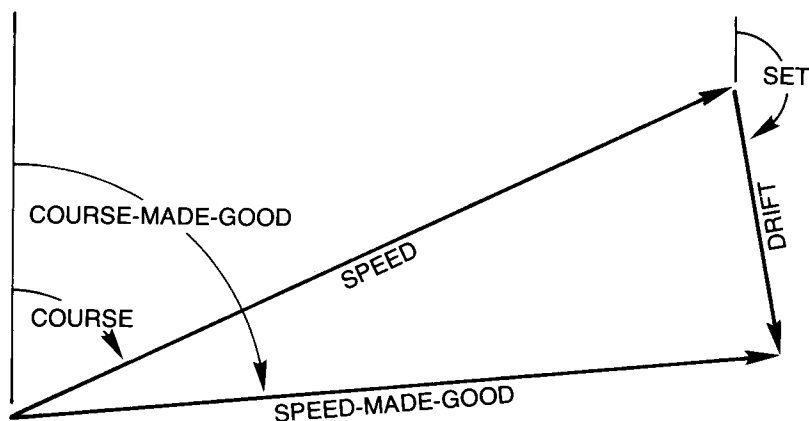
Outputs:

7.0000 ***
 35.3949 *** latitude
 -141.2221 *** longitude
 56.0 *** course
 17.8 *** speed

VELOCITY TRIANGLE and COURSE TO STEER

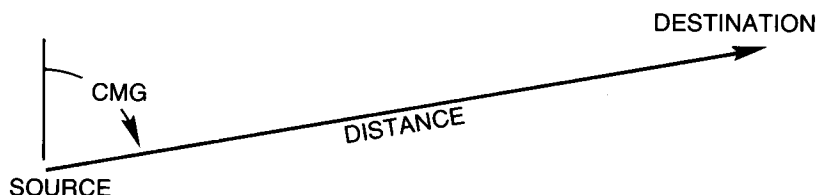


This program is an interchangeable solution for the vector addition problem. Given any two of the vectors shown, the program computes the third.



Compass course is corrected on input for magnetic variation and deviation. True course is decorrected on output to yield compass course. Remember to update the values used for variation (changes with location) and deviation (changes with heading).

Another program on this same card calculates a course to steer given your location, the location where you want to go, your boat's speed through the water, and the set and drift of the current.



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load program			
2	Key in compass corrections:			
	Variation (CHS if West)	Var, deg.	ENTER	
	Deviation (CHS if West)	Dev, deg.	F A	
	Using The Velocity Triangle			
	Program			
3	Key in any two of the three vectors:			
	Heading vector			
	compass course	Cc, deg.	ENTER	
	speed	S, knots	A	Ct, deg.
	Current vector			
	set	Set, deg.	ENTER	
	drift	Drift, knots	B	Set, deg.
	Course vector			
	course-made-good	CMG, deg.	ENTER	
	speed-made-good	SMG, knots	C	CMG, deg.
4	Compute the remaining one:			
	Heading vector			
	speed	none	A	Speed, knots
	compass course		R/S	Cc, deg.
	Current vector			
	drift	none	B	Drift, knots
	set		R S	Set, deg.
	Course vector			
	speed-made-good	none	C	SMG, knots
	course-made-good		R S	CMG, deg.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
	Using The Course-To-Steer Program			
3	Key in locations of Source			
	Latitude	L_1 , D.MS	ENTER	
	Longitude	λ_1 , D.MS	f D	
	Destination			
	Latitude	L_2 , D.MS	ENTER	
	Longitude	λ_2 , D.MS	D	
4	Compute distance and course to make good	none	f E R S	Dist., n. mi. CMG, deg.
5	Key in current vector set	Set, deg.	ENTER	
	drift	Drift, knots	B	Set, deg.
6	Key in speed through water and compute			
	Compass course to steer	Speed, knots	E	Cc, deg.
	Time to reach destination		R S	t, H.MS
	Speed made good over bottom		R S	SMG, knots

Example:

A vessel making 6 knots through the water is at (45°N, 124°40'W) and she wishes to steer a course toward (44°40'N, 124°10'W). The magnetic variation is 20°5E and there is a 2 knot current setting 090°. What course should she steer?

Keystrokes:

20.5 **ENTER** 0 **f A**
 45 **ENTER** 124.40 **f D**
 44.40 **ENTER** 124.10 **D f E** →

Outputs:

29.20 Distance

R/S →
90 ENTER ↓ 2 B 6 E →
R/S →
R/S →

133.23 Desired true course
125.93 Compass course
4.00
7.30 Speed-made-good

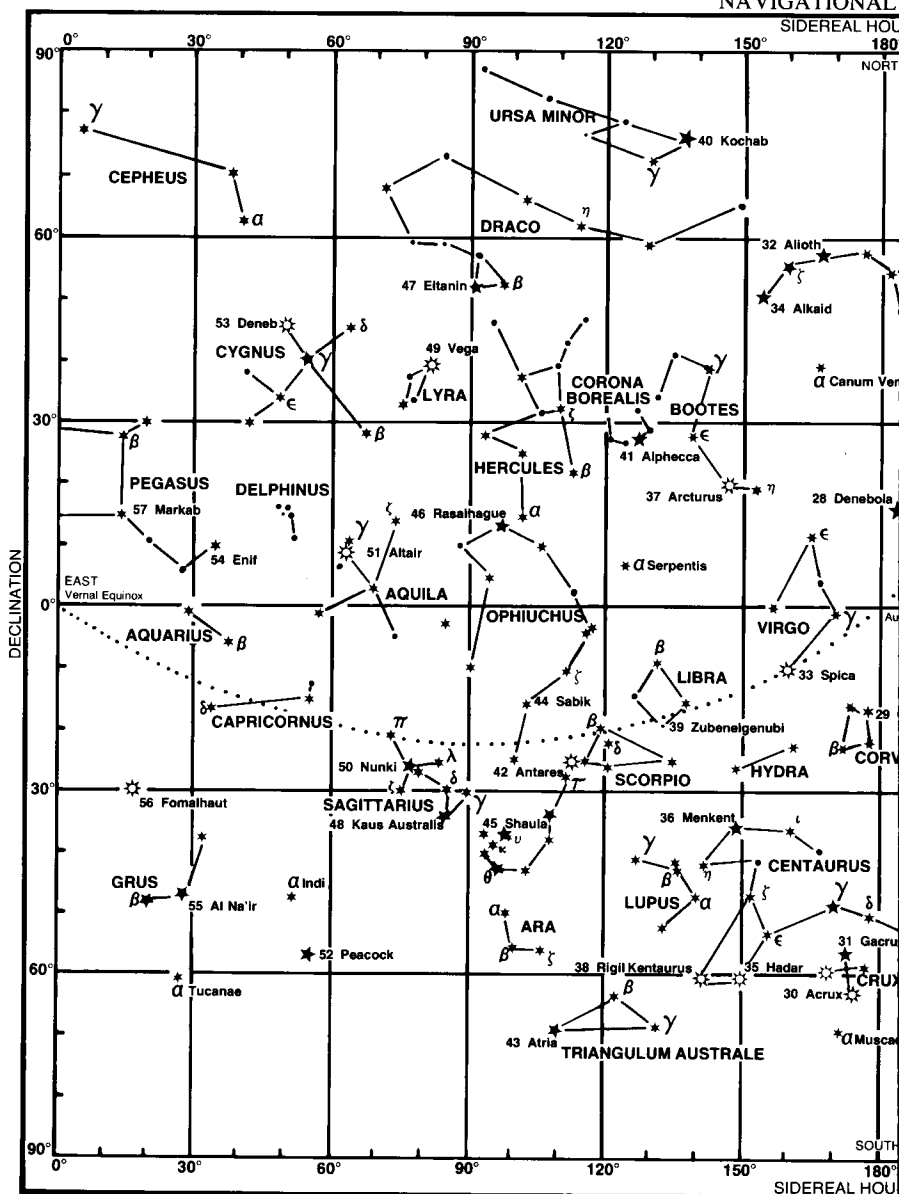
L+A Y+M+D GMT→LIST Dawn Y+M+D→t LIST Dusk Y+M+D→t LIST

Since most star sights are made during twilight, this program also computes the approximate time of the end (or beginning) of civil twilight which corresponds to the middle of the period known as nautical twilight. In polar latitudes during certain seasons, this feature will not work because twilight is not defined.

NAVIGATIONAL

SIDEREAL HOUR

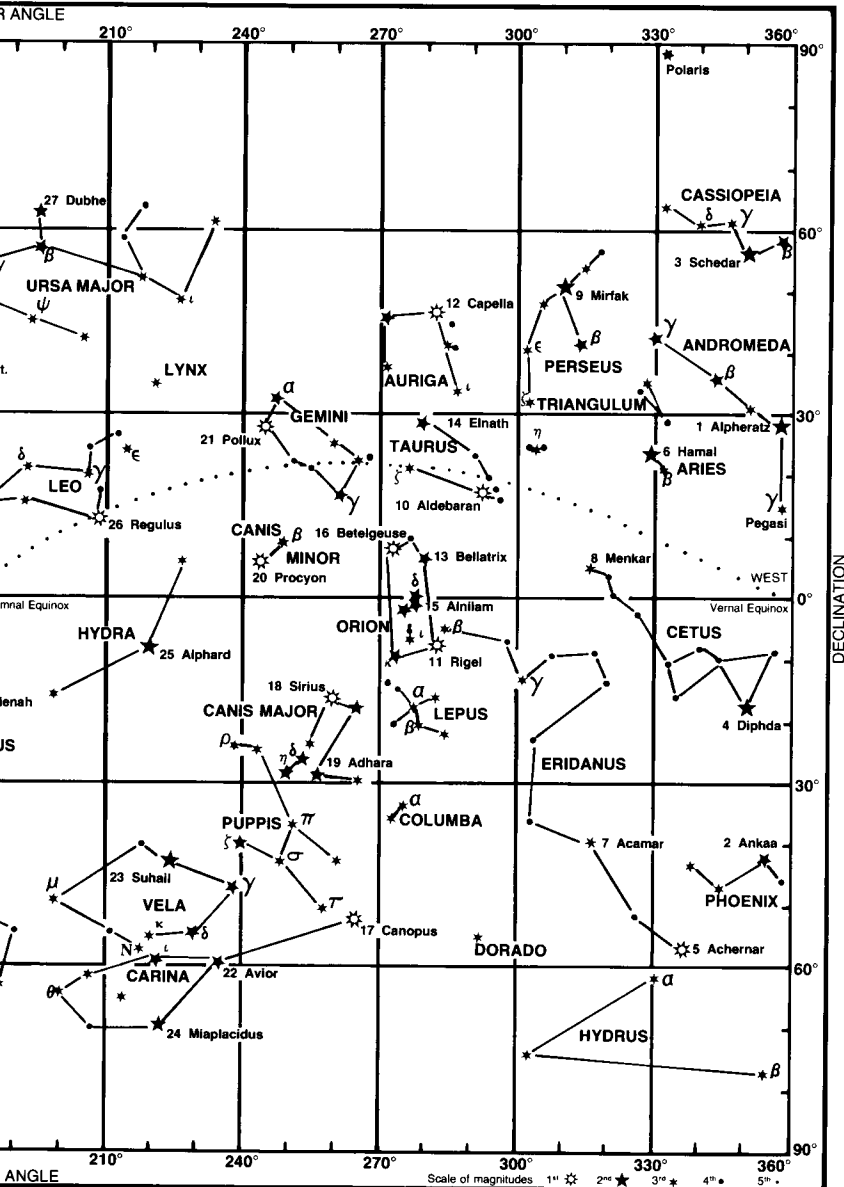
NORTH



Fold-out

STAR CHART

R ANGLE



DECLINATION

No.	Name	S.H.A.	DEC.
0	Polaris	0	N. 90
1	Alpheratz	358	N. 29
3	Schedar	350	N. 56
4	Diphda	349	S. 18
5	Achernar	336	S. 57
6	Hamal	329	N. 23
7	Acamar	316	S. 40
8	Menkar	315	N. 4
9	Mirfak	309	N. 50
10	Alderbaran	291	N. 16
11	Rigel	282	S. 8
12	Capella	281	N. 46
16	Betelgeuse	272	N. 7
17	Canopus	264	S. 53
18	Sirius	259	S. 17
20	Procyon	245	N. 5
21	Pollux	244	N. 28
23	Suhail	223	S. 43
24	Miaplacidus	222	S. 70
25	Alphard	218	S. 9
26	Regulus	208	N. 12
27	Dubhe	194	N. 62
28	Denebola	183	N. 15
29	Gienah	176	S. 17
30	Acrux	174	S. 63
32	Alioth	167	N. 56
33	Spica	159	S. 11
34	Alkaid	153	N. 49
37	Arcturus	146	N. 19
38	Rigil Kentaurus	140	S. 61
40	Kochab	137	N. 74
41	Alphecca	127	N. 27
42	Antares	113	S. 26
45	Shaula	97	S. 37
46	Rasalhague	97	N. 13
49	Vega	81	N. 39
50	Nunki	77	S. 26
51	Altair	63	N. 9
52	Peacock	54	S. 57
53	Deneb	50	N. 45
54	Enif	34	N. 10
56	Fomalhaut	16	S. 30

Name	No.	Pronunciation	S.H.A.	DEC.
Achernar	5	ā'kēr·nār	336	S. 57
Acrux	30	ā'krŭks	174	S. 63
Aldebaran	10	ăl dēb'á·răn	291	S. 16
Alioth	32	ăl'ĩ·ōth	167	N. 56
Alkaid	34	ăl·kad'	153	N. 49
Alphard	25	ăl'fârd	218	S. 9
Alphecca	41	ăl·fěk'â	127	N. 27
Alpheratz	1	ăl·fē'rats	358	N. 29
Altair	51	ăl·târ'	63	N. 9
Antares	42	ăn·tā'rēz	113	S. 26
Arcturus	37	âr·k·tŭ'rŭs	146	N. 19
Betelgeuse	16	bět'ěl·jŭz	272	N. 7
Canopus	17	ká·nō'pŭs	264	S. 53
Capella	12	ká·pěl'ă	281	N. 46
Deneb	53	dēn'ēb	50	N. 45
Denebola	28	dē nēb'ō·lă	183	N. 15
Diphda	4	díf'dă	349	S. 18
Dubhe	27	dŭb'ē	194	N. 62
Enif	54	ěn'íf	34	N. 10
Fomalhaut	56	fō'măl·ôt	16	S. 30
Hamal	6	hăm'âl	329	N. 23
Kochab	40	kō'kăb	137	N. 74
Menkar	8	mēn'kâr	315	N. 4
Miaplacidus	24	mĩ'ă·plăs'ĩ·dŭs	222	S. 70
Mirfak	9	mĩr'făk	309	N. 50
Nunki	50	nŭn'kē	77	S. 26
Peacock	52	pē'kők	54	S. 57
Pollux	21	pől'ŭks	244	N. 28
Polaris	0	pō·lă'rīs	0	N. 90
Procyon	20	prō'sĩ·ōn	245	N. 5
Rasalhague	46	răs'ăl·hă'gwē	97	N. 13
Regulus	26	ręg'ŭ·lŭs	208	N. 12
Rigel	11	rĩ'jěl	282	S. 8
Rigil Kentaurus	38	rĩ'jil kěn·tô'rŭs	140	S. 61
Schedar	3	shěd'âr	350	N. 56
Shaula	45	shô'lă	97	S. 37
Sirius	18	sĩr'ĩ·ŭs	259	S. 17
Spica	33	spĩ'kă	159	S. 11
Suhail	23	sōō·hăl'	223	S. 43
Vega	49	vē'gă	81	N. 39

Guide to pronunciations:

fâte, âdd, finăl, lâst, âbound, ârm; bē, ěnd, caměl, readēr; ĩce, bĩt, an'imal; ōver, pōetic, hőt, lôrd, mōon;
cŭbe, ũnite, tŭb, circŭs, ũrn.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load Star Data Card (NAV-05A2)			
2	Load Star Sight Planner program			
3	Select whether to print or not (repeat if necessary)	none	f A	1 = print 0 = no print
4	Key in approximate location			
	Latitude	L, D.MS	ENTER	
	Longitude	λ , D.MS	A	
5	Key in date			
	Year	Y	ENTER	
	Month	M	ENTER	
	Day	D	B	
6	Key in time and produce list of available stars	GMT. H.MS	C	List*
7	For a new time, repeat step 6.			
8	For a new date, start over at step 4. or			
5	Key in date and compute list of stars available at dawn			
	Year		ENTER	
	Month		ENTER	
	Day		D	GMT, List*
6	For any changes, start over at step 4. or			

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
5	Key in date and compute list of stars available at dusk			
	Year	Y	ENTER	
	Month	M	ENTER	
	Day	D	E	GMT, List
6	For any changes, start over at step 4.			
*	The list consists of:			
	space			
	star # (DSP0)			
	H _c (DSP2)			
	Z _n (DSP1)			
	:			

Example 1:

What evening stars were available to a navigator near the Azores at (38°N, 32°W) on the evening of June 19, 1975?

Keystrokes:

38 ENTER 32 A 1975 ENTER
6 ENTER 19 E →

Outputs:

22.03 *** GMT at Dusk
53. *** Deneb
19.24 ***
47.5 ***
51. *** Altair
7.21 ***
84.3 ***
49. *** Vega
36.53 ***
65.7 ***
46. *** Rasalhague
36.24 ***
102.8 ***

42.	***	Antares
16.54	***	
145.0	***	
41.	***	Alphecca
67.18	***	
112.0	***	
40.	***	Kochab
53.24	***	
6.3	***	
37.	***	Arcturus
70.22	***	
163.9	***	
34.	***	Alkaid
78.52	***	
352.1	***	
33.	***	Spica
40.23	***	
190.8	***	
32.	***	Alioth
66.57	***	
334.0	***	
29.	***	Gienah
30.04	***	
206.2	***	
28.	***	Denebola
53.22	***	
240.0	***	
27.	***	Dubhe
54.21	***	
326.4	***	
26.	***	Regulus
32.57	***	
258.9	***	
25.	***	Alphard
11.45	***	
248.6	***	
21.	***	Pollux
14.23	***	
294.5	***	

12. *** Capella
5.05 ***
327.9 ***
3. *** Schedar
5.25 ***
10.7 ***
0. *** Polaris
38.00 ***
360.0 ***

Example 2:

Produce a list of northern hemisphere stars by keying in a position near the North Pole.

Keystrokes:

The keystrokes are left for the reader.

Outputs:

ALMANAC INTERPOLATOR



A sextant, this program, and The Nautical Almanac are all the items necessary to determine the information needed to plot a line of position from any celestial sight. The program can also be used to compute the sextant setting for locating a difficult-to-see object.

The program requires GHA and DEC for the whole hours immediately preceding and immediately following the time of the observation. It then interpolates to find the location of the object at that time.

The navigator's dead-reckoning location, height-of-eye, and sextant reading are input. The program then corrects the sextant reading for dip of the horizon and mean refraction, compares the corrected reading to the computed position of the object sighted, and displays the azimuth and altitude intercept.

Lines of position from this program may be combined with position lines derived from other programs in this pac. Simply press **[P/S]** between LOP's and then run the position fixing program.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load program			
2	Key in position			
	Latitude ([CHS] if South)	L, D.MS	[ENTER+]	
	Longitude ([CHS] if East)	λ , D.MS	[F A]	L, deg.
3	Key in Height of Eye	HE, feet	[F B]	DIP, deg.
	For MOON sights			
	Press until a 1 appears		[F C]	0 or 1
5	Key in Moon's semidiameter			
	([CHS] if upper limb sight)	SD, D.MS	[F D]	SD, deg.
6	Continue with step 6 below			
	For SUN and STAR sights			
4	Press until a 0 appears		[F C]	0 or 1

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
5	(SUN sights only) Key in Sun's semidiameter (CHS if upper limb sight)	SD, D.MS	F D	SD, deg.
6	Key in time of sight	GMT, H.MS	A	INT [GMT]
7	Key in: GHA of object at previous whole hour	α_1 , D.MS	ENTER	
	GHA of object at next whole hour	α_2 , D.MS	B	
	SHA if object is a star	SHA, D.MS	R/S	
	Key in: DEC of object at previous whole hour	δ_1 , D.MS	ENTER	
	DEC of object at next whole hour	δ_2 , D.MS	C	
9	Key in sextant altitude and compute			
	Azimuth (paused)	h_s , D.MS	D	Z_n , deg.
	Altitude intercept (- = towards + = away)			a, miles
	to see azimuth again		X$\leftrightarrow$Y	Z_n
10	To precompute a sextant setting for finding difficult-to-see objects		E	h_s , D.MS
	then display the direction to face		R/S	Z_n , deg.
11	For another sight on the same object, key in new time and			
	continue with step 9 or 10	GMT, H.MS	F E	

Example 1:

On June 19 a navigator near the Azores at (38°N, 32°W) needed to find the planet Venus to complete a fix with the Sun. Where should he have looked at 1625 GMT?

Keystrokes:

38 **ENTER** 32 **f A** 10

f B f C →

16.25 **A**

11.0636 **ENTER** 26.0642 **B**

18.4012 **ENTER** 18.3924

C E →

R/S →

Outputs:

0.00 repeat **f C** until
0.00 appears

66.5327 sextant altitude
142.5104 azimuth

Example 2:

Where will Venus be found at 1650?

Keystrokes:

16.50 **f E E** →

R/S →

Outputs:

69.2243 sextant altitude
156.9574 azimuth

JUNE 18, 19 20 (WED., THURS., FRI)

		ARIES		VENUS		3.9		MARS		+0.8		JUPITER		1.9		SATURN		+0.4		STARS	
GMT		Dec		Dec		Dec		Dec		Dec		Dec		Dec		Dec		Dec		Dec	
W L D N E S D A Y	18 00	265 36.2	131 03.1	N19 12.2	246 02.2	N 6 27.7	246 57.2	N 6 34.5	155 04.6	N22 01.2	Accomar	915 46.1	540 24.0								
	01	280 39.9	146 33.1	121 26.1	02.9	284 26.1	59.3	34.6	176 06.7	01.1	Achernar	935 48.7	557 21.7								
	02	295 41.8	162 03.2	113 15.6	03.7	294 27.7	01.4	34.7	185 08.9	01.1	Acrux	913 48.1	562 58.2								
	03	311 44.2	178 03.3	105 29.4	04.8	298 29.4	04.8	34.9	196 10.9	01.1	Adelta	907 48.1	578 58.2								
	04	328 46.1	194 03.3	97 43.6	05.7	302 30.2	05.7	35.0	207 12.9	01.1	Adelta	907 48.1	578 58.2								
	05	346 48.0	210 03.4	89 57.1	06.6	306 30.6	06.6	35.2	218 14.9	01.1	Adelta	907 48.1	578 58.2								
	06	365 50.0	226 03.5	82 11.2	07.5	310 31.0	07.5	35.3	229 16.9	01.1	Adelta	907 48.1	578 58.2								
	07	384 51.9	242 03.6	74 25.3	08.4	314 31.4	08.4	35.4	240 18.9	01.1	Adelta	907 48.1	578 58.2								
	08	403 53.8	258 03.7	66 39.4	09.3	318 31.8	09.3	35.5	251 20.9	01.1	Adelta	907 48.1	578 58.2								
	09	422 55.7	274 03.8	58 53.5	10.2	322 32.2	10.2	35.6	262 22.9	01.1	Adelta	907 48.1	578 58.2								
T H U R S D A Y	10 00	441 57.6	290 03.9	51 07.6	11.1	326 32.6	11.1	35.7	273 24.9	01.1	Adelta	907 48.1	578 58.2								
	01	460 59.5	306 04.0	43 21.7	12.0	330 33.0	12.0	35.8	284 26.9	01.1	Adelta	907 48.1	578 58.2								
	02	479 61.4	322 04.1	35 35.8	12.9	334 33.4	12.9	35.9	295 28.9	01.1	Adelta	907 48.1	578 58.2								
	03	498 63.3	338 04.2	27 50.0	13.8	338 33.8	13.8	36.0	306 30.9	01.1	Adelta	907 48.1	578 58.2								
	04	517 65.2	354 04.3	19 54.1	14.7	342 34.2	14.7	36.1	317 32.9	01.1	Adelta	907 48.1	578 58.2								
	05	536 67.1	370 04.4	11 58.2	15.6	346 34.6	15.6	36.2	328 34.9	01.1	Adelta	907 48.1	578 58.2								
	06	555 69.0	386 04.5	3 52.3	16.5	350 35.0	16.5	36.3	339 36.9	01.1	Adelta	907 48.1	578 58.2								
	07	574 70.9	402 04.6	15 46.4	17.4	354 35.4	17.4	36.4	350 38.9	01.1	Adelta	907 48.1	578 58.2								
	08	593 72.8	418 04.7	7 50.5	18.3	358 35.8	18.3	36.5	361 40.9	01.1	Adelta	907 48.1	578 58.2								
	09	612 74.7	434 04.8	19 44.6	19.2	362 36.2	19.2	36.6	372 42.9	01.1	Adelta	907 48.1	578 58.2								
F R I D A Y	11 00	631 76.6	450 04.9	11 38.7	20.1	366 36.6	20.1	36.7	383 44.9	01.1	Adelta	907 48.1	578 58.2								
	01	650 78.5	466 05.0	3 52.8	21.0	370 37.0	21.0	36.8	394 46.9	01.1	Adelta	907 48.1	578 58.2								
	02	669 80.4	482 05.1	15 46.9	21.9	374 37.4	21.9	36.9	405 48.9	01.1	Adelta	907 48.1	578 58.2								
	03	688 82.3	498 05.2	27 51.0	22.8	378 37.8	22.8	37.0	416 50.9	01.1	Adelta	907 48.1	578 58.2								
	04	707 84.2	514 05.3	39 55.1	23.7	382 38.2	23.7	37.1	427 52.9	01.1	Adelta	907 48.1	578 58.2								
	05	726 86.1	530 05.4	51 59.2	24.6	386 38.6	24.6	37.2	438 54.9	01.1	Adelta	907 48.1	578 58.2								
	06	745 88.0	546 05.5	64 03.3	25.5	390 39.0	25.5	37.3	449 56.9	01.1	Adelta	907 48.1	578 58.2								
	07	764 89.9	562 05.6	76 07.4	26.4	394 39.4	26.4	37.4	460 58.9	01.1	Adelta	907 48.1	578 58.2								
	08	783 91.8	578 05.7	88 11.5	27.3	398 39.8	27.3	37.5	471 60.9	01.1	Adelta	907 48.1	578 58.2								
	09	802 93.7	594 05.8	100 15.6	28.2	402 40.2	28.2	37.6	482 62.9	01.1	Adelta	907 48.1	578 58.2								
S A T U R D A Y	12 00	821 95.6	610 05.9	112 19.7	29.1	406 40.6	29.1	37.7	493 64.9	01.1	Adelta	907 48.1	578 58.2								
	01	840 97.5	626 06.0	124 23.8	30.0	410 41.0	30.0	37.8	504 66.9	01.1	Adelta	907 48.1	578 58.2								
	02	859 99.4	642 06.1	136 27.9	30.9	414 41.4	30.9	37.9	515 68.9	01.1	Adelta	907 48.1	578 58.2								
	03	878 101.3	658 06.2	148 32.0	31.8	418 41.8	31.8	38.0	526 70.9	01.1	Adelta	907 48.1	578 58.2								
	04	897 103.2	674 06.3	160 36.1	32.7	422 42.2	32.7	38.1	537 72.9	01.1	Adelta	907 48.1	578 58.2								
	05	916 105.1	690 06.4	172 40.2	33.6	426 42.6	33.6	38.2	548 74.9	01.1	Adelta	907 48.1	578 58.2								
	06	935 107.0	706 06.5	184 44.3	34.5	430 43.0	34.5	38.3	559 76.9	01.1	Adelta	907 48.1	578 58.2								
	07	954 108.9	722 06.6	196 48.4	35.4	434 43.4	35.4	38.4	570 78.9	01.1	Adelta	907 48.1	578 58.2								
	08	973 110.8	738 06.7	208 52.5	36.3	438 43.8	36.3	38.5	581 80.9	01.1	Adelta	907 48.1	578 58.2								
	09	992 112.7	754 06.8	220 56.6	37.2	442 44.2	37.2	38.6	592 82.9	01.1	Adelta	907 48.1	578 58.2								
S U N D A Y	13 00	1011 114.6	770 06.9	232 60.7	38.1	446 44.6	38.1	38.7	603 84.9	01.1	Adelta	907 48.1	578 58.2								
	01	1030 116.5	786 07.0	244 64.8	39.0	450 45.0	39.0	38.8	614 86.9	01.1	Adelta	907 48.1	578 58.2								
	02	1049 118.4	802 07.1	256 68.9	39.9	454 45.4	39.9	38.9	625 88.9	01.1	Adelta	907 48.1	578 58.2								
	03	1068 120.3	818 07.2	268 73.0	40.8	458 45.8	40.8	39.0	636 90.9	01.1	Adelta	907 48.1	578 58.2								
	04	1087 122.2	834 07.3	280 77.1	41.7	462 46.2	41.7	39.1	647 92.9	01.1	Adelta	907 48.1	578 58.2								
	05	1106 124.1	850 07.4	292 81.2	42.6	466 46.6	42.6	39.2	658 94.9	01.1	Adelta	907 48.1	578 58.2								
	06	1125 126.0	866 07.5	304 85.3	43.5	470 47.0	43.5	39.3	669 96.9	01.1	Adelta	907 48.1	578 58.2								
	07	1144 127.9	882 07.6	316 89.4	44.4	474 47.4	44.4	39.4	680 98.9	01.1	Adelta	907 48.1	578 58.2								
	08	1163 129.8	898 07.7	328 93.5	45.3	478 47.8	45.3	39.5	691 100.9	01.1	Adelta	907 48.1	578 58.2								
	09	1182 131.7	914 07.8	340 97.6	46.2	482 48.2	46.2	39.6	702 102.9	01.1	Adelta	907 48.1	578 58.2								
M E R C U R Y	14 00	1201 133.6	930 07.9	352 101.7	47.1	486 48.6	47.1	39.7	713 104.9	01.1	Adelta	907 48.1	578 58.2								
	01	1220 135.5	946 08.0	364 105.8	48.0	490 49.0	48.0	39.8	724 106.9	01.1	Adelta	907 48.1	578 58.2								
	02	1239 137.4	962 08.1	376 109.9	48.9	494 49.4	48.9	39.9	735 108.9	01.1	Adelta	907 48.1	578 58.2								
	03	1258 139.3	978 08.2	388 114.0	49.8	498 49.8	49.8	40.0	746 110.9	01.1	Adelta	907 48.1	578 58.2								
	04	1277 141.2	994 08.3	400 118.1	50.7	502 50.7	50.7	40.1	757 112.9	01.1	Adelta	907 48.1	578 58.2								
	05	1296 143.1	1010 08.4	412 122.2	51.6	506 50.6	51.6	40.2	768 114.9	01.1	Adelta	907 48.1	578 58.2								
	06	1315 145.0	1026 08.5	424 126.3	52.5	510 51.0	52.5	40.3	779 116.9	01.1	Adelta	907 48.1	578 58.2								
	07	1334 146.9	1042 08.6	436 130.4	53.4	514 51.4	53.4	40.4	790 118.9	01.1	Adelta	907 48.1	578 58.2								
	08	1353 148.8	1058 08.7	448 134.5	54.3	518 51.8	54.3	40.5	801 120.9	01.1	Adelta	907 48.1	578 58.2								
	09	1372 150.7	1074 08.8	460 138.6	55.2	522 52.2	55.2	40.6	812 122.9	01.1	Adelta	907 48.1	578 58.2								
V E N U S	15 00	1391 152.6	1090 08.9	472 142.7	56.1	526 52.6	56.1	40.7	823 124.9	01.1	Adelta	907 48.1	578 58.2								
	01	1410 154.5	1106 09.0	484 146.8	57.0	530 53.0	57.0	40.8	834 126.9	01.1	Adelta	907 48.1	578 58.2								
	02	1429 156.4	1122 09.1	496 150.9	57.9	534 53.4	57.9	40.9	845 128.9	01.1	Adelta	907 48.1	578 58.2								
	03	1448 158.3	1138 09.2	508 155.0	58.8	538 53.8	58.8	41.0	856 130.9	01.1	Adelta	907 48.1	578 58.2								
	04	1467 160.2	1154 09.3	520 159.1	59.7	542 54.2	59.7	41.1	867 132.9	01.1	Adelta	907 48.1	578 58.2								
	05	1486 162.1	1170 09.4	532 163.2	60.6	546 54.6	60.6	41.2	878 134.9	01.1	Adelta	907 48.1	578 58.2								
	06	1505 164.0	1186 09.5	544 167.3	61.5	550 55.0	61.5	41.3	889 136.9	01.1	Adelta	907 48.1	578 58.2							</	

JUNE 18, 19, 20 (WED., THURS., FRI.)

G.M.T.	ARIES			VENUS -3.9			MARS +0.8			JUPITER -1.9			SATURN +0.4			STARS		
	G.H.A.	G.H.A.	Dec.	G.H.A.	G.H.A.	Dec.	G.H.A.	G.H.A.	Dec.	G.H.A.	G.H.A.	Dec.	G.H.A.	G.H.A.	Dec.	Name	S.H.A.	Dec.
18 00	265 36.8	131 03.1	N19 12.9	246 02.2	N 6 27.7	246 57.2	N 6 34.5	155 04.6	N22 01.2	245 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Acomar	315 40.3	540 24.0
01	280 39.3	146 03.1	12.1	261 02.9	28.4	261 59.3	34.6	170 06.7	01.1	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Achernar	335 48.2	557 21.4
02	295 41.8	161 03.2	11.3	276 03.7	29.1	277 01.4	34.7	185 08.9	01.1	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Acrux	173 41.1	562 58.2
03	310 44.2	176 03.3	10.5	291 04.5	29.8	292 03.4	34.9	200 11.0	01.1	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Adhara	255 35.3	528 56.4
04	325 46.7	191 03.3	09.7	306 05.2	30.5	307 05.5	35.0	215 13.1	01.0	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Aldebaran	291 22.4	516 27.6
05	340 49.2	206 03.4	08.9	321 06.0	31.2	322 07.6	35.2	230 15.3	01.0	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7			
06	355 51.6	221 03.5	N19 08.1	336 06.8	N 6 31.8	337 09.7	N 6 35.3	245 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Alioth	166 45.5	N56 05.8
07	10 54.1	236 03.5	07.2	351 07.5	32.5	352 11.8	35.5	260 19.5	00.9	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Alkaid	153 21.0	N49 26.3
08	25 56.6	251 03.6	06.4	6 08.3	33.2	7 13.9	35.6	275 21.7	00.9	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Al Na'ir	28 19.2	547 04.5
09	40 59.0	266 03.7	05.6	21 09.1	33.9	22 16.0	35.7	290 23.8	00.8	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Alnilam	276 15.6	5 1 13.1
10	56 01.5	281 03.8	04.8	36 09.8	34.6	37 18.1	35.9	305 25.9	00.8	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Alphard	218 24.3	5 8 33.3
11	71 03.9	296 03.8	04.0	51 10.6	35.3	52 20.2	36.0	320 28.1	00.7	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7			
12	86 06.4	311 03.9	N19 03.2	66 11.4	N 6 35.9	67 22.3	N 6 36.2	335 30.2	N22 00.7	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Alphecca	126 34.8	N26 47.9
13	101 08.9	326 04.0	02.4	81 12.1	36.6	82 24.4	36.3	350 32.4	00.7	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Alpheratz	358 13.0	N28 57.2
14	116 11.3	341 04.1	01.6	96 12.9	37.3	97 26.5	36.4	5 34.5	00.6	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Altair	62 35.7	N 8 48.2
15	131 13.8	356 04.1	19 00.8	111 13.7	38.0	112 28.6	36.6	20 36.6	00.6	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Ankaa	353 43.8	542 26.0
16	146 16.3	11 04.2	18 59.9	126 14.4	38.7	127 30.6	36.7	35 38.8	00.5	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Antares	113 00.9	526 22.7
17	161 18.7	26 04.3	59.1	141 15.2	39.3	142 32.7	36.9	50 40.9	00.5	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7			
18	176 21.2	41 04.4	N18 58.3	156 16.0	40.0	157 34.8	N 6 37.0	65 43.0	N22 00.5	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Arcturus	146 21.5	N19 18.6
19	191 23.7	56 04.5	57.5	171 16.7	40.7	172 36.9	37.1	80 45.2	00.4	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Attra	108 27.8	568 59.1
20	206 26.1	71 04.6	56.7	186 17.5	41.4	187 39.0	37.3	95 47.3	00.4	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Avior	234 30.2	559 26.1
21	221 28.6	86 04.7	55.9	201 18.3	42.1	202 41.1	37.4	110 49.4	00.3	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Bellatrix	279 02.9	N 6 19.6
22	236 31.1	101 04.8	55.0	216 19.0	42.8	217 43.2	37.6	125 51.6	00.3	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Betelgeuse	271 32.5	N 7 24.1
23	251 33.5	116 04.8	54.2	231 19.8	43.4	232 45.3	37.7	140 53.7	00.3	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7			
19 00	266 36.0	131 04.9	N18 53.4	246 20.6	N 6 44.1	247 47.4	N 6 37.8	155 55.8	N22 00.2	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Canopus	264 09.3	552 41.0
01	281 38.4	146 05.0	52.6	261 21.3	44.8	262 49.5	38.0	170 58.0	00.2	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Capella	281 17.0	N45 58.4
02	296 40.9	161 05.1	51.8	276 22.1	45.5	277 51.6	38.1	186 00.1	00.1	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Deneb	49 50.5	N45 11.5
03	311 43.4	176 05.2	50.9	291 22.9	46.2	292 53.7	38.3	201 02.2	00.1	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Denebola	183 02.7	N14 42.6
04	326 45.8	191 05.3	50.1	306 23.6	46.8	307 55.8	38.4	216 04.4	00.1	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Diphda	349 24.5	518 07.1
05	341 48.3	206 05.4	49.3	321 24.4	47.5	322 57.9	38.5	231 06.5	00.0	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7			
06	356 50.8	221 05.5	N18 48.5	336 25.2	N 6 48.2	338 00.0	N 6 38.7	246 08.8	N22 00.0	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Dubhe	194 26.6	N61 53.2
07	11 53.2	236 05.6	47.7	351 25.9	48.9	353 02.1	38.8	261 10.8	21 59.4	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Elath	278 49.0	N28 57.2
08	26 56.7	251 05.7	46.8	6 26.7	49.5	7 40.2	39.0	276 12.9	59.9	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Elnath	90 58.8	N51 29.6
09	41 58.2	266 05.8	46.0	21 27.5	50.2	22 06.3	39.1	291 15.0	59.9	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Enif	34 14.9	N 9 45.8
10	57 00.6	281 05.9	45.2	36 28.2	50.9	38 08.4	39.2	306 17.2	59.9	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Fomalhaut	15 55.2	529 44.9
11	72 03.1	296 06.0	44.4	51 29.0	51.6	53 10.5	39.4	321 19.3	59.8	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7			
12	87 05.5	311 06.1	N18 43.5	61 29.0	N 6 52.3	68 12.6	N 6 39.5	336 21.4	N21 59.7	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Gacrux	172 32.6	556 58.9
13	102 08.0	326 06.3	42.7	81 30.5	52.9	83 14.7	39.7	351 23.6	59.7	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Gienah	176 21.6	517 24.5
14	117 10.5	341 06.4	41.9	96 31.3	53.6	98 16.7	39.8	6 25.7	59.7	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Hadar	149 28.0	560 15.6
15	132 12.9	356 06.5	41.1	111 32.1	54.3	113 18.8	39.9	21 27.8	59.6	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Hamal	328 43.1	N23 20.7
16	147 15.4	11 06.6	40.2	126 32.8	55.0	128 20.9	40.1	36 30.0	59.6	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Kaus Astar	84 21.2	534 23.7
17	162 17.9	26 06.7	39.4	141 33.6	55.7	143 23.0	40.2	51 32.1	59.5	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7			
18	177 20.3	41 06.8	N18 38.6	156 34.4	N 6 56.3	158 25.1	N 6 40.4	66 34.2	N21 59.5	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Kochab	137 18.0	N74 15.6
19	192 22.8	56 06.9	37.8	171 35.1	57.0	173 27.2	40.5	81 36.4	59.4	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Markab	14 06.6	N15 04.4
20	207 25.3	71 07.1	36.9	186 35.9	57.7	188 29.3	40.6	96 38.5	59.4	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Menkar	314 45.1	N 3 59.6
21	222 27.7	86 07.2	36.1	201 36.7	58.4	203 31.4	40.8	11 40.6	59.4	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Menkent	148 41.0	536 15.2
22	237 30.2	101 07.3	35.3	216 37.4	59.0	218 33.5	40.9	26 42.7	59.3	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Miaplacidus	221 46.3	569 37.3
23	252 32.7	116 07.4	34.4	231 38.2	6 59.7	233 35.6	41.0	41 44.9	59.3	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7			
20 00	267 35.1	131 07.5	N18 33.6	246 39.0	N 7 00.4	248 37.7	N 6 41.2	156 47.0	N21 59.3	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Mirfak	309 21.6	N49 46.3
01	282 37.6	146 07.7	32.8	261 39.7	01.1	263 39.8	41.3	171 49.1	59.2	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Nunki	76 33.2	526 19.6
02	297 40.0	161 07.8	31.9	276 40.5	01.7	278 41.9	41.5	186 51.3	59.2	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Peacock	54 03.5	556 48.6
03	312 42.5	176 07.9	31.1	291 41.3	02.4	293 44.0	41.6	201 53.4	59.1	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Pollux	244 02.9	N28 05.7
04	327 45.0	191 08.0	30.3	306 42.0	03.1	308 46.1	41.7	216 55.5	59.1	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7	Procyon	245 28.8	N 5 17.2
05	342 47.4	206 08.2	29.4	321 42.9	03.8	323 48.2	41.9	231 57.7	59.1	246 17.4	N22 00.7	245 17.4	N22 00.7	245 17.4	N22 00.7			
06	357 49.9	221 08.3	N18 28.6	336 43.6	N 7 0													

SUN LINE OF POSITION



The Sun Almanac program computes altitude intercepts from Sun sights. Sextant readings are corrected for dip of the horizon, mean refraction, and semidiameter of the Sun. The almanac equations used agree, to acceptable tolerances (less than .5 mi. error), with available almanacs from 1933 to 1978.*

Sun lines obtained using this program may be combined with position lines derived from other programs in this pac. Simply press **[P&S]** between LOP's and then run the position fixing program.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load program			
2	Key in position			
	Latitude ([CHS] for South)	L, D.MS	[ENTER]	
	Longitude ([CHS] for East)	λ , D.MS	[F] [A]	
3	Key in height of eye	HE, feet	[F] [B]	
4	Key in date:			
	Year	Y	[ENTER]	
	Month	M	[ENTER]	
	Day	D	[A]	360.0
5	Key in time and compute:			
	Sun's azimuth	GMT	[B]	Z_n , deg.
	Sun's Altitude			H_c , D.MS
6	Key in sextant altitude and			
	compute intercept (- = Toward			
	+ = Away)			
	For lower limb sight	h_s , D.MS	[D]	a, miles
	For upper limb sight	h_s , D.MS	[E]	a, miles
	For a new time, go to step 5.			
	For a new sextant height, go to			
	step 6.			

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
	To use this program with other			
	cards in the LOP series, press			
	[P/S] before running another			
	LOP card, then run the FIX			
	card.			
	To store the results of two Sun			
	sights, press [P/S] between			
	sights and run again starting			
	with step 2.			

Example:

On June 19, 1975, a navigator obtained an uncorrected altitude of $58^{\circ}06'$ for the Sun at $16^{\text{h}}23^{\text{m}}51^{\text{s}}$ from a height of eye of 10 feet. His dead reckoning position was (38°N , 32°W). What is the altitude intercept resulting from this Sun sight?

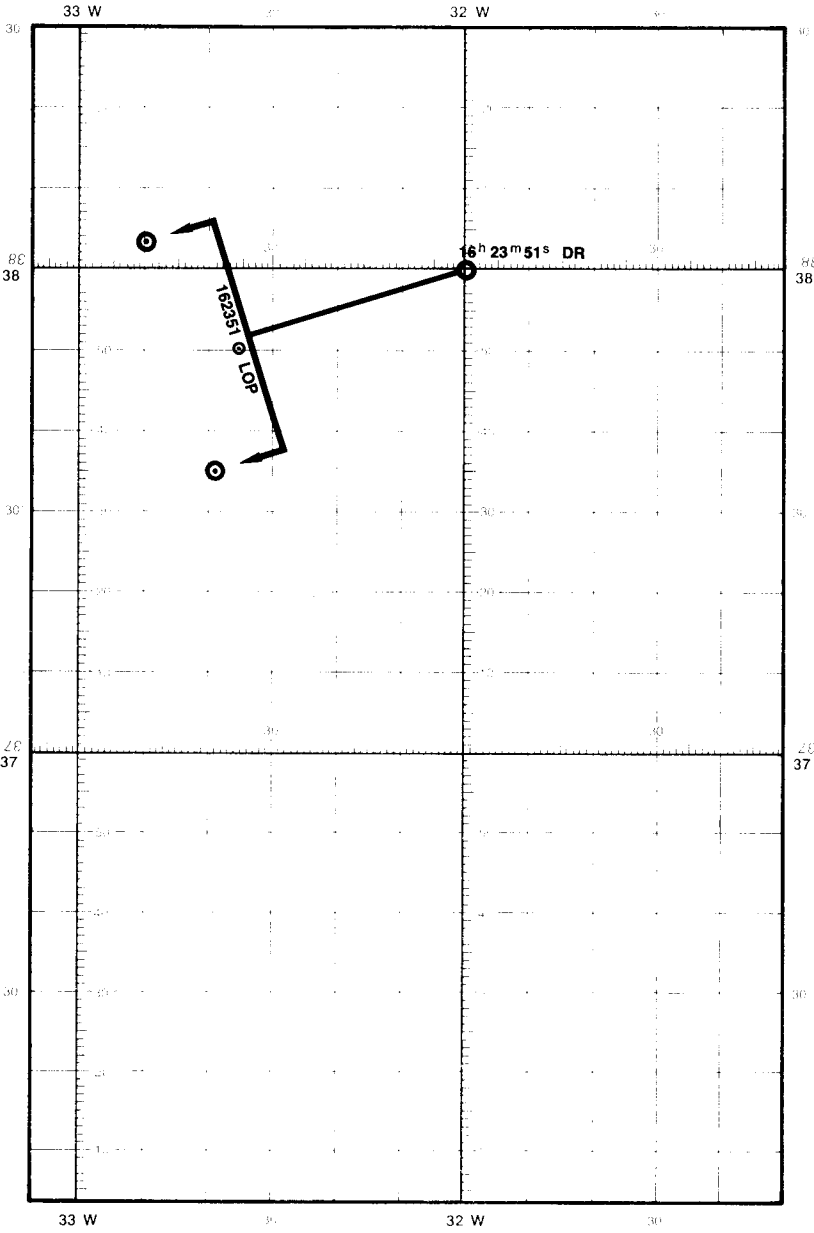
Keystrokes:

38 **[ENTER]** 32 **[f]** **[A]** 10 **[f]** **[B]**
 1975 **[ENTER]** 6 **[ENTER]** 19
[A] 16.2351 **[B]** $\longrightarrow$
 58.06 **[D]** $\longrightarrow$

Outputs:

252.9 *** Z_n
 57.5007 H_c (in display)
 -28.0 28 miles toward

*Note: Although almanacs were not available beyond 1978 when we developed this program, there is no reason to believe that it will not work for a long time.



STAR LINE OF POSITION

STAR LINE OF POSITION		
Y+M+D	GMT-Z ₀ H _c	h _c +a

STAR DATA 1				
Alloth 32	Alkaid 34	Al Nair	Alnilam	Alphard 25

STAR DATA 2				
Arcturus 37	Atria	Axos	Belatrix	Betelgeuse 1b

STAR DATA 3				
Dubhe 27	Elnath	Eltaim	Enif 54	Gammahaut 56

STAR DATA 4				
Kochab 40	Mikab	Menkai 8	Menkent	Muplacidus 24

STAR DATA 5				
Procyon 20	Rasalhague 4b	Regulus 26	Rigel 11	Rigel Kent 38

STAR DATA 6		
Suhail 23	Vega 49	Zubenelgenubi

The Star Almanac program computes altitude intercepts from star sights. Sextant readings are corrected for dip of the horizon and mean refraction. The almanac equations used account for aberration, precession and nutation of the equinoxes, and partially for proper motion of the stars themselves. The data cards include all 57 navigational stars plus Polaris.

Star lines obtained using this program may be combined with position lines derived from other programs in this pac. Simply press **[PzS]** between LOP's and then run the position fixing program.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load one of the STAR DATA cards and select the appropriate star (they are arranged alphabetically)			
2	Load this program			
3	Key in position			
	Latitude (CHS for South)	L, D.MS	ENTER	
	Longitude (CHS for East)	λ , D.MS	1 A	
4	Key in height of eye and compute dip	HE, feet	1 B	DIP, deg.
5	Key in date:			
	Year	Y (A.D.)	ENTER	
	Month	M (1 to 12)	ENTER	
	Day	D (1 to 31)	A	360
6	Key in time of sight and compute:			
	Star's azimuth	GMT, H.MS	B	Z_n , deg.
	Star's altitude			H_c , D.MS
7	Key in sextant altitude and compute altitude intercept			
	(- = Toward; + = Away)	h_s , D.MS	C	a, miles

Example:

A navigator at ($35^{\circ}53'05''\text{N}$, $141^{\circ}46'36''\text{E}$) shoots Deneb from a height of eye of 65 feet on February 10, 1977, at 0820 GMT. His sextant reading is $20^{\circ}25'$. Plot the LOP.

Keystrokes:

Load Star Data 3

f **C** (Deneb) $\longrightarrow$

Load Star Line of Position

35.5305 **ENTER** 141.4636

CHS **f** **A** 65 **f** **B** 1977

ENTER 2 **ENTER** 10 **A**

8.20 **B** $\longrightarrow$

20.25 **C** $\longrightarrow$

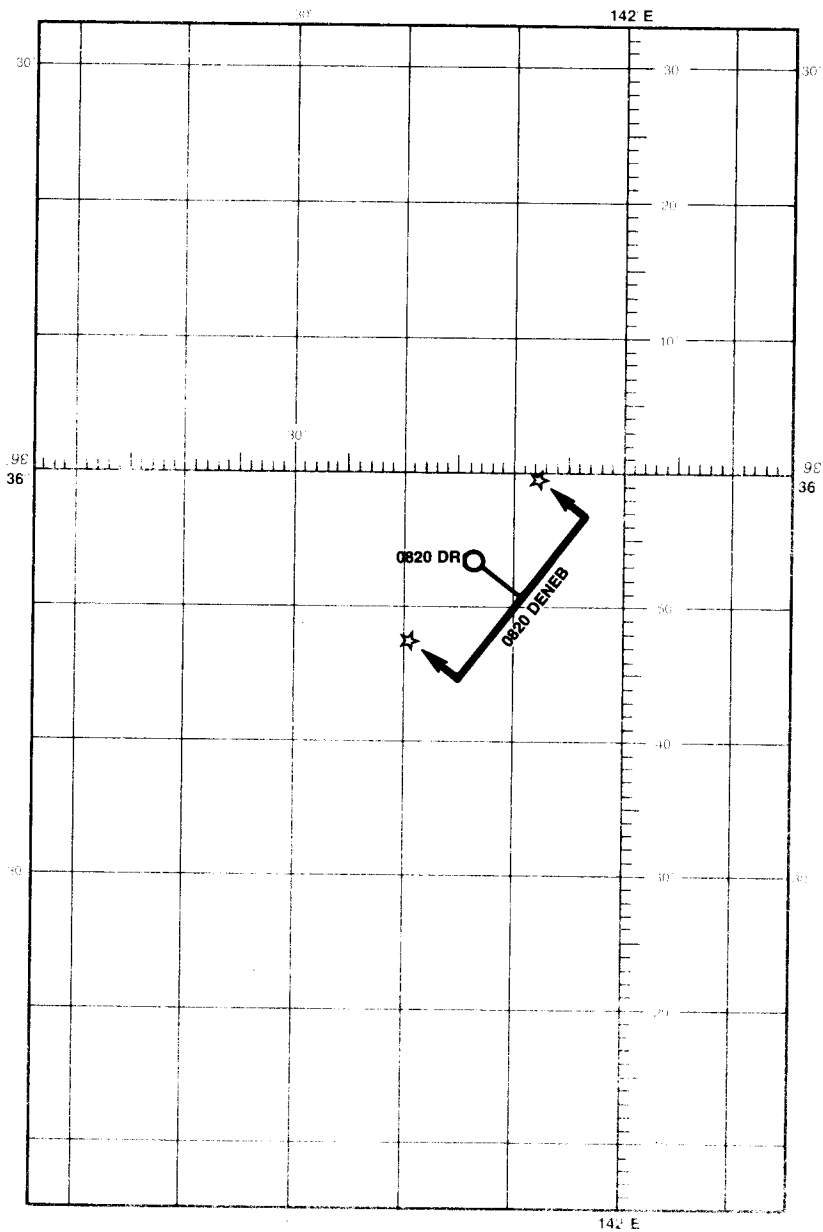
Outputs:

45.17 ignore display

311.8 *** Z_n

20.1843 H_c

4.1 away



BEARING LINE OF POSITION

BEARING LINE OF POSITION

$$L_1 + \lambda_1 - Z_1 \quad L_2 + \lambda_2 - Z_2 \quad C + S + T - L - \lambda \quad -L - \lambda$$

This program computes your location given bearings to two known objects. The fix may be a stationary fix or a running fix. If only one object is available for sighting, it may be used as both the first and second objects.

This program also may be used in conjunction with one of the other LOP cards and "Fix From Two Lines of Position" to produce a fix based on one bearing and some other line of position.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load program			
2	Key in coordinates and bearings of two objects			
	Latitude of first object	L_1 , D.MS	ENTER	
	Longitude of first object	λ_1 , D.MS	A	
	Bearing of first object	Z_1 , deg.	RS	
	Latitude of second object	L_2 , D.MS	ENTER	
	Longitude of second object	λ_2 , D.MS	B	
	Bearing of second object	Z_2 , D.MS	RS	
	For a Stationary Fix			
3	Compute fix latitude	none	D	L , D.MS
	longitude		RS	λ , D.MS
	For a Running Fix			
3	Key in:			
	Course (true)	C , deg.	ENTER	
	Speed	S , knots	ENTER	

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
	Time on course and compute			
	latitude	Δt , H.MS	C	L, D.MS
	longitude		R/S	λ , D.MS
	To use this card to make an			
	LOP for use with an LOP from			
	another program, key in only			
	one object and bearing in step			
	2. Be sure to press P/S			
	between the LOP's.			

Example 1:

A boat in San Luis Obispo Bay observes White Rock, (35°09'48"N, 120°42'31"W), bearing 346° and Howell Rock, (35°09'32"N, 120°43'38"W), bearing 318°9. What is the position of the boat?

Keystrokes:

35.0948 **ENTER** 120.4231

A 346 **R/S**

35.0932 **ENTER** 120.4338 **B**

318.9 **R/S** **D** →

R/S →

Outputs:

35.0758 ***

120.4157 ***

Example 2:

A navigator bound for the entrance to Tillamook Bay (45°34'N, 123°57'40"W) on course 035° observes the radio beacon on Yaquina Head (44°40'40"N, 124°04'45"W) to bear 137.5. Where is the fix?

Keystrokes:

Load "Bearing Line of Position"

45.34 **ENTER** 123.5740 **A**

35 **R/S** 44.4040 **ENTER**

124.0445 **B** 137.5 **R/S**

Load "Fix from Two Lines of Position"

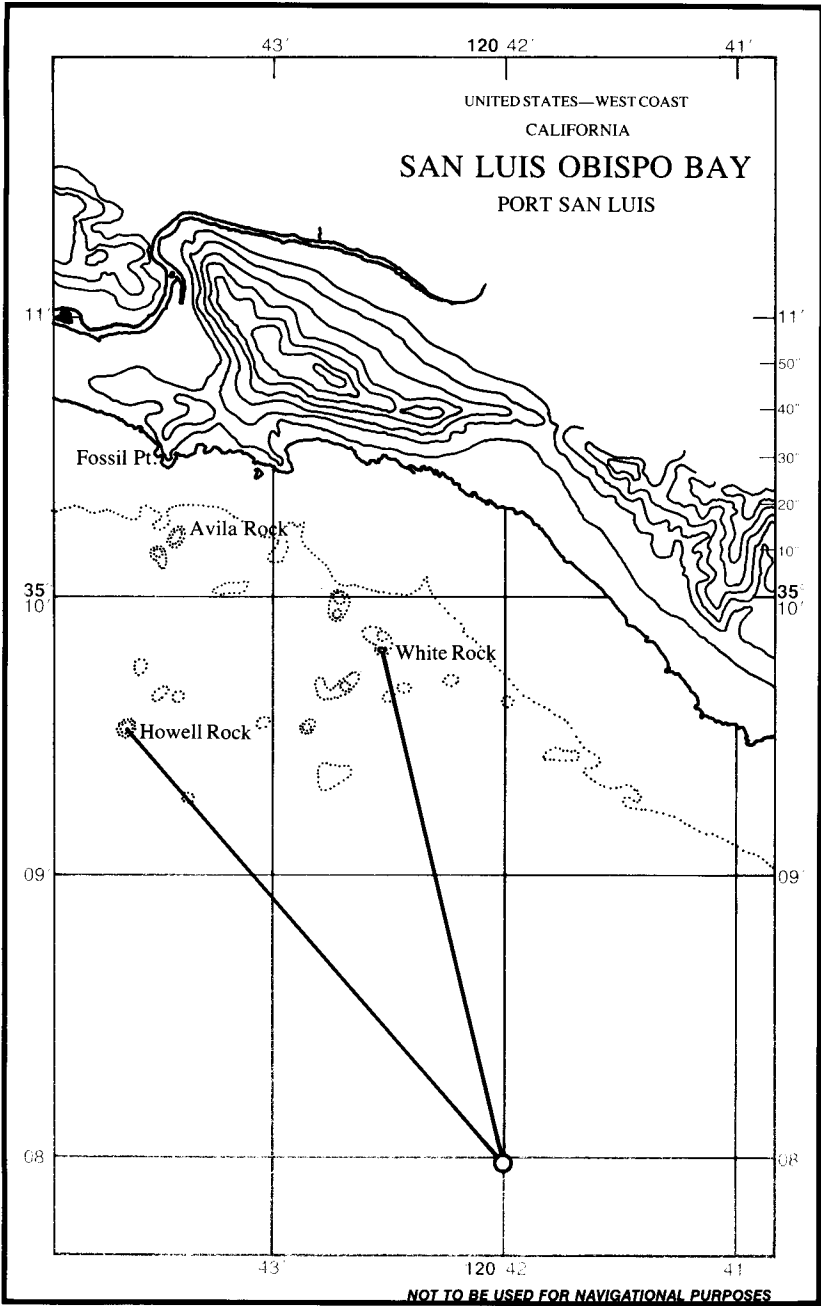
0 **A** →

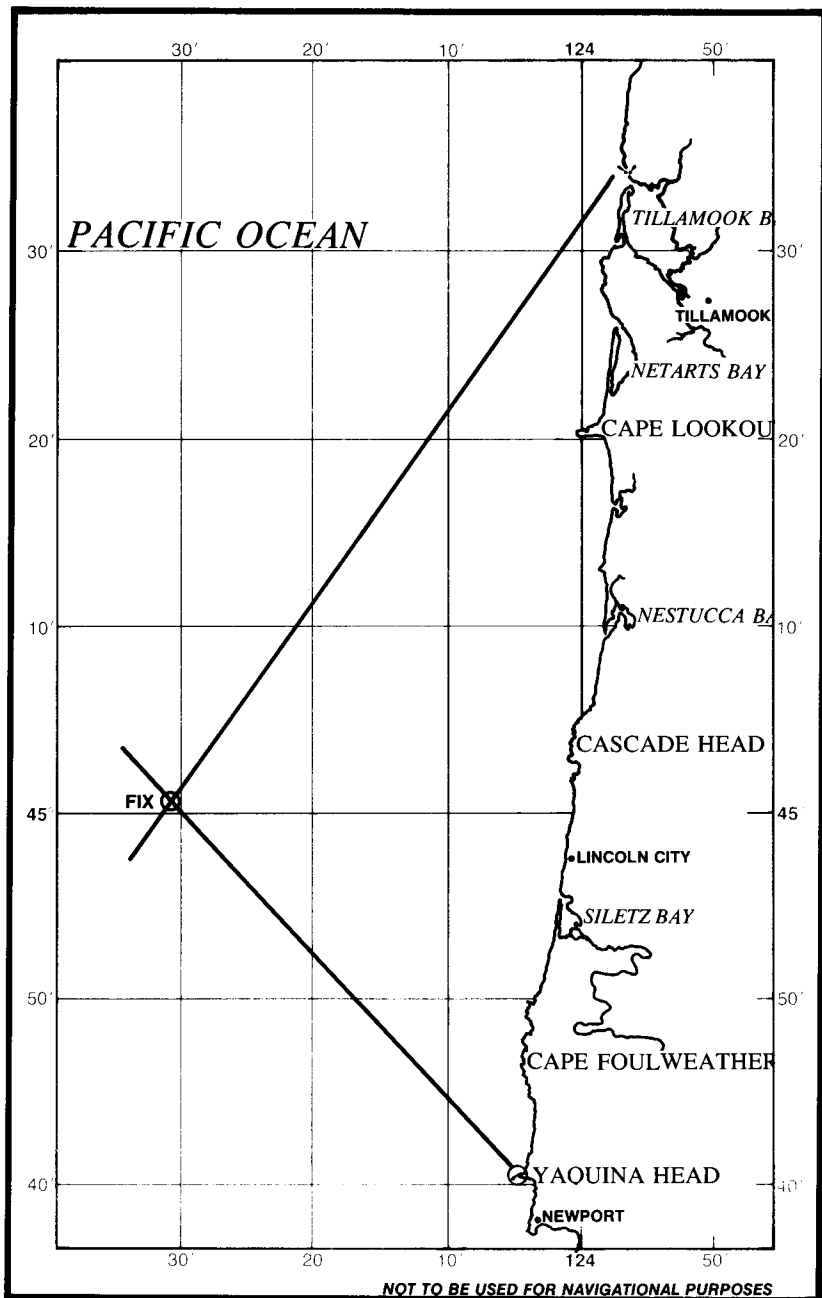
R/S →

Outputs:

45.0036 L 45°0'36"N

124.3040 λ 124°30'40"W





TWO-ANGLE LINE OF POSITION

TWO-ANGLE LINE OF POSITION

$$L_A + \lambda_A \quad \Delta Z_{AC} = L \cdot \lambda \quad L_C + \lambda_C \quad Z_C = Z \quad \Delta Z_{CE} = L \cdot \lambda \quad L_E + \lambda_E$$

This program allows you to determine a fix from three objects at known locations. The coordinates of three stations are input along with the approximate bearing of the second station and the horizontal sextant angles between the first and second stations and second and third stations. From each horizontal sextant angle an LOP and an approximate fix are computed. A more accurate stationary fix may be obtained by continuing with the FIX card using a time increment of zero.

This program may also be used to store an LOP from two stations for use by the FIX card by entering only two stations, the approximate bearing of the second station, and the horizontal sextant angle between the two stations.

By providing the approximate bearing of the second station, the "revolver" problem, occurring when the fix is on the same circle as the three stations, is avoided.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load program			
2	Key in position of station A:			
	Latitude (CHS if South)	L_A , D.MS	ENTER	
	Longitude (CHS if East)	λ_A , D.MS	A	
3	Key in position of station C:			
	Latitude (CHS if South)	L_C , D.MS	ENTER	
	Longitude (CHS if East)	λ_C , D.MS	C	
4	Key in true bearing to station C	Z_C , deg.	RS	
5	Key in position of station E:			
	Latitude (CHS if South)	L_E , D.MS	ENTER	
	Longitude (CHS if East)	λ_E , D.MS	E	
6	Key in horizontal sextant angle			
	between stations A can C and			
	compute a fix	Z_{AC} , D.MS	B	L , D.MS
	Note: This approximate fix			
	depends on the accuracy of Z_C .		RS	λ , D.MS

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
7	Key in horizontal sextant angle			
	between stations C and E and			
	compute a fix	Z_{CE} , D.MS	D	L , D.MS
			R/S	λ , D.MS
	Note: This approximate fix			
	depends on the accuracy of Z_c .			
	To get an accurate stationary			
	fix, load the "Fix by two LOP's"			
	card, key in zero, and press			
	A .			
	To obtain an LOP from two			
	stations, perform only steps 1,			
	2, 3, 4, and 6. Be sure to press			
	PRE between LOP's.			
	If you are going to use this card			
	to produce an LOP for a running			
	fix, Z_c must be accurate.			

The following problem is from Bowditch, p. 282. It is based on these fictitious points.

	Latitude	Longitude
Jones Point Light	40°20'6N	164°20'5W
Parker Point Light	40°23'7N	164°21'2W
Point Carlson Light	40°22'0N	164°28'3W
North Baker Range Light	40°39'9N	164°38'2W
South Baker Range Light	40°31'5N	164°37'7W
Hanford Mid-channel Buoy	40°22'9N	164°34'1W
Water tower	40°36'2N	164°27'9W
West Bank Lightship	40°39'5N	164°20'3W
Cupola	40°25'4N	164°21'3W

Example 1:

Using horizontal sextant angles, a navigator measures the angle between South Baker Range Light and Point Carlson Light to be 85°45'. At the same time an assistant measures the angle between Parker Point Light and Point Carlson Light to be 35°10'. Find the fix at the time of observation.

Keystrokes:

Outputs:

Load "Two-Angle LOP"

40.3130 **ENTER**

164.3442 **A**

40.2200 **ENTER** 164.2818

C

190 **R/S**

85.45 **B** →

R/S →

40.2342 **ENTER** 164.2112

E →

35.10 **D** →

R/S →

Load "Fix From Two Lines of Position"

0 **A** →

R/S →

40.2954

164.2628

40.1732

164.2920

40.3132

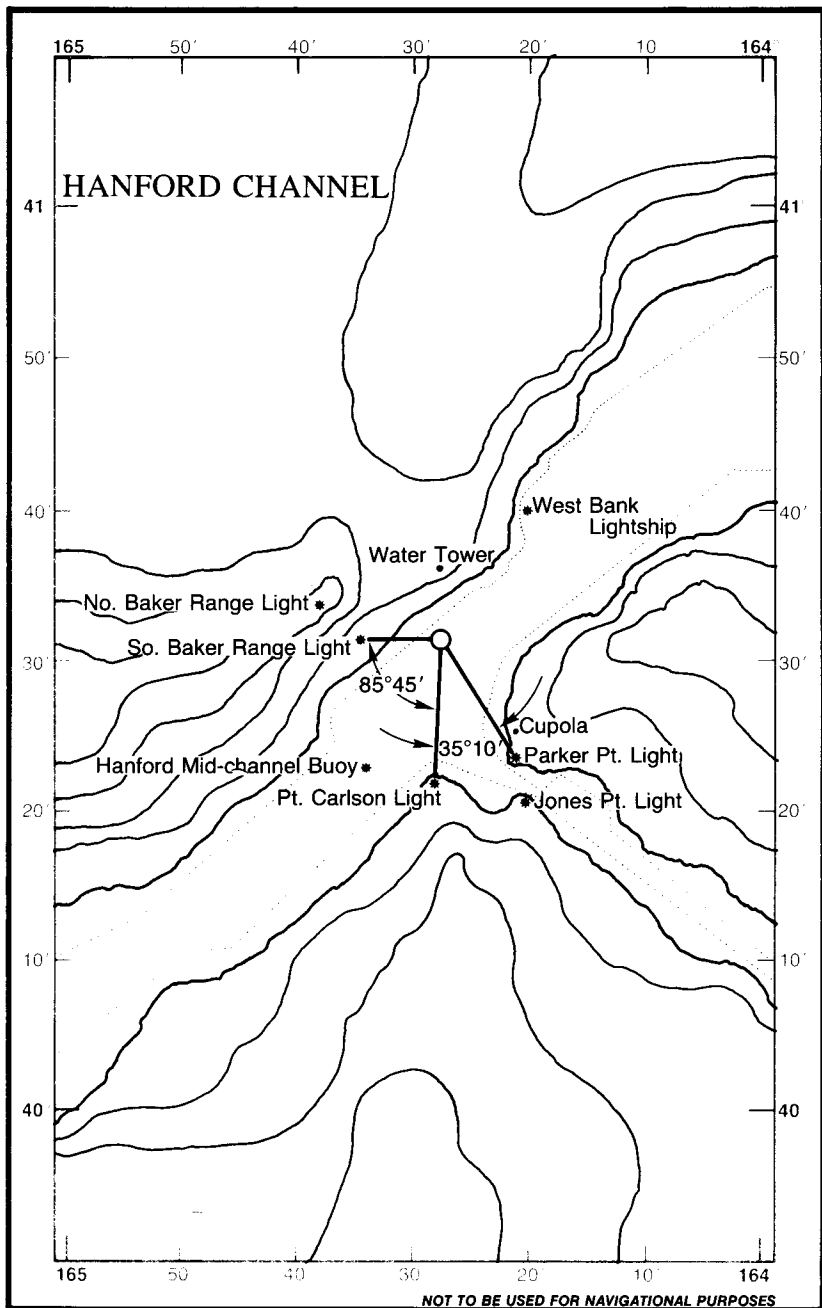
164.2727

South Baker Range
Light

Point Carlson Light
approximate true
bearing of Point
Carlson Light
approximate L
approximate λ

Parker Point Light
approximate L
approximate λ

L 40°31'32"N
λ 164°27'27"W



FIX FROM TWO LINES OF POSITION

FIX FROM TWO LINES OF POSITION

C:551=L A

:D Z₀ + :D' Z₀

This program is intended to follow the almanac interpolator, any of the other celestial sight assistance programs, the angle or bearing fix programs, or a combination of them. This program uses the data stored by the LOP programs to compute the latitude and longitude of the intersection of two lines of position (actually circles). Either a running or a stationary fix may be obtained with this program.

Errors in h_s will show up as lateral movement of the lines of position. A trapezoidal figure results from perturbing both lines of position. The diagonals of this error trapezoid, the worst-case distance errors, are also computed by this program assuming a 1' sextant error.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	First use some combination of the LOP cards to get two LOP's (be sure to push PXS between the two LOP's)			
2	Load this program			
3	Key in course information from first LOP to second and compute fix			
	Course (true)	C, deg.	ENTER	
	Speed	S, knots	ENTER	
	Time	Δt , H.MS	A	L, D.MS
			R/S	λ , D.MS
	Note: For a stationary fix, simply key in 0 for Δt	0	A	L, D.MS
			R/S	λ , D.MS

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
	Note: If the positions used for			
	the LOP's were the actual DR			
	positions, the course infor-			
	mation is not used—simply			
	press		f E	L, D.MS
			R S	λ , D.MS
4	To obtain worst-case distance			
	errors and bearing of such			
	errors ($\pm 180^\circ$) for each minute			
	of error in hs_1 , press		C	ΔD_1 , n. mi.
			R S	Z_1 , deg.
4a	For errors due to errors in hs_2 ,			
	press		D	ΔD_2 , n. mi.
			R S	Z_2 , deg.

Example:

In the Tasman Sea on December 30, 1974 the navigator observes two stars for his 0940 fix. His DR is $L40^\circ 12'S$, $\lambda 159^\circ 57'E$, and the observations are made from 35 feet. What is the fix?

	Rigel Kentaurus	Procyon
GMT	$9^h 40^m 21^s$	$9^h 40^m 59^s$
h_s	$11^\circ 24'$	$11^\circ 21' 42''$

Keystrokes:

Load Star Data 5

f E (Rigel Kentaurus)

Load Star Line of Position

40.12 **CHS** **ENTER** 159.57

CHS **f A** 35 **f B** 1974

ENTER 12 **ENTER** 30

Outputs:

ignore output

11-03

A 9.4021 **B** →

11.24 **C** →

P↔S →

Load Star Data 5

A (Procyon)

Load Star Line of Position

40.12 **CHS** **ENTER** 159.57 **CHS**

f **A** 35 **f** **B** 1974 **ENTER**

12 **ENTER** 30 **A** 9.4059

B →

11.2142 **C** →

Load Fix from Two Lines of Position

0 **A** →

R/S →

178.0 *** Z_n

10.59 H_c

-14.6 14.6 miles toward

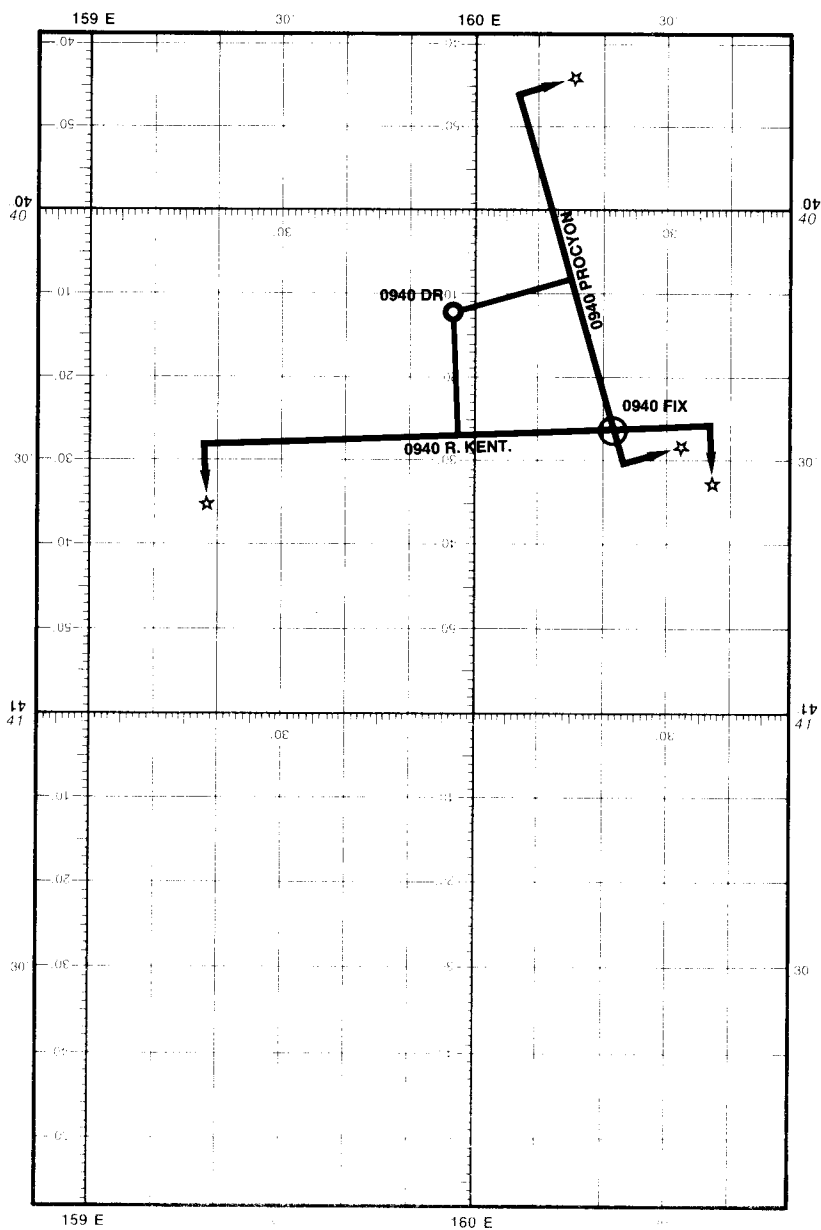
73.4 *** Z_n

10.5643 H_c

-14.6 a

-40.2551 L 40°25'51'' S

-160.2228 λ 160°22'28'' E



Example 2:

A navigator's DR on February 10, 1977 at 0700 is $35^{\circ}39'49''\text{N}$, $141^{\circ}22'21''\text{E}$. He shoots the Sun from a 65 foot height of eye and finds the Sun's altitude to be 12° . Determine an estimated position by crossing the Sun LOP with the 056° course line.

Keystrokes:

Load Sun Line of Position

35.3949 **ENTER** 141.2221

CHS **f** **A** 65 **f** **B** 1977

ENTER 2 **ENTER** 10

A 7 **B** $\longrightarrow$

12 **D** $\longrightarrow$

P $\rightarrow$ S $\longrightarrow$

Load "Bearing Line of Position"

35.3949 **ENTER** 141.2221

CHS **A** 56 **R/S** $\longrightarrow$

Load Fix From Two Lines of Position

0 **A** $\longrightarrow$

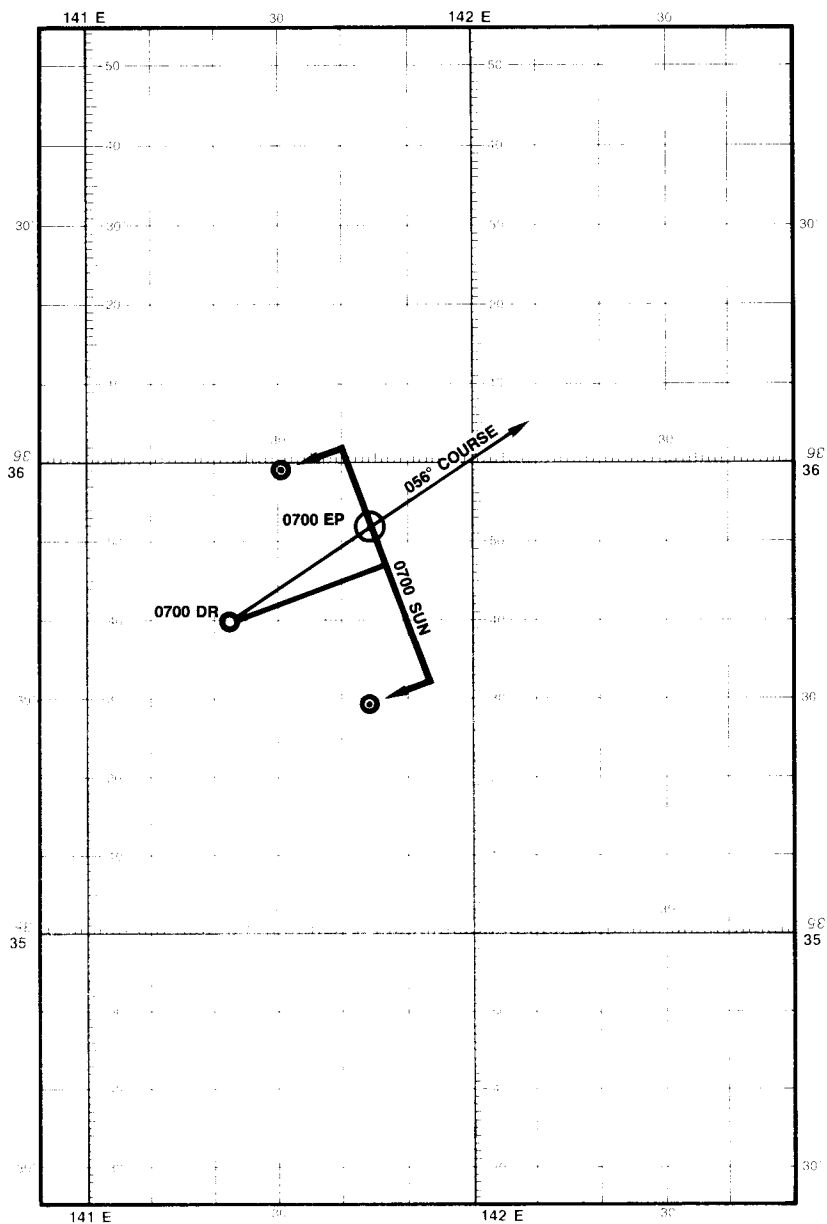
R/S $\longrightarrow$

Outputs:

241.92 *** Z_n is printed
12.2526 H_c is displayed
21.4 away
set up for second
LOP

ignore output

35.5150 L $35^{\circ}51'50''\text{N}$
141.4423 λ $141^{\circ}44'23''\text{W}$



Example:

A ship is on course 248°, speed 10 knots, on April 14, 1977. Her dead reckoning position at 2250 GMT is L27°11'14"N, λ139°28'45"W. Her navigator shoots the Sun at 2250 from a 35' height of eye and gets a sextant height of 62°. At 0355 on the 15th he shoots Capella and gets 51°30'. Compute the 0355 running fix.

Keystrokes:**Load Sun LOP**27.1114 **ENTER** 139.2845**f** **A** 35 **f** **B** 1977 **ENTER** 4**ENTER** 14 **A** 22.50 **B** →62 **D** →**P** **S** →**Load Star Data 3****f** **B** (Capella) →**Load Star LOP**27.1114 **ENTER** 139.2845**f** **A** 35 **f** **B** 1977 **ENTER**4 **ENTER** 15 **A** 3.55 **B** →51.3 **C** →**Load Two LOP Fix**248 **ENTER** 10 **ENTER** 5.05**A** →**R/S** →**Outputs:**

235.4 *** Sun's azimuth

62.0640 *** Sun's altitude

-3.1 3.1 miles toward
store this LOP

ignore output

310.5 *** Capella's azimuth

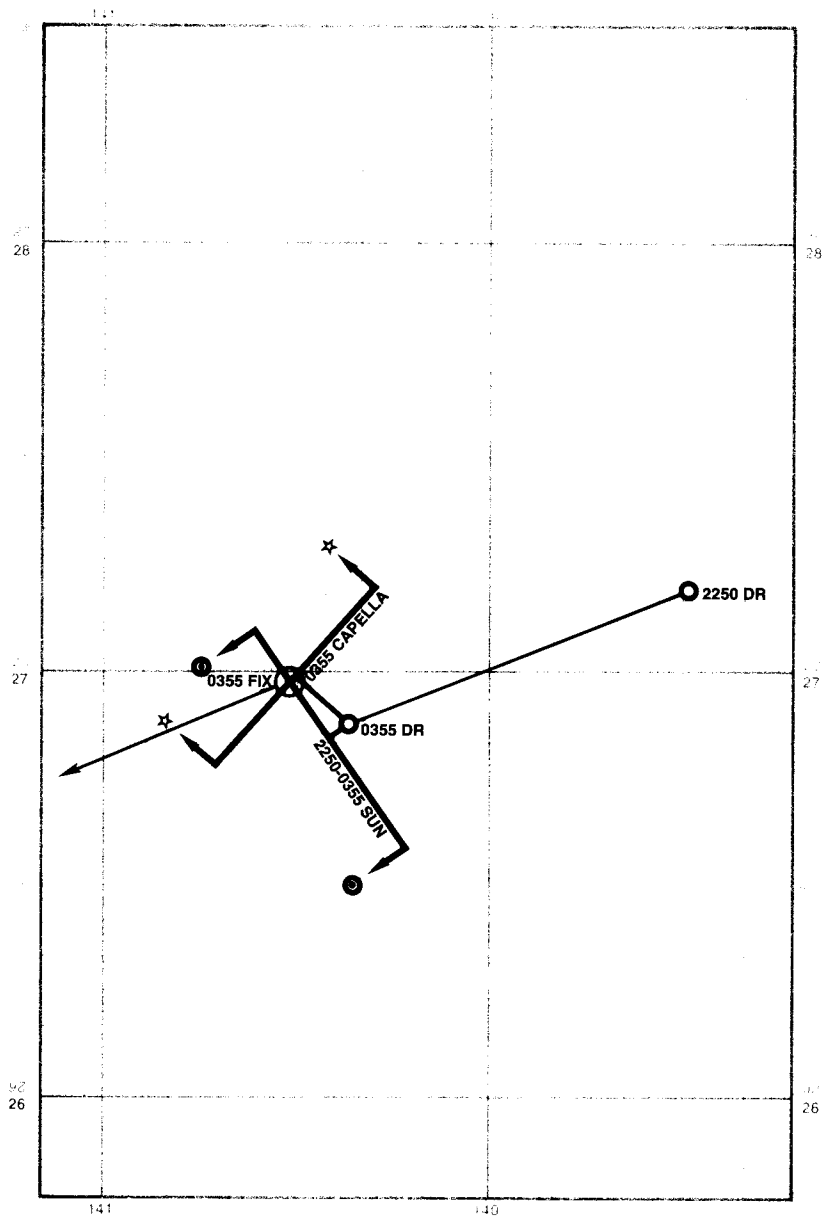
50.4958 *** Capella's altitude

-33.5 33.5 miles toward

26.5823 fix latitude

140.3053 fix longitude

This example could have been solved by first running the Dead Reckoning program to determine the 0355 DR, running the Sun LOP and Star LOP programs at their respective times, and then simply pressing **f E** on the Two LOP Fix program. In fact, this is how we made the sketch.



Example:

A small craft is adrift near $L23^{\circ}N$, $\lambda 150^{\circ}W$. Her navigator observes the Sun at 2145 GMT on June 4, 1977 and gets an altitude of $86^{\circ}07'$. He observes the sun again at 2200 and gets an altitude of 89° . Use the SUN LOP and Position Fixing programs to determine the intersection of the equal-altitude circles.

Keystrokes:

Load Sun Line of Position

23 **ENTER** 150 **f** **A** 0 **f** **B**

1977 **ENTER** 6 **ENTER** 4 **A**

21.45 **B** →

86.07 **D** →

P/S →

23 **ENTER** 150 **f** **A** 0 **f** **B**

1977 **ENTER** 6 **ENTER** 4 **A**

22 **B** →

89 **D** →

Load "Fix From Two Lines of Position"

0 **A** →

R/S →

Outputs:

98.7 *** Z_n

86.5325 *** H_c

30.7 30.7 miles away

save the first LOP

217.8 *** Z_n

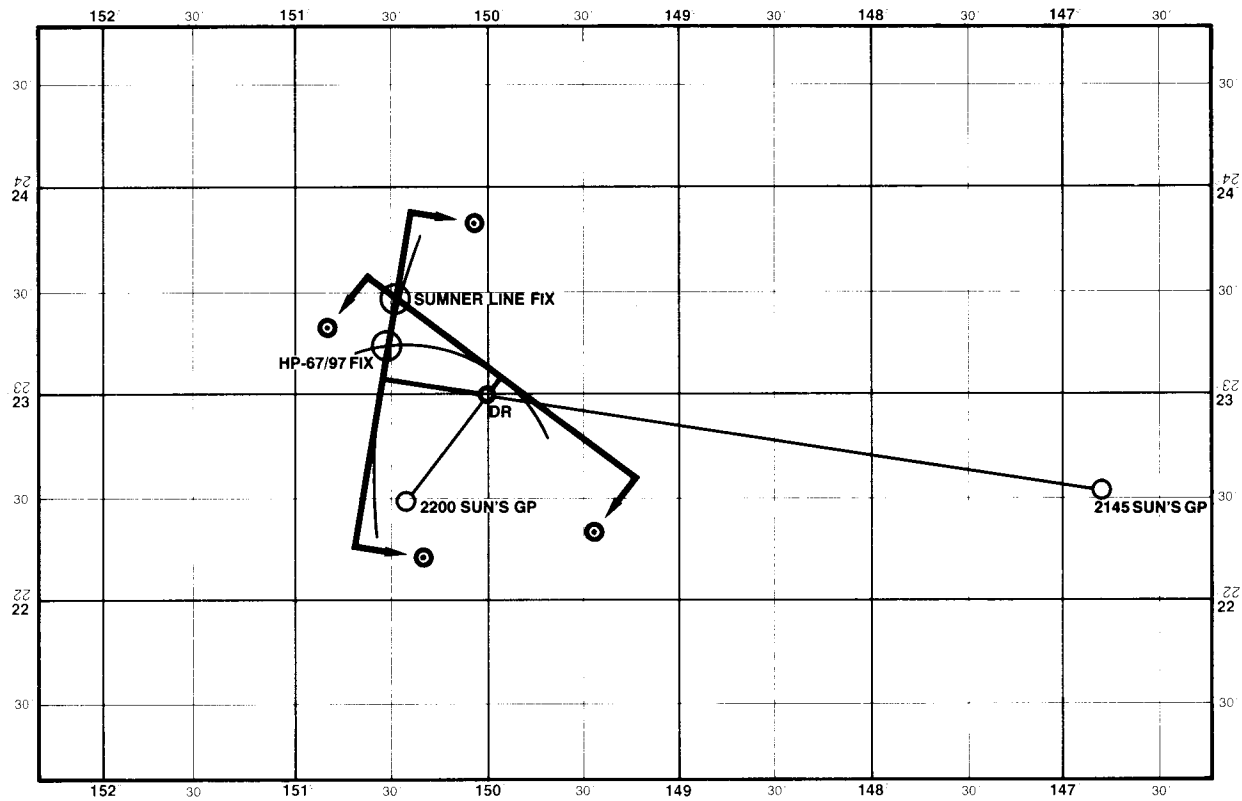
89.2154 *** H_c

6.1 6.1 miles away

23.1345 fix latitude is
 $23^{\circ}13'45''N$

150.3116 fix longitude is
 $150^{\circ}31'16''W$

Notice that the program has computed the point of intersection of the circles of equal altitude.



DISTANCE BY HORIZON ANGLE

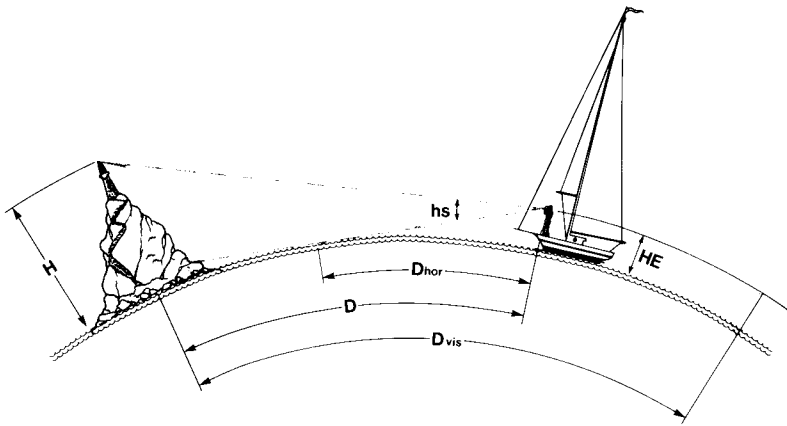
DISTANCE BY HORIZON ANGLE				NAV-13A
HE	H	beyond $h_s + D$	short $h_s + D$	$D + h_s + H$

This program computes the distance to an object of known height whose base is obscured by the horizon and whose top subtends a sextant altitude h_s with the horizon. The sextant altitude is corrected from height of eye. Additional features are the calculation of the distance to the horizon for a given height of eye and distance of visibility of an object of height H above sea level.

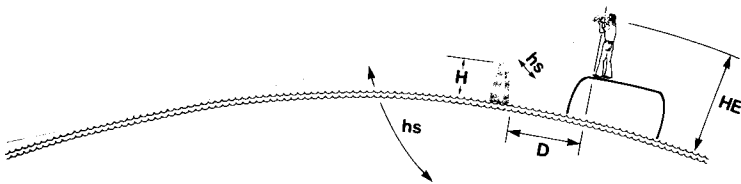
This program also calculates the distance between an observer and an object when (1) the vertical angle between its waterline and the horizon has been observed from a known height of eye or (2) the object's height is known, together with its subtended angle. An additional feature is the calculation of the height of an object if its subtended angle and distance from the observer are known.

Note: $h_s < 10'$ may make D unreliable due to atmospheric conditions when vertical sextant altitude between object and horizon is taken.

DISTANCE TO OR BEYOND HORIZON



DISTANCE SHORT OF HORIZON



STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load program			
	To compute distances			
	BEYOND the horizon			
2	Key in Height of Eye	HE, ft.	A	
3	Key in Height of object sighted	H, ft.	B	
4	Key in horizon angle and com-			
	pute distance	h_s , D.MS	C	D, n. mi.
5	Compute Distance to horizon	none	f A	D_{hor} , n. mi.
6	Compute Distance of visibility	none	f B	D_{vis} , n. mi.
	To compute distances SHORT			
	of the horizon			
2	Key in Height if object sighted	H, ft.	B	
3	Key in horizon angle and com-			
	pute distance	h_s , D.MS	D	D, ft.
			R/S	D, n. mi.
4	Key in Height of object and its			
	measured sextant angle and			
	compute distance	H, ft.	ENTER	
		h_s , D.MS	f E	D, ft.
			R/S	D, n. mi.
5	Key in Distance of object and			
	its measured sextant angle and			
	compute its height	D, n. mi.	ENTER	
		h_s , D.MS	E	H, ft.

Example 1:

If the height of eye of an observer is 9 feet above sea level, how far away is his horizon? (3.43 nautical miles)

Keystrokes:

9 **A f A** → 3.43

Outputs:

Example 2:

An observer "bobs" Farallon Light on the horizon and finds his height of eye to be 16 feet. The light is 358 feet above sea level. How far is the observer from the light? (Accuracy is affected by abnormal refraction)

Keystrokes:

16 **A** 358 **B f B** →

Outputs:

26.22 n. mi.

Example 3:

The top of a lighthouse, whose base is obscured by the horizon, is known to be 300 feet above sea level. It is found to have a sextant altitude of $26^{\circ}9'$ above the horizon. The height of eye is 20 feet.

What is the distance to the lighthouse?

What is the distance to the horizon?

It has been determined that the luminous range of the light is "strong", now compute its visibility for the given height of eye.

Keystrokes:

20 **A** 300 **B** .2654 **C** →
f A →
f B →

Outputs:

6.28 n. mi.
 5.12 n. mi.
 24.93 n. mi.

The sextant altitude subtended by the base and the top of a 41 foot light tower is $54^{\circ}3'$. How far is the observer from the light tower?

Keystrokes:

41 **ENTER** .5418 **f E** →
R/S →

Outputs:

2595.50 ft.
 0.43 n.m.

Example 4:

A vessel is anchored 2015 feet from an lighthouse. The sextant altitude subtended by the lighthouse is $1^{\circ}15'2''$. How high is the lighthouse?

Keystrokes:

2015 **ENTER** 1.1512 **E R/S** →

Outputs:

44.08 ft.

CLOSEST POINT OF APPROACH

 RADAR PLOTTING
 CLOSEST POINT OF APPROACH

 $t_2 \cdot B_2 \cdot R_2 \rightarrow CPA, B$ (+His C) (+His S) t_{CPA} RIGHT TURN

Given two bearings and ranges on another vessel, this program computes the change of heading required to pass at a specified minimum distance. A closest point of approach smaller than the minimum distance is flashed in the display.

Two targets may be tracked simultaneously using this program. If you change course to avoid one target, be sure to pay particular attention to the other one to avoid it also.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load program			
2	Key in:			
	Course	C, D.MS	ENTER	
	Speed	S, knots	F B	
3	Key in desired miss distance	MD, miles	F C	
4	Select target number (repeat as necessary)	none	F D	1 or 2
5	Key in first radar contact			
	Time	t_1 , H.MS	ENTER	
	Bearing	B_1 , deg.	ENTER	
	Range	R_1 , miles	F A	
6	Key in next radar contact and compute CPA			
	Time	t_2 , H.MS	ENTER	
	Bearing	B_2 , deg.	ENTER	
	Range	R_2 , miles	A	CPA*
			R S	Bearing
7	(optional) Compute course of target		B	C, deg.
8	(optional) Compute speed of target		C	S, knots
9	(optional) Compute time of CPA		D	t_{CPA} , H.MS

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
10	Compute new heading to avoid target by turning left† at a specified time	t_3 , H.MS	f E	C, left turn
11	Compute new heading to avoid target by turning right† at a specified time	t_3 , H.MS	E	C, right turn
*	If CPA is less than MISS DIST, the display will blink.			
†	If you are not on a collision heading, both solutions may yield left or right turns. One will be to the left of the zero-miss-distance heading and the other will be to the right.			

Example 1:

We are on course 000° speed 24 knots. At 2252 a vessel is observed by radar to bear 026° distant 14.4 miles. At 2300 she bears 025°, distant 11.9 miles. What is the CPA? What is the time of the CPA? What evasive action can we take at 2308 to avoid the target by 1.5 miles?

Keystrokes:

0 **ENTER** 24 **B** 1.5 **C** →
 22.52 **ENTER** 26 **ENTER** 14.4
A →
 23 **ENTER** 25 **ENTER** 11.9
A →

R/S →
D →
 23.08 **E** →
 23.08 **f E** →

Outputs:

set up

 first contact

 1. (blinking: CPA within desired 1.5 mi. miss distance)
 1.2 distance of CPA
 301 bearing of CPA
 23.3744 time of CPA
 2 right turn
 346 left turn

Example 2:

We are on course 030°, speed 15 knots. At 1530 a target bears 040°, distant 30 miles. At 1535 it is 29 miles away at 038°. What and when is the CPA? To what heading should we come at 1545 to close the target to 1 mile?

Keystrokes:

30 **ENTER** 15 **f** **B** 1 **f** **C** →
 15.30 **ENTER** 40 **ENTER** →
 30 **f** **A** →
 15.35 **ENTER** 38 **ENTER** 29
A →
D →
 15.45 **E** →

Outputs:

set up
 first contact
 21.2 CPA
 16.4406 time of CPA
 320 heading to intercept

Example 3:

Our speed is 17 knots on an arbitrary course. At 1832 a target is located bearing 025° relative, distant 30 miles. A second target is 28 miles away, bearing 095° relative at 1834. By 1840 the first target bears 020° relative, distant 25 miles, and the second bears 090°, distant 27 miles. We wish to pass at least 5 miles clear of these two vessels. Is any change required in our heading?

Keystrokes:

0 **ENTER** 17 **f** **B** 5 **f** **C**
f **D** ... **f** **D** →
 18.32 **ENTER** 25 **ENTER** 30
f **A** →
f **D** →
 18.34 **ENTER** 95 **ENTER** 28
f **A** **f** **D** →
 18.40 **ENTER** 20 **ENTER** 25 **A** →
R/S →
D →
f **D** →
 18.40 **ENTER** 90 **ENTER** 27 **A** →
R/S →
D →

Outputs:

set up (use C = 0°
 for convenience)
 0 or 1 repeat until 1
 appears
 2. second target
 1. first target
 11.8 CPA
 318 bearing of CPA
 19.1149 time of CPA
 2 second target
 25.4 CPA₂
 70 bearing of CPA
 19.0126 time of CPA

BEATING TO WINDWARD

BEATING TO WINDWARD

 $S_r + S + W_r + i$ PORT $C_r + V + D - W_m$ STBD $C_r + V + D - W_m$ $S_r + Dr$ $C_m + D$

In order to sail into the wind, a sailing vessel must tack. That is, she must sail with the wind at some angle to her bow in order to make progress in the desired direction. After sailing some distance on a given tack, it is possible to sail directly to the upwind mark on the opposite tack along what is called the "lay line." Unfortunately, in most sailing situations, the relationship among the vessel's motion, the current, and the wind is not simple to visualize.

This program provides a simple solution to the problem of determining the direction of the lay line. From measurements made aboard a properly instrumented sailboat, the program computes the course and speed made good on both tacks, the heading of the lay line, and the time at which the lay line will be reached.

When current is present, it is impossible to observe the true wind from a sailboat in motion. Therefore, the program computes a "modified true wind" from which the remainder of the desired quantities can be determined. The technique used was developed by Mr. Mortimer Rogoff and is fully documented in his book *Calculator Navigation* (W.W. Norton and Co., 1977).

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load program			
	relative wind speed	S_a , knots	ENTER	
	vessel speed	S , knots	ENTER	
	relative wind angle	W_a , deg.	ENTER	
	angle of heel	i , deg.	A	
	and see			
	speed of modified wind			MW, knots
	tack angle			W_t , deg.
3	Key in course information			
	compass course	C_c , deg.	ENTER	
	magnetic variation (CHS if West)	Var., deg.	ENTER	

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
	magnetic deviation (CHS if West)	Dev., deg.		
	select whether port (B) or starboard (C) tack and see angle of modified wind		B or C	W_m , deg.
4	Key in current set of current drift of current and see for this tack	Set, deg. Drift, knots	ENTER D	
	speed-made-good			SMG, knots
	course-made-good			CMG, knots
	for the next tack true course (flashes until a new value for deviation is keyed in)	Dev., deg.	none	
	compass course on next tack			C_c , deg.
	speed-made-good			SMG, deg.
	course-made-good			CMG, deg.
5	Key in			
	course to mark	C_m , deg.	ENTER	
	distance to mark	D , n. mi.	E	
	and see			
	distance to mark along lay line			D_m , n. mi.
	time to mark along lay line			Δt_m , H.MS
	distance to lay line			D_{LL} , n. mi.
	time to lay line			Δt_{LL} , H.MS

Example:

An instrumented sailboat is sailing to an upwind mark bearing 030° true distant 5 miles. Use this program to complete the table below.

Time		0800	0830	0910	0955	0956:22
Rel. Wind Speed	Sa	15.1	17.1	14.78	14.78	14.78
Vessel Speed	S	5.2	6	5.1	5.1	5.1
Rel. Wind Angle	Wa	33.3	33.2	33.5	33.5	33.5
Angle of heel	i	30°	35°	25°	25°	25°
Speed of Mod. Wind	MW	11.71	13.4	11.3	11.3	11.3
Tack Angle	Wt	47.4	47.4	47.9	47.9	47.1
Leeway* (not an input)		3	2	3	3	3
Compass Course ± Leeway	Cc	77	56	321	57	321.2
Magnetic Variation	Var	11W	11W	11W	11W	11W
Deviation	Dev	0	0	0	0	0
Which Tack		Port	Port	Stbd	Port	Stbd
Angle of Mod-Wind	Wm	18.6	357.6	357.9	358.1	358.1
Set of Current	Set	160	175	180	250	250
Drift of Current	Drift	2	1.5	0.5	0.3	0.3
SMG this Tack		5.44	5.17	4.79	4.83	5.26
CMG this Tack		87.5	57.9	305.4	44.6	307.4
True C Next Tack	Ct	331.2	310.2	45.8	310.2	46
New Deviation		0	0	0	0	0
Compass Course Next Tack	Cc	342.2	321.2	56.8	321.2	57
New Leeway* (not an input)		2	2	3	3	3
SMG next Tack		3.24	5.05	4.77	5.26	4.83
CMG next Tack		325.7	298.1	50.2	307.3	44.6
Course to Mark	Cm	30	357	307.2	325	307.4
Distance to Mark	D	5	4.22	3.94	.36	.36
Distance to Mark along Lay Line		4.96	4.24	.13	.36	~0
Time to Mark along Lay Line		1:31:56	:50:27	:01:36	:04:04	~0
Distance to L.L.		5.3	4.18	3.97	.11	.36
Time to L.L.		:58:26	:48:19	:49:42	:01:22	:04:07
Time from Start		.30/	.40	.45	.0122	.0407
Distance from Mark		4.22	3.94	.36	.36	0
Bearing of Mark		357.0	307.2	325.1	307.4	0

* Note that the values to use for leeway must be estimated by the skipper. The compass course computed by the program must be corrected to account for the estimated leeway.

Keystrokes are given only for the first column of the table. Notice how some outputs are used as inputs for the next column's problem.

Keystrokes:15.10 **ENTER** →5.20 **ENTER** →33.30 **ENTER** →30.00 **A** →77 **ENTER** →11 **CHS** **ENTER** →0 **B** →160 **ENTER** 2 **D** →

0 →

30 **ENTER** 5 **E** →.30 **f** **E** →**Outputs:**

11.71 ***

47.4 ***

18.6 ***

5.44 ***

87.5 ***

331.2 *** (blinking)

342.2 ***

3.24 ***

325.7 ***

4.96 ***

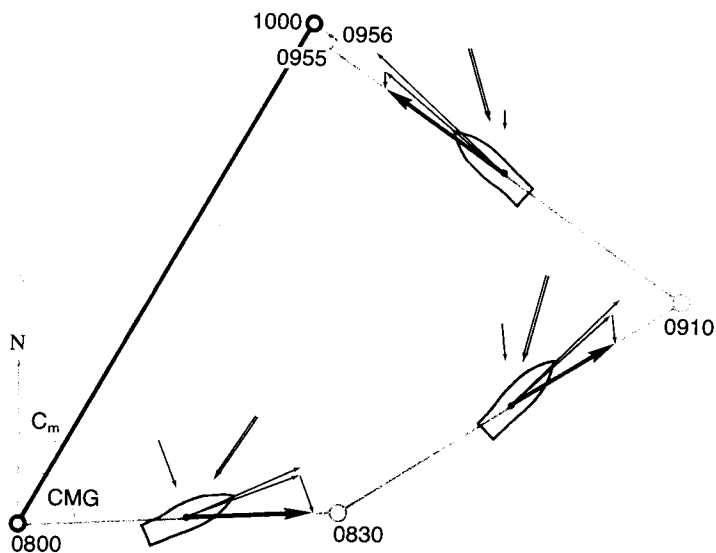
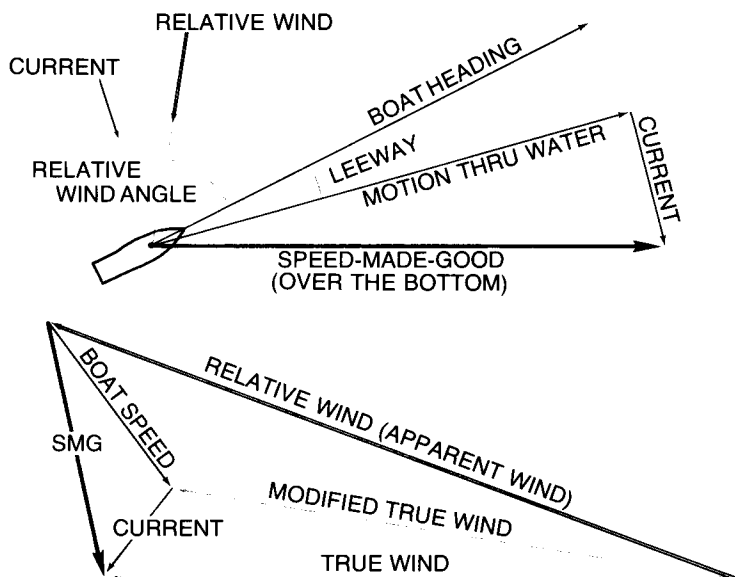
1.3156 ***

5.30 ***

0.5826 ***

4.22 ***

357.0 ***



APPENDIX 1

The contents of the six star cards are listed here for the convenience of those who prefer to store a star's SHA and declination by hand rather than letting a program do it.

1969 POSITION			
Star Number	Star Name	Declination	Sidereal Hour Angle
		(STO D)	(STO E)
0	Polaris	89.1214	329.3708
1	Alpheratz	28.9194	358.3050
2	Ankaa	-42.4744	353.8113
3	Schedar	56.3678	350.3163
4	Diphda	-18.1564	349.4917
5	Achernar	-57.3959	335.8596
6	Hamal	23.3167	328.6450
7	Acamar	-40.4281	315.7288
8	Menkar	3.9692	314.8358
9	Mirfak	49.7522	309.4750
10	Aldebaran	16.4483	291.4650
11	Rigel	-8.2361	281.7383
12	Capella	45.9683	281.4008
13	Bellatrix	6.3231	279.1333
14	Elnath	28.5828	278.9175
15	Alnilam	-1.2203	276.3400
16	Betelgeuse	7.4028	271.6267
17	Canopus	-52.6783	264.1854
18	Sirius	2863.3278	1339.0542
19	Adhara	-28.9289	255.6483
20	Procyon	1805.3056	1325.5800
21	Pollux	28.1025	1324.1446
22	Avior	-59.4094	234.5300
23	Suhail	-43.3069	223.2863
24	Miaplacidus	-69.5894	221.7829
25	Alphard	-8.5233	218.4842
26	Regulus	12.1194	208.3142
27	Dubhe	61.9186	194.5429
28	Denebola	14.7453	1263.1300
29	Gienah	-17.3700	176.4479
30	Acrux	-62.9275	173.7850
31	Gacrux	-56.9400	172.6413
32	Alioth	56.1278	166.8325
33	Spica	-11.0000	159.1108
34	Alkaid	49.4675	153.4200
35	Hadar	-60.2244	149.5950
36	Menkent	683.7817	1228.7875
37	Arcturus	3619.3431	2666.4383
38	Rigel Kentaurus	-1500.7086	13460.6300
39	Zubenelgenubi	-15.9142	137.7100
40	Kochab	74.2822	137.3058
41	Alphecca	26.8181	126.6567
42	Antares	-26.3647	113.1242
43	Atria	-68.9733	108.6588
44	Sabik	-15.6881	102.8508
45	Shaula	-37.0831	97.1246
46	Rasalhague	12.5811	96.6267
47	Eltanin	51.4919	91.0287
48	Kaus Australis	-34.4011	84.4717
49	Vega	38.7539	81.0279
50	Nunki	-26.3969	76.6642
51	Altair	-711.2147	-1017.3175
52	Peacock	-56.8361	54.1988
53	Deneb	45.1689	49.9067
54	Enif	9.7322	34.3346
55	Al Na'ir	-47.1119	28.4283
56	Fomalaut	-29.7869	16.0150
57	Markab	15.0381	14.1967

APPENDIX 2

OTHER PROGRAMS

Although it contains solutions to the most-often asked questions in navigation, this pac cannot include a program for every conceivable navigation problem. A partial list of navigation programs from the Users' Library is included here. If you are not able to find the solution you need on the pac, perhaps you can find it here.

Program Title	Program Number
Voyage Planning	.00443D
Great Circle	.00444D
Rhumb Line Sailing	.00445D
Great Circle Sailing (incl. Composite Sailing)	.00446D
Mercator Sailing	.00447D
Mercator Traverse Sailing	.00448D
RPM Speed, Ship Fuel Cons.	.00449D
Dist. off by 2 Bearings and Dist. Run	.00450D
Sun Azimuth for Compass Adjustment	.00451D
Stars and Planets	.00452D
Planets Sight Reduction	.00453D
Moon Sight Reduction	.00454D
Sun LOP Sight Reduction	.00455D
Time of Meridian Transit of Sun and Altitude Meridian	.00456D
Time of Sunrise and Sunset	.00457D
Radar Plotting-2 Targets	.00458D
Merchant Ship Stability	.00459D
Oil Conversion	.00460D
Volumes & Location of Centroid of Ships Tanks	.00461D
Great Circle & Rhumb Line Sailing	.00468D
Mercator Sailing-Course & Distance	.00510D
Mercator Sailing-Destination Coordinates	.00511D
Great Circle Navigation	.00521D
Sight Reduction & Estimated Position	.00715D
Great Circle-L & λ Position	.00726D

APPENDIX 3

EQUATIONS AND TECHNIQUES

The programs in this pac are based on the following equations. The actual implementation of the equations may not always be straightforward, but this is where we started.

COURSE PLANNING PROGRAM

Estimated Time of Arrival

$$D = S (t_a - t_d)$$

Great Circle and Rhumb Line Navigation

$$D_{\text{great circle}} = 60 \cos^{-1} [\sin L_1 \sin L_2 + \cos L_1 \cos L_2 \cos (\lambda_2 - \lambda_1)]$$

$$H_{\text{great circle}} = \cos^{-1} \left[\frac{\sin L_2 - \sin L_1 \cos (D/60)}{\sin (D/60) \cos L_1} \right]$$

$$\tan C_{\text{rhumb}} = \frac{\pi (\lambda_1 - \lambda_2)}{180 \left(\ln \tan \left(45 + \frac{L_2}{2} \right) - \ln \tan \left(45 + \frac{L_1}{2} \right) \right)}$$

$$D_{\text{rhumb}} = \begin{cases} 60 (\lambda_2 - \lambda_1) \cos C; \cos C = 0 \\ 60 \frac{L_2 - L_1}{\cos C}; \text{otherwise} \end{cases}$$

$$L_{\text{vertex}} = \cos^{-1} (\sin C \cos L_1)$$

Dead Reckoning

$$L_i = L_1 + \frac{\Delta t S \cos C}{60}$$

$$\lambda_i = \begin{cases} \lambda_1 + \frac{180 \tan C \left(\ln \tan \left(45 + \frac{L_1}{2} \right) - \ln \tan \left(45 + \frac{L_i}{2} \right) \right)}{\pi}; \\ \quad C = 90^\circ \text{ or } 270^\circ \\ \lambda_1 - \frac{\Delta t S \sin C}{60 \cos L_1}; 90^\circ \text{ or } 270^\circ \end{cases}$$

ALMANAC PROGRAMS

Star Finder Data

Each register of the Star Finder Data card contains declination, SHA, and a code for each of two stars. The numbers are so encoded that the program can reconstitute declination, SHA and star #.

The encoding formula for a star in register r whose star number is:

$$\# = 2r + \Delta x$$

is

$$\text{code} = \frac{\frac{r}{45} + \frac{\Delta x}{18} + \frac{\text{SHA} - 347}{540} + \cos^{-1}(\sin \text{dec})}{180}$$

The data from the star chart in this book are encoded by the above formula and stored as shown here:

0.0000000	0	}	Primary Registers
0.3393721	1		
18941.60088	2		
81717.37302	3		
72264.47856	4		
22270.41177	5		
54476.24512	6		
46256.79618	7		
59588.47426	8		
34622.74119	9	}	Secondary Registers
89094.55238	0		
43536.15781	1		
41856.59664	2		
85192.19148	3		
56337.23035	4		
39743.84219	5		
9228.353662	6		
64772.70977	7		
43175.28825	8	}	Primary Registers
64907.45486	9		
82118.25485	A		
44886.67166	B		
0.0000000	C		
0.0000000	D	}	
0.0000000	E		
0.0000000	I		

Sextant Corrections for Refraction and Height of Eye

$$H_0 = h_s + 0.97 \left\{ \tan \left[h_s - \tan^{-1} 12 (h_s + 3) \right] - \sqrt{HE} \right\}$$

Sight Reduction

$$Z_n = 180 + \tan^{-1} \frac{\sin t}{\cos t \sin L - \cos L \tan d}$$

$$H_c = \sin^{-1} \left[\sin d \sin L + \cos L \cos t \cos d \right]$$

$$a = H_c - H_0$$

Sun Almanac

The Sun Almanac equations are based on formulas found in Smart, *A Textbook on Spherical Trigonometry*.

From the date (Y, M, D) the day of year DOY is computed, then the longitude of the Moon's ascending node Ω is computed:

$$\Omega = 20 \left(Y - 1969.1 + \frac{\text{DOY}}{365} \right)$$

Then a quantity $\odot$ related to the Greenwich Hour Angle of Aries is computed:

$$\odot = \text{DOY} + 101.18 + \text{Frac} \left\{ \frac{2000 - Y}{4} \right\} + \frac{Y \cdot y - 1969}{128} + .004 \sin \Omega$$

GHA Υ maybe computed from $\odot$ and the time of day t by:

$$\text{GHA } \Upsilon = .9856 \left(\odot + \frac{t}{24} \right) + 15 t$$

The Earth's mean anomaly M and longitude of perigee $\bar{\omega}$ are computed together:

$$M + \bar{\omega} = .9856 \left(\odot + \frac{t}{24} \right)$$

Then an approximation to Kepler's equation is used to compute the true anomaly ν :

$$\text{where } \theta = \nu + \bar{\omega} = M + \bar{\omega} + 1.92 \sin M + .02 \sin 2M$$

The longitude of perigee $\bar{\omega}$ is given by:

$$\bar{\omega} = .01717 (Y - 1969) - 77.56$$

The obliquity of the ecliptic is:

$$\epsilon = 23.4433 - 1.3 \times 10^{-4} (Y - 1969) + .0028 \cos \Omega$$

Using the above values we now compute the Greenwich Hour Angle GHA $\odot$ and declination δ of the Sun.

$$\begin{aligned} \text{GHA } \odot &= M + \bar{\omega} - \tan^{-1} (\tan \theta \cos \epsilon) + 180 + 15 t \\ \delta &= \sin^{-1} (\sin \theta \sin \epsilon) \end{aligned}$$

Star Almanac

For stars, Ω and $\odot$ from the above equations are used in the following formulas to compute star positions to approximately 0.1 accuracy.

$$\begin{aligned} \text{SHA} \star = \alpha &= \alpha_0 + (Y - 1969) (20'' \sin \alpha_0 \tan \delta_0 - 46'') && \text{precession} \\ &+ 8'' \cos (\Omega - \alpha_0) \tan \delta_0 - 15'' .8 \sin \Omega && \text{nutaton} \\ &- 21'' \frac{\cos (\alpha_0 - \odot)}{\cos \delta_0} && \text{aberration} \end{aligned}$$

$$\begin{aligned} \text{DEC} \star = \delta &= \delta_0 + (Y - 1969) 20'' \cos \alpha_0 && \text{precession} \\ &+ 8'' \sin (\Omega - \alpha_0) && \text{nutaton} \\ &+ 21'' \sin \delta_0 \sin (\alpha_0 - \odot) + 8'' \odot \cos \delta_0 && \text{aberration} \end{aligned}$$

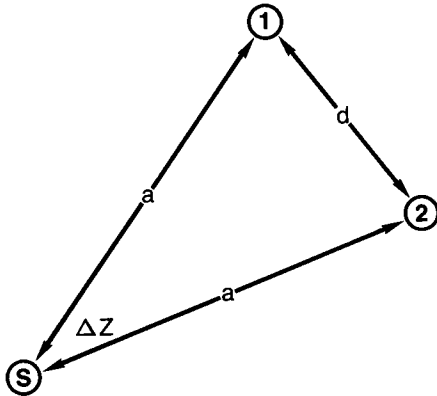
where (α_0, δ_0) is the star's 1969 mean place (see the table in appendix 1).

The star data also contains an encoded correction to both α and δ to account for proper motion for the fastest-moving star.

LINE OF POSITION PROGRAMS

Two-Angle Line of Position

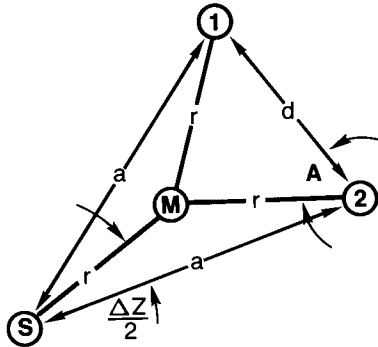
An observer at ③ ("ship") measures the angle between ① and ②.



Assume equal sides a :

$$a = \sin^{-1} \frac{\sin d/2}{\sin \Delta Z/2}$$

Then bisect ΔZ to find r (radius of circle)



$$r = \tan^{-1} \frac{1 - \cos a}{\sin a \cos \Delta Z/2}$$

$$H = 90 - r = \tan^{-1} \frac{\sin a \cos \Delta Z/2}{1 - \cos a}$$

$$A = \cos^{-1} \left(\frac{1 - \cos d}{\sin d} \tan H \right)$$

Now locate center ③ by going distance r from ② at bearing Z :

$$Z = \begin{cases} Z_{21} + A; \sin(Z_{21} - Z_2) \cos \Delta Z > 0 \\ Z_{21} - A; \sin(Z_{21} - Z_2) \cos \Delta Z < 0 \end{cases}$$

③ is at (α_m, δ_m)

$$\delta_m = \sin^{-1} (\sin H \sin L_2 + \cos H \cos L_2 \cos (Z_{21} \pm A))$$

$$\alpha_m = \lambda_2 - \tan^{-1} \left(\frac{\sin (Z_{21} \pm A) \cos H}{\cos L_2 \sin H - \sin L_2 \cos H \cos (Z_{21} \pm A)} \right)$$

These data now are the same as if a star having GHA α_m and declination δ_m had been observed with an altitude intercept of r .

Given the azimuth Z_2 between ⑤ and ② we can get an approximate position for ⑤:

$$L_s = L_2 + \frac{(L_1 - L_2) \tan Z_1 + (\lambda_1 - \lambda_2) \cos L_2}{\tan Z_1 - \tan Z_2}$$

$$\lambda_s = \lambda_2 - \frac{\tan Z_2}{\cos L_2} \frac{(L_1 - L_2) \tan Z_1 + (\lambda_1 - \lambda_2) \cos L_2}{\tan Z_1 - \tan Z_2}$$

These data, combined with a similar set of numbers from another observation, can be used by the Two-Lop Fix card.

Bearing Line of Position

This program locates a false star at a distance of 90° from L_1, λ_1 at a bearing 90° from Z_1 :

$$\delta_1 = - \sin^{-1} (\sin Z_1 \cos L_1)$$

$$\alpha_1 = \lambda_1 - \tan^{-1} \left(\frac{\cos Z_1}{\sin Z_1 \sin L_1} \right)$$

CLOSEST POINT OF APPROACH

The bearing of CPA is given in terms of ranges r and bearings B as follows:

$$B_{CPA} = \tan^{-1} \frac{r_2 \cos B_2 - r_1 \cos B_1}{r_1 \sin B_1 - r_2 \sin B_2}$$

The range is

$$r_{CPA} = r_2 \cos (B_{CPA} - B_2)$$

The relative motion $rm = rm < h_r$ is

$$rm = \frac{r_2 - r_1}{t_2 - t_1}$$

The heading to come to at t_3 in order to intercept the target is

$$h_r + \theta = B_3 + 180$$

Let

$em = em < h$ = speed and heading of target

$er = er < C$ = speed and heading of our ship

Then the change to $h_r + \theta$ to pass at distance D is

$$\phi = \sin^{-1} \frac{D}{r_3}$$

Now let

$$\beta = \begin{cases} \theta & \text{to intercept} \\ \theta + \phi & \text{miss to the right of the intercept heading} \\ \theta - \phi & \text{miss to the left of the intercept heading} \end{cases}$$

Then the new course α at time t_3 is

$$\alpha = h_r + 180 + \beta - \sin^{-1} \left(\frac{em}{er} \sin (h - h_r - \beta) \right)$$

DISTANCE BY HORIZON ANGLE

Distance of an object between the observer and the horizon is computed using one of these formulas

$$D = \frac{HE}{\tan (hs + .97 \sqrt{HE})}$$

$$D = \frac{H}{\tan (hs)}$$

where:

D = distance to object, feet

HP = height of eye, feet

H = height of object, feet

hs = sextant altitude between object's waterline and horizon

The distance to or beyond the horizon are computed as follows:

$$D = \sqrt{\left(\frac{\tan h_a}{2.46 \times 10^{-4}}\right)^2 + \frac{H - HE}{0.74736}} - \frac{\tan h_a}{2.46 \times 10^{-4}}$$

$$D_{hor} = 1.144 \sqrt{HE}$$

$$D_{vis} = 1.114 (\sqrt{HE} + \sqrt{H})$$

where:

D = distance to object, nautical miles

D_{hor} = distance to horizon, nautical miles

D_{vis} = distance of visibility, nautical miles

H = height of object beyond horizon, feet

HE = height of eye, feet

$h_a = hs + IC - 0.97 \sqrt{HE}$

hs = sextant altitude

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Smart, W.M., *Text-Book on Spherical Astronomy*, Fifth Edition, Cambridge University Press, Cambridge, 1971.

PROGRAM LISTINGS

The following listings are included for your reference. A table of keycodes and keystrokes corresponding to the symbols used in the listings can be found in Appendix E of your Owner's Handbook.

Program	Page
1. Estimated Time of Arrival	L01-01
2. Great Circle and Rhumb Line Navigation	L02-01
3. Dead Reckoning	L03-01
4. Velocity Triangle and Course to Steer	L04-01
5. Star Sight Planner	L05-01
6. Almanac Interpolator	L06-01
7. Sun Line of Position	L07-01
8. Star Line of Position	L08-01
Star Data 1	L08-03
Star Data 2	L08-05
Star Data 3	L08-07
Star Data 4	L08-09
Star Data 5	L08-11
Star Data 6	L08-13
9. Bearing Line of Position	L09-01
10. Two-Angle Line of Position	L10-01
11. Fix From Two Lines of Position	L11-01
12. Radar Plotting Closest Point of Approach	L12-01
13. Distance by Horizon Angle	L13-01
14. Beating to Windward	L14-01

ESTIMATED TIME OF ARRIVAL

001 *LBLB		057 *LBLA	
002 DSP1	Store distance	058 ST08	Store ZD _A
003 GSB1	IF new data THEN STOP	059 1	
004 F3?		060 5	Store approximate λ_A
005 RTN		061 x	
006 RCL7	ELSE	062 ST03	
007 RCL5	Compute Distance	063 RTN	$\lambda \rightarrow ZD$
008 -		064 *LBLk	
009 2		065 HMS+	
010 4		066 DSP0	
011 x		067 1	
012 RCL8		068 5	DEPARTURE
013 RCL6		069 ÷	
014 -		070 RND	
015 +		071 RTN	
016 RCL2		072 *LBLC	Store day
017 x		073 DSP4	
018 GSB1		074 INT	
019 RTN		075 ST05	
020 *LBL1		076 LSTX	
021 6		077 FRC	
022 0		078 EEX	
023 ÷		079 2	
024 ST04	Store D/60	080 x	
025 LSTX		081 HMS+	
026 x		082 RCL1	
027 RTN		083 GSBk	
028 *LBLC		084 ST0A	
029 DSP2		085 DSP4	
030 ST02		086 +	
031 F3?	Store speed	087 ST06	Store time
032 RTN	IF new data THEN STOP	088 F3?	IF new data THEN STOP
033 RCL4	ELSE	089 RTN	
034 6	Compute Speed	090 RCL7	ELSE
035 0		091 RCL8	Compute Day and Time
036 x		092 RCL4	of Departure
037 RCL7		093 6	
038 RCL5		094 6	
039 -		095 x	
040 2		096 RCL2	
041 4		097 ÷	
042 x		098 CHS	
043 RCL8		099 GSB8	
044 RCL6		100 ST06	
045 -		101 RCL4	
046 +		102 -	
047 ÷		103 X<0?	
048 ST02		104 GSB7	
049 RTN		105 GSY	
050 *LBLA		106 ST05	
051 ST0A		107 GSB9	
052 1	Store ZD _D	108 RTN	
053 5		109 *LBL7	
054 x	Store approximate λ_D	110 2	
055 ST01		111 4	
056 RTN		112 +	

REGISTERS

0	1	2	3	4	5	6	7	8	9
Used	λ_D	S	λ_A	D/60	D _D	GMT _D	D _A	GMT _A	
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A	B	C	D	E	F	G	H	I	J
ZD _D	ZD _A								

113	XZY				165	RTN		
114	1				170	*LBL0		
115	-				171	XZY		
116	XZY				172	1		
117	RTN				173	-		
118	*LBL0	Arrival			174	XZY		
119	DSP4				175	1		
120	INT				176	+		
121	ST07	Store day			177	2		
122	LSTX				178	4		
123	FRC				179	x		
124	EEX				180	RTN		
125	2				181	*LBL9		
126	x				182	XZY		
127	HMS+				183	+HMS		
128	RCL2				184	EEX		
129	GSB6				185	2		
130	ST08				186	÷		
131	DSP4				187	+		
132	+				188	X00?		
133	ST08	Store time			189	RTN		
134	F3?	IF new data			190	INT		
135	RTN	THEN STOP			191	LSTX		
136	RCL5	ELSE			192	FRC		
137	RCL6	Compute Day and Time			193	1		
138	RCL4	of Arrival			194	+		
139	6				195	-		
140	0				196	RTN		
141	x				197	R/S		
142	RCL2							
143	÷							
144	GSB8							
145	ST08							
146	RCL8							
147	-							
148	X00?							
149	GSB7							
150	XZY							
151	ST07							
152	GSB9							
153	RTN							
154	*LBL8	Subroutine to add time to						
155	+	days						
156	2							
157	4							
158	÷							
159	ST08							
160	INT							
161	+							
162	RCL8							
163	FRC							
164	X00?							
165	GT00							
166	2							
167	4							
168	x							

LABELS					FLAGS	SET STATUS							
A	ZD _A	B	DIST	C	SPEED	D	Departure	E	Arrival	0	FLAGS	TRIG	DISP
a	ZD _D	b	λ + ZD	c		d		e		1	ON OFF		
0	1	2		3		4		2		0	☐ ☐ ☒	DEG ☒	FIX ☒
5	6	7		8		9		3		1	☐ ☐ ☒	GRAD ☐	SCI ☐
										2	☐ ☐ ☒	RAD ☐	ENG ☐
										3	☐ ☐ ☒		n <u>4</u>

GREAT CIRCLE AND RHUMB LINE NAVIGATION

001 #LBL	Store Source coordinates	057 -	
002 HMS		058 CWS	
003 ST01		059 CT00	
004 R		060 #LBL1	
005 HMS		061 R	
006 ST00		062 #LBL0	Print H _i
007 RTN		063 ST05	
008 #LBLA		064 CSB5	
009 HMS	Store Destination coordinates	065 RTN	
010 ST03		066 #BLC	Store longitude increment
011 R		067 HMS	
012 HMS		068 ST06	
013 ST02		069 RTN	
014 RTN		070 #BLD	
015 #LBLB	Compute great-circle distance and initial heading	071 RCL	
016 RCL0		072 COS	
017 SIN		073 COS	
018 RCL2		074 RCL6	Compute number of rhumb lines needed
019 SIN		075 +	
020 x		076 ABS	
021 RCL0		077 STC1	
022 COS		078 RCL0	
023 RCL2		079 ST06	
024 COS		080 DSP4	Print L _i
025 x		081 CSB0	
026 RCL3		082 RCL1	Print λ _i
027 RCL1		083 ST0A	
028 -		084 CSB0	
029 ST0E		085 HMS	Increment λ
030 COS		086 CSB9	BEGIN loop 3
031 x		087 #LBL3	
032 +		088 CSB0	
033 COS		089 RCL3	
034 ST04		090 RCL8	
035 CSBc		091 ST0A	
036 RCL2		092 CSB9	
037 SIN		093 DSZ1	
038 RCL0		094 CT03	If not finished yet THEN REPEAT loop 3
039 SIN		095 RCL4	
040 RCL4		096 RCL3	
041 COS		097 X=Y?	If λ _i = λ ₂ THEN STOP
042 x		098 RTN	ELSE do one more
043 -		099 #LBL0	
044 RCL4		100 ST08	
045 SIN		101 CSB7	Subroutine to compute and print C, D, L _{next} .
046 ÷		102 CSBc	λ _{next}
047 RCL0		103 F0?	
048 COS		104 SPC	
049 ÷		105 RCL9	
050 COS		106 DSP4	
051 RCL		107 ST08	
052 SIN		108 CSB8	Print L _i
053 X=0?		109 RCL0	Print λ _i
054 CT01		110 #LBL0	
055 R		111 +HMS	Convert to D.MS, then print
056 CSBd		112 #LBL5	

REGISTERS

0 L ₁	1 λ ₁	2 L ₂	3 λ ₂	4 D/60	5 H _i	6 Δλ	7	8 λ _i	9 L _i
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A λ _{i-1}	B L _{i-1}	C λ _{i-1}	D Used	E λ ₂ - λ ₁	F				

113	F0?	IF flag 0	169	ABS	
114	PRTX	THEN PRINT	170	DSF0	
115	F0?		171	GSE5	
116	RTN	ELSE	172	RCLC	
117	R/S	DISPLAY	173	RCL9	
118	RTN		174	COS	
119	*LBL9	Subroutine to increment	175	X	
120	RCL6	longitude and account for	176	ENT↑	
121	+	dateline	177	RCL5	
122	1		178	RCLB	
123	→R		179	-	
124	→P		180	RCLD	
125	R↓		181	COS	
126	RTN		182	X#0?	
127	*LBLd	Subroutine to put 360 in	183	÷	
128	3	x-register	184	ENT↑	
129	6		185	X=0?	
130	0		186	R↑	
131	RTN		187	ABS	
132	*LBLe	Subroutine to compute	188	*LBLc	
133	F0?	course and distance to next	189	6	Print distance
134	SFC	point	190	0	
135	RCLA		191	X	
136	RCLB		192	GT05	
137	-		193	*LBL4	Subroutine to compute
138	STOC		194	2	
139	2		195	÷	
140	÷		196	4	
141	SIN		197	5	In tan (45 + L/2)
142	SIN↑		198	+	
143	9		199	TAN	
144	0		200	LN	
145	÷		201	RTN	
146	Pi		202	*LBL7	Subroutine to compute
147	X		203	RCLA	L ₁ from λ ₁
148	RCL9		204	-	
149	GSE4		205	SIN	
150	RCLB		206	RCL2	
151	GSE4		207	TAN	
152	-		208	X	
153	→P		209	RCL8	
154	R↓		210	RCL3	
155	STOD		211	-	
156	RCLC		212	SIN	
157	SIN		213	RCLB	
158	SIN↑		214	TAN	
159	X#0?		215	X	
160	GT00		216	-	
161	RCLD		217	RCL3	
162	GT01		218	RCLA	
163	*LBL0		219	-	
164	GSEd		220	SIN	
165	RCLD		221	÷	
166	ABS		222	TAN↑	
167	-		223	ST09	
168	*LBL1		224	RTN	

LABELS					FLAGS	SET STATUS		
A	L ₂ ↑ λ ₂	B	→D, H ₁	C	Δλ	D	→LIST	E
a	L ₁ ↑ λ ₁	b		c		d		e
0		1		2		3		4
5		6		7		8		9

FLAGS	TRIG	DISP
ON OFF		
0 ☐ ☐	DEG ☐	FIX ☐
1 ☐ ☐	GRAD ☐	SCI ☐
2 ☐ ☐	RAD ☐	ENG ☐
3 ☐ ☐		n <u>4</u>

DEAD RECKONING

001	*LBLb		057	RCL0	
002	+		058	CSB9	
003	ST08	Store correction	059	-	
004	RTN		060	RCL9	
005	*LBLA		061	TAN	
006	HMS+		062	x	
007	ST01	Store λ	063	1	
008	R4		064	0	
009	HMS+		065	0	
010	ST08	Store L	066	x	
011	RTN		067	P1	
012	*LBLB		068	÷	
013	ST02	Store CC	069	RCL1	
014	RCL8		070	X $\div$ Y	
015	+	Display TC	071	-	
016	RTN		072	1	
017	*LBLC		073	+R	
018	ST03	Store speed	074	+P	
019	RTN		075	X $\div$ Y	
020	*LBLc		076	ST01	
021	SF1	Set list flag	077	CSB3	
022	HMS+		078	RCL7	
023	ST04	Store Δt	079	ST08	
024	RCL5		080	CT01	
025	+		081	*LBL0	
026	ST06		082	LSTX	
027	CT08		083	SIN	
028	*LBLD		084	RCL3	
029	HMS+		085	x	
030	ST05	Store t_0	086	RCL6	
031	RTN		087	RCL5	
032	*LBL E		088	-	
033	CF1	Clear list flag	089	x	
034	HMS+		090	6	
035	ST06	Store t_1	091	0	
036	*LBL0		092	÷	
037	RCL2	Rhumb Line Equations	093	RCL0	
038	RCL8		094	COS	
039	+		095	÷	
040	ST09		096	IT-1	
041	COS		097	CSB3	
042	X=0?		098	*LBL1	
043	CT08		099	F0?	
044	RCL3		100	SPC	
045	x		101	RCL6	
046	RCL6		102	ST05	
047	RCL5		103	+HMS	
048	-		104	DSP4	
049	x		105	CSB5	
050	6		106	HMS+	
051	0		107	ST06	
052	÷		108	RCL8	
053	RCL0		109	+HMS	
054	+		110	CSB5	
055	ST07		111	HMS+	
056	CSB9		112	ST08	

REGISTERS								
0	1	2	3	4	5	6	7	8
L_1	λ_1	CC	S	Δt	t_{i-1}	t_i	L_i	Var + Dev
S0	S1	S2	S3	S4	S5	S6	S7	S8
A	B	C	D	E	F	G	H	I

Course = 90 or 270

Display routine

 t_i L_i

113	RCL1	λ_i		
114	HMMS			
115	GSB5			
116	HMMS			
117	STO1			
118	RCL2			
119	DSP1	CC		
120	GSB5			
121	STO2			
122	RCL3			
123	GSB5	S		
124	STO3			
125	RCL6			
126	RCL4			
127	+			
128	STO6			
129	F1?	$t_i \leftarrow t_i + \Delta t$		
130	CTO0			
131	CLX			
132	RTN			
133	F1?			
134	CTO0			
135	RTN			
136	*LBL9	Subroutine to compute		
137	2			
138	÷			
139	4	$\ln \tan \left(\frac{1}{2} \right) + 45$		
140	5			
141	+			
142	TAN			
143	LN			
144	RTN			
145	*LBL5	Print routine		
146	F0?			
147	PRTX			
148	PSE			
149	RTN			
150	*LBL3	Subroutine to ensure that		
151	RCL1			
152	1			
153	→R			
154	→P	$-180 < \lambda \leq 180$		
155	X↔Y			
156	STO1			
157	RTN			
158	*LBLA	Print toggle		
159	F0?			
160	CTO2			
161	SF0			
162	1			
163	RTN			
164	*LBL2			
165	CF0			
166	0			
167	RTN			

LABELS										FLAGS	SET STATUS				
A	L ↑ λ	B	CC	C	SPEED	D	to	E	T → L, λ	0	PRINT	FLAGS		TRIG	DISP
a		b	Var ↑ Dev	c	PRINT?	d		e	ΔT → LIST	1	LIST	ON OFF			
0										2		1 ☐ 0 ☐	DEG ☐		FIX ☐
Used		1	Used	2	Used	3	λ < 180°	4		2		2 ☐ 0 ☐	GRAD ☐		SCI ☐
5	PRINT	6		7		8		9	Used	3		3 ☐ 0 ☐	RAD ☐		ENG ☐
															n <u>4</u>

VELOCITY TRIANGLE AND COURSE TO STEER

001 #LBL		057 #LBLE	
002 ST00		058 F3?	
003 R4		059 GT03	
004 ST01		060 RCLA	Compute SMG, CMC
005 CLX		061 RCL8	
006 RTN		062 RCL4	
007 #LBLE		063 RCL1	
008 F3?		064 CSB8	
009 GT01		065 ST08	
010 RCLC	Compute Speed, C_t , C_c	066 XZY	
011 RCL8		067 CSB9	
012 RCL4		068 ST0C	
013 RCL1		069 #LBLE	
014 CHS		070 F2?	Display results alternately
015 CSB8		071 RTN	
016 ST08		072 XZY	
017 XZY		073 R/S	
018 CSB9		074 GT04	
019 ST0A	Store C_t	075 #LBLE	
020 RCL8		076 ST08	Store SMG, CMC
021 -		077 XZY	
022 RCL1		078 ST0C	
023 -		079 RTN	
024 CSB9		080 #LBLE	
025 ST02	Store C_c	081 +R	Subroutine to add vectors
026 GT04		082 R4	
027 #LBLE		083 R4	
028 ST08		084 +R	
029 XZY		085 XZY	
030 ST02		086 R4	
031 RCL8		087 +	
032 +		088 R4	
033 RCL1		089 +	
034 +		090 R4	
035 CSB9		091 +P	
036 ST0A		092 RTN	
037 RTN		093 #LBLE	
038 #LBLE		094 3	Subroutine to normalize angles
039 F3?		095 6	
040 GT02		096 0	
041 RCLC	Compute Drift, Set	097 +R	
042 RCL8		098 +P	
043 RCLA		099 XZY	
044 RCL8		100 X<0?	
045 CHS		101 GT00	
046 CSB8		102 XZY	
047 ST01		103 R4	
048 XZY		104 RTN	
049 CSB9		105 #LBLE	
050 ST04		106 +	
051 GT04		107 RTN	
052 #LBLE	Store Drift, Set	108 #LBLE	
053 ST01		109 HMS+	Store L_1 , λ_1
054 XZY		110 ST05	
055 ST04		111 XZY	
056 RTN		112 HMS+	

REGISTERS								
0 Dev	1 Var	2 C_c	3 L_1	4 Set	5 λ_1	6 L_2	7 λ_2	8 Speed
S0	S1	S2	S3	S4	S5	S6	S7	S8
A C_t	B SMG	C CMG	D DIST	E	F	G	H Drift	I

113	ST03			169	+		
114	RTN			170	+HMS		
115	*LBLD	Store L_1, λ_1		171	R/S		
116	HMS+			172	RCLB		
117	ST07			173	RTN		
118	XZY						
119	HMS+						
120	ST06						
121	RTN						
122	*LBLB	Compute distance and CMG					
123	RCL3						
124	RCL6						
125	+						
126	2						
127	÷						
128	COS						
129	RCL5						
130	RCL7						
131	-						
132	x						
133	RCL6						
134	RCL3						
135	-						
136	+P						
137	6						
138	0						
139	x						
140	ST00	Store speed					
141	XZY	Compute $C_0, \Delta t$, and SMG					
142	CSB9						
143	ST0C						
144	ST04						
145	*LBLB						
146	ST08						
147	RCLC						
148	RCL4						
149	RCLC						
150	-						
151	SIN						
152	RCL1						
153	x						
154	RCL8						
155	÷						
156	SIN ⁻¹						
157	-						
158	CSB9						
159	ST0A						
160	CF3						
161	SF2						
162	CSBC						
163	CF3						
164	SF2						
165	CSBA						
166	R/S						
167	RCLD						
168	RCLB						

LABELS					FLAGS	SET STATUS		
A ↔ C_0 , Speed	B ↔ Set, Drift	C ↔ CMG, SMG	D $L_1 \uparrow \lambda_1$	E S → LIST	0	FLAGS	TRIG	DISP
F Var ↑ Dev	b	c	d $L_1 \uparrow \lambda_1$	g → DIST, CMC	1	ON OFF	DEG ☒	FIX ☒
0	1	2	3	4	2	0 ☐ ☒	GRAD ☐	SCI ☐
5	6	7	8	9	3	1 ☐ ☒	RAD ☐	ENG ☐
						2 ☐ ☒		n <u>2</u>
						3 ☐ ☒		

STAR SIGHT PLANNER

[illegible]

A	L + λ	B DATE	C GMT → LIST	D DAWN	E DUSK	F FLAGS	G SET STATUS
							FLAGS TRIG DISP
0	PRINT?	1	c	d	e	1	ON OFF 0 ☐ ☐
1		2	3	4	5	2	DEG ☐ FIX ☐ GRAD ☐ SCI ☐ RAD ☐ ENG ☐ ☐ n
5		6	7	8	9	3	

ALMANAC INTERPOLATOR

001 *LBL*	Store L, λ	057 RCL0	
002 HMS*		058 +	
003 STOI		059 SIN+	
004 R4		060 STOB	
005 HMS*		061 RCLB	
006 STOI		062 -	
007 RTN		063 RCLB	
008 *LBL*	Store HE	064 COS	
009 STOB		065 RCL0	
010 RTN		066 ABS	
011 *LBL*	MOON-STARS Toggle	067 TAN	
012 FI?		068 3	
013 STOI		069 .	
014 SF1		070 6	
015 0	0 = SUN, STARS	071 7	
016 *LBL*		072 x	
017 HMS*		073 SIN+	
018 STOB	Store semidiameter	074 FI?	
019 RTN		075 CLX	
020 *LBL*		076 x	
021 CF1		077 -	
022 1	1 = MOON	078 RCL0	
023 RTN		079 -	
024 *LBL*		080 6	
025 HMS*	Store GMT	081 0	
026 STOI		082 x	
027 INT		083 STOB	
028 STOB		084 RTN	
029 RTN		085 *LBL*	Compute h_s, Z_n
030 *LBL*	Input GHA's	086 DSP4	
031 HMS*		087 0	
032 X2Y		088 GSB1	
033 HMS*		089 RCL9	
034 STOB		090 RCL9	
035 -		091 +	
036 SIN		092 SIN+	
037 SIN+		093 STOB	
038 STOB		094 GSB2	
039 R/S		095	
040 HMS*	Input SHA of star	096 RCL9	
041 ST+5		097 COS	
042 RTN		098 RCL0	
043 *LBL*		099 ABS	
044 HMS*	Input declinations	100 TAN	
045 X2Y		101 3	
046 HMS*		102 .	
047 STOB		103 6	
048 -		104 7	
049 STOB		105 x	
050 RTN		106 SIN+	
051 *LBL*	$h_s \rightarrow Z_n, a$	107 FI?	
052 DSP1		108 CLX	
053 HMS*		109 x	
054 GSB1		110 -	
055 PRT		111 RCL0	
056 RCL9		112 -	

REGISTERS									
0 α_1	1 da/dt	2 δ_1	3 $d\delta/dt$	4 5D	5 L	6 λ	7 Z_n	8 H_c	9 a
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A	B $h_s - D - R_n$	C HE	D	E α_T	I GMT				

113	+HMS			169	ENT↑				
114	R/S			170	ENT↑				
115	RCL7			171	3				
116	RTN			172	+				
117	*LBL1			173	1				
118	STOB			174	2				
119	RCL6			175	x				
120	RCL1			176	TAN←				
121	RCL5			177	-				
122	-			178	TAN				
123	x			179	RCLC				
124	RCL5			180	4X				
125	+			181	-				
126	STO2			182	6				
127	RCLD			183	2				
128	RCL1			184	÷				
129	RCL5			185	RTN				
130	-			186	*LBL6				
131	x			187	HMS→				
132	RCLA			188	STOI				
133	+			189	RTN				
134	STO4								
135	RCLB								
136	CSB2								
137	+								
138	STOB								
139	RCL3								
140	1								
141	+R								
142	STO9								
143	RCL2								
144	RCL1								
145	-								
146	RCL4								
147	COS								
148	+R								
149	ST×9								
150	R↑								
151	STOB								
152	x								
153	R↑								
154	RCL4								
155	SIN								
156	ST×8								
157	x								
158	-								
159	+P								
160	R↓								
161	1								
162	8								
163	0								
164	+								
165	STO7								
166	RTN								
167	*LBL2								
168	ENT↑								

LABELS					FLAGS	SET STATUS			
A GMT	B $\alpha_1 \alpha_2$; (SHA)	C $\delta_1 \uparrow \delta_2$	D $h_1 \rightarrow Z_n, a$	E $\rightarrow h_2; Z_n$	0	FLAGS		TRIG	DISP
$\alpha \uparrow \lambda$	HE	MOON? (=1)	S_D	New GMT	1	ON	OFF		
0	1	2	3	4	2	☐	☐	DEG ☒	FIX ☒
						☒	☐	GRAD ☐	SCI ☐
5	6	7	8	9	3	☐	☒	RAD ☐	ENG ☐
						☐	☐		n <u>1</u>

SUN LINE OF POSITION

001	*LBLA			057	+				
002	ST06			058	8				
003	XZY			059	9				
004	ST04	Store month		060	6				
005	3			061	±				
006	0			062	-				
007	5			063	ST-6				
008	6			064	3				
009	x			065	6				
010	INT			066	0				
011	ST+6			067	ST0C				
012	R†			068	ST+6				
013	ST0B	Store year		069	RTN				
014	RCL4			070	*LBLA				
015	3			071	HMS+				
016	X>Y?			072	ST01	Store λ			
017	1			073	XZY				
018	RCLB			074	HMS+				
019	4			075	ST03	Store L			
020	÷			076	RTN				
021	FRC			077	*LBLB	GMT			
022	+			078	HMS+				
023	1			079	1				
024	XZY			080	5				
025	X=Y?			081	x				
026	2			082	ST02				
027	RCLB			083	RCL6				
028	7			084	+				
029	-			085	RCLA				
030	RCL6			086	±				
031	3			087	1				
032	6			088	1				
033	5			089	8				
034	.			090	.				
035	2			091	1				
036	5			092	RCLB				
037	ST0A			093	9				
038	÷			094	6				
039	+			095	8				
040	ST04			096	÷				
041	2			097	-				
042	0			098	+				
043	x			099	.				
044	ST0B			100	2				
045	SIN	Ω, long. of Moon's ascending node		101	+R				
046	4			102	9				
047	x			103	.				
048	5			104	5				
049	0			105	8				
050	9			106	-				
051	4			107	ST0B				
052	1			108	x	Semidiameter			
053	+			109	+				
054	RCL4			110	RCLB				
055	7			111	4				
056	x			112	2				

REGISTERS									
0	SD	1	λ	2	α = GHA	3	L	4	δ
5	HE	6	Days	7	Z _n	8	H _c	9	a
S0		S1		S2		S3		S4	
A	365.25	B	YR, Ω	C	360	D		E	L

113	7				165	DSP1			
114	÷				170	PRTX			
115	RCLB				171	DSP4			
116	COS				172	RCL1			H _c , computed altitude
117	-				173	STOB			
118	8				174	+HMS			
119	5				175	PRTX			
120	3				176	RTN			
121	1				177	*LBLE			
122	-				178	SF2			UPPER LIMB FLAG
123	5				179	*LBLO			
124	-				180	HMS+			
125	RCLC				181	ENT↑			
126	÷				182	ENT↑			
127	CHS				183	ENT↑			
128	XZY				184	3			
129	1				185	+			
130	CHS				186	1			
131	+R				187	2			
132	R4				188	x			
133	+R				189	TAN+			
134	R↑				190	-			
135	+P				191	TAN			Mean refraction
136	R4				192	RCL5			
137	XZY				193	JX			
138	STOB				194	-			
139	SIN+				195	6			
140	STO4				196	2			
141	R4				197	÷			
142	-				198	+			
143	ST+2				199	RCL8			Dip correction
144	RCL2				200	-			
145	RCL1				201	CHS			
146	-				202	6			
147	RCL4				203	0			
148	COS				204	x			
149	+R				205	RCL8			
150	RCL3				206	3			
151	STOI				207	6			
152	XZY				208	2			
153	+R				209	+			
154	X2I				210	3			
155	RCL8				211	-			
156	+R				212	F29			
157	X2I				213	CHS			IF upper limb THEN subtract SD
158	+				214	+			
159	SIN+				215	STO9			
160	X2I				216	DSP1			Store a, intercept
161	-				217	RTN			
162	+P				218	*LBLE			
163	R4				219	STO5			
164	1				220	RTN			Store HE
165	8								
166	0								
167	+								
168	STO7								

STAR LINE OF POSITION

001 *LBLA	Store Day	057 ST+6	
002 ST06		058 1	
003 XZY	Store Month	059 9	
004 ST04		060 GSB2	
005 3		061 RCLC	
006 0		062 -	
007 5		063 .	
008 6		064 8	
009 2		065 +R	
010 INT		066 ST08	
011 ST+6		067 R4	
012 R†		068 ST04	
013 ST05	Store Year	069 RCLC	
014 RCL4		070 2	
015 3		071 GSB2	
016 XZY?		072 +R	
017 1		073 ST+4	
018 RCL5		074 R4	
019 4		075 RCLD	
020 +		076 TAN	
021 FRC		077 ST×0	
022 +		078 x	
023 1		079 9	
024 XZY		080 3	
025 X=YY		081 RCLC	
026 2		082 GSB1	
027 ST-6		083 -	
028 1		084 ST+0	
029 9		085 RCL6	
030 6		086 RCLC	Mean anomaly
031 9		087 +	
032 .		088 2	
033 1	Whole years from 1960.1	089 +R	
034 ST-5		090 RCLD	
035 RCL6		091 1	
036 3		092 +R	
037 6		093 XZY	
038 5		094 R†	
039 .		095 x	
040 2		096 ST+4	
041 5		097 R4	
042 ST0A		098 +	
043 +		099 ST-0	
044 ST+5	Add fractional year	100 RCL6	
045 3		101 LSTX	
046 6		102 +R	
047 0		103 .	
048 ST0C		104 8	
049 ST×6		105 x	
050 2		106 ST+4	
051 5		107 0	
052 9		108 RCLD	
053 8		109 GSB1	
054 6		110 ST+4	
055 ST+6		111 RCLC	
056 RCLA		112 ST+0	

REGISTERS									
0	1 λ	2 GHA*	3 L	4 δ	5 YEAR	6 DAY	7 Z _n	8 H _c	9 a
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A 365.25	B HE	C 360	D δ 69	E α 69	I				

113 ST+4		169 PRTX	
114 RCLD		170 RCL I	H _e , altitude
115 ST+4		171 ST00	
116 RCLE		172 *HMS	
117 ST+0		173 DSP4	
118 RCLC		174 PRTX	
119 RTN		175 RTN	
120 *LBLA		176 *LBLC	
121 HMS+		177 DSP1	
122 ST01	Store λ	178 HMS+	
123 X= Y		179 ENT?	
124 HMS+		180 ENT?	
125 ST03	Store L	181 ENT?	
126 RTN		182 3	
127 *LBLB		183 +	
128 HMS+		184 1	
129 1		185 2	
130 5		186 x	
131 .		187 TAN ⁻¹	
132 0		188 -	Mean Refraction
133 4		189 TAN	
134 1		190 RCLB	
135 0		191 FX	
136 7		192 -	
137 x		193 6	
138 RCL6		194 2	
139 +		195 +	Dip
140 RCL8		196 +	
141 +		197 RCL8	
142 ST02		198 -	
143 RCL1		199 CHS	
144 -		200 6	
145 RCL4		201 0	
146 COS		202 x	
147 +R		203 ST09	
148 RCL3		204 RTN	
149 ST01		205 *LBL1	
150 X= Y		206 RCLC	
151 +R		207 +	Decode proper motion correction
152 X= I		208 INT	
153 RCL4		209 -	
154 SIN		210 5	
155 +R		211 0	
156 X= I		212 +	
157 +		213 *LBL2	
158 SIN ⁻¹		214 RCL5	
159 X= I		215 x	
160 -		216 RTN	
161 +P		217 *LBL4	
162 R4		218 ST08	
163 1		219 RTN	
164 0			
165 0			
166 +			
167 ST07	Z _n , azimuth		
168 DSP1			

LABELS			FLAGS		SET STATUS			
A Y M D	B GMT → Z _n , H _e	C h _s → a	D	E	0	FLAGS	TRIG	DISP
* L t λ	D HE	c	d	e	1	ON OFF		
0	1	2	3	4	2	0 ☐ ☐	DEG ☐	FIX ☐
						1 ☐ ☐	GRAD ☐	SCI ☐
						2 ☐ ☐	RAD ☐	ENG ☐
5	6	7	8	9	3	3 ☐ ☐		n <u>1</u>

STAR DATA 1

001 #LBLa	ACAMAR	057 CTOI	ADHARA						
002 3		058 #LBLd							
003 1		059 2							
004 5		060 5							
005 .		061 5							
006 7		062 .							
007 2		063 6							
008 8		064 4							
009 8		065 8							
010 STOE		066 3							
011 4		067 STOE							
012 0		068 2							
013 .		069 8							
014 4		070 .							
015 2		071 9							
016 8		072 2							
017 1		073 8							
018 CHS		074 9							
019 CTOI		075 CHS							
020 #LBLb	ACHERNAR	076 CTOI	ALDEBARAN						
021 3		077 #LBLc							
022 3		078 2							
023 5		079 9							
024 .		080 1							
025 8		081 .							
026 5		082 4							
027 9		083 6							
028 6		084 5							
029 STOE		085 0							
030 5		086 STOE							
031 7		087 1							
032 .		088 6							
033 3		089 .							
034 9		090 4							
035 3		091 4							
036 9		092 8							
037 CHS		093 3							
038 CTOI		094 CTOI							
039 #LBLc	ACRUX	095 #LBLA	ALIOTH						
040 1		096 1							
041 7		097 6							
042 3		098 6							
043 .		099 .							
044 7		100 8							
045 8		101 3							
046 5		102 2							
047 0		103 5							
048 STOE		104 STOE							
049 6		105 5							
050 2		106 6							
051 .		107 .							
052 9		108 1							
053 2		109 2							
054 7		110 7							
055 5		111 8							
056 CHS		112 CTOI							
REGISTERS									
0	1	2	3	4	5	6	7	8	9
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A	B	C	D	E	I				

STAR DATA 2

001	*LBL	ALPHECCA	057	CHS					
002	1		058	CTOI					
003	2		059	*LBL	ANKAA				
004	6		060	3					
005	.		061	5					
006	6		062	3					
007	5		063	.					
008	6		064	8					
009	7		065	1					
010	STOE		066	1					
011	2		067	3					
012	6		068	STOE					
013	.		069	4					
014	8		070	2					
015	1		071	.					
016	8		072	4					
017	1		073	7					
018	CTOI		074	4					
019	*LBL	ALPHERATZ	075	4					
020	3		076	CHS					
021	5		077	CTOI					
022	8		078	*LBL	ANTARES				
023	.		079	1					
024	3		080	1					
025	0		081	3					
026	5		082	.					
027	8		083	1					
028	STOE		084	2					
029	2		085	4					
030	8		086	2					
031	.		087	STOE					
032	9		088	2					
033	1		089	6					
034	9		090	.					
035	4		091	3					
036	CTOI		092	6					
037	*LBL	ALTAIR	093	4					
038	1		094	7					
039	8		095	CHS					
040	1		096	CTOI					
041	7		097	*LBL	ARCTURUS				
042	.		098	2					
043	3		099	6					
044	1		100	6					
045	7		101	6					
046	5		102	.					
047	CHS		103	4					
048	STOE		104	3					
049	7		105	8					
050	1		106	3					
051	1		107	STOE					
052	.		108	3					
053	2		109	6					
054	1		110	1					
055	4		111	9					
056	7		112	.					
REGISTERS									
0	1	2	3	4	5	6	7	8	9
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A	B	C	D	E	F	G	H	I	J

113	3			169	1				
114	4			170	GT01				
115	3			171	*LBL			BETELGEUSE	
116	1			172	2				
117	GT01			173	7				
118	*LBL	ATRIA		174	1				
119	1			175	.				
120	0			176	6				
121	8			177	2				
122	.			178	6				
123	6			179	7				
124	5			180	STOE				
125	8			181	7				
126	0			182	.				
127	STOE			183	4				
128	6			184	0				
129	8			185	2				
130	.			186	9				
131	9			187	*LBL				
132	7			188	STOD				
133	3			189	RTM				
134	3								
135	CHS								
136	GT01								
137	*LBL	AVIOR							
138	2								
139	3								
140	4								
141	.								
142	5								
143	3								
144	STOE								
145	5								
146	9								
147	.								
148	4								
149	0								
150	9								
151	4								
152	CHS								
153	GT01								
154	*LBL	BELLATRIX							
155	2								
156	7								
157	9								
158	.								
159	1								
160	3								
161	3								
162	3								
163	STOE								
164	6								
165	.								
166	3								
167	2								
168	3								

LABELS					FLAGS	SET STATUS			
A	B	C	D	E	0	FLAGS	TRIG	DISP	
a	b	c	d	e	1	0 ☐ ON OFF ☐	DEG ☐	FIX ☐	
0	1	2	3	4	2	1 ☐	GRAD ☐	SCI ☐	
5	6	7	8	9	3	2 ☐	RAD ☐	ENG ☐	
						3 ☐		n ☐	

STAR DATA 3

001	*LBLa	CANOPUS	057	2					
002	2		058	6					
003	6		059	3					
004	4		060	.					
005	.		061	1					
006	1		062	3					
007	8		063	STOE					
008	5		064	1					
009	4		065	4					
010	STOE		066	.					
011	5		067	7					
012	2		068	4					
013	.		069	5					
014	6		070	3					
015	7		071	CTOI					
016	9		072	*LBLc	DIPHDA				
017	3		073	3					
018	CHS		074	4					
019	CTOI		075	9					
020	*LBLb	CAPELLA	076	.					
021	2		077	4					
022	8		078	9					
023	1		079	1					
024	.		080	7					
025	4		081	STOE					
026	8		082	1					
027	8		083	8					
028	8		084	.					
029	STOE		085	1					
030	4		086	5					
031	5		087	6					
032	.		088	4					
033	9		089	CHS					
034	6		090	CTOI					
035	8		091	*LBLA	DUBHE				
036	3		092	1					
037	CTOI		093	9					
038	*LBLc	DENEB	094	4					
039	4		095	.					
040	9		096	5					
041	.		097	4					
042	9		098	2					
043	8		099	9					
044	6		100	STOE					
045	7		101	6					
046	STOE		102	1					
047	4		103	.					
048	5		104	9					
049	.		105	1					
050	1		106	8					
051	6		107	6					
052	8		108	CTOI					
053	9		109	*LBLB	ELNATH				
054	CTOI		110	2					
055	*LBLd	DENEbola	111	7					
056	1		112	8					
REGISTERS									
0	1	2	3	4	5	6	7	8	9
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A	B	C	D	E	F	G	H	I	J

113	.				165	2		
114	9				170	9		
115	1				171	.		
116	7				172	7		
117	5				173	8		
118	STOE				174	6		
119	2				175	9		
120	8				176	CHS		
121	.				177	*LBL1		
122	5				178	STOD		
123	8				179	RTN		
124	2							
125	8							
126	GT01	ELTANIN						
127	*LBLC							
128	9							
129	1							
130	.							
131	0							
132	2							
133	0							
134	7							
135	STOE							
136	5							
137	1							
138	.							
139	4							
140	9							
141	1							
142	9							
143	GT01	ENIF						
144	*LBLD							
145	3							
146	4							
147	.							
148	3							
149	3							
150	4							
151	6							
152	STOE							
153	9							
154	.							
155	7							
156	3							
157	2							
158	2							
159	GT01	FOMALHAUT						
160	*LBL E							
161	1							
162	6							
163	.							
164	0							
165	1							
166	5							
167	0							
168	STOE							

LABELS					FLAGS	SET STATUS			
A	B	C	D	E	0	FLAGS	TRIG	DISP	
a	b	c	d	e	1	ON OFF		FIX	
0	1	2	3	4	2	0 ☐ ☐	DEG ☐	SCI ☐	
						1 ☐ ☐	GRAD ☐	ENG ☐	
						2 ☐ ☐	RAD ☐		
5	6	7	8	9	3	3 ☐ ☐		n	

STAR DATA 4

001	*LBLa	GACRUX	057	.					
002	1		058	6					
003	7		059	4					
004	2		060	5					
005	.		061	STOE					
006	6		062	2					
007	4		063	3					
008	1		064	.					
009	3		065	3					
010	STOE		066	1					
011	5		067	6					
012	6		068	7					
013	.		069	GT01					
014	9		070	*LBLa	KAUS AUSTRALIS				
015	4		071	8					
016	CHS		072	4					
017	GT01		073	.					
018	*LBLb	GIENAH	074	4					
019	1		075	7					
020	7		076	1					
021	6		077	7					
022	.		078	STOE					
023	4		079	3					
024	4		080	4					
025	7		081	.					
026	9		082	4					
027	STOE		083	0					
028	1		084	1					
029	7		085	1					
030	.		086	CHS					
031	3		087	GT01					
032	7		088	*LBLa	KOCHAB				
033	CHS		089	1					
034	GT01		090	3					
035	*LBLa	HADAR	091	7					
036	1		092	.					
037	4		093	3					
038	9		094	0					
039	.		095	5					
040	5		096	8					
041	9		097	STOE					
042	5		098	7					
043	STOE		099	4					
044	6		100	.					
045	0		101	2					
046	.		102	8					
047	2		103	2					
048	2		104	2					
049	4		105	GT01					
050	4		106	*LBLb	MARKAB				
051	CHS		107	1					
052	GT01		108	4					
053	*LBLa	HAMAL	109	.					
054	3		110	1					
055	2		111	9					
056	8		112	6					
REGISTERS									
0	1	2	3	4	5	6	7	8	9
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A	B	C	D	E	F	G	H	I	J

113	7			169	STOE		
114	STOE			170	6		
115	1			171	9		
116	5			172	.		
117	.			173	5		
118	0			174	8		
119	3			175	9		
120	8			176	4		
121	1			177	CHS		
122	GT01			178	LBL1		
123	LBLC	MENKAR		179	STOD		
124	3			180	RTM		
125	1						
126	4						
127	.						
128	8						
129	3						
130	5						
131	8						
132	STOE						
133	3						
134	.						
135	9						
136	6						
137	9						
138	2						
139	GT01						
140	LBLD	MENKENT					
141	1						
142	2						
143	2						
144	8						
145	.						
146	7						
147	8						
148	7						
149	5						
150	STOE						
151	6						
152	8						
153	3						
154	.						
155	7						
156	8						
157	1						
158	7						
159	GT01						
160	LBL E	MIAPLACIDUS					
161	2						
162	2						
163	1						
164	.						
165	7						
166	8						
167	2						
168	9						

LABELS					FLAGS	SET STATUS			
A	B	C	D	E	0	FLAGS	TRIG	DISP	
a	b	c	d	e	1	ON OFF			
0	1	2	3	4	2	0 ☐ ☐	DEG ☐	FIX ☐	
5	6	7	8	9	3	1 ☐ ☐	GRAD ☐	SCI ☐	
						2 ☐ ☐	RAD ☐	ENG ☐	
						3 ☐ ☐		n	

STAR DATA 5

001	*LBL	MIRFAK	057	3					
002	3		058	2					
003	6		059	9					
004	9		060	.					
005	.		061	3					
006	4		062	7					
007	7		063	0					
008	5		064	8					
009	STOE		065	STOE					
010	CLRC		066	8					
011	STOE		067	9					
012	4		068	.					
013	9		069	1					
014	.		070	2					
015	7		071	1					
016	5		072	4					
017	2		073	GT01					
018	2		074	*LBL	POLLUX				
019	GT01		075	1					
020	*LBL	NUNKI	076	3					
021	7		077	2					
022	6		078	4					
023	.		079	.					
024	6		080	1					
025	6		081	4					
026	4		082	4					
027	2		083	6					
028	STOE		084	STOE					
029	2		085	2					
030	6		086	0					
031	.		087	.					
032	3		088	1					
033	3		089	0					
034	6		090	2					
035	9		091	5					
036	CHS		092	GT01					
037	GT01		093	*LBL	PROCYON				
038	*LBL	PEACOCK	094	1					
039	5		095	3					
040	4		096	2					
041	.		097	5					
042	1		098	.					
043	9		099	5					
044	0		100	8					
045	8		101	STOE					
046	STOE		102	1					
047	5		103	8					
048	6		104	0					
049	.		105	5					
050	8		106	.					
051	3		107	3					
052	6		108	0					
053	1		109	5					
054	CHS		110	6					
055	GT01		111	GT01					
056	*LBL	POLARIS	112	*LBL	RASALHAGUE				
REGISTERS									
0	1	2	3	4	5	6	7	8	9
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A	B	C	D	E	F	G	H	I	J

113	9			169	6		
114	6			170	8		
115	.			171	.		
116	6			172	6		
117	2			173	3		
118	6			174	STOE		
119	7			175	1		
120	STOE			176	5		
121	1			177	8		
122	2			178	8		
123	.			179	.		
124	5			180	7		
125	8			181	8		
126	1			182	8		
127	1			183	6		
128	GT01			184	CHS		
129	*LBLC	REGULUS		185	*LBL1		
130	2			186	STOD		
131	8			187	RTN		
132	8						
133	.						
134	3						
135	1						
136	9						
137	2						
138	STOE						
139	1						
140	2						
141	.						
142	1						
143	1						
144	9						
145	4						
146	GT01						
147	*LBLD	RIGEL					
148	2						
149	8						
150	1						
151	.						
152	7						
153	3						
154	8						
155	3						
156	STOE						
157	8						
158	.						
159	2						
160	3						
161	6						
162	1						
163	CHS						
164	GT01						
165	*LBLE	RIGIL KENTAURUS					
166	1						
167	3						
168	4						

LABELS					FLAGS	SET STATUS		
A	B	C	D	E	0	FLAGS	TRIG	DISP
a	b	c	d	e	1	ON OFF	DEG ☐	FIX ☐
0	1	2	3	4	2	1 ☐	GRAD ☐	SCI ☐
5	6	7	8	9	3	2 ☐	RAD ☐	ENG ☐
						3 ☐		n _____

STAR DATA 6

001	#LBLa					057	1		
002	1					058	3		
003	0					059	3		
004	2					060	9		
005	.					061	.		
006	8					062	0		
007	5					063	5		
008	0					064	4		
009	8					065	2		
010	STOE					066	STOE		
011	1					067	2		
012	5					068	8		
013	.					069	6		
014	6					070	3		
015	8					071	.		
016	0					072	3		
017	1					073	2		
018	CHS					074	7		
019	GTOI					075	8		
020	#LBLb	SCHEDAR				076	GTOI		
021	3					077	#LBLc	SPICA	
022	5					078	1		
023	0					079	5		
024	.					080	9		
025	3					081	.		
026	1					082	1		
027	6					083	1		
028	3					084	0		
029	STOE					085	8		
030	5					086	STOE		
031	6					087	1		
032	.					088	1		
033	3					089	CHS		
034	6					090	GTOI		
035	7					091	#LBLA	SUHAIL	
036	8					092	2		
037	GTOI					093	2		
038	#LBLc	SHAULA				094	3		
039	9					095	.		
040	7					096	2		
041	.					097	8		
042	1					098	6		
043	2					099	3		
044	4					100	STOE		
045	6					101	4		
046	STOE					102	3		
047	3					103	.		
048	7					104	3		
049	.					105	0		
050	0					106	6		
051	8					107	9		
052	3					108	CHS		
053	1					109	GTOI		
054	CHS					110	#LBLB	VEGA	
055	GTOI					111	8		
056	#LBLd	SIRIUS				112	1		
REGISTERS									
0	1	2	3	4	5	6	7	8	9
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A	B	C	D	E	F	G	H	I	J

BEARING LINE OF POSITION

001 #LBLA		057 LSTX							
002 HMS+	Store λ_1	058 CSB5	Move Geographical position of first false star along a rhumb line						
003 ST01		059 RCL3							
004 XZY	Store L_1	060 CSB5							
005 HMS+		061 -							
006 ST03		062 RCLB							
007 0		063 1							
008 ST08	H_c and $a = 0$	064 +R							
009 ST09		065 X=0?							
010 3		066 GT04							
011 6		067 ÷							
012 0		068 x							
013 ST0C		069 5							
014 R/S		070 7							
015 ST06	Store Z_1	071 .							
016 9		072 3							
017 0		073 x							
018 +		074 GT06							
019 ST07	Store $Z_1 + 90$	075 #LBL4							
020 RCL3		076 RCLB							
021 RCL1		077 SIN							
022 RCL6		078 RCLA							
023 CSB3	Compute location of "false star"	079 x							
024 0		080 RCL5							
025 RTN	-----	081 COS							
026 #LBLB		082 ÷							
027 P=S		083 CHS							
028 CSBA	Store L_2, λ_2 , and Z_2	084 #LBL6							
029 RCL1		085 RCL1							
030 RCL3		086 +							
031 P=S	Rearrange registers	087 CSB2							
032 ST05		088 ST01							
033 XZY		089 P=S							
034 ST08		090 #LBLD							
035 RCL1		091 P=S							
036 RCL3		092 RCL1							
037 P=S		093 RCL0							
038 ST03		094 -							
039 XZY		095 CSB2							
040 ST01		096 RCL5							
041 RTN		097 COS							
042 #LBLC		098 x							
043 HMS+		099 RCL5							
044 x		100 RCL3							
045 6		101 -							
046 0		102 CHS							
047 ÷	Distance	103 RCL6							
048 ST0A		104 TAN							
049 XZY		105 x							
050 ST0B	Store course	106 +							
051 COS		107 RCL6							
052 x		108 TAN							
053 P=S		109 P=S							
054 RCL3		110 RCL6							
055 +		111 P=S							
056 ST03		112 TAN							
REGISTERS									
0	1 λ_2, λ_1	2 α_2	3 L_2, L_1	4 δ_2	5	6 Z_2	7 Z_{n2}	8 0	9 0
S0 λ_2	S1 λ_1	S2 α_1	S3 L_1	S4 δ_1	S5 L_2	S6 Z_1	S7 Z_{n1}	S8 0	S9 0
A D, L	B C, λ	C 360	D	E	F	G	H	I	J

113	-		169	RTN	
114	+				
115	STO1				
116	RCL5				
117	+				
118	STOA				
119	+HMS				
120	RCL0				
121	RCL1				
122	P=S				
123	RCL6				
124	P=S				
125	TAN				
126	x				
127	RCL5				
128	COS				
129	+				
130	-				
131	SSB2				
132	STOB				
133	+HMS				
134	X=Y				
135	R/S				
136	X=Y				
137	P=S				
138	RTN				
139	*LBL2				
140	1				
141	+R				
142	+P				
143	R+				
144	RTN				
145	*LBL3				
146	1				
147	+R				
148	X=Y				
149	R+				
150	X=Y				
151	+R				
152	SIN-				
153	CNS				
154	STO4				
155	R+	Store declination of "false star"			
156	+P				
157	R+				
158	-				
159	STO2				
160	RTN	Store GHA of "false star"			
161	*LBL5				
162	2	Subroutine for part of rhumb line equations			
163	÷				
164	4				
165	5				
166	+				
167	TAN				
168	LN				

LABELS				FLAGS		SET STATUS			
A ₁ ↑ λ ₁ ; Z ₁	B ₁ ↑ λ ₂ ; Z ₂	C ₁ ↑ λ ₃ ; Z ₃	D ₁ ↑ λ ₄ ; Z ₄	E	F	FLAGS	TRIG	DISP	
a	b	c	d	e	f	0 ☐ ON ☐ OFF	DEG ☐	FIX ☐	
0	1	2	3	4	5	1 ☐	GRAD ☐	SCI ☐	
5	6	7	8	9	0	2 ☐	RAD ☐	ENG ☐	
						3 ☐		n <u>4</u>	

TWO-ANGLE LINE OF POSITION

001	*LBLA		057	SIN					
002	HMS+		058	RCL2					
003	ST00	Store λ_A	059	+					
004	XZY		060	+					
005	HMS+		061	SIN					
006	ST01	Store λ_A	062	+					
007	RTN		063	RCL2					
008	*LBLC		064	2					
009	HMS+		065	+					
010	ST05	Store λ_C	066	COS					
011	XZY		067	XZY					
012	HMS+		068	x					
013	ST06	Store λ_C	069	LSTX					
014	R/S		070	SIN+					
015	ST0A	Store Z_C	071	COS					
016	RTN		072	1					
017	*LBL E		073	-					
018	P/S	Store λ_E , λ_E in secondary registers	074	CNS					
019	GSBA		075	+					
020	P/S		076	TAN+					
021	RTN		077	ST0B					
022	*LBLB		078	TAN					
023	HMS+		079	RCL4					
024	ST02	Store ΔZ_{AC}	080	COS					
025	RCLA		081	1					
026	XZY		082	-					
027	-		083	CNS					
028	ST03	Store Z_A	084	x					
029	GSB5	Compute approximate L , λ	085	RCL4					
030	RTN		086	SIN					
031	*LBLD		087	+					
032	RCL5		088	COS+					
033	RCL6		089	R+					
034	P/S		090	RCLA					
035	ST06		091	-					
036	R+		092	SIN					
037	ST05		093	RCL2					
038	R+		094	COS					
039	HMS+		095	x					
040	ST02		096	ABS					
041	RCLA		097	LSTX					
042	+		098	+					
043	ST03	Store Z_E	099	x					
044	GSB5	Compute approximate L , λ	100	+					
045	RTN		101	RCL6					
046	*LBL5		102	RCL8					
047	RCL5		103	GSB3					
048	RCL8		104	SIN+					
049	-		105	ST04					
050	RCL6		106	R+					
051	RCL1		107	CNS					
052	GSB3		108	RCL5					
053	COS+	Distance A to C	109	+					
054	ST04		110	ST02					
055	2		111	*LBL4					
056	+		112	RCL6					

REGISTERS									
0 λ_A	1 λ_A	2 $\Delta Z_{AC}, \alpha_1$	3 Z_A	4 d, δ_1	5 λ_C	6 L_C	7	8	9
S0 λ_E	S1 λ_E	S2 $\Delta \lambda_{CE}, \alpha_2$	S3 Z_E	S4 d, δ_2	S5 λ_C	S6 L_C	S7	S8	S9
A Z_C	B	C	D	E	F	G	H	I	J

113	ENT	169	P2S		
114	COS	170	ST05		
115	RCL0	171	R4		
116	RCL5	172	ST06		
117	-	173	R4		
118	GSB2	174	9		
119	x	175	0		
120	RCL1	176	ST-7		
121	RCL6	177	-		
122	-	178	ST0A		
123	RCL3	179	RCL1		
124	TAN	180	ST0B		
125	x	181	RCL3		
126	+	182	ST01		
127	RCL3	183	RCL7		
128	TAN	184	ST03		
129	RCL4	185	ST04		
130	TAN	186	*LBL3		
131	-	187	I		
132	÷	188	+R		
133	+	189	R↑		
134	ST03	190	X2Y		
135	RCL5	191	+R		
136	LSTX	192	R↑		
137	RCL4	193	ST01		
138	TAN	194	X2Y		
139	x	195	+R		
140	RCL6	196	X2I		
141	COS	197	R↑		
142	÷	198	+R		
143	-	199	X2I		
144	ST01	200	+		
145	RCL2	201	X2I		
146	-	202	-		
147	RCL3	203	CHS		
148	RCL4	204	+P		
149	GSB3	205	X2I		
150	R4	206	RTN		
151	ST07				
152	0				
153	ST09				
154	RCL3				
155	+HNS				
156	R/S				
157	RCL1				
158	+HNS				
159	*LBL2				
160	I				
161	+R				
162	+P				
163	R4				
164	RTN				
165	*LBL4				
166	RCL7				
167	RCL3				
168	RCL1				

LABELS					FLAGS	SET STATUS			
A LA ↑ λA	B ΔZAC → L, λ	C Lc ↑ λc; Zc	D ΔZCD → L, λ	E Lc ↑ λE	0	FLAGS	TRIG	DISP	
a	b	c	d	e	1	ON OFF			
0	1	2	3	4	2	0 ☐ ☐	DEG ☐	FIX ☐	
5	6	7	8	9	3	1 ☐ ☐	GRAD ☐	SCI ☐	
						2 ☐ ☐	RAD ☐	ENG ☐	
						3 ☐ ☐		n 4	

Celestial Triangle
Subroutine

z = t
inputs: y = L
x = d

outputs: y = Z - 180
x = sin(h)

Store Z_n

a = 0

approximate L

approximate λ

Subroutine to force
|x| < 180°

113	RCL	169	+R		
114	RCL	170	XZ I		
115	GSB2	171	+		
116	SIN	172	XZ I		
117	RCL2	173	-		
118	XZY	174	CHS		
119	F19	175	→P		
120	PZS	176	XZ I		
121	STOS	177	RTN		
122	R4	178	#LBL5		
123	+	179	RCL1		
124	1	180	RCL6		
125	→R	181	-		
126	→P	182	RCL5		
127	XZY	183	RCL3		
128	STO6	184	GSB2		
129	F22	185	COS		
130	GTO8	186	RTN		
131	SF2	187	#LBL6		
132	PZS	188	2		
133	CF1	189	÷		
134	RCL0	190	4		
135	GTO4	191	5		
136	#LBL8	192	+		
137	GSB5	193	TAN		
138	PZS	194	LN		
139	STO8	195	RTN		
140	GSB5	196	#LBLC		
141	RCL0	197	SF2		
142	PZS	198	#BLD		
143	XZY	199	PZS		
144	GTO7	200	RCL7		
145	PZS	201	PZS		
146	SF2	202	RCL7		
147	#LBL7	203	+		
148	RCL6	204	2		
149	RCL5	205	÷		
150	→MMS	206	F22		
151	F22	207	9		
152	PZS	208	0		
153	R/S	209	+		
154	XZY	210	COS		
155	→MMS	211	COS		
156	RTN	212	STOI		
157	#LBL2	213	RCL7		
158	1	214	-		
159	→R	215	COS		
160	R↑	216	1/X		
161	XZY	217	ABS		
162	→R	218	R/S		
163	R↑	219	RCL1		
164	STOI	220	RTN		
165	XZY				
166	→R				
167	XZ I				
168	R↑				

Distance 1, 2

Store trial L

$|\lambda| < 180^\circ$

Store trial λ

First time through

Second time through

Select proper fix

Display L

Display λ

Celestial Triangle

Subroutine

inputs: $z = t$
 $y = L$
 $x = d$

outputs: $y = Z - 180$
 $x = \sin(h)$

Subroutine to get distance from L, λ to GP₁ or GP₂

Subroutine for rhumb line equations

Compute worst-case error for 1' error in h_1 or h_2

Normalize Z

LABELS					FLAGS	SET STATUS			
A → L, λ	B	C → D, Z_D	D → AD', Z_D'	E	0	FLAGS		TRIG	DISP
#CtStΔt	b	c	d	e → L, λ	1	0	☐ OFF		
0	1	2	3	4	2	1	☐ DEG	☐ SCI	☐ FIX
0	1	2	3	4	2	2	☐ GRAD	☐ RAD	☐ ENG
5	6	7	8	9	3	3	☐ RAD		n 4

RADAR PLOTTING CLOSEST POINT OF APPROACH

001	*LBLb	Store course and speed	057	6	Bearing of CPA
002	STOC		058	0	
003	XZY		059	XZY	
004	STOB		060	XZY?	
005	RTN	-----	061	+	Range of CPA
006	*LBLc	062	STO9		
007	STOA	063	RCL7		
008	RTN	064	-		
009	*LBLd	Store Miss Distance	065	COS	Relative speed
010	DSP0		066	RCL8	
011	P25		067	X	
012	E1?		068	+R	
013	GTO1	THEN GTO 1	069	+P	Relative course
014	1	Display 1	070	STOB	
015	SF1	Display 2	071	RCL7	
016	RTN		072	RCL8	
017	*LBL1		073	RCL4	
018	2		074	RCL5	
019	CF1	First time	075	CHS	IF $r_{CPA} < \text{MISS DIST}$ THEN blink display
020	RTN		076	GSB8	
021	*LBLa		077	RCL6	
022	SF2		078	RCL3	
023	*LBLA	Range	079	-	Display range of CPA
024	RCL8		080	÷	
025	STO5		081	STO2	
026	R4		082	XZY	
027	STOB	Bearing	083	STO1	Display bearing of CPA
028	R4		084	RCLA	
029	RCL7		085	RCL8	
030	STO4		086	XZY?	
031	R4	Time	087	PSE	His course
032	STO7		088	XZY?	
033	R4		089	PSE	
034	HMS+		090	XZY?	
035	RCL6	Stop here first time	091	PSE	Display range of CPA
036	STO3		092	DSP1	
037	R4		093	R/S	
038	STO6		094	DSP8	
039	F2?	-----	095	RCL9	Display bearing of CPA
040	RTN		096	RTN	
041	RCL7		097	*LBLB	
042	RCL8		098	DSP8	
043	+R	His course	099	RCL1	Display range of CPA
044	RCL4		100	RCL2	
045	RCL5		101	RCL8	
046	+R		102	RCLC	
047	XZY	-----	103	GSB8	Display bearing of CPA
048	R4		104	STOE	
049	-		105	XZY	
050	R4		106	3	
051	-	His course	107	6	Display range of CPA
052	Rt		108	0	
053	XZY		109	XZY	
054	+P		110	XZY?	
055	XZY	-----	111	+	Display bearing of CPA
056	3		112	STOD	

REGISTERS																							
0	r_{CPA}	1	t_r	2	rm	3	t_1	4	ϕ_1	5	D_1	6	t_2	7	ϕ_2	8	D_2	9	ϕ_{CPA}, θ				
S0	r_{CPA}	S1	t_r	S2	rm	S3	t_1	S4	ϕ_1	S5	D_1	S6	t_2	S7	ϕ_2	S8	D_2	S9	ϕ_{CPA}, θ				
A		MISS DIST		B		COURSE		C		SPEED		D		h		E		em		I		t_3	

113 RTN	-----	169 CHS	
114 *LBLC	His speed	170 SIN	
115 DSP1		171 RCLC	
116 GSB8		172 x	
117 RCLC		173 RCLC	
118 RTN	-----	174 +	
119 *LBLC	t → New course, Left	175 SIN+	
120 DSP0		176 -	
121 GSB0		177 3	
122 -		178 6	
123 GSB1	-----	179 0	
124 RTN	t → New course, Right	180 +R	
125 *LBLC		181 +P	
126 DSP0		182 XZY	
127 GSB0		183 X<0?	
128 +		184 +	
129 GSB1		185 RTN	
130 RTN		186 *LBL0	
131 *LBL0		187 +R	
132 HMS+		188 R+	
133 STOI		189 R+	
134 RCL1		190 +R	
135 RCL2		191 XZY	
136 RCL1		192 R+	
137 RCL6		193 +	
138 -		194 R+	
139 x		195 +	
140 RCL7		196 R+	
141 RCL8		197 +P	
142 GSB8		198 RTN	
143 XZY		199 *LBL0	Time of CPA
144 1		200 DSP4	
145 0		201 RCL9	
146 0		202 RCL0	
147 +		203 RCL7	
148 RCL1		204 RCL0	
149 -		205 CHS	
150 STOI		206 GSB8	
151 XZY		207 RCL2	
152 RCL1		208 +	
153 +		209 RCL6	
154 1/X		210 +	
155 SIN+		211 +HMS	Display time
156 RTN		212 RTN	
157 *LBL1			
158 RCL1			
159 +			
160 ENT+			
161 ENT+			
162 1			
163 0			
164 0			
165 +			
166 XZY			
167 RCL0			
168 -			

LABELS					FLAGS	SET STATUS			
A ₂ ↑B ₂ ↑R ₂	B ₂ ↑HIS Course	C ₂ ↑HIS speed	D ₂ ↑CPA	E ₂ ↑right turn	0	FLAGS		TRIG	DISP
*t ₁ ↑B ₁ ↑R ₁	*course↑speed	*MISS DIST	*TARGET?	*left turn	1 TARGET	ON OFF			
0	1	2	3	4	2 first time	0	☐ ON ☐ OFF	DEG ☐	FIX ☐
						1	☐ ON ☐ OFF	GRAD ☐	SCI ☐
						2	☐ ON ☐ OFF	RAD ☐	ENG ☐
						3	☐ ON ☐ OFF		n <u>0</u>

DISTANCE BY HORIZON ANGLE

001	*LBLA	Store HE	057	RCL1				
002	ST01		058	JX				
003	RTN	-----	059	RCL2				
004	*LBLB		060	JX				
005	ST02	Store H	061	+				
006	RTN	-----	062	1				
007	*LBLC	Short of horizon	063	.				
008	HMS+	$h_s \rightarrow D$	064	1				
009	RCL1		065	4				
010	JX		066	4				
011	.		067	x				
012	0		068	RTN				
013	1		069	*LBLD	Beyond horizon			
014	6		070	HMS+	$h_s \rightarrow D$			
015	2		071	ST04				
016	x		072	RCL1				
017	-		073	JX				
018	ST03		074	.				
019	TAN		075	0				
020	2		076	1				
021	.		077	6				
022	4		078	2				
023	6		079	x				
024	EEX		080	+				
025	CNS		081	ST04				
026	4		082	TAN				
027	÷		083	RCL1				
028	CNS		084	X ² Y				
029	ENT↑		085	÷				
030	ENT↑		086	CT00				
031	x		087	*LBL _e	H ↑ $h_s \rightarrow D$			
032	RCL2		088	HMS+				
033	RCL1		089	TAN				
034	-		090	+				
035	.		091	CT00				
036	7		092	*LBL _e				
037	4		093	HMS+	D ↑ $h_s \rightarrow H$			
038	7		094	TAN				
039	3		095	x				
040	6		096	6				
041	÷		097	0				
042	+		098	7				
043	JX		099	6				
044	+		100	x				
045	RTN		101	*LBL0				
046	*LBL _e	Distance to horizon	102	R/S				
047	RCL1		103	6				
048	JX		104	0				
049	1		105	7				
050	.		106	6				
051	1		107	÷				
052	4		108	RTN				
053	4							
054	x							
055	RTN							
056	*LBL _e	Distance of visibility						
REGISTERS								
0	1 HE	2 H	3	4	5	6	7	8
S0	S1	S2	S3	S4	S5	S6	S7	S8
A	B	C	D	E	F	G	H	I

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LABELS					FLAGS	SET STATUS			
A	B	C	D	E		FLAGS		TRIG	DISP
HE	H	$h_s \rightarrow D$		$D \uparrow h_s \rightarrow H$	0				
$\rightarrow D_{hor}$	$\rightarrow D_{vis}$			$H \uparrow h_s \rightarrow D$	1				
0	1	2	3	4	2				
5	6	7	8	9	3				

0	☐ ON	☒ OFF			
1	☐	☒		DEG ☒	FIX ☒
2	☐	☒		GRAD ☐	SCI ☐
3	☐	☒		RAD ☐	ENG ☐
					n <u>2</u>

BEATING TO WINDWARD

001	#LBLA					057	-			
002	SPC					058	CSB9			
003	R4	Store W _a				059	ST03			
004	ST09					060	RND			
005	R4	Store S				061	CT05			
006	ST00					062	#LBLC			
007	R4	Store S _a				063	CF1			
008	ST07					064	CSB0			
009	R4					065	+			
010	COS					066	CSB9			
011	X*					067	ST03			
012	ST0A					068	CT05			
013	RCL9					069	#LBL0			
014	1	Correct S _a for angle of heel				070	SPC			
015	+R					071	ST00			
016	X*Y					072	R4			
017	X*Y					073	ST01			
018	X*					074	X*Y			
019	RCLA					075	ST02			
020	X					076	R†			
021	+					077	+			
022	JX	Store new S _a				078	+			
023	RCL7					079	CSB9			
024	X*Y					080	ST0A			
025	÷					081	RCL6			
026	ST07					082	RTM			
027	RCL9					083	#LBL0			
028	X*Y					084	+R			
029	+R	Compute MW				085	R4			
030	RCL8					086	R4			
031	-					087	+R			
032	+P					088	X*Y			
033	ST05					089	R4			
034	DSP2					090	+			
035	PRTX					091	R4			
036	RCL7					092	+			
037	X*					093	R†			
038	RCL0					094	+P			
039	X*					095	RTM			
040	-	Compute W _t				096	#LBLD			
041	RCL5					097	ST01			
042	X*					098	X*Y			
043	-					099	ST04			
044	2					100	X*Y			
045	÷					101	RCLA			
046	RCL8					102	RCL0			
047	÷					103	CSB8			
048	RCL5					104	DSP2			
049	÷					105	PRTX			
050	COS ⁻¹					106	ST0B			
051	ST06					107	X*Y			
052	DSP1					108	CSB9			
053	CT05					109	PRTX			
054	#LBLB	Port Tack				110	ST0C			
055	SF1					111	RCL3			
056	CSB0					112	RCL6			

REGISTERS																			
0	Dev	1	Var	2	C _c	3	W _m	4	Set	5	MW	6	W _t	7	S _a	8	S	9	W _a
S0	C _m	S1	D	S2	t _{Lay}	S3	t _{next}	S4		S5		S6		S7		S8		S9	Used
A	C _t	B	SMG (this tack)	C	CM (this tack)	D	SM (next tack)	E	CMG (next tack)	I	Drift								

113	F1?			169	STO2		
114	CMS			170	+HMS		
115	+			171	DSP4		
116	GSB9			172	PRTX		
117	STOE			173	RCLC		
118	PRTX	C _t next tack		174	RCLB		
119	CF3			175	-		
120	SPC			176	SIN		
121	*LBL7	Wait loop		177	RCL9		
122	PSE			178	x		
123	F3?			179	ABS		
124	GT08	Wait for new dev		180	DSP2		
125	GT07			181	GSB5		
126	*LBL0			182	RCLB		
127	RCLC			183	+		
128	XZY			184	STO3		
129	STO0			185	DSP4		
130	-			186	GSB4		
131	RCL1			187	PZS		
132	-			188	SPC		
133	GSB9			189	RTN		
134	PRTX	C _c next tack		190	*LBL4		
135	RCLC			191	+HMS		
136	RCLB			192	*LBL5		
137	RCL4			193	PRTX		
138	RCL1			194	RTN		
139	GSB8			195	*LBL6		
140	DSP2			196	PZS		
141	PRTX			197	HMS+		
142	STO0	SMG next tack		198	RCLB		
143	XZY			199	x		
144	GSB9			200	RCLC		
145	STOE			201	XZY		
146	GT05			202	CMS		
147	*LBL6	CMG next tack		203	RCL0		
148	PZS			204	RCL1		
149	STO1			205	GSB8		
150	XZY	Store D		206	PZS		
151	STO0			207	DSP2		
152	XZY	Store C _m		208	PRTX		
153	RCLC			209	XZY		
154	RCLC			210	GSB9		
155	-			211	PRTX		
156	SIN			212	RTN		
157	+			213	*LBL9		
158	STO9			214	DSP1		
159	RCLB			215	3		
160	RCLC			216	6		
161	-			217	0		
162	SIN			218	+R		
163	x			219	+P		
164	ABS			220	XZY		
165	DSP2			221	X(0?)		
166	PRTX			222	+		
167	RCLD	Distance along lay line		223	RTN		
168	+						

LABELS					FLAGS	SET STATUS			
A ₀ †STW ₀ †t	B PORT	C STBD	D S ₁ †D	E C _m †D	0	FLAGS	TRIG	DISP	
a	b	c	d	e Δt→C _m ,D	1	0 ☐ ON ☐ OFF	DEG ☐	FIX ☐	
0	1	2	3	4	2	1 ☐ ☐ ☐	GRAD ☐	SCI ☐	
5	6	7	8	9	3	2 ☐ ☐ ☐	RAD ☐	ENG ☐	
						3 ☐ ☐ ☐		n 2	



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