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-65 and Navigation Pac 1 as insurance against calculator failure or battery discharge.

PRINTED IN U.S.A.

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; Commander Basil DeOliviera, 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.).

TABLE OF CONTENTS

Appendices

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 (***).

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.MS	Degrees, minutes, and seconds
Dr	Drift
GMT	Greenwich Mean Time
H	Height (a vertical distance)
H_c	Computed height (an angle)
HE	Height of eye
h_s	Sextant height (an angle)
L	Latitude
M	Month
R	Range
S	Speed
Sa	Apparent speed
St	Set
SD	Semidiameter
t	Time
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? A	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 A	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 A	This special command indicates that the last value or set of values input may be deleted by pressing A.
x; ... A	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

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 Naviagtion'' 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	f 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°40′N, 120°10′W) to Honolulu (21°16′N, 157°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 f A
21.16 ENTER↑ 157.50 A B → 2124.6341 distance
259.3521 initial course

Load "Estimated Time of Arrival"

8 f A 10 A 17 C
25.12 E D → 20.0901 The voyage begins at 0900 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 f A 8 A same time zone
597 B 50 C .1440 D E → 1.0236

He arrives at 0236 the following morning.

GREAT CIRCLE AND RHUMBLINE NAVIGATION

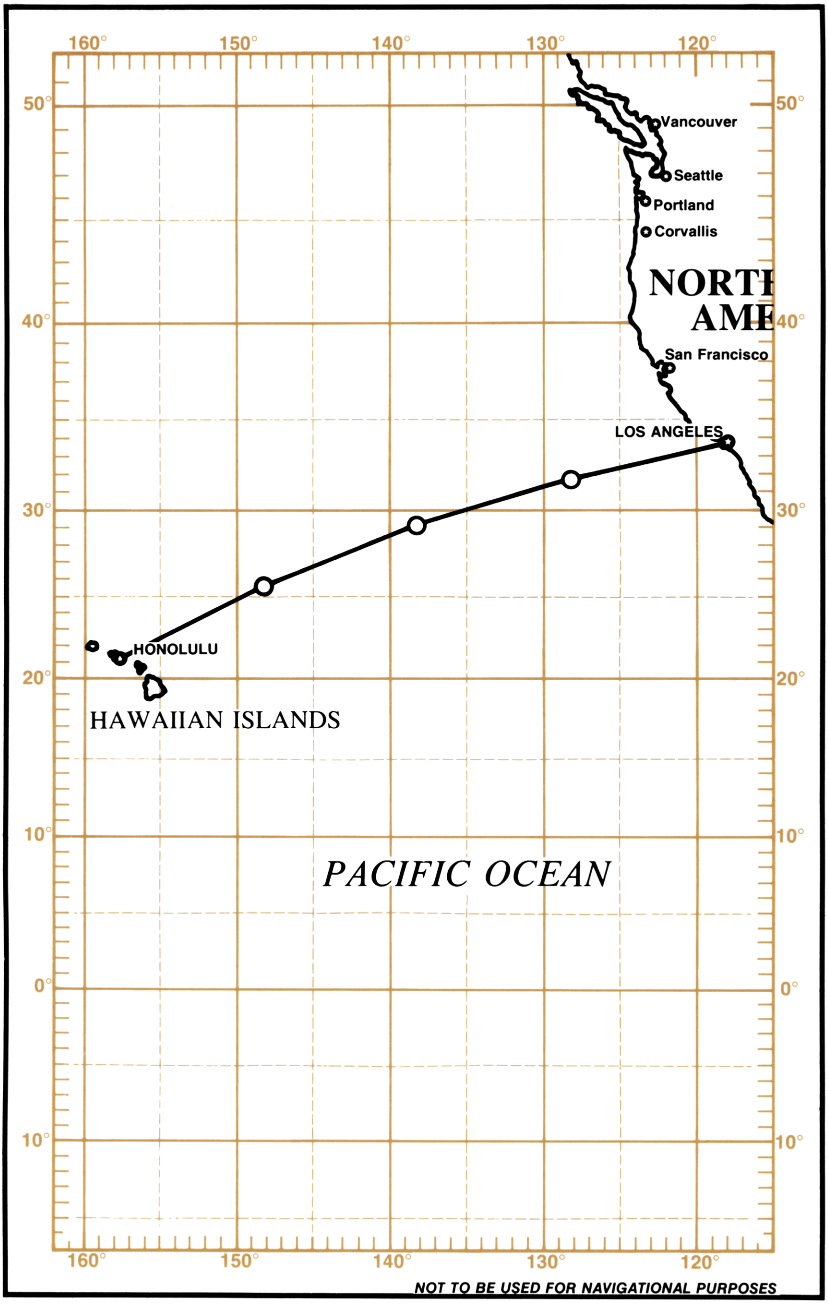
This program computes the great-circle distance between two points. It also may be used to produce a list of points on that great circle which are separated by a specified longitude difference. The list of great-circle points is printed along with the rhumbline courses and distances between successive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

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load program			
2	Key in intial 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	
			→H.MS	$\Delta\lambda$, D.MS
*	The output is:			
	L_1			
	λ_1			
	C			
	D			
	$L_1 + \Delta L_1$			
	$\lambda_1 + \Delta\lambda$			
	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
			× COS⁻¹	L_{max}

Example:
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 rhumblines to approximate the great-circle track between the two points. Use a 10° longitude increment.

Keystrokes:	Outputs:
Load "Great Circle and Rhumbline Navigation"	
33.45 ENTER↑ 118.15 f A	
21.18 ENTER↑ 157.52 A B →	2220.4104 *** distance
	260.7546 *** initial course
10 C D →	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 ***


160°
150°
140°
130°
120°
50°
40°
30°
20°
10°
0°
10°
Vancouver
Seattle
Portland
Corvallis
NORTH AME
San Francisco
LOS ANGELES
HONOLULU
HAWAIIAN ISLANDS
PACIFIC OCEAN
NOT TO BE USED FOR NAVIGATIONAL PURPOSES

Example:

A well-known amateur naviagator sailed from St. George's Harbor, Bermuda, (32°23′N, 64°41′W), to Horta, Fayal Island, (38°32′N, 28°38′W). Plot the great-circle track at 5 degree intervals.

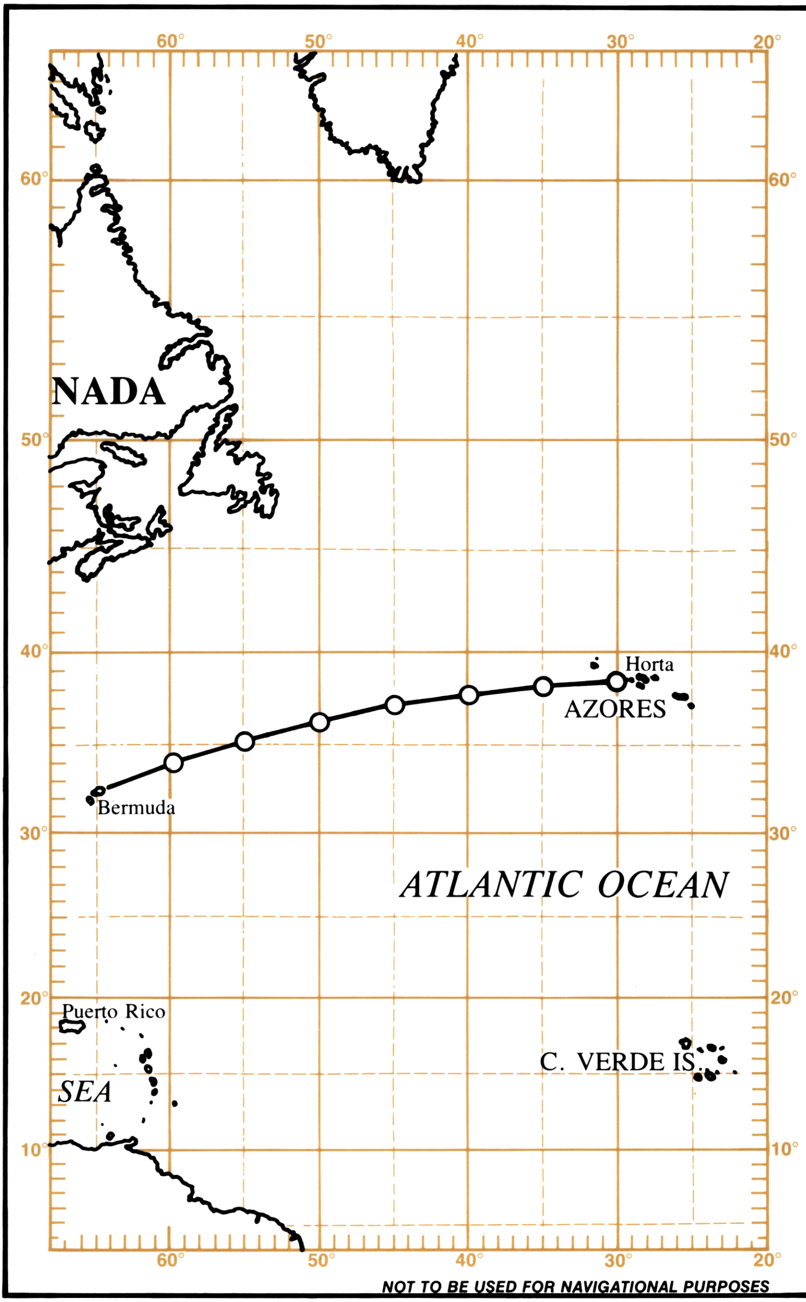
Keystrokes:	Outputs:
32.23 ENTER↑ 64.41 f A	
38.32 ENTER↑ 23.38 A B ⟶	1788.1514 *** distance
	67.8537 *** initial C.C. course
5 CHS C D ⟶	32.2300 *** St. George's
	64.4100 *** Harbor
	69. *** course
	269. *** distance
	33.5820 ***
	59.4100 ***
	72. ***
	260. ***
	35.1831 ***
	54.4100 ***
	75. ***
	252. ***
	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. ***

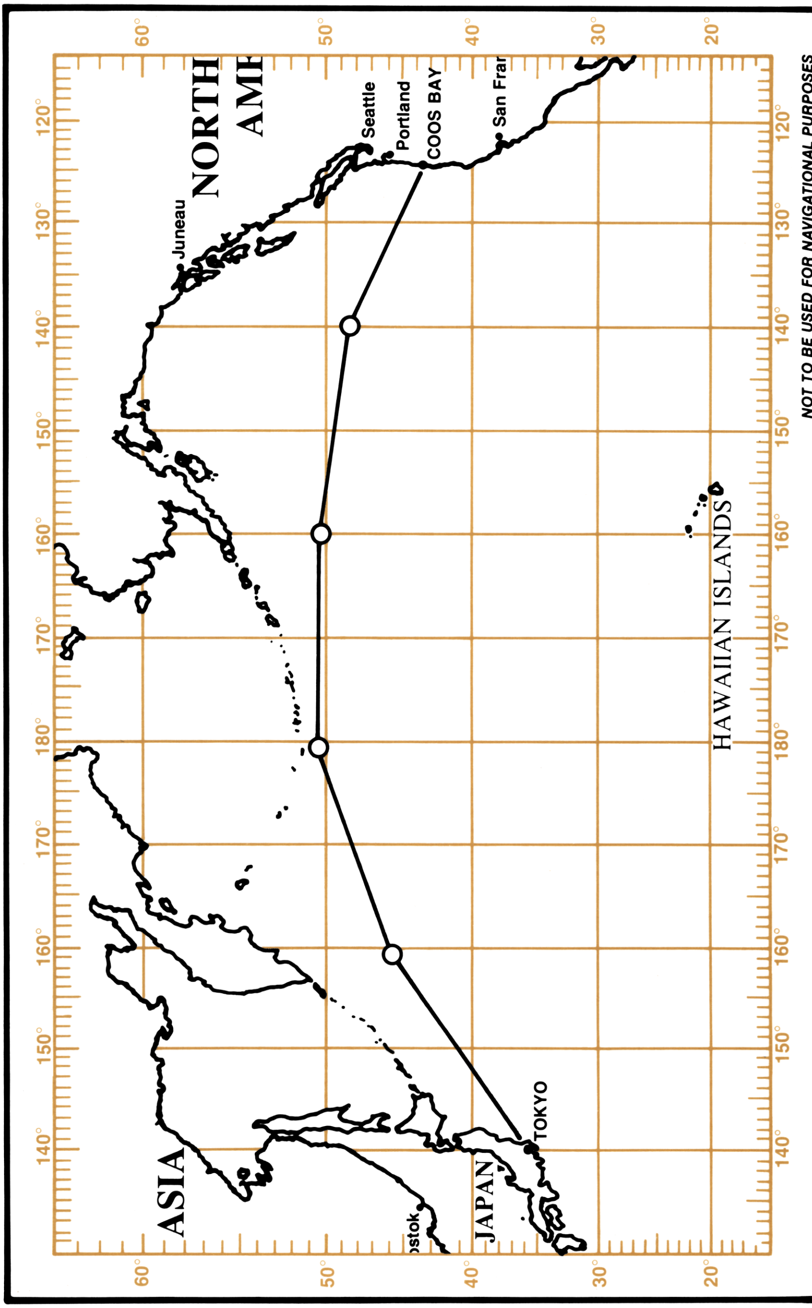
38.3200 *** Horta
28.3800 ***


60°
50°
40°
30°
20°
60°
60°
NADA
50°
50°
40°
40°
Horta
AZORES
Bermuda
30°
30°
ATLANTIC OCEAN
20°
20°
Puerto Rico
C. VERDE IS.
SEA
10°
10°
60°
50°
40°
30°
20°
NOT TO BE USED FOR NAVIGATIONAL PURPOSES

Example:

A ship leaves Tokyo (35°40′N, 139°45′E) bound for Coos Bay, Oregon (43°22′N, 124°13′W). Plot her position in 20° increments.

Keystrokes:	Outputs:	
35.4 ENTER↑ 139.45 CHS f		
A 43.22 ENTER↑ 124.13		
A B ⟶	4213.6169 ***	
	50.1964 ***	
20 CHS C D ⟶	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 ***	



NORTH AME
ASIA
JAPAN
HAWAIIAN ISLANDS
Juneau
Seattle
Portland
COOS BAY
San Fran
TOKYO
ostok
60°
50°
40°
30°
20°
120°
130°
140°
150°
160°
170°
180°
NOT TO BE USED FOR NAVIGATIONAL PURPOSES

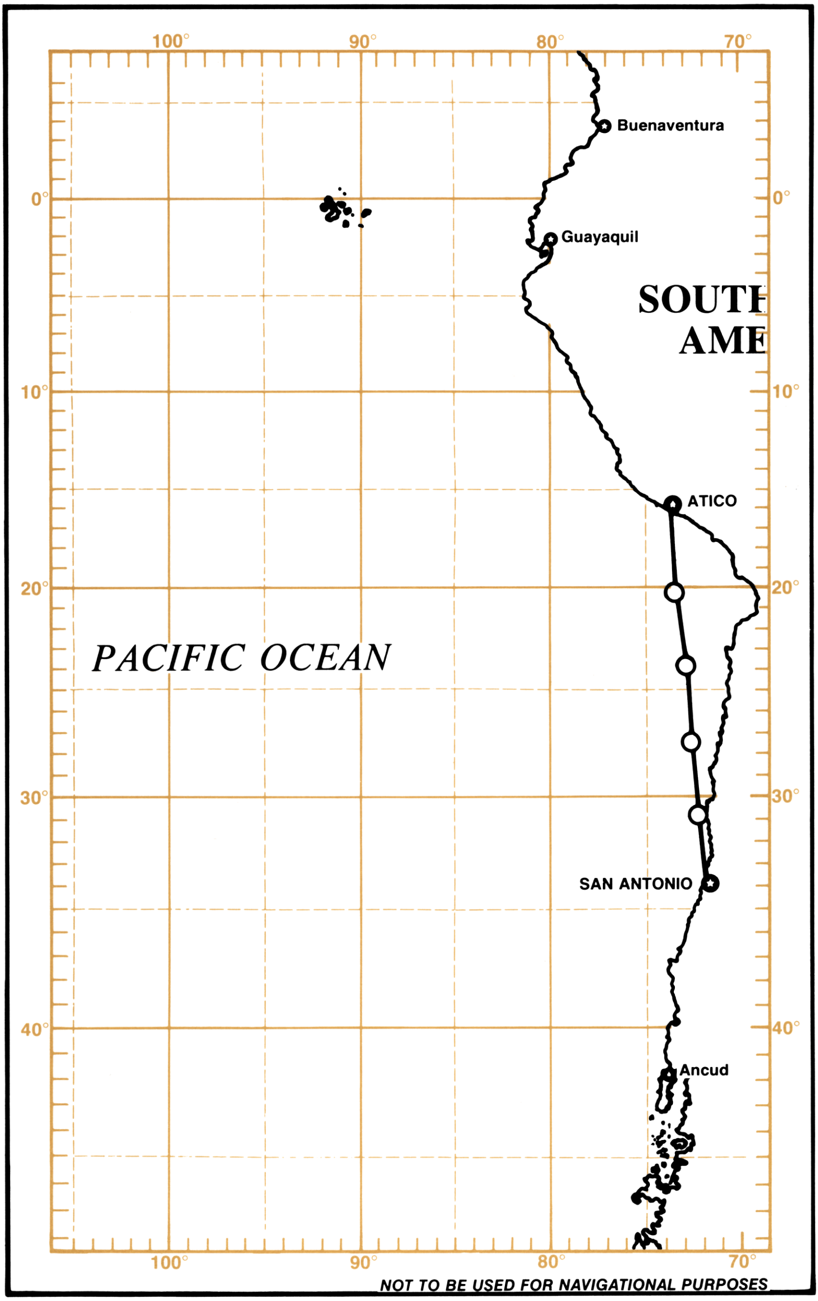
Example:

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

Keystrokes:	Outputs:
16.14 [CHS] [ENTER↑] 73.37 [f] [A]	
33.35 [CHS] [ENTER↑] 71.38	
[A] [B] →	1046.5098 ***
	174.4801 ***
.24 [CHS] [C] [D] →	-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] [→H.MS] [C] [D] →	-16.1400 ***
	73.3700 ***
	174. ***
	1047. ***
	-33.3500 ***
	71.3800 ***


100°
90°
80°
70°
0°
10°
20°
30°
40°
Buenaventura
Guayaquil
SOUTH
AME
ATICO
PACIFIC OCEAN
SAN ANTONIO
Ancud
NOT TO BE USED FOR NAVIGATIONAL PURPOSES

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 C	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:

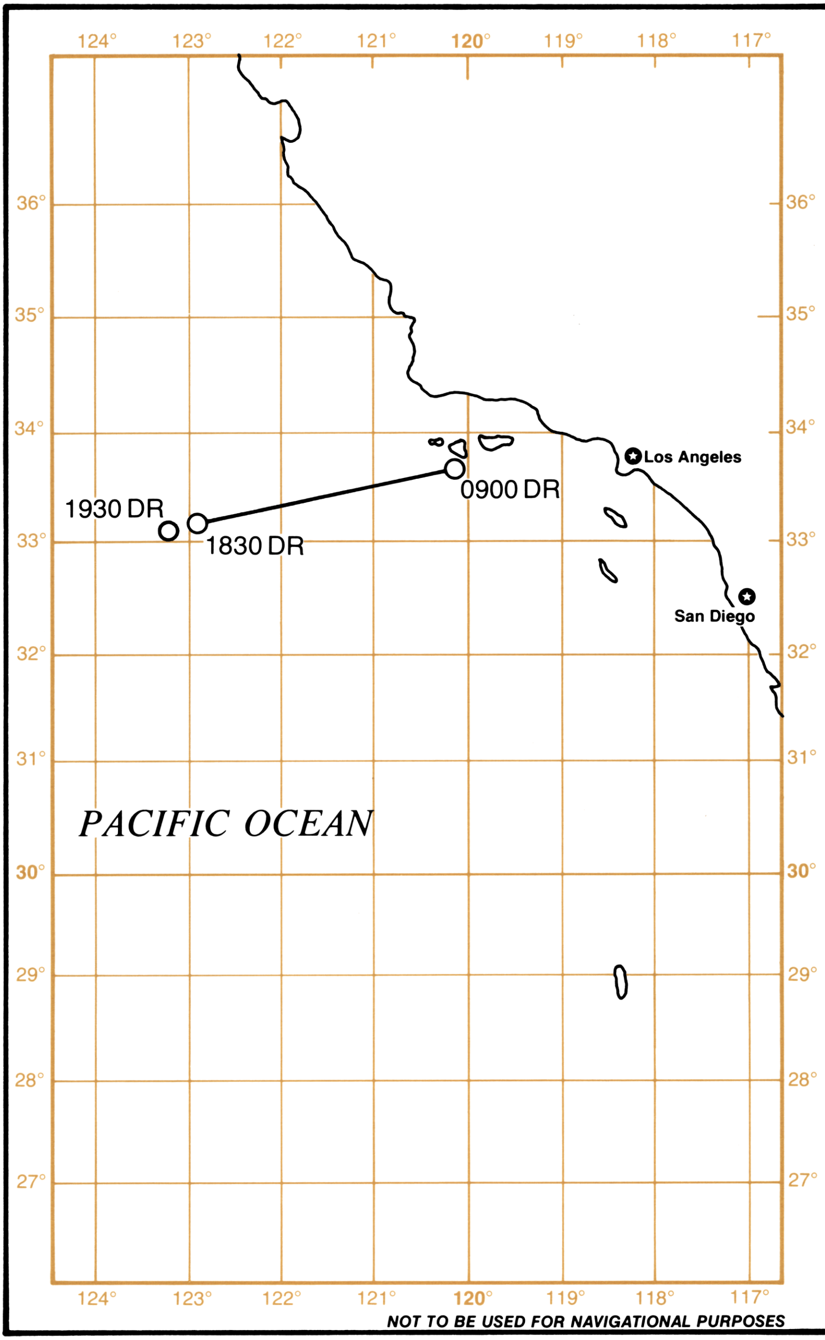
A vessel departs at 0900 from 33°40′N, 120°10′W, on course 258 true at 15 knots. Predict her position at 1830.

Keystrokes	Outputs
33.40 ENTER↑ 120.10 A 0	
ENTER↑ 0 f B 258 B 15	
C 9 D 18.30 E ⟶	18.3000 ***
	33.1022 *** 33°10′22″
	122.5660 *** 122°57′00″
	258.0 ***
	15.0 ***

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:	Outputs:
.20 f E ⟶	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.


124°
123°
122°
121°
120°
119°
118°
117°
36°
35°
34°
33°
32°
31°
30°
29°
28°
27°
1930 DR
1830 DR
0900 DR
Los Angeles
San Diego
PACIFIC OCEAN
NOT TO BE USED FOR NAVIGATIONAL PURPOSES

Example 3:

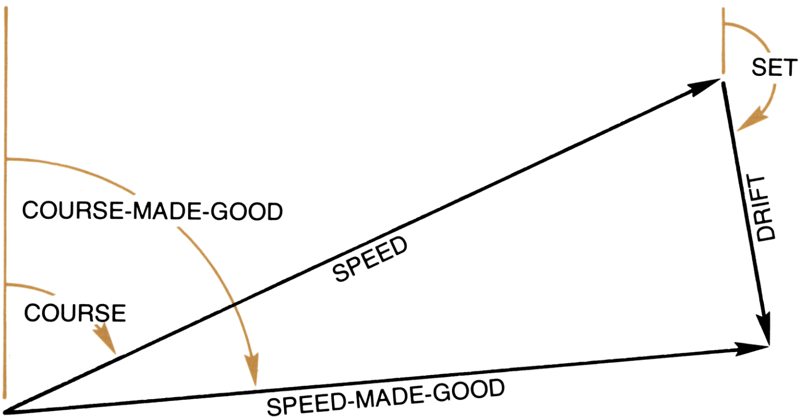
On February 10, 1977 at 0300 GMT a ship leaves Tokyo (35°N, 140°10′E) at 17.8 knots on course 056° bound for Coos Bay, Oregon (43°22′N, 124°13′W). What DR should her navigator use for a Sun sight at 0700 GMT?

Keystrokes:	**Outputs:**
35 ENTER↑ 140.1 CHS A 0	
ENTER↑ 0 f B 56 B 17.8	
C 3 D 7 E ⟶	7.0000 ***
	35.3949 *** latitude
	-141.2221 *** longitude
	56.0 *** course
	17.8 *** speed

Notes

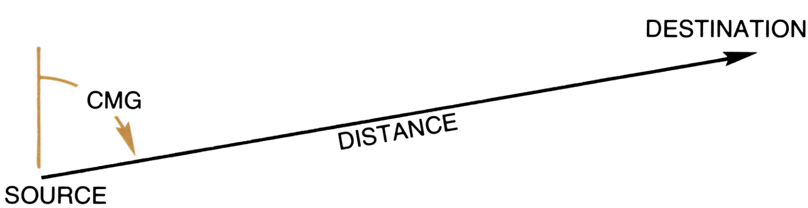
VELOCITY TRIANGLE and COURSE TO STEER

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	none	f E	Dist., n. mi.
	and course to make good		R/S	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 magentic variation is 20°.5E and there is a 2 knot current setting 090°. What course should she steer?

Keystrokes:	**Outputs:**	
20.5 ENTER↑ 0 f A		
45 ENTER↑ 124.40 f D		
44.40 ENTER↑ 124.10 D f E →	29.20	Distance

R/S ⟶	133.23	Desired true course
90 ENTER↑ 2 B 6 E ⟶	125.93	Compass course
R/S ⟶	4.00	
R/S ⟶	7.30	Speed-made-good

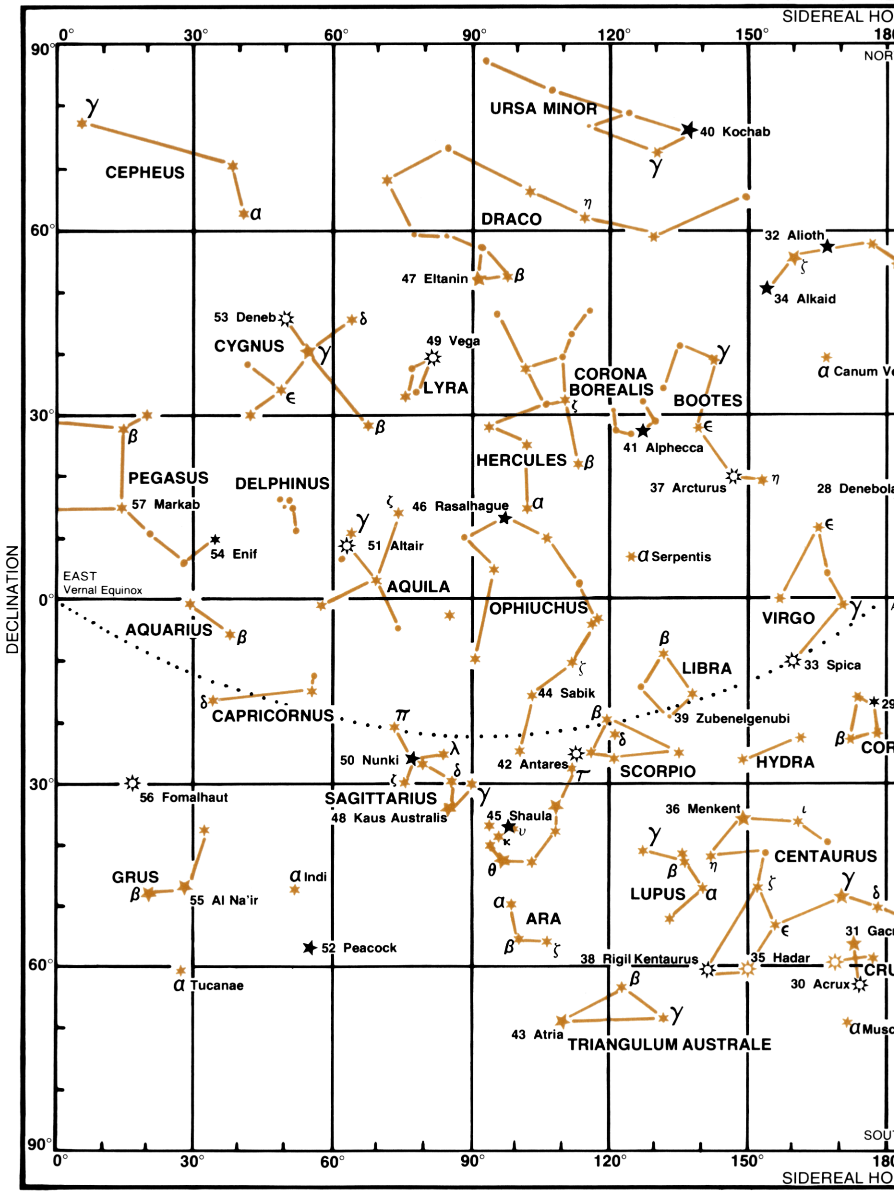
STAR SIGHT PLANNING

This program produces a list of selected stars that are above the horizon at any place and time. The stars are those used in Volume 1 of H.O. 249. From the list produced by this program, a navigator can easily select stars which are well-distributed in azimuth.

The altitudes computed by the program are displayed to two places in the format D.M to distinguish them from azimuths which are displayed to one decimal place in the format D.d. Even though altitudes are expressed in degrees and minutes, it is doubtful that they are accurate to more than the nearest degree.

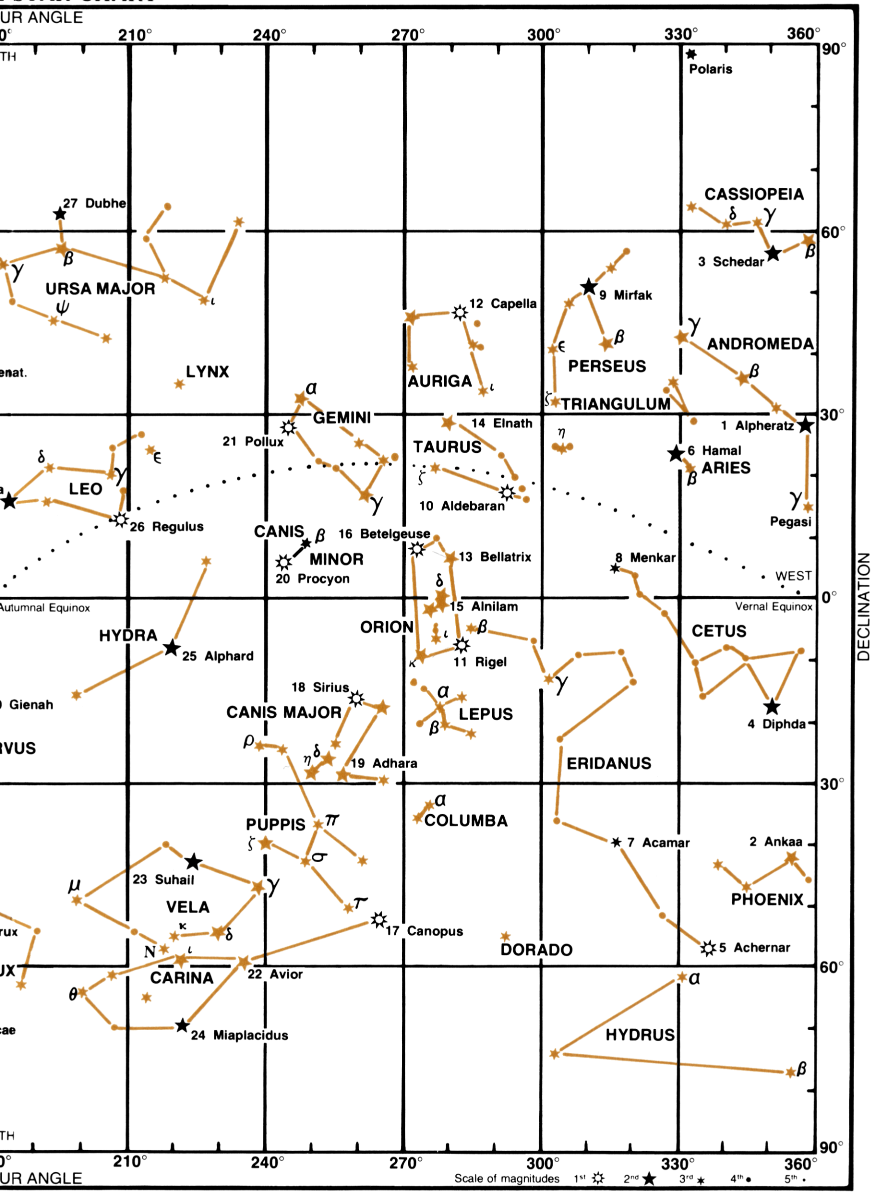
Since most star sights are made during twilight, this program also computes the approximate time of the end (or beginning) of civil twilight which corresponds to the middle of the period known as nautical twilight. In polar latitudes during certain seasons, this feature will not work because twilight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

NAVIGATIONAL



Fold-out

L STAR CHART


UR ANGLE
0°
210°
240°
270°
300°
330°
360°
TH
90°
Polaris
CASSIOPEIA
3 Schedar
60°
27 Dubhe
URSA MAJOR
LYNX
enat.
12 Capella
AURIGA
9 Mirfak
PERSEUS
ANDROMEDA
TRIANGULUM
GEMINI
21 Pollux
14 Elnath
TAURUS
1 Alpheratz
30°
6 Hamal
ARIES
LEO
26 Regulus
10 Aldebaran
Pegasi
CANIS
MINOR
16 Betelgeuse
13 Bellatrix
20 Procyon
8 Menkar
WEST
0°
Autumnal Equinox
Vernal Equinox
15 Alnilam
HYDRA
ORION
CETUS
25 Alphard
11 Rigel
Gienah
18 Sirius
CANIS MAJOR
LEPUS
4 Diphda
RVUS
ERIDANUS
19 Adhara
30°
COLUMBA
PUPPIS
7 Acamar
2 Ankaa
23 Suhail
VELA
PHOENIX
rux
17 Canopus
DORADO
5 Achernar
UX
CARINA
22 Avior
60°
HYDRUS
cae
24 Miaplacidus
TH
90°
0°
210°
240°
270°
300°
330°
360°
UR ANGLE
Scale of magnitudes 1st 2nd 3rd 4th 5th
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′kẽr·när	336	S. 57
Acrux	30	ā′krŭks	174	S. 63
Aldebaran	10	ăl dĕb′ȧ·răn	291	S. 16
Alioth	32	ăl′ĭ·ŏth	167	N. 56
Alkaid	34	ăl·kad′	153	N. 49
Alphard	25	ăl′färd	218	S. 9
Alphecca	41	ăl·fĕk′ǡ	127	N. 27
Alpheratz	1	ăl·fē′rats	358	N. 29
Altair	51	ăl·tār′	63	N. 9
Antares	42	ăn·tā′rēz	113	S. 26
Arcturus	37	ärk·tū′rŭs	146	N. 19
Betelgeuse	16	bĕt′ĕl·jūz	272	N. 7
Canopus	17	kȧ·nō′pŭs	264	S. 53
Capella	12	kȧ·pĕl′ǡ	281	N. 46
Deneb	53	dĕn′ĕb	50	N. 45
Denebola	28	dĕ nĕb′ō̇·lǡ	183	N. 15
Diphda	4	dĭf′dǡ	349	S. 18
Dubhe	27	dŭb′ē	194	N. 62
Enif	54	ĕn′ĭf	34	N. 10
Fomalhaut	56	fō′măl·ôt	16	S. 30
Hamal	6	hăm′ȧl	329	N. 23
Kochab	40	kō′kăb	137	N. 74
Menkar	8	mĕn′kär	315	N. 4
Miaplacidus	24	mī′ȧ·plăs′ĭ·dŭs	222	S. 70
Mirfak	9	mĭr′făk	309	N. 50
Nunki	50	nŭn′kē	77	S. 26
Peacock	52	pē′kŏk	54	S. 57
Pollux	21	pŏl′ŭks	244	N. 28
Polaris	0	pō̇·lā′rĭs	0	N. 90
Procyon	20	prō′sĭ·ŏn	245	N. 5
Rasalhague	46	rȧs′ăl·hā′gwē	97	N. 13
Regulus	26	rĕg′ū̇·lŭs	208	N. 12
Rigel	11	rī′jĕl	282	S. 8
Rigil Kentaurus	38	rī′jĭl kĕn·tô′rŭs	140	S. 61
Schedar	3	shĕd′ǡr	350	N. 56
Shaula	45	shô′lǡ	97	S. 37
Sirius	18	sĭr′ĭ·ŭs	259	S. 17
Spica	33	spī′kǡ	159	S. 11
Suhail	23	so͞o·hāl′	223	S. 43
Vega	49	vē′gǡ	81	N. 39

Guide to pronunciations:

fāte, ădd, finăl, lȧst, ǡbound, ärm; bē, ĕnd, camĕl, readẽr; īce, bĭt, anĭmal; ōver, pō̇etic, hŏt, lôrd, mo͞on; cūbe, ūnite, tŭb, circŭs, ûrn.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load Star Data Card			
2	Load Star Sight Planning			
	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: **Outputs:**

The keystrokes are left for the reader.

Notes

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 preceeding 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	f	
	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⇄y	Z_n
10	To precompute a sextant set-			
	ting 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:	Outputs:	
38 ENTER↑ 32 f A 10		
f B f C ⟶	0.00	repeat f C until 0.00 appears
16.25 A		
11.0636 ENTER↑ 26.0642 B		
18.4012 ENTER↑ 18.3924		
C E ⟶	66.5327	sextant altitude
R/S ⟶	142.5104	azimuth

Example 2:

Where will Venus be found at 1650?

Keystrokes:	Outputs:
16.50 f E E ⟶	69.2243
R/S ⟶	156.9574

1975 JUNE 18, 19, 20 (WED., THURS., FRI.)

G.M.T. d h	ARIES G.H.A. ° ′	VENUS −3.9 G.H.A. ° ′	VENUS Dec. ° ′	MARS +0.8 G.H.A. ° ′	MARS Dec. ° ′	JUPITER −1.9 G.H.A. ° ′	JUPITER Dec. ° ′	SATURN +0.4 G.H.A. ° ′	SATURN Dec. ° ′
18 (Wednesday) 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
01	280 39.3	146 03.1	12.1	261 02.9	28.4	261 59.3	34.6	170 06.7	01.1
02	295 41.8	161 03.2	11.3	276 03.7	29.1	277 01.4	34.7	185 08.9	01.1
03	310 44.2	176 03.3	· · 10.5	291 04.5	· · 29.8	292 03.4	· · 34.9	200 11.0	· · 01.1
04	325 46.7	191 03.3	09.7	306 05.2	30.5	307 05.5	35.0	215 13.1	01.0
05	340 49.2	206 03.4	08.9	321 06.0	31.2	322 07.6	35.2	230 15.3	01.0
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 00.9
07	10 54.1	236 03.5	07.2	351 07.5	32.5	352 11.8	35.5	260 19.5	00.9
08	25 56.6	251 03.6	06.4	6 08.3	33.2	7 13.9	35.6	275 21.7	00.9
09	40 59.0	266 03.7	· · 05.6	21 09.1	· · 33.9	22 16.0	· · 35.7	290 23.8	· · 00.8
10	56 01.5	281 03.8	04.8	36 09.8	34.6	37 18.1	35.9	305 25.9	00.8
11	71 03.9	296 03.8	04.0	51 10.6	35.3	52 20.2	36.0	320 28.1	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
13	101 08.9	326 04.0	02.4	81 12.1	36.6	82 24.4	36.3	350 32.4	00.7
14	116 11.3	341 04.1	01.6	96 12.9	37.3	97 26.5	36.4	5 34.5	00.6
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
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
17	161 18.7	26 04.3	59.1	141 15.2	39.3	142 32.7	36.9	50 40.9	00.5
18	176 21.2	41 04.4	N18 58.3	156 16.0	N 6 40.0	157 34.8	N 6 37.0	65 43.0	N22 00.5
19	191 23.7	56 04.5	57.5	171 16.7	40.7	172 36.9	37.1	80 45.2	00.4
20	206 26.1	71 04.6	56.7	186 17.5	41.4	187 39.0	37.3	95 47.3	00.4
21	221 28.6	86 04.7	· · 55.9	201 18.3	· · 42.1	202 41.1	· · 37.4	110 49.4	· · 00.3
22	236 31.1	101 04.8	55.0	216 19.0	42.8	217 43.2	37.6	125 51.6	00.3
23	251 33.5	116 04.8	54.2	231 19.8	43.4	232 45.3	37.7	140 53.7	00.3
19 (Thursday) 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
01	281 38.4	146 05.0	52.6	261 21.3	44.8	262 49.5	38.0	170 58.0	00.2
02	296 40.9	161 05.1	51.8	276 22.1	45.5	277 51.6	38.1	186 00.1	00.1
03	311 43.4	176 05.2	· · 50.9	291 22.9	· · 46.2	292 53.7	· · 38.3	201 02.2	· · 00.1
04	326 45.8	191 05.3	50.1	306 23.6	46.8	307 55.8	38.4	216 04.4	00.1
05	341 48.3	206 05.4	49.3	321 24.4	47.5	322 57.9	38.5	231 06.5	00.0
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 08.6	N22 00.0
07	11 53.2	236 05.6	47.7	351 25.9	48.9	353 02.1	38.8	261 10.8	21 59.9
08	26 55.7	251 05.7	46.8	6 26.7	49.5	8 04.2	39.0	276 12.9	59.9
09	41 58.2	266 05.8	· · 46.0	21 27.5	· · 50.2	23 06.3	· · 39.1	291 15.0	· · 59.9
10	57 00.6	281 05.9	45.2	36 28.2	50.9	38 08.4	39.2	306 17.2	59.8
11	72 03.1	296 06.0	44.4	51 29.0	51.6	53 10.5	39.4	321 19.3	59.8
12	87 05.5	311 06.1	N18 43.5	66 29.8	N 6 52.3	68 12.6	N 6 39.5	336 21.4	N21 59.7
13	102 08.0	326 06.3	42.7	81 30.5	52.9	83 14.7	39.7	351 23.6	59.7
14	117 10.5	341 06.4	41.9	96 31.3	53.6	98 16.7	39.8	6 25.7	59.7
15	132 12.9	356 06.5	· · 41.1	111 32.1	· · 54.3	113 18.8	· · 39.9	21 27.8	· · 59.6
16	147 15.4	**11 06.6**	**40.2**	126 32.8	55.0	128 20.9	40.1	36 30.0	59.6
17	162 17.9	**26 06.7**	**39.4**	141 33.6	55.7	143 23.0	40.2	51 32.1	59.5
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
19	192 22.8	56 06.9	37.8	171 35.1	57.0	173 27.2	40.5	81 36.4	59.5
20	207 25.3	71 07.1	36.9	186 35.9	57.7	188 29.3	40.6	96 38.5	59.4
21	222 27.7	86 07.2	· · 36.1	201 36.7	· · 58.4	203 31.4	· · 40.8	111 40.6	· · 59.4
22	237 30.2	101 07.3	35.3	216 37.4	59.0	218 33.5	40.9	126 42.7	59.3
23	252 32.7	116 07.4	34.4	231 38.2	6 59.7	233 35.6	41.0	141 44.9	59.3
20 (Friday) 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
01	282 37.6	146 07.7	32.8	261 39.7	01.1	263 39.8	41.3	171 49.1	59.2
02	297 40.0	161 07.8	31.9	276 40.5	01.7	278 41.9	41.5	186 51.3	59.2
03	312 42.5	176 07.9	· · 31.1	291 41.3	· · 02.4	293 44.0	· · 41.6	201 53.4	· · 59.1
04	327 45.0	191 08.0	30.3	306 42.0	03.1	308 46.1	41.7	216 55.5	59.1
05	342 47.4	206 08.2	29.4	321 42.8	03.8	323 48.2	41.9	231 57.7	59.1
06	357 49.9	221 08.3	N18 28.6	336 43.6	N 7 04.5	338 50.3	N 6 42.0	246 59.8	N21 59.0
07	12 52.4	236 08.4	27.8	351 44.3	05.1	353 52.4	42.1	262 01.9	59.0
08	27 54.8	251 08.6	26.9	6 45.1	05.8	8 54.5	42.3	277 04.1	58.9
09	42 57.3	266 08.7	· · 26.1	21 45.9	· · 06.5	23 56.6	· · 42.4	292 06.2	· · 58.9
10	57 59.8	281 08.8	25.3	36 46.6	07.2	38 58.7	42.6	307 08.3	58.9
11	73 02.2	296 09.0	24.4	51 47.4	07.8	54 00.8	42.7	322 10.5	58.8
12	88 04.7	311 09.1	N18 23.6	66 48.2	N 7 08.5	69 02.9	N 6 42.8	337 12.6	N21 58.8
13	103 07.2	326 09.2	22.8	81 48.9	09.2	84 05.0	43.0	352 14.7	58.7
14	118 09.6	341 09.4	21.9	96 49.7	09.9	99 07.2	43.1	7 16.9	58.7
15	133 12.1	356 09.5	· · 21.1	111 50.5	· · 10.5	114 09.3	· · 43.2	22 19.0	· · 58.7
16	148 14.5	11 09.7	20.2	126 51.2	11.2	129 11.4	43.4	37 21.1	58.6
17	163 17.0	26 09.8	19.4	141 52.0	11.9	144 13.5	43.5	52 23.3	58.6
18	178 19.5	41 10.0	N18 18.6	156 52.8	N 7 12.6	159 15.6	N 6 43.6	67 25.4	N21 58.5
19	193 21.9	56 10.1	17.7	171 53.5	13.2	174 17.7	43.8	82 27.5	58.5
20	208 24.4	71 10.3	16.9	186 54.3	13.9	189 19.8	43.9	97 29.6	58.5
21	223 26.9	86 10.4	· · 16.1	201 55.1	· · 14.6	204 21.9	· · 44.1	112 31.8	· · 58.4
22	238 29.3	101 10.6	15.2	216 55.8	15.2	219 24.0	44.2	127 33.9	58.4
23	253 31.8	116 10.7	14.4	231 56.6	15.9	234 26.1	44.3	142 36.0	58.3
Mer. Pass.	h m 6 12.6	v 0.1	d 0.8	v 0.8	d 0.7	v 2.1	d 0.1	v 2.1	d 0.0

STARS

Name	S.H.A. ° ′	Dec. ° ′
Acamar	315 40.3	S40 24.0
Achernar	335 48.2	S57 21.4
Acrux	173 41.1	S62 58.2
Adhara	255 35.3	S28 56.4
Aldebaran	291 22.4	N16 27.6
Alioth	166 45.5	N56 05.8
Alkaid	153 21.0	N49 26.3
Al Na'ir	28 19.2	S47 04.5
Alnilam	276 15.6	S 1 13.1
Alphard	218 24.3	S 8 33.3
Alphecca	126 34.8	N26 47.9
Alpheratz	358 13.0	N28 57.2
Altair	62 35.7	N 8 48.2
Ankaa	353 43.8	S42 26.0
Antares	113 00.9	S26 22.7
Arcturus	146 21.5	N19 18.6
Atria	108 27.8	S68 59.1
Avior	234 30.2	S59 26.1
Bellatrix	279 02.9	N 6 19.6
Betelgeuse	271 32.5	N 7 24.1
Canopus	264 09.3	S52 41.0
Capella	281 17.0	N45 58.4
Deneb	49 50.5	N45 11.5
Denebola	183 02.7	N14 42.5
Diphda	349 24.5	S18 07.1
Dubhe	194 26.6	N61 53.2
Elnath	278 49.0	N28 35.2
Eltanin	90 58.8	N51 29.6
Enif	34 14.9	N 9 45.8
Fomalhaut	15 55.2	S29 44.9
Gacrux	172 32.6	S56 58.9
Gienah	176 21.6	S17 24.5
Hadar	149 28.0	S60 15.6
Hamal	328 33.1	N23 20.7
Kaus Aust.	84 21.2	S34 23.7
Kochab	137 18.0	N74 15.6
Markab	14 06.6	N15 04.4
Menkar	314 45.1	N 3 59.6
Menkent	148 41.0	S36 15.2
Miaplacidus	221 46.3	S69 37.3
Mirfak	309 21.6	N49 46.3
Nunki	76 33.2	S26 19.6
Peacock	54 03.5	S56 48.6
Pollux	244 02.9	N28 05.2
Procyon	245 29.8	N 5 17.2
Rasalhague	96 32.5	N12 34.7
Regulus	208 13.9	N12 05.2
Rigel	281 39.8	S 8 13.8
Rigil Kent.	140 30.2	S60 44.3
Sabik	102 44.9	S15 41.7
Schedar	350 13.2	N56 24.0
Shaula	97 00.2	S37 05.2
Sirius	258 59.2	S16 41.1
Spica	159 01.2	S11 02.1
Suhail	223 13.7	S43 20.3
Vega	80 57.8	N38 45.7
Zuben'ubi	137 36.7	S15 56.5

	S.H.A. ° ′	Mer. Pass. h m
Venus	224 29.0	15 16
Mars	339 44.6	7 34
Jupiter	341 11.4	7 28
Saturn	249 19.8	13 34

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↑	360.0
	Month	M	ENTER↑	
	Day	D	A	
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.			

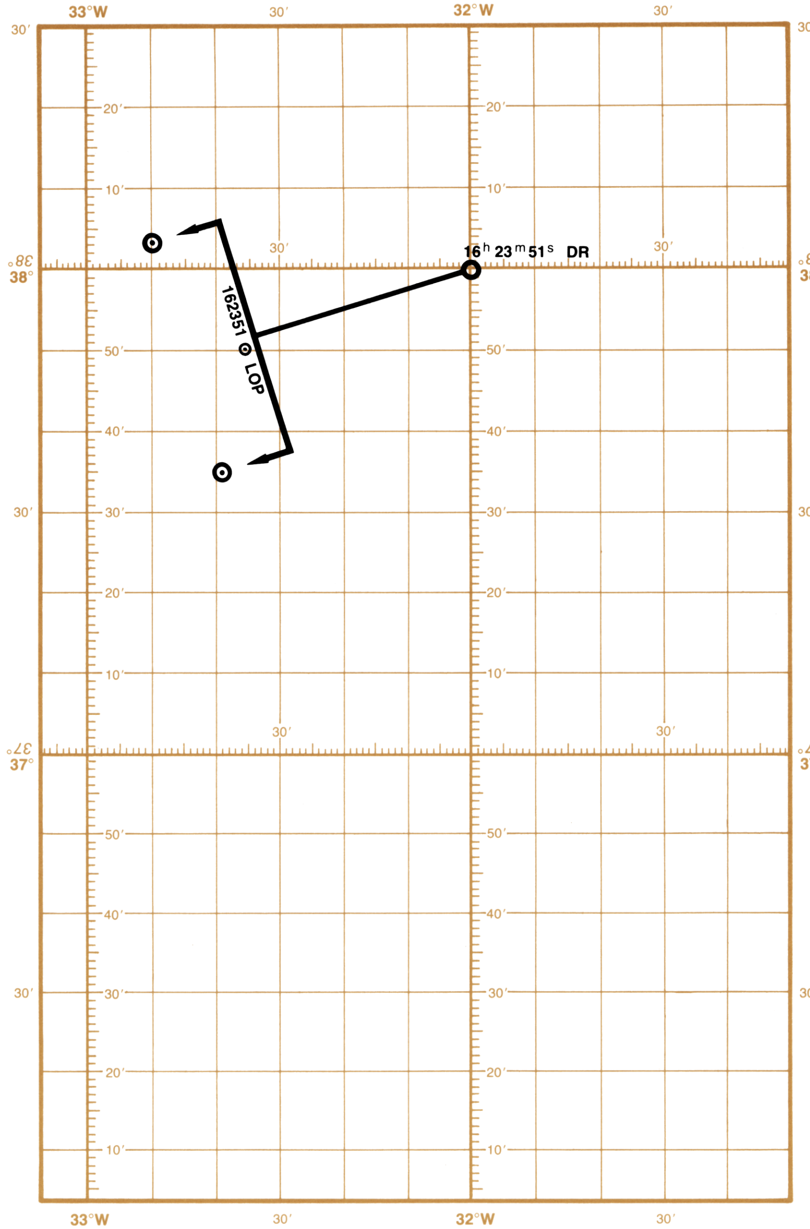
STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
	To use this program with other			
	cards in the LOP series, press			
	[P⇄S] before running another			
	LOP card, then run the FIX			
	card.			
	To store the results of two Sun			
	sights, press [P⇄S] between			
	sights and run again starting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

Example:

On June 19, 1975, a navigator obtained an uncorrected altitude of 58°06′ for the Sun at $16^h23^m51^s$ 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:	Outputs:	
38 [ENTER↑] 32 [f] [A] 10 [f] [B]		
1975 [ENTER↑] 6 [ENTER↑] 19		
[A] 16.2351 [B] ⟶	252.9 ***	Z_n
	57.5007	H_c (in display)
58.06 [D] ⟶	−28.0	28 miles toward

07-03



Notes

STAR LINE OF POSITION

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 abberation, 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.

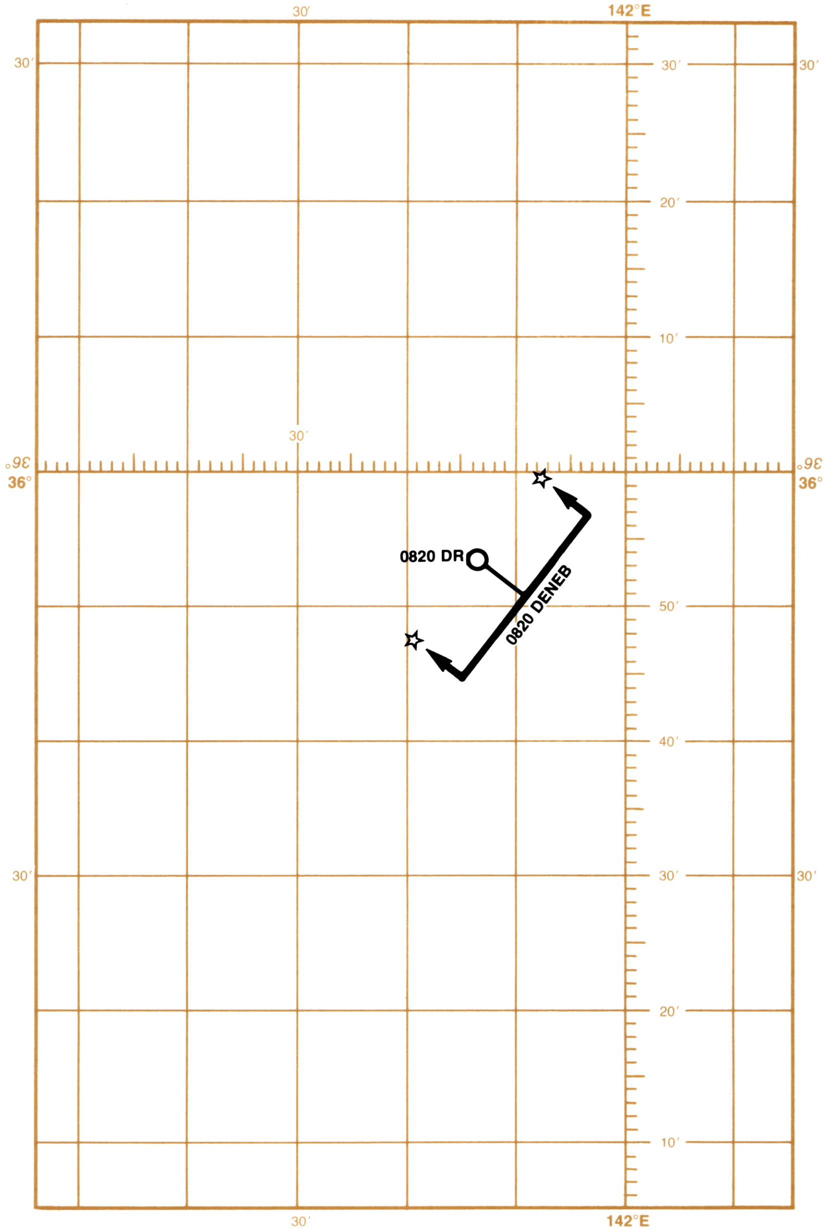
Star lines obtained using this program may be combined with position lines derived from other programs in this pac. Simply press [P⇌S] between LOP's and then run the position fixing program.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS	OUTPUT DATA/UNITS
1	Load one of the STAR DATA			
	cards and select the appropri-			
	ate 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	f A	
4	Key in height of eye and com-			
	pute dip	HE, feet	f 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, H.MS	C	a, miles

Example:

A navigator at (35°53′05″N, 141°46′36″E) shoots Deneb from a height of eye of 65 feet on February 10, 1977, at 0820 GMT. His sextant reading is 20°25′. Plot the LOP.

Keystrokes:	**Outputs:**	
Load Star Data 3		
f C (Deneb) ⟶	45.17	ignore display
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 ⟶	311.8 ***	Z_n
	20.1843	H_c
20.25 C ⟶	4.1	away



30′
142°E
30′
20′
10′
30′
36°
50′
40′
30′
20′
10′
0820 DR
0820 DENEB

BEARING LINE OF POSITION

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 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.	R/S	
	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	R/S	
	For a Stationary Fix			
3	Compute fix latitude	none	D	L, D.MS
	longitude		R/S	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 While 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?

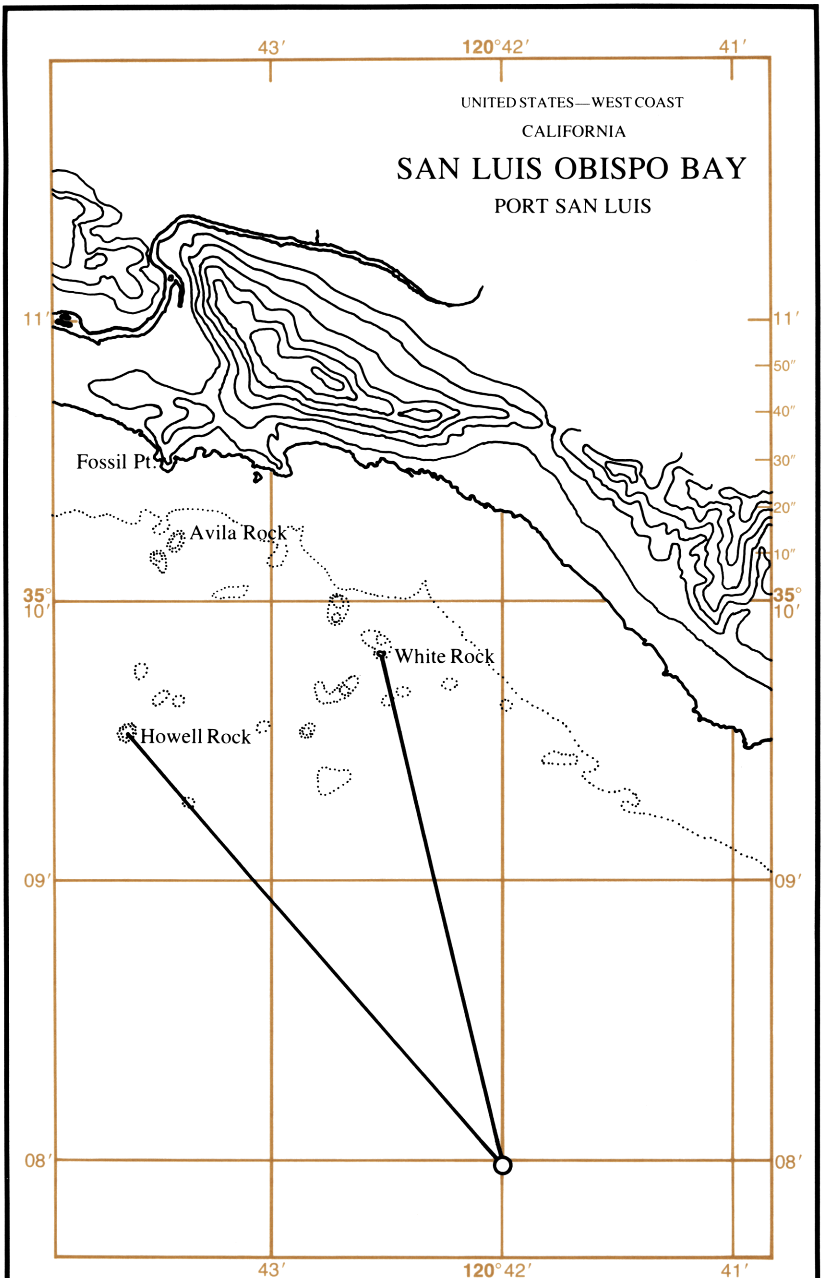
Keystrokes:	Outputs:
35.0948 ENTER↑ 120.4231	
A 346 R/S 35.0932 ENTER↑	
120.4338 B 318.9 R/S D ⟶	35.0758 ***
R/S ⟶	120.4157 ***

Example 2:

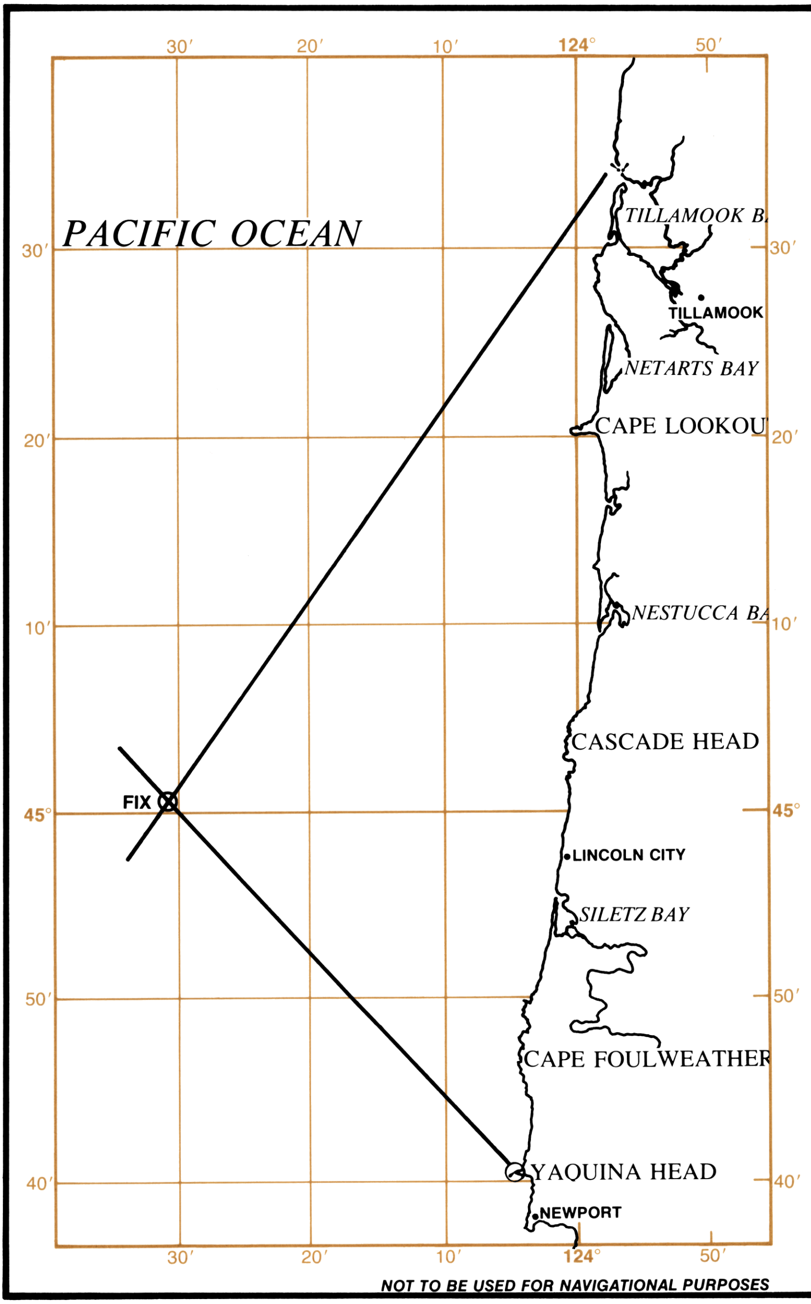
A navigator bound for the entrance to Tillamook Bay (45°34′N, 123°57′40″W) on course 035° observes the radio beacon on Yaquina Head (44°40′40″N, 124°04′45″W) to bear 137.5. Where is the fix?

Keystrokes:	Outputs:	
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 ⟶	45.0036	L 45°0′36″N
R/S ⟶	124.3040	λ 124°30′40″W

09-03



NOT TO BE USED FOR NAVIGATIONAL PURPOSES


30′
20′
10′
124°
50′
PACIFIC OCEAN
TILLAMOOK B
TILLAMOOK
NETARTS BAY
CAPE LOOKOU
NESTUCCA BA
CASCADE HEAD
FIX
45°
LINCOLN CITY
SILETZ BAY
CAPE FOULWEATHER
YAQUINA HEAD
NEWPORT
40′
NOT TO BE USED FOR NAVIGATIONAL PURPOSES

TWO-ANGLE LINE OF POSITION

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.	R/S	
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.		R/S	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			
	P⇄S between LOP's.			
	If you are going to use this card			
	to produce an LOP for a running			
	fix, Z_c must be accurate.			

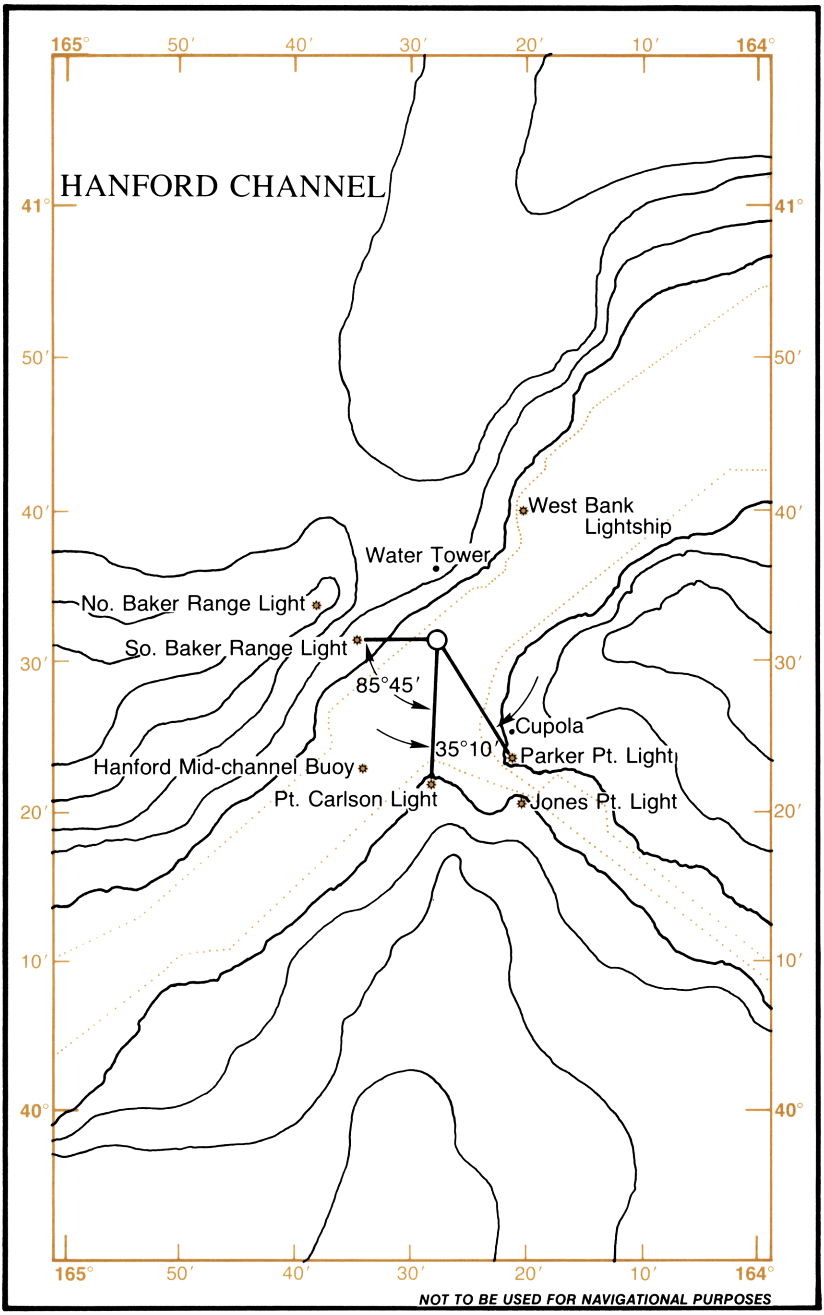
The following problem is from Bowditch, p. 282. It is based on these fictitious points.

	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 ——→		South Baker Range Light
40.2200 ENTER↑ 164.2818		
C ——→		Point Carlson Light
190 R/S ——→		approximate true bearing of Point Carlson Light
85.45 B ——→	40.2954	approximate L
R/S ——→	164.2628	approximate λ
40.2342 ENTER↑ 164.2112		
E ——→		Parker Point Light
35.10 D ——→	40.1732	approximate L
R/S ——→	164.2920	approximate λ
Load "Fix from Two Lines of Position"		
0 A ——→	40.3132	L 40°31′32″N
R/S ——→	164.2727	λ 164°27′27″W


HANFORD CHANNEL
165°
50′
40′
30′
20′
10′
164°
41°
40°
West Bank
Lightship
Water Tower
No. Baker Range Light
So. Baker Range Light
85°45′
35°10′
Cupola
Parker Pt. Light
Hanford Mid-channel Buoy
Pt. Carlson Light
Jones Pt. Light
NOT TO BE USED FOR NAVIGATIONAL PURPOSES

FIX FROM TWO LINES OF POSITION

This program is intended to follow the almanac interpolater, 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 [P⇄S] 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 (±180°) 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°12′S, λ159°57′E, and the observations are made from 35 feet. What is the fix?

	Rigil Kentaurus	Procyon
GMT	$9^h40^m21^s$	$9^h40^m59^s$
h_s	11°24′	11°21′42″

Keystrokes: **Outputs:**

Load Star Data 5

E (Rigil Kentaurus) ignore output

Load Star Line of Position

40.12 CHS ENTER↑ 159.57
CHS f A 35 f B 1974
ENTER↑ 12 ENTER↑ 30

A 9.4021 **B** →	178.0 ***	Z_n
	10.59	H_C
11.24 **C** →	-14.6	14.6 miles toward
P⇄S →		

Load Star Data 5

A (Procyon)

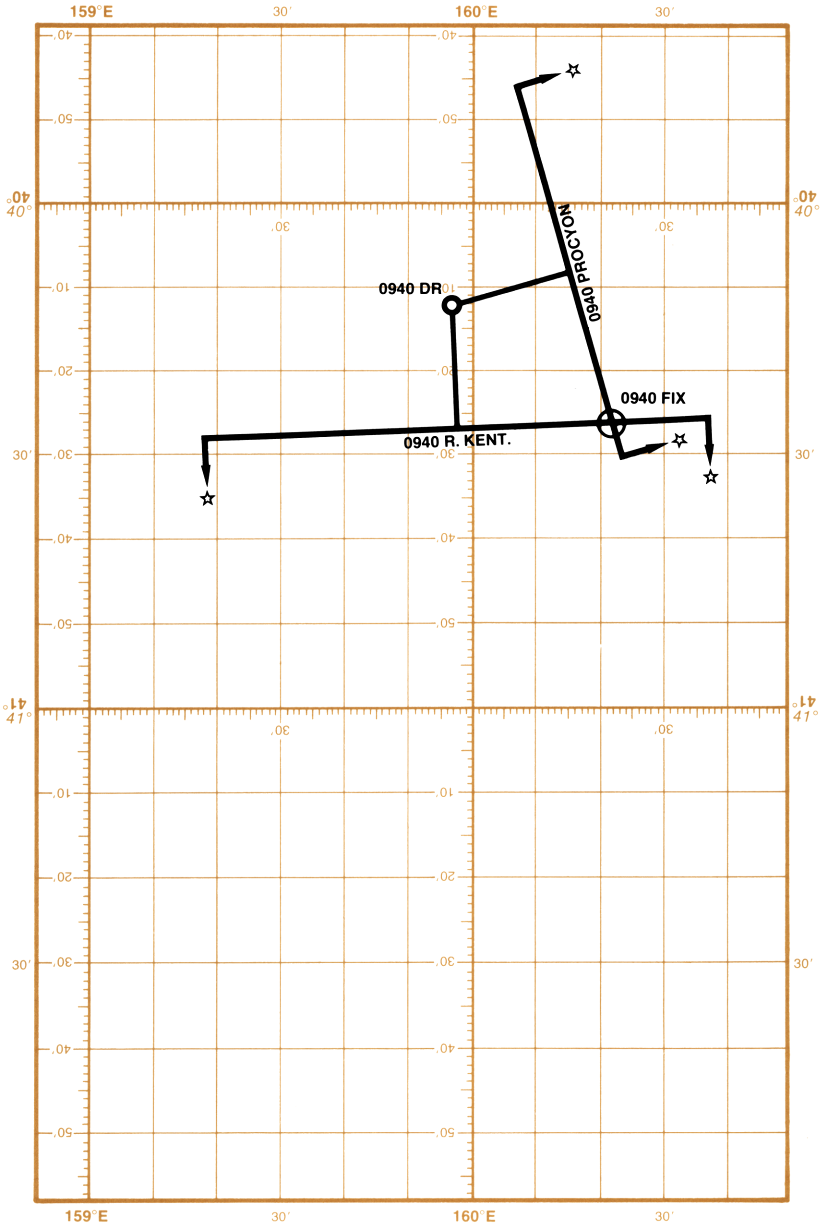
Load Star Line of Position

40.12 **CHS** **ENTER↑** 159.57 **CHS**
f **A** 35 **f** **B** 1974 **ENTER↑**
12 **ENTER↑** 30 **A** 9.4059

B →	73.4 ***	Z_n
	10.5643	H_c
11.2142 **C** →	-14.6	a

Load Fix from Two Lines of Position

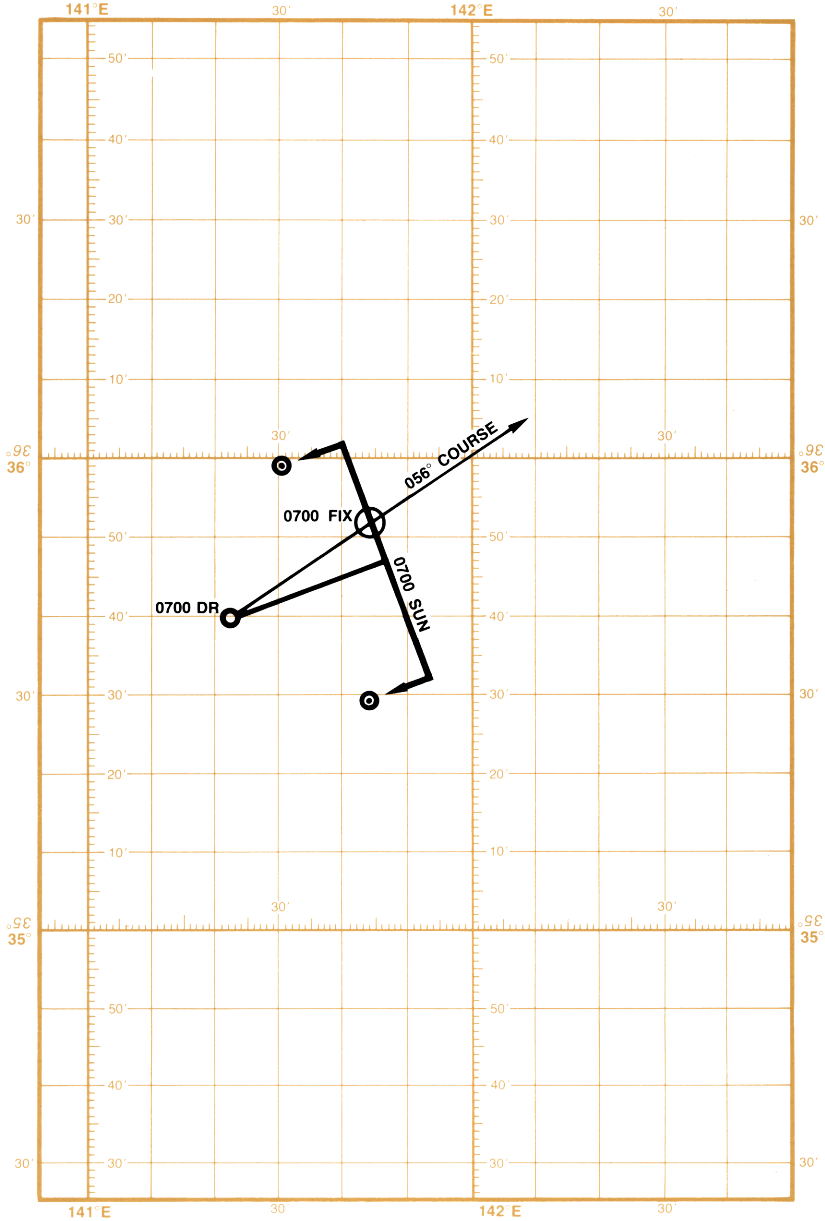
0 **A** →	-40.2551	L 40°25′51″S
R/S →	-160.2228	λ 160°22′28″E


159°E
30′
160°E
30′
40°
30′
41°
30′
0940 PROCYON
0940 DR
0940 FIX
0940 R. KENT.

Example 2:

A navigator's DR on February 10, 1977 at 0700 is 35°39′49″N, 141°22′21″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:	**Outputs:**	
Load Sun Line of Position		
35.3949 [ENTER↑] 141,2221		
[CHS] [f] [A] 65 [f] [B] 1977		
[ENTER↑] 2 [ENTER↑] 10		
[A] 7 [B] →	241.92 ***	Z_n is printed
	12.25	H_c is displayed
12 [D] →	21.68	away
[P⇄S] →		set up for second LOP
Load Two Bearing Fix		
35.3949 [ENTER↑] 141.2221		
[CHS] [A] 56 [R/S] →		ignore output
Load Fix From Two Lines of Position		
0 [A] →	35.5151	L 35°51′51″N
[R/S] →	141.4425	λ 141°44′25″W

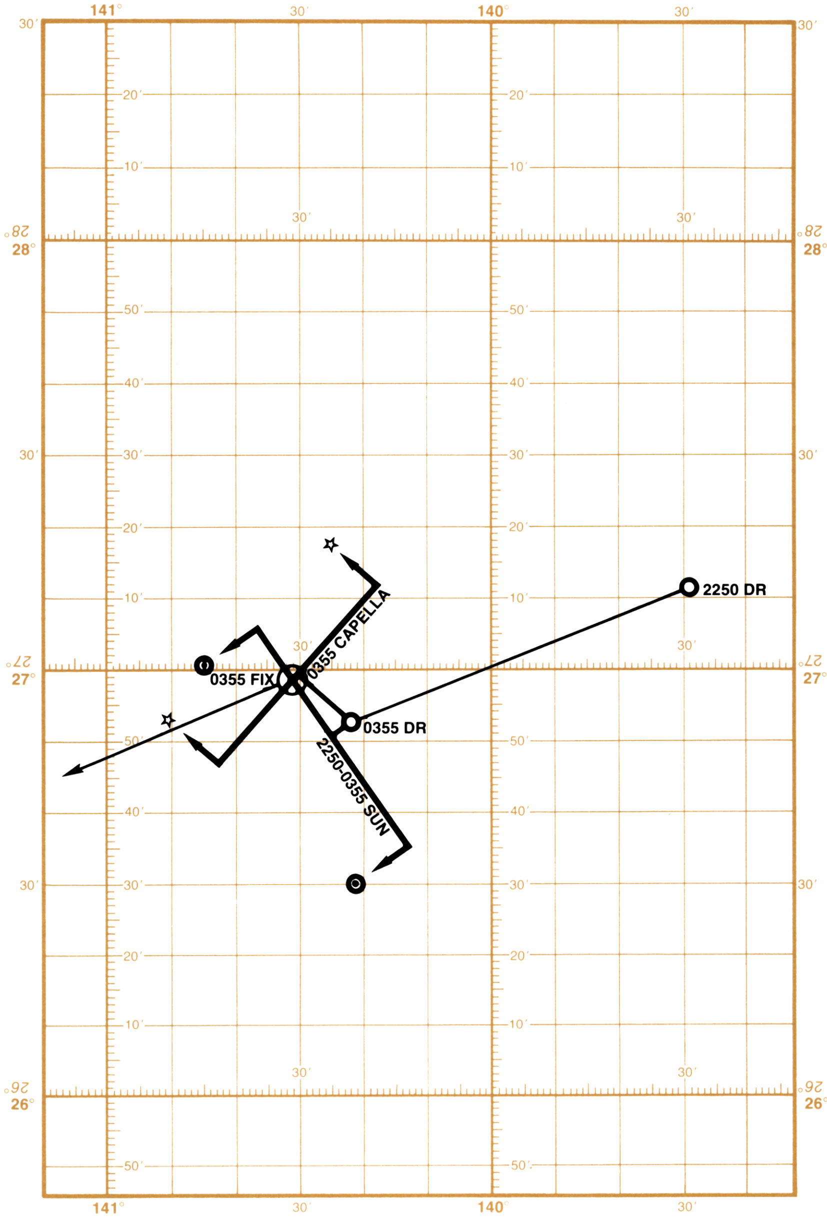

141°E
142°E
30′
50′
40′
20′
10′
36°
35°
056° COURSE
0700 FIX
0700 DR
0700 SUN

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 2250from 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:	**Outputs:**	
Load Sun LOP		
27.1114 ENTER↑ 139.2845		
f A 35 f B 1977 ENTER↑ 4		
ENTER↑ 14 A 22.50 B →	235.4 ***	Sun's azimuth
	62.0640 ***	Sun's altitude
62 D →	-3.1	3.1 miles toward
P⇄S →		store this LOP
Load Star Data 3		
f B (Capella) →		ignore output
Load Star LOP		
27.1114 ENTER↑ 139.2845		
f A 35 f B 1977 ENTER↑		
4 ENTER↑ 15 A 3.55 B →	310.5 ***	Capella's azimuth
	50.4958 ***	Capella's altitude
51.3 C →	-33.5	33.5 miles toward
Load Two LOP Fix		
248 ENTER↑ 10 ENTER↑ 5.05		
A →	26.5823	fix latitude
R/S →	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.

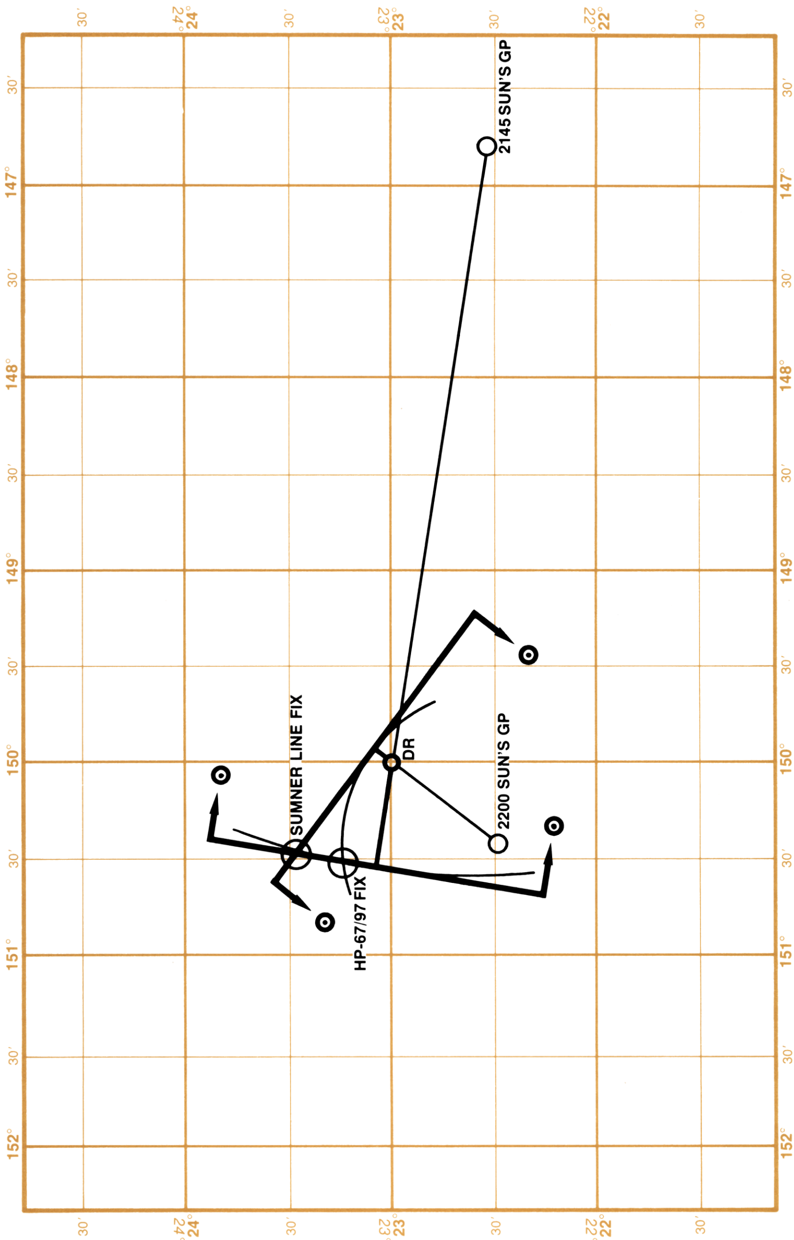

141°
30′
140°
30′
28°
27°
26°
20′
10′
50′
40′
30′
2250 DR
0355 CAPELLA
0355 FIX
0355 DR
2250-0355 SUN

Example:

A small craft is adrift near L23°N, λ150°W. Her navigator observes the Sun at 2145 GMT on June 4, 1977 and gets an altitude of 86°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:	Outputs:	
Load Sun Line of Position		
23 ENTER↑ 150 f A 0 f B		
1977 ENTER↑ 6 ENTER↑ 4 A		
21.45 B →	98.7 ***	Z_n
	86.5325 ***	H_c
86.07 D →	30.7	30.7 miles away
P⇄S →		save the first LOF
23 ENTER↑ 150 f A 0 f B		
1977 ENTER↑ 6 ENTER↑ 4 A		
22 B →	217.8 ***	Z_n
	89.2154 ***	H_c
89 D →	6.1	6.1 miles away
Load Fix by Two Lines of Position		
0 A →	23.1345	fix latitude is 23°13′45″ N
R/S →	150.3116	fix longitude is 150°31′16″ W

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


2145 SUN'S GP
SUMNER LINE FIX
DR
2200 SUN'S GP
HP-67/97 FIX
147°
148°
149°
150°
151°
152°
24°
23°
22°
30'

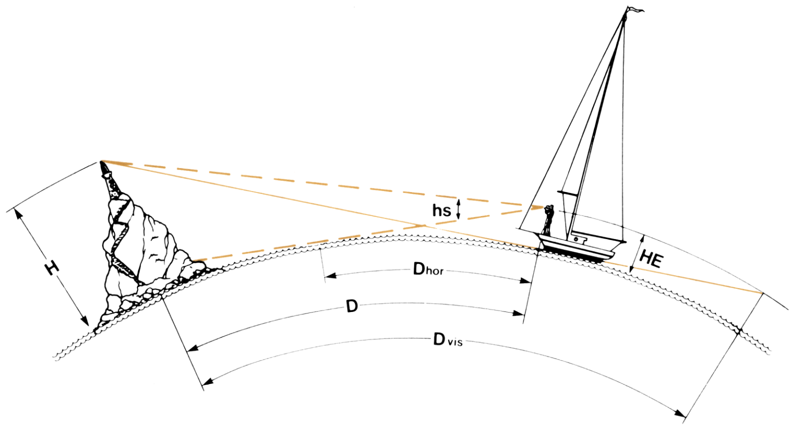
DISTANCE BY HORIZON ANGLE

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 hs 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.

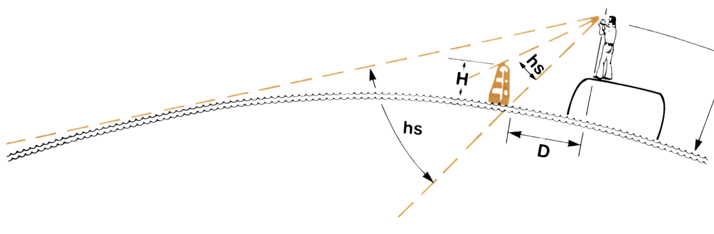
This program also calculates the distance between an observer and an object when (1) the vertical angle between its waterline and the horizon has been observed from a known height of eye or (2) the object's height is known, together with its subtended angle. An additional feature is the calculation of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

Note: $hs < 10'$ 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:

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

Keystrokes: **Outputs:**

9 A f A ——————→ 3.43

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? (26.22 nautical miles) (Accuracy is affected by abnormal refraction)

Keystrokes:	Outputs:
16 [A] 358 [B] [f] [B] ⟶	26.22

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.'9 above the horizon. The height of eye is 20 feet.

What is the distance to the lighthouse? (6.28 nautical miles)

What is the distance to the horizon? (5.12 nautical miles)

It has been determined that the luminous range of the light is "strong", now compute its visibility for the given height of eye. (24.93 nautical miles)

Keystrokes:	Outputs:
20 [A] 300 [B] .2654 [C] ⟶	6.28
[f] [A] ⟶	5.12
[f] [B] ⟶	24.93

The sextant altitude subtended by the base and the top of a 41 foot light tower is 54′.3. How far is the observer from the light tower?

Keystrokes:	Outputs:
41 [ENTER↑] .5418 [f] [E] ⟶	2595.50 ft.
[R/S] ⟶	0.43 n.m.

Example 4:

A vessel is anchored 2015 feet from an lighthouse. The sextant altitude subtended by the lighthouse is 1°15.′2. How high is the lighthouse?

Keystrokes:	Outputs:
2015 [ENTER↑] 1.1512 [E] ⟶	44.08 ft.

CLOSEST POINT OF APPROACH

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 speci-			
	fied 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:	Outputs:	
0 ENTER↑ 24 f B 1.5 f C →		set up
22.52 ENTER↑ 26 ENTER↑ 14.4		
f A →		first contact
23 ENTER↑ 25 ENTER↑ 11.9		
A →	1.	(blinking: CPA within desired 1.5 mi. miss distance)
	1.2	distance of CPA
R/S →	301	bearing of CPA
D →	23.3744	time of CPA
23.08 E →	2	right turn
23.08 f E →	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:	Outputs:	
30 ENTER↑ 15 f B 1 f C →		set up
15.30 ENTER↑ 40 ENTER↑		
30 f A →		first contact
15.35 ENTER↑ 38 ENTER↑ 29		
A →	21.2	CPA
D →	16.4406	time of CPA
15.45 E →	320	heading to intercept

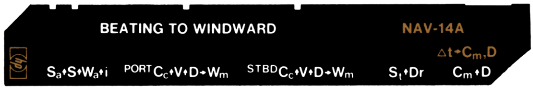
Example 3:

Our speed is 17 knots. 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:	Outputs:	
0 ENTER↑ 17 f B 5 f C		set up (use C = 0° for convenience)
f D ... f D →	0 or 1	repeat until 1 appears
18.32 ENTER↑ 25 ENTER↑ 30		
f A →		
f D →	2.	second target
18.34 ENTER↑ 95 ENTER↑ 28		
f A f D →	1.	first target
18.40 ENTER↑ 20 ENTER↑		
25 A →	11.8	CPA
R/S →	318	bearing of CPA
D →	19.1149	time of CPA
f D →	2	second target
18.40 ENTER↑ 90 ENTER↑		
27 A →	25.4	CPA_2
R/S →	70	bearing of CPA
D →	19.0126	time of CPA

Notes

BEATING TO WINDWARD



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		B or C	W_m, deg.
	starboard (C) tack and see			
	angle of modified wind			
4	Key in current			
	set of current	Set, deg.	ENTER↑	
	drift of current	Drift, knots	D	
	and see			
	for this tack			
	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:

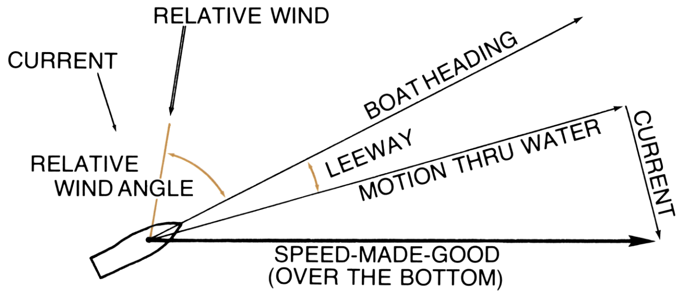
An instrumented sailboat is sailing to an upwind mark bearing 030° true distant 5 miles. Use this program to complete the table below.

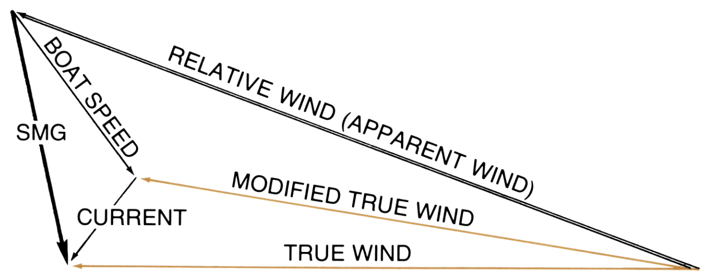
Time		0800	0830	0910	0955	0956:22
Rel. Wind Speed	Sa	15.1	17.1	14.78	14.78	14.78
Vessel Speed	S	5.2	6	5.1	5.1	5.1
Rel. Wind Angle	Wa	33.3	33.2	33.5	33.5	33.5
Angle of heel	i	30°	35°	25°	25°	25°
Speed of Mod. Wind	MW	11.71	13.4	11.3	11.3	11.3
Tack Angle	Wt	47.4	47.4	47.9	47.9	47.1
Leeway* (not an input)		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

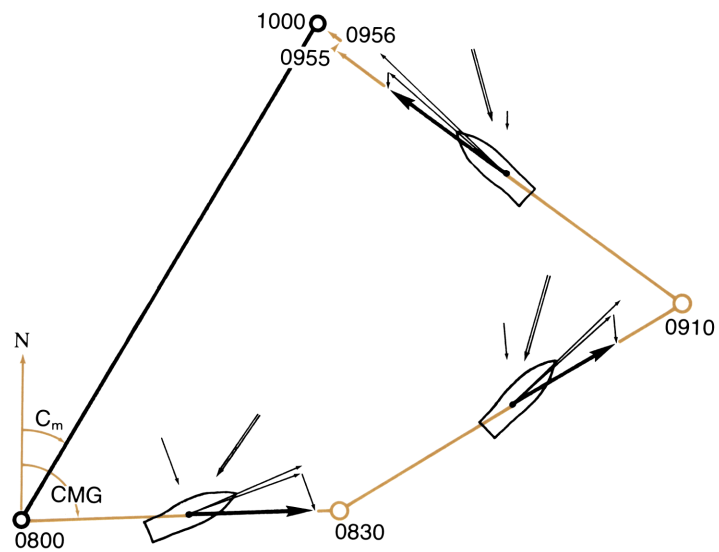
* Note that the values to use for leeway must be estimated by the skipper. The compass course computed by the program must be corrected to account for the estimated leeway.

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:	Outputs:
15.10 ENTER↑	
5.20 ENTER↑	
33.30 ENTER↑	
30.00 A →	11.71 ***
	47.4 ***
77 ENTER↑	
11 CHS ENTER↑	
0 B →	18.6 ***
160 ENTER↑ 2 D →	5.44 ***
	87.5 ***
	331.2 *** (blinking)
0 →	342.2 ***
	3.24 ***
	325.7 ***
30 ENTER↑ 5 E →	4.96 ***
	1.3156 ***
	5.30 ***
	0.5826 ***
.30 f E →	4.22 ***
	357.0 ***


RELATIVE WIND
CURRENT
BOAT HEADING
LEEWAY
MOTION THRU WATER
CURRENT
RELATIVE
WIND ANGLE
SPEED-MADE-GOOD
(OVER THE BOTTOM)


BOAT SPEED
RELATIVE WIND (APPARENT WIND)
SMG
MODIFIED TRUE WIND
CURRENT
TRUE WIND


1000
0956
0955
0910
N
C_m
CMG
0800
0830

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.

Star Number	Star Name	1969 POSITION Declination (STO D)	Sidereal Hour Angle (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	Rigil 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 User's 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

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

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

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

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

Dead Reckoning

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

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

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

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

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	
18941.60086	2	
81717.37302	3	
72264.47856	4	
22270.41177	5	
54476.24512	6	
46256.79618	7	
59588.47426	8	
34622.74119	9	
89094.55238	0	Secondary Registers
43536.15781	1	
41856.59664	2	
85192.19148	3	
56337.23035	4	
39743.84219	5	
9228.353662	6	
64772.70977	7	
43175.28825	8	
64907.45486	9	
82118.25485	A	Primary Registers
44885.67166	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 mode Ω is computed:

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

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

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

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 ω 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:

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

The longitude of perigee ω 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.

$$\text{GHA} \odot = M + \bar{\omega} - \tan^{-1}(\tan \theta \cos \epsilon) + 180 + 15\,t$$

$$\delta = \sin^{-1}(\sin \theta \sin \epsilon)$$

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.

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

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

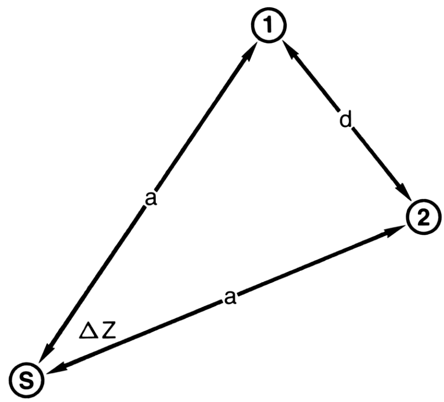
where (α_0, δ_0) is the star's 1969 mean place (see the table in appendix 1).

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

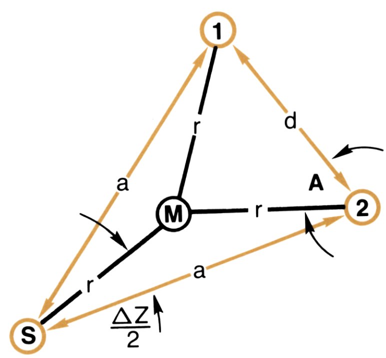
An observer at Ⓢ ("ship") measures the angle between ① and ②.



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 Ⓜ by going distance r from ② at bearing Z:

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

Ⓜ 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 Ⓢ and ② we can get an approximate position for Ⓢ:

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

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

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

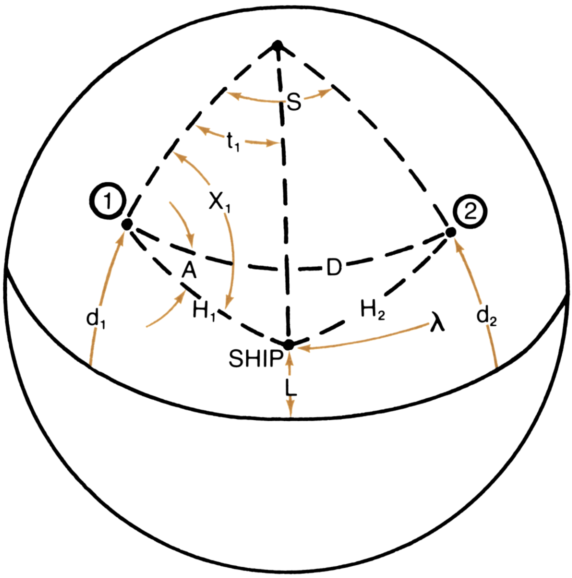
This program locates a false star at a distance of 90° from L_1, λ_1 at a bearing 90° from Z_1:

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

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

Fix From Two Lines of Position

This program is an implementation of Dozier's formulas on page 549 of Bowditch.



$$\cos D = \sin d_1 \sin d_2 + \cos d_1 \cos d_2 \cos S$$

$$\tan(X_1 \pm A_1) = \frac{\sin S \cos d_2}{\cos d_1 \sin d_2 - \sin d_1 \cos d_2 \cos S}$$

$$\cos A_1 = \frac{\sin H_2 - \cos D \sin H_1}{\cos H_1 \sin D}$$

$$X_1 = (X_1 \pm A_1) \mp A_1$$

$$\sin L = \sin d_1 \sin H_1 + \cos d_1 \cos H_1 \cos X_1$$

$$\tan t_1 = \frac{\sin X_1 \cos H_1}{\cos d_1 \sin H_1 - \sin d_1 \cos H_1 \cos X_1}$$

$$\lambda = GHA_1 \pm t_1$$

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

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

hs = sextant altitude

BIBLIOGRAPHY

Bowditch, *American Practical Navigator,* H.O. Pub. No. 9, U.S. Naval Oceanographic Office, Washington, D.C., 1966.

Buckley, William F., Jr., *Airborne,* Macmillan Publishing Co., Inc., New York, 1976.

Dunlap, G.D. and Shufeldt, H.H., *Dutton's Navigation and Piloting,* Twelfth Edition, United States Naval Institute, Annapolis, 1969.

Hobbs, Richard R., *Marine Navigation 1, Piloting,* United States Naval Institute, Annapolis, 1974.

Hobbs, Richard R., *Marine Navigation 2, Celestial and Electronic,* United States Naval Institute, Annapolis, 1974.

Melluish, R.K., *An Introduction to the Mathematics of Map Projections,* Cambridge University Press, London, 1931.

Mueller, Ivan I., *Spherical and Practical Astronomy as Applied to Geodesy,* Fredric Ungar Publishing Co., Inc., 1969.

Norton, A.P. and Inglis, J.G., *Norton's Star Atlas,* Fifteenth Edition, Gall and Inglis, Edinburgh, 1964.

Shufeldt, H.H., *Slide Rule for the Mariner,* United States Naval Institute, Annapolis, 1972.

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**

ESTIMATED TIME OF ARRIVAL

Step	Key	Comments
001	*LBLB	
002	DSP1	
003	GSB1	Store distance
004	F3?	IF new data THEN STOP
005	RTN	
006	RCL7	ELSE
007	RCL5	Compute Distance
008	-	
009	2	
010	4	
011	x	
012	RCL8	
013	RCL6	
014	-	
015	+	
016	RCL2	
017	x	
018	GSB1	
019	RTN	
020	*LBL1	
021	6	
022	0	
023	÷	
024	STO4	Store D/60
025	LSTX	
026	x	
027	RTN	
028	*LBLC	
029	DSP2	
030	STO2	Store speed
031	F3?	IF new data THEN STOP
032	RTN	
033	RCL4	ELSE
034	6	Compute Speed
035	0	
036	x	
037	RCL7	
038	RCL5	
039	-	
040	2	
041	4	
042	x	
043	RCL8	
044	RCL6	
045	-	
046	+	
047	÷	
048	STO2	
049	RTN	
050	*LBLa	
051	STOA	
052	1	Store ZD$_D$
053	5	
054	x	Store approximate λ_D
055	STO1	
056	RTN	
057	*LBLA	Store ZD$_A$
058	STOB	
059	1	
060	5	Store approximate λ_A
061	x	
062	STO3	
063	RTN	$\lambda \rightarrow$ ZD
064	*LBLb	
065	DSP0	
066	1	
067	5	DEPARTURE
068	÷	
069	RND	
070	RTN	
071	*LBLD	Store day
072	DSP4	
073	INT	
074	STO5	
075	LSTX	
076	FRC	
077	EEX	
078	2	
079	x	
080	HMS+	
081	RCL1	
082	GSBb	
083	STOA	
084	DSP4	
085	+	
086	STO6	Store time
087	F3?	IF new data THEN STOP
088	RTN	
089	RCL7	ELSE
090	RCL8	Compute Day and Time
091	RCL4	of Departure
092	6	
093	0	
094	x	
095	RCL2	
096	÷	
097	CHS	
098	GSB8	
099	STO6	
100	RCLA	
101	-	
102	X<0?	
103	GSB7	
104	X⇄Y	
105	STO5	
106	GSB9	
107	RTN	
108	*LBL7	
109	2	
110	4	
111	+	
112	X⇄Y	

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	I
ZD$_D$	ZD$_A$				

Step	Key	Comments
113	1	
114	-	
115	X⇄Y	
116	RTN	
117	*LBLE	Arrival
118	DSP4	
119	INT	
120	STO7	Store day
121	LSTX	
122	FRC	
123	EEX	
124	2	
125	x	
126	HMS+	
127	RCL3	
128	GSBb	
129	STOB	
130	DSP4	
131	+	
132	STO8	Store time
133	F3?	IF new data
134	RTN	THEN STOP
135	RCL5	ELSE
136	RCL6	Compute Day and Time
137	RCL4	of Arrival
138	6	
139	0	
140	x	
141	RCL2	
142	÷	
143	GSB8	
144	STO8	
145	RCLB	
146	-	
147	X<0?	
148	GSB7	
149	X⇄Y	
150	STO7	
151	GSB9	
152	RTN	
153	*LBL8	Subroutine to add time to days
154	+	
155	2	
156	4	
157	÷	
158	STO0	
159	INT	
160	+	
161	RCL0	
162	FRC	
163	X<0?	
164	GTO0	
165	2	
166	4	
167	x	
168	RTN	
169	*LBL0	
170	X⇄Y	
171	1	
172	-	
173	X⇄Y	
174	1	
175	+	
176	2	
177	4	
178	x	
179	RTN	
180	*LBL9	Subroutine to concatenate day and time
181	X⇄Y	
182	→HMS	
183	EEX	
184	2	
185	÷	
186	+	
187	X>0?	
188	RTN	
189	INT	
190	LSTX	
191	FRC	
192	1	
193	+	
194	-	
195	RTN	

LABELS

A ZD_A	B DIST	C SPEED	D Departure	E Arrival
a ZD_D	b λ → ZD	c	d	e
0	1	2	3	4
5	6	7	8	9

FLAGS

0	
1	
2	
3	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☐	DEG	☒	FIX	☒
1	☐	☐	GRAD	☐	SCI	☐
2	☐	☐	RAD	☐	ENG	☐
3	☐	☐			n	4

GREAT CIRCLE AND RHUMB LINE NAVIGATION

*LBLa	Store Source coordinates
HMS→	
STO1	
R↓	
HMS→	
STO0	
RTN	— — — — — — — — — — — —
*LBLA	Store Destination coordinates
HMS→	
STO3	
R↓	
HMS→	
STO2	
RTN	— — — — — — — — — — — —
*LBLE	Compute great-circle distance and initial heading
RCL0	
SIN	
RCL2	
SIN	
×	
RCL0	
COS	
RCL2	
COS	
×	
RCL3	
RCL1	
-	
STOE	
COS	
×	
+	
COS⁻¹	
STO4	
GSBc	
RCL2	
SIN	
RCL0	
SIN	
RCL4	
COS	
×	
-	
RCL4	
SIN	
÷	
RCL0	
COS	
÷	
COS⁻¹	
RCLE	
SIN	
X<0?	
GTO1	
R↓	
GSBd	
-	
CHS	
GTO0	
*LBL1	
R↓	
*LBL0	
STO5	Print H_i
GSB5	
RTN	— — — — — — — — — — —
*LBLC	Store longitude increment
HMS→	
STO6	
RTN	— — — — — — — — — — —
*LBLD	
RCLE	
COS	
COS⁻¹	
RCL6	Compute number of rhumb lines needed
÷	
ABS	
STOI	
RCL0	
STOB	
DSP4	
GSB8	Print L_1
RCL1	
STOA	
GSB8	Print λ_1
HMS→	
GSB9	Increment λ BEGIN loop 3
*LBL3	
GSB0	
RCL3	
RCL8	
STOA	
GSB9	
DSZI	
GTO3	If not finished yet THEN REPEAT loop 3
RCLA	
RCL3	
X=Y?	If $\lambda_i = \lambda_2$ THEN STOP
RTN	ELSE do one more
*LBL0	— — — — — — — — — — —
STO8	Subroutine to compute and print C, D, L_{next}, λ_{next}
GSB7	
GSBe	
F0?	
SPC	
RCL9	
DSP4	
STOB	
GSB8	
RCL8	Print L_i Print λ_i
*LBL8	
→HMS	— — — — — — — — — — —
*LBL5	Convert to D.MS, then print

REGISTERS

0	1	2	3	4	5	6	7	8	9
L_1	λ_1	L_2	λ_2	D/60	H_i	$\Delta\lambda$		λ_i	L_i
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
λ_{i-1}	L_{i-1}	λ_{i-1}	Used	$\lambda_2 - \lambda_1$	

```
F0?
PRTX
F0?
RTN
R/S
RTN
*LBL9
RCL6
+
1
→R
→P
R↓
RTN
*LBLd
3
6
0
RTN
*LBLe
F0?
SF0
RCLA
RCLB
-
STOC
2
÷
SIN
SIN⁻¹
9
0
÷
Pi
x
RCL9
GSB4
RCLB
GSB4
-
→P
R↓
STOD
RCLC
SIN
SIN⁻¹
X<0?
GTO0
RCLD
GTO1
*LBL0
GSBd
RCLD
ABS
-
*LBL1
```

IF flag 0
THEN PRINT

ELSE
DISPLAY

Subroutine to increment longitude and account for dateline

Subroutine to put 360 in x-register

Subroutine to compute course and distance to next point

```
ABS
DSF0
GSB5
RCLC
RCL9
COS
x
ENT↑
RCL9
RCLB
-
RCLD
COS
X≠0?
÷
ENT↑
X=0?
R↑
ABS
*LBLc
6
0
x
GTO5
*LBL4
2
÷
4
5
+
TAN
LN
RTN
*LBL7
RCLA
-
SIN
RCL2
TAN
x
RCL8
RCL3
-
SIN
RCLB
TAN
x
-
RCL3
RCLA
-
SIN
÷
TAN⁻¹
STO9
RTN
```

Print distance

Subroutine to compute

ln tan (45 + L/2)

Subroutine to compute L_i from λ_i

LABELS

A $L_2 \uparrow \lambda_2$	B →D, H_i	C $\Delta\lambda$	D →LIST	E
a $L_1 \uparrow \lambda_1$	b	c	d	e
0	1	2	3	4
5	6	7	8	9

FLAGS

0	
1	
2	
3	

SET STATUS

FLAGS	ON	OFF
0	☒	☐
1	☐	☒
2	☐	☒
3	☐	☒

TRIG	
DEG	☒
GRAD	☐
RAD	☐

DISP	
FIX	☒
SCI	☐
ENG	☐
n	4

DEAD RECKONING

Key	Comment
*LBLb	
+	
STO8	Store correction
RTN	
*LBLA	
HMS→	
STO1	Store λ
R↓	
HMS→	
STO0	Store L
RTN	
*LBLB	
STO2	Store CC
RCL8	
+	Display TC
RTN	
*LBLC	
STO3	Store speed
RTN	
*LBLe	
SF1	Set list flag
HMS→	
STO4	Store Δt
RCL5	
+	
STO6	
GTO0	
*LBLD	
HMS→	
STO5	Store t_0
RTN	
*LBLE	
CF1	Clear list flag
HMS→	
STO6	Store t_i
*LBL0	
RCL2	Rhumb Line Equations
RCL8	
+	
STO9	
COS	
X=0?	
GTO8	
RCL3	
x	
RCL6	
RCL5	
-	
x	
6	
0	
÷	
RCL0	
+	
STO7	
GSB9	
RCL0	
GSB9	
-	
RCL9	
TAN	
x	
1	
8	
0	
x	
Pi	
÷	
RCL1	
X⇄Y	
-	
1	
→R	
→P	
X⇄Y	
STO1	
GSB3	
RCL7	
STO0	
GTO1	
*LBL8	Course = 90 or 270
LSTX	
SIN	
RCL3	
x	
RCL6	
RCL5	
-	
x	
6	
0	
÷	
RCL0	
COS	
÷	
ST-1	
GSB3	
*LBL1	Display routine
F0?	
SPC	
RCL6	t_i
STO5	
→HMS	
DSP4	
GSB5	
HMS→	
STO6	
RCL0	
→HMS	L_i
GSB5	
HMS→	
STO0	

REGISTERS

0	1	2	3	4	5	6	7	8	9
L_i	λ_i	CC	S	Δt	t_{i-1}	t_i	L_i	Var + Dev	TC
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

Key	Comments
RCL1	
→HMS	λ$_i$
GSB5	
HMS→	
STO1	
RCL2	
DSP1	CC
GSB5	
STO2	
RCL3	
GSB5	S
STO3	
RCL6	
RCL4	
+	
STO6	
F1?	$t_i \leftarrow t_i + \Delta t$
GTO0	
CLX	
RTN	
F1?	
GTO0	
RTN	
*LBL9	Subroutine to compute
2	
÷	
4	$\ln \tan\left(\frac{L}{2}\right) + 45$
5	
+	
TAN	
LN	
RTN	
*LBL5	
F0?	Print routine
PRTX	
PSE	
RTN	
*LBL3	
RCL1	Subroutine to ensure that
1	
→R	
→P	
X⇄Y	$-180 < \lambda \leqslant 180$
STO1	
RTN	
*LBLa	
F0?	Print toggle
GTO2	
SF0	
1	
RTN	
*LBL2	
CF0	
0	
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 ☒ ☐ 1 ☐ ☒ 2 ☐ ☒ 3 ☐ ☒	DEG ☒ GRAD ☐ RAD ☐	FIX ☒ SCI ☐ ENG ☐ n 4
0 Used	1 Used	2 Used	3 $\lvert\lambda\rvert \leqslant 180°$	4	2			
5 PRINT	6	7	8	9 Used	3			

VELOCITY TRIANGLE AND COURSE TO STEER

Step	Key	Comment
001	*LBLa	
002	STO0	
003	R↓	
004	STO1	
005	CLX	
006	RTN	
007	*LBLA	
008	F3?	
009	GTO1	
010	RCLC	Compute Speed, C_t, C_c
011	RCLB	
012	RCL4	
013	RCLI	
014	CHS	
015	GSB8	
016	STO8	
017	X⇄Y	
018	GSB9	
019	STOA	Store C_t
020	RCL0	
021	-	
022	RCL1	
023	-	
024	GSB9	
025	STO2	Store C_c
026	GTO4	
027	*LBL1	
028	STO8	
029	X⇄Y	
030	STO2	
031	RCL0	
032	+	
033	RCL1	
034	+	
035	GSB9	
036	STOA	
037	RTN	
038	*LBLE	
039	F3?	
040	GTO2	
041	RCLC	
042	RCLB	Compute Drift, Set
043	RCLA	
044	RCL8	
045	CHS	
046	GSB8	
047	STOI	
048	X⇄Y	
049	GSB9	
050	STO4	
051	GTO4	
052	*LBL2	Store Drift, Set
053	STOI	
054	X⇄Y	
055	STO4	
056	RTN	
057	*LBLC	
058	F3?	
059	GTO3	
060	RCLA	Compute SMG, CMC
061	RCL8	
062	RCL4	
063	RCLI	
064	GSB8	
065	STOB	
066	X⇄Y	
067	GSB9	
068	STOC	
069	*LBL4	
070	F2?	Display results alternately
071	RTN	
072	X⇄Y	
073	R/S	
074	GTO4	
075	*LBL3	
076	STOB	Store SMG, CMC
077	X⇄Y	
078	STOC	
079	RTN	
080	*LBL8	Subroutine to add vectors
081	→R	
082	R↓	
083	R↓	
084	→R	
085	X⇄Y	
086	R↓	
087	+	
088	R↓	
089	+	
090	R↑	
091	→P	
092	RTN	
093	*LBL9	Subroutine to normalize angles
094	3	
095	6	
096	0	
097	→R	
098	→P	
099	X⇄Y	
100	X<0?	
101	GTO0	
102	X⇄Y	
103	R↓	
104	RTN	
105	*LBL0	
106	+	
107	RTN	
108	*LBLd	
109	HMS→	
110	STO5	Store L_1, λ_1
111	X⇄Y	
112	HMS→	

REGISTERS

0	1	2	3	4	5	6	7	8	9
Dev	Var	C_c	L_1	Set	λ_1	L_2	λ_2	Speed	

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
C_t	SMG	CMG	DIST		Drift

Step	Key	Comments
113	STO3	
114	RTN	
115	*LBLD	Store L_2, λ_2
116	HMS+	
117	STO7	
118	X⇄Y	
119	HMS+	
120	STO6	
121	RTN	
122	*LBLe	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	STOD	
141	X⇄Y	
142	GSB9	
143	STOC	
144	GTO4	
145	*LBLE	Store speed Compute C_c, Δt, and SMG
146	STO8	
147	RCLC	
148	RCL4	
149	RCLC	
150	-	
151	SIN	
152	RCLI	
153	x	
154	RCL8	
155	÷	
156	SIN⁻¹	
157	-	
158	GSB9	
159	STOA	
160	CF3	
161	SF2	
162	GSBC	
163	CF3	
164	SF2	
165	GSBA	
166	R/S	
167	RCLD	
168	RCLB	
169	÷	
170	→HMS	
171	R/S	
172	RCLB	
173	RTN	

LABELS

A ↔ C_c, Speed	B ↔ Set, Drift	C ↔ CMG, SMG	D L_2 ↑ λ_2	E S → LIST
a Var ↑ Dev	b	c	d L_1 ↑ λ_1	e →DIST, CMC
0	1	2	3	4
5	6	7	8	9

FLAGS

0	
1	
2	
3	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☒
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☐
3	☐	☒			n	2

STAR SIGHT PLANNER

Step	Key	Comment	Step	Key	Comment
001	*LBLa	Print?	057	X⇄Y	
002	DSP0		058	2	
003	F0?		059	0	
004	GTO0		060	-	
005	0		061	COS	
006	SF0		062	2	
007	RTN		063	3	
008	*LBL0		064	.	
009	1		065	3	
010	CF0		066	x	
011	RTN	– – – – – – – – – – – –	067	CHS	
012	*LBLA	L ↑ λ	068	STOE	
013	HMS→		069	SIN	
014	STOC		070	RCL0	
015	R↓		071	SIN	
016	HMS→		072	x	
017	STO0	Store L	073	-	
018	RTN	– – – – – – – – – – – –	074	RCL0	
019	*LBLB	DATE: Y ↑ M ↑ D	075	COS	
020	STOD		076	÷	
021	X⇄Y		077	RCLE	
022	STOI		078	COS	
023	3		079	÷	
024	0		080	COS^{-1}	
025	5		081	RCLC	
026	6		082	X⇄Y	
027	%		083	F2?	
028	INT		084	CHS	
029	R↑		085	-	
030	STOE		086	*LBL0	
031	R↓		087	X⇄I	
032	RCLD		088	7	
033	+		089	2	
034	STOD		090	.	
035	RCL4		091	2	
036	3		092	+	
037	X>Y?		093	RCLC	
038	1		094	-	
039	RCL5		095	STOE	Store GHA $\Upsilon - \lambda$
040	4		096	STOC	
041	÷		097	RTN	
042	FRC		098	*LBLE	
043	+		099	SF2	
044	1		100	*LBLD	DUSK
045	X⇄Y		101	CF3	
046	X=Y?		102	GSBB	DAWN
047	2		103	RCLI	
048	RCLD		104	1	
049	-		105	5	
050	CHS		106	÷	
051	STOI		107	1	
052	F3?		108	2	
053	GTO0		109	+	
054	6		110	→HMS	
055	CHS		111	DSP2	
056	SIN		112	PRTX	Time of Dawn or Dusk

REGISTERS

0 L	1 *0 *1	2 *3 *4	3 *5 *6	4 *7 *8	5 *9 *10	6 *11 *12	7 *16 *17	8 *18 *20	9 *21 *22
0.000000000	0.339372100	18941.60088	81717.37302	72264.47856	22270.41177	54476.24512	46256.79618	59588.47426	34622.74119
S0 *24 *25	S1 *26 *27	S2 *28 *29	S3 *30 *32	S4 *33 *34	S5 *37 *38	S6 *40 *41	S7 *42 *45	S8 *46 *49	S9 *50 *51
89094.55238	43536.15781	41856.59664	85192.19148	56337.23035	39743.84219	9228.353662	64772.70977	43175.28825	64907.45486

A *52 *53	B *54 *56	C λ, GHA $\Upsilon - \lambda$	D	E GHA $\Upsilon - \lambda$ tist	I
82118.25485	44888.67166	0.000000000	0.000000000	0.000000000	0.000000000

```
*LBLC      TIME → LIST
HMS→
1
5
x
RCLC
+
STOE
2
1
STOI
*LBL7      Begin Loop 7
RCLi
FRC
GSBe
RCLi
INT
EEX
5
÷
GSBe
DSZI       IF not done yet
GTO7       THEN repeat loop 7
RTN        - - - - - - - - - - - -
*LBLe
1
0          Decode star information
x
GSBb
GSBb
3
0
x
3
4
7
+
X⇄Y
INT
RCLI
STOC
+
RCLI
+
2
-
STOD
6
x
-
DSP0
RND
RCLE
+
X⇄Y
INT
COS
SIN⁻¹
RCL0
X⇄Y        Sight Reduction
1
→R         Equations
R↑
X⇄Y
→R
R↑
STOI
X⇄Y
→R
X⇄I
R↑
→R
X⇄I
+
X⇄I
-
→P
R↓
1
9
0
+
RCLC
X⇄I
SIN⁻¹      Hc
5
X≤Y?
GSB0
RTN
*LBL0
SPC
CLX
RCLD
GSB5       Star #
DSP2
→HMS       Hc
GSB5
DSP1
*LBL5      Zn
PRTX
F0?
R/S
R↓
RTN
*LBLb
1
8
x
FRC
LSTX
X⇄Y
RTN
```

LABELS					FLAGS
A L↑λ	B DATE	C GMT → LIST	D DAWN	E DUSK	0
a PRINT?	b	c	d	e	1
0	1	2	3	4	2
5	6	7	8	9	3

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☒
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☐
3	☐	☒			n	1

ALMANAC INTERPOLATOR

Step	Key	Comments
001	*LBLa	Store L, λ
002	HMS→	
003	STO1	
004	R↓	
005	HMS→	
006	STO3	
007	RTN	
008	*LBLb	Store HE
009	STOC	
010	RTN	
011	*LBLc	MOON-STARS Toggle
012	F1?	
013	GTO1	
014	SF1	
015	0	0 = SUN, STARS
016	*LBLd	
017	HMS→	
018	STO0	Store semidiameter
019	RTN	
020	*LBL1	
021	CF1	
022	1	1 = MOON
023	RTN	
024	*LBLA	
025	HMS→	Store GMT
026	STOI	
027	INT	
028	STOE	
029	RTN	
030	*LBLB	
031	HMS→	Input GHA's
032	X⇄Y	
033	HMS→	
034	STO5	
035	-	
036	SIN	
037	SIN⁻¹	
038	STO6	
039	R/S	
040	HMS→	
041	ST+5	Input SHA of star
042	RTN	
043	*LBLC	
044	HMS→	
045	X⇄Y	Input declinations
046	HMS→	
047	STOA	
048	-	
049	STOD	
050	RTN	
051	*LBLD	$h_s \rightarrow Z_n$, a
052	DSP1	
053	HMS→	
054	GSB1	
055	PRT	
056	RCL9	
057	RCL8	
058	+	
059	SIN⁻¹	
060	STO8	
061	RCLB	
062	-	
063	RCL8	
064	COS	
065	RCL0	
066	ABS	
067	TAN	
068	3	
069	.	
070	6	
071	7	
072	×	
073	SIN⁻¹	
074	F1?	
075	CLX	
076	×	
077	-	
078	RCL0	
079	-	
080	6	
081	0	
082	×	
083	STO9	
084	RTN	
085	*LBLE	Compute h_s, Z_n
086	DSP4	
087	0	
088	GSB1	
089	RCL9	
090	RCL8	
091	+	
092	SIN⁻¹	
093	STO8	
094	GSB2	
095	-	
096	RCL8	
097	COS	
098	RCL0	
099	ABS	
100	TAN	
101	3	
102	.	
103	6	
104	7	
105	×	
106	SIN⁻¹	
107	F1?	
108	CLX	
109	×	
110	-	
111	RCL0	
112	-	

REGISTERS

0	1	2	3	4	5	6	7	8	9
α_1	dα/dt	δ_1	dδ/dt	5D	L	λ	Z_n	H_c	a

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
	$h_s - D - R_n$	HE		α_T	GMT

Step	Key	Comments
113	→HMS	
114	R/S	
115	RCL7	
116	RTN	
117	*LBL1	Subroutine to compute Z_n and most of H_c
118	STOB	
119	RCL6	
120	RCLI	
121	RCLE	
122	-	
123	x	
124	RCL5	
125	+	
126	STO2	
127	RCLD	
128	RCLI	
129	RCLE	
130	-	
131	x	
132	RCLA	
133	+	
134	STO4	
135	RCLB	
136	GSB2	
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	STO8	
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↑	
169	ENT↑	
170	ENT↑	
171	3	
172	+	
173	1	
174	2	
175	x	
176	TAN⁻¹	
177	-	
178	TAN	
179	RCLC	
180	√X	
181	-	
182	6	
183	2	
184	÷	
185	RTN	
186	*LBLe	New GMT
187	HMS→	
188	STOI	
189	RTN	

LABELS

A	B	C	D	E
GMT	$\alpha_1 \uparrow \alpha_2$; (SHA)	$\delta_1 \uparrow \delta_2$	$h_s \rightarrow Z_n$, a	$\rightarrow h_s$; Z_n
a: L ↑ λ	b: HE	c: MOON? (=1)	d: S_D	e: New GMT
0	1	2	3	4
5	6	7	8	9

FLAGS

Flag	
0	
1	
2	
3	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☒
1	☒	☐	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☐
3	☐	☒			n	1

SUN LINE OF POSITION

Step	Key	Comment	Step	Key	Comment
001	*LBLA		057	+	
002	STO6		058	8	
003	X⇄Y		059	9	
004	STO4	Store month	060	6	
005	3		061	÷	
006	0		062	-	
007	5		063	ST-6	
008	6		064	3	
009	%		065	6	
010	INT		066	0	
011	ST+6		067	STOC	
012	R↑		068	ST×6	
013	STOB	Store year	069	RTN	-----------
014	RCL4		070	*LBLa	
015	3		071	HMS→	
016	X>Y?		072	STO1	Store λ
017	1		073	X⇄Y	
018	RCLB		074	HMS→	
019	4		075	STO3	Store L
020	÷		076	RTN	-----------
021	FRC		077	*LBLB	GMT
022	+		078	HMS→	
023	1		079	1	
024	X⇄Y		080	5	
025	X=Y?		081	×	
026	2		082	STO2	
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	STOA		093	9	
038	÷		094	6	
039	+		095	8	
040	STO4		096	÷	
041	2		097	-	
042	0		098	+	
043	×		099	.	
044	STOB	Ω, long. of Moon's ascending mode	100	2	
045	SIN		101	→R	
046	4		102	9	
047	×		103	.	
048	5		104	5	
049	0		105	8	
050	9		106	-	
051	4		107	STO0	Semidiameter
052	1		108	×	
053	+		109	+	
054	RCL4		110	RCLB	
055	7		111	4	
056	×		112	2	

REGISTERS

0	1	2	3	4	5	6	7	8	9
SD	λ	α = GHA	L	δ	HE	Days	Z_n	H_c	a
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
365.25	YR, Ω	360			L

Step	Key	Comment
113	7	
114	÷	
115	RCLB	
116	COS	
117	-	
118	8	
119	5	
120	3	
121	1	
122	.	
123	5	
124	-	
125	RCLC	
126	÷	
127	CHS	
128	X⇄Y	
129	1	
130	CHS	
131	→R	
132	R↓	
133	→R	
134	R↑	
135	→P	
136	R↓	
137	X⇄Y	
138	STO8	
139	SIN⁻¹	
140	STO4	Declination
141	R↓	
142	-	
143	ST+2	GHA
144	RCL2	
145	RCL1	
146	-	LHA
147	RCL4	
148	COS	
149	→R	
150	RCL3	
151	STOI	
152	X⇄Y	
153	→R	
154	X⇄I	
155	RCL8	
156	→R	
157	X⇄I	
158	+	
159	SIN⁻¹	
160	X⇄I	
161	-	
162	→P	
163	R↓	
164	1	
165	8	
166	0	
167	+	
168	STO7	Z_n, azimuth

Step	Key	Comment
169	DSP1	
170	PRTX	
171	DSP4	
172	RCLI	
173	STO8	H_c, computed altitude
174	→HMS	
175	PRTX	
176	RTN	------------
177	*LBLE	
178	SF2	UPPER LIMB FLAG
179	*LBLD	
180	HMS→	
181	ENT↑	
182	ENT↑	
183	ENT↑	
184	3	
185	+	
186	1	
187	2	
188	x	
189	TAN⁻¹	
190	-	
191	TAN	Mean refraction
192	RCL5	
193	√X	
194	-	
195	6	
196	2	
197	÷	
198	+	Dip correction
199	RCL8	
200	-	
201	CHS	
202	6	
203	0	
204	x	
205	RCL0	
206	3	
207	6	
208	%	
209	+	
210	3	
211	-	
212	F2?	IF upper limb
213	CHS	THEN subtract SD
214	+	
215	STO9	Store a, intercept
216	DSP1	
217	RTN	------------
218	*LBLb	
219	STO5	Store HE
220	RTN	

LABELS

A DATE	B GMT → Z_n H_c	C	D h_s ☉ → a	E h_s ☉ → a
a L ↑ λ	b HE	c	d	e
0	1	2	3	4
5	6	7	8	9

FLAGS

0	
1	
2	
3	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☒
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☐
3	☐	☒			n	1

STAR LINE OF POSITION

Step	Key	Comment
001	*LBLA	
002	STO6	Store Day
003	X⇄Y	
004	STO4	Store Month
005	3	
006	0	
007	5	
008	6	
009	%	
010	INT	
011	ST+6	
012	R↑	
013	STO5	Store Year
014	RCL4	
015	3	
016	X>Y?	
017	1	
018	RCL5	
019	4	
020	÷	
021	FRC	
022	+	
023	1	
024	X⇄Y	
025	X=Y?	
026	2	
027	ST-6	
028	1	
029	9	
030	6	
031	9	
032	.	
033	1	Whole years from 1969.1
034	ST-5	
035	RCL6	
036	3	
037	6	
038	5	
039	.	
040	2	
041	5	
042	STOA	
043	÷	
044	ST+5	Add fractional year
045	3	
046	6	
047	0	
048	STOC	
049	ST×6	
050	2	
051	5	
052	9	
053	8	
054	6	
055	ST+6	
056	RCLA	

Step	Key	Comment
057	ST÷6	
058	1	
059	9	
060	GSB2	
061	RCLE	
062	-	
063	.	
064	8	
065	→R	
066	STO0	
067	R↓	
068	STO4	
069	RCLE	
070	2	
071	GSB2	
072	→R	
073	ST+4	
074	R↓	
075	RCLD	
076	TAN	
077	ST×0	
078	×	
079	9	
080	3	
081	RCLE	
082	GSB1	
083	-	
084	ST+0	
085	RCL6	
086	RCLE	Mean anomaly
087	+	
088	2	
089	→R	
090	RCLD	
091	1	
092	→R	
093	X⇄Y	
094	R↑	
095	×	
096	ST+4	
097	R↓	
098	÷	
099	ST-0	
100	RCL6	
101	LSTX	
102	→R	
103	.	
104	8	
105	×	
106	ST+4	
107	0	
108	RCLD	
109	GSB1	
110	ST+4	
111	RCLC	
112	ST÷0	

REGISTERS

0	1	2	3	4	5	6	7	8	9
	λ	GHA★	L	δ	YEAR	DAY	Z_n	H_c	a

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I
365.25	HE	360	δ 69	α 69	

```
113  ST÷4
114  RCLD
115  ST+4
116  RCLE
117  ST+0
118  RCLC
119  RTN
---------------------------
120  *LBLa
121  HMS→
122  STO1          Store λ
123  X⇄Y
124  HMS→
125  STO3          Store L
126  RTN
---------------------------
127  *LBLB
128  HMS→
129  1
130  5
131  .
132  0
133  4
134  1
135  6
136  7
137  ×
138  RCL6
139  +
140  RCL0
141  +
142  STO2
143  RCL1
144  -
145  RCL4
146  COS
147  →R
148  RCL3
149  STOI
150  X⇄Y
151  →R
152  X⇄I
153  RCL4
154  SIN
155  →R
156  X⇄I
157  +
158  SIN⁻¹
159  X⇄I
160  -
161  →P
162  R↓
163  1
164  8
165  0
166  +
167  STO7          Zn, azimuth
168  DSP1
169  PRTX
170  RCLI
171  STO8          Hc, altitude
172  →HMS
173  DSP4
174  PRTX
175  RTN
---------------------------
176  *LBLC
177  DSP1
178  HMS→
179  ENT↑
180  ENT↑
181  ENT↑
182  3
183  +
184  1
185  2
186  ×
187  TAN⁻¹
188  -             Mean Refraction
189  TAN
190  RCLB
191  √X
192  -
193  6
194  2
195  ÷             Dip
196  +
197  RCL8
198  -
199  CHS
200  6
201  0
202  ×
203  STO9
204  RTN
---------------------------
205  *LBL1
206  RCLC
207  ÷             Decode proper motion
208  INT           correction
209  -
210  5
211  0
212  ÷
---------------------------
213  *LBL2
214  RCL5
215  ×
216  RTN
---------------------------
217  *LBLb
218  STOB
219  RTN
```

LABELS

A Y↑M↑D	B GMT → Z_n, H_c	C h_s → a	D	E
a L↑λ	b HE	c	d	e
0	1	2	3	4
5	6	7	8	9

FLAGS

0	
1	
2	
3	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☒
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☐
3	☐	☒			n	1

STAR DATA 1

Step	Key	Star
001	*LBLa	ACAMAR
002	3	
003	1	
004	5	
005	.	
006	7	
007	2	
008	6	
009	8	
010	STOE	
011	4	
012	0	
013	.	
014	4	
015	2	
016	8	
017	1	
018	CHS	
019	GTO1	
020	*LBLb	ACHERNAR
021	3	
022	3	
023	5	
024	.	
025	8	
026	5	
027	9	
028	6	
029	STOE	
030	5	
031	7	
032	.	
033	3	
034	9	
035	3	
036	9	
037	CHS	
038	GTO1	
039	*LBLc	ACRUX
040	1	
041	7	
042	3	
043	.	
044	7	
045	8	
046	5	
047	0	
048	STOE	
049	6	
050	2	
051	.	
052	9	
053	2	
054	7	
055	5	
056	CHS	
057	GTO1	
058	*LBLd	ADHARA
059	2	
060	5	
061	5	
062	.	
063	6	
064	4	
065	8	
066	3	
067	STOE	
068	2	
069	8	
070	.	
071	9	
072	2	
073	8	
074	9	
075	CHS	
076	GTO1	
077	*LBLe	ALDEBARAN
078	2	
079	9	
080	1	
081	.	
082	4	
083	6	
084	5	
085	0	
086	STOE	
087	1	
088	6	
089	.	
090	4	
091	4	
092	8	
093	3	
094	GTO1	
095	*LBLA	ALIOTH
096	1	
097	6	
098	6	
099	.	
100	8	
101	3	
102	2	
103	5	
104	STOE	
105	5	
106	6	
107	.	
108	1	
109	2	
110	7	
111	8	
112	GTO1	

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

Program	Comments
113 *LBLB	ALKAID
114 1	
115 5	
116 3	
117 .	
118 4	
119 2	
120 STOE	
121 4	
122 9	
123 .	
124 4	
125 6	
126 7	
127 5	
128 GTO1	
129 *LBLC	ALNA'IR
130 2	
131 8	
132 .	
133 4	
134 2	
135 8	
136 3	
137 STOE	
138 4	
139 7	
140 .	
141 1	
142 1	
143 1	
144 9	
145 CHS	
146 GTO1	
147 *LBLD	
148 2	ALNILAM
149 7	
150 6	
151 .	
152 3	
153 4	
154 STOE	
155 1	
156 .	
157 2	
158 2	
159 0	
160 3	
161 CHS	
162 GTO1	
163 *LBLE	ALPHARD
164 2	
165 1	
166 8	
167 .	
168 4	
169 8	
170 4	
171 2	
172 STOE	
173 8	
174 .	
175 5	
176 2	
177 3	
178 3	
179 CHS	
180 *LBL1	
181 STOD	
182 RTN	

LABELS					FLAGS
A	B	C	D	E	0
a	b	c	d	e	1
0	1	2	3	4	2
5	6	7	8	9	3

SET STATUS		
FLAGS	TRIG	DISP
ON OFF		
0 ☐ ☐	DEG ☐	FIX ☐
1 ☐ ☐	GRAD ☐	SCI ☐
2 ☐ ☐	RAD ☐	ENG ☐
3 ☐ ☐		n ____

STAR DATA 2

Step	Key	Star	Step	Key	Star
001	*LBLa	ALPHECCA	057	CHS	
002	1		058	GTO1	
003	2		059	*LBLd	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	GTO1		074	4	
019	*LBLb	ALPHERATZ	075	4	
020	3		076	CHS	
021	5		077	GTO1	
022	8		078	*LBLe	ANTARES
023	.		079	1	
024	3		080	1	
025	0		081	3	
026	5		082	.	
027	2		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	GTO1		092	6	
037	*LBLc	ALTAIR	093	4	
038	1		094	7	
039	0		095	CHS	
040	1		096	GTO1	
041	7		097	*LBLA	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	I

Step	Key	Comment
113	3	
114	4	
115	3	
116	1	
117	GTO1	
118	*LBLB	ATRIA
119	1	
120	0	
121	8	
122	.	
123	6	
124	5	
125	8	
126	8	
127	STOE	
128	6	
129	8	
130	.	
131	9	
132	7	
133	3	
134	3	
135	CHS	
136	GTO1	
137	*LBLC	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	GTO1	
154	*LBLD	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	
169	1	
170	GTO1	
171	*LBLE	BETELGEUSE
172	2	
173	7	
174	1	
175	.	
176	6	
177	2	
178	6	
179	7	
180	STOE	
181	7	
182	.	
183	4	
184	0	
185	2	
186	9	
187	*LBL1	
188	STOD	
189	RTN	

LABELS					FLAGS
A	B	C	D	E	0
a	b	c	d	e	1
0	1	2	3	4	2
5	6	7	8	9	3

SET STATUS

FLAGS	TRIG	DISP
ON OFF		
0 ☐ ☐	DEG ☐	FIX ☐
1 ☐ ☐	GRAD ☐	SCI ☐
2 ☐ ☐	RAD ☐	ENG ☐
3 ☐ ☐		n ______

STAR DATA 3

Step	Key	Star
001	*LBLa	CANOPUS
002	2	
003	6	
004	4	
005	.	
006	1	
007	8	
008	5	
009	4	
010	STOE	
011	5	
012	2	
013	.	
014	6	
015	7	
016	9	
017	3	
018	CHS	
019	GTO1	
020	*LBLb	CAPELLA
021	2	
022	8	
023	1	
024	.	
025	4	
026	0	
027	0	
028	8	
029	STOE	
030	4	
031	5	
032	.	
033	9	
034	6	
035	8	
036	3	
037	GTO1	
038	*LBLc	DENEB
039	4	
040	9	
041	.	
042	9	
043	0	
044	6	
045	7	
046	STOE	
047	4	
048	5	
049	.	
050	1	
051	6	
052	8	
053	9	
054	GTO1	
055	*LBLd	DENEBOLA
056	1	

Step	Key	Star
057	2	
058	6	
059	3	
060	.	
061	1	
062	3	
063	STOE	
064	1	
065	4	
066	.	
067	7	
068	4	
069	5	
070	3	
071	GTO1	
072	*LBLe	DIPHDA
073	3	
074	4	
075	9	
076	.	
077	4	
078	9	
079	1	
080	7	
081	STOE	
082	1	
083	8	
084	.	
085	1	
086	5	
087	6	
088	4	
089	CHS	
090	GTO1	
091	*LBLA	DUBHE
092	1	
093	9	
094	4	
095	.	
096	5	
097	4	
098	2	
099	9	
100	STOE	
101	6	
102	1	
103	.	
104	9	
105	1	
106	8	
107	6	
108	GTO1	
109	*LBLB	ELNATH
110	2	
111	7	
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	I

```
113       .
114       9
115       1
116       7
117       5
118    STOE
119       2
120       8
121       .
122       5
123       8
124       2
125       8
126    GTO1
127   *LBLC       ELTANIN
128       9
129       1
130       .
131       0
132       2
133       8
134       7
135    STOE
136       5
137       1
138       .
139       4
140       9
141       1
142       9
143    GTO1
144   *LBLD       ENIF
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    GTO1
160   *LBLE       FOMALHAUT
161       1
162       6
163       .
164       0
165       1
166       5
167       0
168    STOE
169       2
170       9
171       .
172       7
173       8
174       6
175       9
176     CHS
177   *LBL1
178    STOD
179     RTN
```

LABELS					FLAGS
A	B	C	D	E	0
a	b	c	d	e	1
0	1	2	3	4	2
5	6	7	8	9	3

SET STATUS

FLAGS			TRIG	DISP
	ON	OFF		
0	☐	☐	DEG ☐	FIX ☐
1	☐	☐	GRAD ☐	SCI ☐
2	☐	☐	RAD ☐	ENG ☐
3	☐	☐		n ______

L08-09

STAR DATA 4

Step	Instruction	Star
001	*LBLa	GACRUX
002	1	
003	7	
004	2	
005	.	
006	6	
007	4	
008	1	
009	3	
010	STOE	
011	5	
012	6	
013	.	
014	9	
015	4	
016	CHS	
017	GTO1	
018	*LBLb	GIENAH
019	1	
020	7	
021	6	
022	.	
023	4	
024	4	
025	7	
026	9	
027	STOE	
028	1	
029	7	
030	.	
031	3	
032	7	
033	CHS	
034	GTO1	
035	*LBLc	HADAR
036	1	
037	4	
038	9	
039	.	
040	5	
041	9	
042	5	
043	STOE	
044	6	
045	0	
046	.	
047	2	
048	2	
049	4	
050	4	
051	CHS	
052	GTO1	
053	*LBLd	HAMAL
054	3	
055	2	
056	8	
057	.	
058	6	
059	4	
060	5	
061	STOE	
062	2	
063	3	
064	.	
065	3	
066	1	
067	6	
068	7	
069	GTO1	
070	*LBLe	KAUS AUSTRALIS
071	8	
072	4	
073	.	
074	4	
075	7	
076	1	
077	7	
078	STOE	
079	3	
080	4	
081	.	
082	4	
083	0	
084	1	
085	1	
086	CHS	
087	GTO1	
088	*LBLA	KOCHAB
089	1	
090	3	
091	7	
092	.	
093	3	
094	0	
095	5	
096	6	
097	STOE	
098	7	
099	4	
100	.	
101	2	
102	8	
103	2	
104	2	
105	GTO1	
106	*LBLB	MARKAB
107	1	
108	4	
109	.	
110	1	
111	9	
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	I

```
113      7
114   STOE
115      1
116      5
117      .
118      2
119      3
120      8
121      1
122   GTO1
123  *LBLC      MENKAR
124      3
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   GTO1
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   GTO1
160  *LBLE      MIAPLACIDUS
161      2
162      2
163      1
164      .
165      7
166      8
167      2
168      9
169   STOE
170      6
171      9
172      .
173      5
174      8
175      9
176      4
177    CHS
178  *LBL1
179   STOD
180    RTN
```

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

STAR DATA 5

001	*LBLa	MIRFAK
002	3	
003	6	
004	9	
005	.	
006	4	
007	7	
008	5	
009	STO3	
010	CLRG	
011	STOE	
012	4	
013	9	
014	.	
015	7	
016	5	
017	2	
018	2	
019	GTO1	
020	*LBLb	NUNKI
021	7	
022	6	
023	.	
024	6	
025	6	
026	4	
027	2	
028	STOE	
029	2	
030	6	
031	.	
032	3	
033	3	
034	6	
035	9	
036	CHS	
037	GTO1	
038	*LBLc	PEACOCK
039	5	
040	4	
041	.	
042	1	
043	9	
044	8	
045	8	
046	STOE	
047	5	
048	6	
049	.	
050	8	
051	3	
052	6	
053	1	
054	CHS	
055	GTO1	
056	*LBLd	POLARIS

057	3	
058	2	
059	9	
060	.	
061	3	
062	7	
063	0	
064	8	
065	STOE	
066	8	
067	9	
068	.	
069	1	
070	2	
071	1	
072	4	
073	GTO1	
074	*LBLe	POLLUX
075	1	
076	3	
077	2	
078	4	
079	.	
080	1	
081	4	
082	4	
083	6	
084	STOE	
085	2	
086	8	
087	.	
088	1	
089	0	
090	2	
091	5	
092	GTO1	
093	*LBLA	PROCYON
094	1	
095	3	
096	2	
097	5	
098	.	
099	5	
100	8	
101	STOE	
102	1	
103	8	
104	0	
105	5	
106	.	
107	3	
108	0	
109	5	
110	6	
111	GTO1	
112	*LBLB	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	I

Step	Key	Comment
113	9	
114	6	
115	.	
116	6	
117	2	
118	6	
119	7	
120	STOE	
121	1	
122	2	
123	.	
124	5	
125	8	
126	1	
127	1	
128	GTO1	
129	*LBLC	REGULUS
130	2	
131	0	
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	GTO1	
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	GTO1	
165	*LBLE	RIGIL KENTAURUS
166	1	
167	3	
168	4	
169	6	
170	0	
171	.	
172	6	
173	3	
174	STOE	
175	1	
176	5	
177	0	
178	0	
179	.	
180	7	
181	0	
182	8	
183	6	
184	CHS	
185	*LBL1	
186	STOD	
187	RTN	

LABELS					FLAGS
A	B	C	D	E	0
a	b	c	d	e	1
0	1	2	3	4	2
5	6	7	8	9	3

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☐	DEG	☐	FIX	☐
1	☐	☐	GRAD	☐	SCI	☐
2	☐	☐	RAD	☐	ENG	☐
3	☐	☐			n ______	

STAR DATA 6

001	*LBLa	SABIK	057	*LBLd	
002	1		058	1	
003	6		059	3	
004	2		060	3	
005	.		061	9	
006	8		062	.	
007	5		063	0	
008	0		064	5	
009	8		065	4	
010	STOE		066	2	
011	1		067	STOE	
012	5		068	2	
013	.		069	8	
014	6		070	6	
015	8		071	3	
016	8		072	.	
017	1		073	3	
018	CHS		074	2	
019	GTO1		075	7	
020	*LBLb	SCHEDAR	076	8	
021	3		077	GTO1	SPICA
022	5		078	*LBLe	
023	0		079	1	
024	.		080	5	
025	3		081	9	
026	1		082	.	
027	6		083	1	
028	3		084	1	
029	STOE		085	0	
030	5		086	8	
031	6		087	STOE	
032	.		088	1	
033	3		089	1	
034	6		090	CHS	
035	7		091	GTO1	
036	8		092	*LBLA	SUHAIL
037	GTO1		093	2	
038	*LBLc		094	2	
039	9	SHAULA	095	3	
040	7		096	.	
041	.		097	2	
042	CHS		098	8	
043	1		099	6	
044	2		100	3	
045	4		101	STOE	
046	6		102	4	
047	STOE		103	3	
048	3		104	.	
049	7		105	3	
050	.		106	0	
051	0		107	6	
052	6		108	9	
053	3		109	CHS	
054	1		110	GTO1	
055	CHS		111	*LBLB	VEGA
056	GTO1	SIRIUS	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	I

113	1	
114	.	
115	0	
116	2	
117	7	
118	9	
119	STOE	
120	3	
121	8	
122	.	
123	7	
124	5	
125	3	
126	9	
127	GTO1	
128	*LBLC	ZUBENELGENUBI
129	1	
130	3	
131	7	
132	.	
133	7	
134	1	
135	STOE	
136	1	
137	5	
138	.	
139	9	
140	1	
141	4	
142	2	
143	CHS	
144	*LBL1	
145	STOD	
146	RTN	

LABELS					FLAGS
A	B	C	D	E	0
a	b	c	d	e	1
0	1	2	3	4	2
5	6	7	8	9	3

SET STATUS

FLAGS			TRIG	DISP
	ON	OFF		
0	☐	☐	DEG ☐	FIX ☐
1	☐	☐	GRAD ☐	SCI ☐
2	☐	☐	RAD ☐	ENG ☐
3	☐	☐		n_____

BEARING LINE OF POSITION

Key	Comment
*LBLA	
HMS→	
STO1	Store λ_1
X⇄Y	
HMS→	Store L_1
STO3	
0	
STO8	H_c and a = 0
STO9	
3	
6	
0	
STOC	
R/S	
STO6	Store Z_1
9	
0	
+	
STO7	Store Z_1 + 90
RCL3	
RCL1	
RCL6	
GSB3	Compute location of "false star"
0	
RTN	
*LBLB	
P⇄S	
GSBA	Store L_2, λ_2, and Z_z
RCL1	
RCL3	
P⇄S	Rearrange registers
STO5	
X⇄Y	
STO0	
RCL1	
RCL3	
P⇄S	
STO3	
X⇄Y	
STO1	
RTN	
*LBLC	
HMS→	
×	
6	
0	
÷	Distance
STOA	
X⇄Y	Store course
STOB	
COS	
×	
P⇄S	
RCL3	
+	
STO3	
LSTX	
GSB5	Move Geographical position of first false star along a rhumb line
RCL3	
GSB5	
-	
RCLB	
1	
→R	
X=0?	
GTO4	
÷	
×	
5	
7	
.	
3	
×	
GTO6	
*LBL4	
RCLB	
SIN	
RCLA	
×	
RCL5	
COS	
÷	
CHS	
*LBL6	
RCL1	
+	
GSB2	
STO1	
P⇄S	
*LBLD	
P⇄S	
RCL1	
RCL0	
-	
GSB2	
RCL5	
COS	
×	
RCL5	
RCL3	
-	
CHS	
RCL6	
TAN	
×	
+	
RCL6	
TAN	
P⇄S	
RCL6	
P⇄S	
TAN	

REGISTERS

0	1	2	3	4	5	6	7	8	9
	λ_2, λ_1	α_2	L_2, L_1	δ_2		Z_2	Z_{n2}	0	0

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
λ_2	λ_1	α_1	L_1	δ_1	L_2	Z_1	Z_{n1}	0	0

A	B	C	D	E	I
D, L	C, λ	360			

```
-
÷
STOI
RCL5
+
STOA
→HMS
RCL0
RCLI
P⇄S
RCL6
P⇄S
TAN
x
RCL5
COS
÷
-
GSB2
STOB
→HMS
X⇄Y
R/S
X⇄Y
P⇄S
RTN
*LBL2
1
→R
→P
R↓
RTN
-------------------------
*LBL3
1
→R
X⇄Y
R↑
X⇄Y
→R
SIN⁻¹
CHS
STO4        Store declination of "false star"
R↓
→P
R↓
-
STO2        Store GHA of "false star"
RTN
-------------------------
*LBL5       Subroutine for part of rhumb line equations
2
÷
4
5
+
TAN
LN
RTN
```

LABELS					FLAGS
A $L_1 \uparrow \lambda_1 ; Z_1$	B $L_2 \uparrow \lambda_2 ; Z_2$	C C↑S↑T→L_1 λ	D →L, λ	E	0
a	b	c	d	e	1
0	1	2	3	4	2
5	6	7	8	9	3

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☒
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☐
3	☐	☒			n	4

TWO-ANGLE LINE OF POSITION

Step	Key	Comment
001	*LBLA	
002	HMS→	
003	STO0	Store λ_A
004	X⇄Y	
005	HMS→	
006	STO1	Store L_A
007	RTN	------------
008	*LBLC	
009	HMS→	
010	STO5	Store λ_C
011	X⇄Y	
012	HMS→	
013	STO6	Store L_C
014	R/S	
015	STOA	Store Z_C
016	RTN	------------
017	*LBLE	
018	P⇄S	Store L_E, λ_E in secondary registers
019	GSBA	
020	P⇄S	
021	RTN	------------
022	*LBLB	
023	HMS→	
024	STO2	Store ΔZ_{AC}
025	RCLA	
026	X⇄Y	
027	-	
028	STO3	Store Z_A
029	GSB5	Compute approximate L, λ
030	RTN	------------
031	*LBLD	
032	RCL5	
033	RCL6	
034	P⇄S	
035	STO6	
036	R↓	
037	STO5	
038	R↓	
039	HMS→	
040	STO2	
041	RCLA	
042	+	
043	STO3	Store Z_E
044	GSB5	Compute approximate L, λ
045	RTN	------------
046	*LBL5	
047	RCL5	
048	RCL0	
049	-	
050	RCL6	
051	RCL1	
052	GSB3	
053	COS⁻¹	Distance A to C
054	STO4	
055	2	
056	÷	

Step	Key	Comment
057	SIN	
058	RCL2	
059	2	
060	÷	
061	SIN	
062	÷	
063	RCL2	
064	2	
065	÷	
066	COS	
067	X⇄Y	
068	x	
069	LSTX	
070	SIN⁻¹	
071	COS	
072	1	
073	-	
074	CHS	
075	÷	
076	TAN⁻¹	
077	STO8	Store "H_c"
078	TAN	
079	RCL4	
080	COS	
081	1	
082	-	
083	CHS	
084	x	
085	RCL4	
086	SIN	
087	÷	
088	COS⁻¹	
089	R↑	
090	RCLA	
091	-	
092	SIN	
093	RCL2	
094	COS	
095	x	
096	ABS	
097	LSTX	
098	÷	
099	x	
100	+	
101	RCL6	
102	RCL8	
103	GSB3	
104	SIN⁻¹	
105	STO4	Store declination of "false star"
106	R↓	
107	CHS	
108	RCL5	
109	+	
110	STO2	Store GHA of "false star"
111	*LBL4	
112	RCL6	

REGISTERS

0	1	2	3	4	5	6	7	8	9
λ_A	L_A	$\Delta Z_{Ac}, \alpha_1$	Z_A	d, δ_1	λ_c	L_c			

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
λ_E	L_E	$\Delta A_{cE}, \alpha_2$	Z_E	d, δ_2	λ_c	L_c			

A	B	C	D	E	I
Z_c					

Step	Key	Comments
113	ENT↑	
114	COS	
115	RCL8	
116	RCL5	
117	-	
118	GSB2	
119	×	
120	RCL1	
121	RCL6	
122	-	
123	RCL3	
124	TAN	
125	×	
126	+	
127	RCL3	
128	TAN	
129	RCLA	
130	TAN	
131	-	
132	÷	
133	+	
134	STO3	
135	RCL5	
136	LSTX	
137	RCLA	
138	TAN	
139	×	
140	RCL6	
141	COS	
142	÷	
143	-	
144	STO1	
145	RCL2	
146	-	
147	RCL3	
148	RCL4	
149	GSB3	
150	R↓	
151	STO7	Store Z_n
152	0	
153	STO9	a = 0
154	RCL3	
155	→HMS	approximate L
156	R/S	
157	RCL1	
158	→HMS	approximate λ
159	*LBL2	- - - - - - - - Subroutine to force $\|x\| \leqslant 180°$
160	1	
161	→R	
162	→P	
163	R↓	
164	RTN	- - - - - - - - - - - - -
165	*LBLe	
166	RCL7	
167	RCL3	
168	RCL1	

Step	Key	Comments
169	P⇄S	
170	STO5	
171	R↓	
172	STO6	
173	R↓	
174	9	
175	0	
176	ST-7	
177	-	
178	STOA	
179	RCL1	
180	STO0	
181	RCL3	
182	STO1	
183	RCL7	
184	STO3	
185	GTO4	- - - - - - - - - - -
186	*LBL3	Celestial Triangle Subroutine
187	1	z = t
188	→R	inputs: y = L
189	R↑	x = d
190	X⇄Y	
191	→R	
192	R↑	
193	STOI	
194	X⇄Y	
195	→R	
196	X⇄I	
197	R↑	
198	→R	
199	X⇄I	
200	+	
201	X⇄I	
202	-	
203	CHS	
204	→P	outputs: y = Z − 180
205	X⇄I	x = sin(h)
206	RTN	- - - - - - - - - - -

LABELS

A	B	C	D	E
$L_A \uparrow \lambda_A$	$\Delta Z_{AC} \to L, \lambda$	$L_c \uparrow \lambda_c; Z_c$	$\Delta Z_{CD} \to L, \lambda$	$L_E \uparrow \lambda_E$
a	b	c	d	e
0	1	2	3	4
5	6	7	8	9

FLAGS

0	
1	
2	
3	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☒
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☐
3	☐	☒			n	4

FIX FROM TWO LINES OF POSITION

Step	Key	Comment
001	*LBLA	C ↑ S ↑ Δt
002	HMS→	
003	×	
004	6	
005	0	
006	÷	D = S Δt
007	STO0	
008	X⇄Y	
009	STOI	
010	COS	
011	×	
012	P⇄S	
013	RCL3	Move geographical position
014	P⇄S	of body used for first LOP
015	+	using rhumb line equations
016	STO3	
017	LSTX	
018	GSBc	
019	RCL3	
020	GSBc	
021	-	
022	RCLI	
023	1	
024	→R	
025	X=0?	
026	GTOd	
027	÷	
028	×	
029	5	
030	7	
031	.	
032	3	
033	×	
034	GTOb	- - - - - - - -
035	*LBLd	
036	RCLI	
037	SIN	
038	RCL0	
039	×	
040	RCL3	
041	COS	
042	÷	
043	CHS	
044	*LBLb	
045	P⇄S	
046	RCL1	
047	P⇄S	
048	+	
049	STO1	- - - - - - - - - - - -
050	*LBLe	IF this is first time
051	F0?	THEN
052	GTO9	replace H_c with H_0
053	RCL9	
054	6	
055	0	
056	÷	
057	ST-8	
058	P⇄S	
059	RCL9	
060	LSTX	
061	÷	
062	ST-8	
063	P⇄S	- - - - - - -
064	*LBL9	Compute fix using
065	SF0	Dozier's method
066	SF1	
067	P⇄S	
068	RCL2	
069	P⇄S	
070	RCL2	
071	-	
072	RCL4	
073	P⇄S	
074	RCL4	
075	GSB2	
076	STOA	
077	X⇄Y	
078	STOB	
079	RCL1	
080	P⇄S	
081	RCL1	
082	-	
083	RCL3	
084	P⇄S	
085	RCL3	
086	X⇄Y	
087	GSB2	
088	SIN⁻¹	Distance GP_1 to GP_2
089	X⇄Y	
090	RCL7	
091	-	
092	X⇄Y	
093	RCL8	
094	GSB2	
095	P⇄S	
096	RCL8	
097	RCLA	
098	→R	
099	R↓	
100	-	
101	R↑	
102	RCLA	
103	COS⁻¹	
104	TAN	
105	×	
106	÷	
107	COS⁻¹	
108	STO0	A
109	CHS	
110	*LBL4	
111	RCLB	
112	+	

REGISTERS

0	1	2	3	4	5	6	7	8	9
D	λ_2	α_1 = GHA_2	L_2	δ_2	L?	λ?	Z_{n2}	H_{c2}	A_2

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
A	λ_1	α_1	L_1	δ_1	L?	λ'?	Z_{n1}	H_{c1}	A_1

A	B	C	D	E	I
cos D	x ≠ A	360	SCRATCH, D	SCRATCH	SCRATCH

Step	Key	Comments
113	RCL4	
114	RCL8	
115	GSB2	
116	SIN⁻¹	Distance 1, 2
117	RCL2	
118	X⇄Y	
119	F1?	
120	P⇄S	
121	STO5	Store trial L
122	R↓	
123	+	
124	1	
125	→R	
126	→P	$\lvert\lambda\rvert \leq 180°$
127	X⇄Y	
128	STO6	Store trial λ
129	F2?	
130	GTO8	
131	SF2	
132	P⇄S	
133	CF1	First time through
134	RCL0	
135	GTO4	- - - - - - - -
136	*LBL8	Second time through
137	GSB5	
138	P⇄S	
139	STO0	
140	GSB5	
141	RCL0	
142	P⇄S	
143	X≤Y?	Select proper fix
144	GTO7	
145	P⇄S	
146	SF2	
147	*LBL7	
148	RCL6	
149	RCL5	
150	→HMS	
151	F2?	
152	P⇄S	
153	R/S	
154	X⇄Y	Display L
155	→HMS	
156	RTN	Display λ
157	*LBL2	- - - - - - - - - - - -
158	1	Celestial Triangle Subroutine
159	→R	inputs: z = t
160	R↑	y = L
161	X⇄Y	x = d
162	→R	
163	R↑	
164	STOI	
165	X⇄Y	
166	→R	
167	X⇄I	
168	R↑	
169	→R	
170	X⇄I	
171	+	outputs: y = Z − 180
172	X⇄I	x = sin(h)
173	-	
174	CHS	
175	→P	
176	X⇄I	
177	RTN	- - - - - - - - - - -
178	*LBL5	Subroutine to get distance from L, λ to GP_1 or GP_2
179	RCL1	
180	RCL6	
181	-	
182	RCL5	
183	RCL3	
184	GSB2	
185	COS⁻¹	
186	RTN	- - - - - - - - - - -
187	*LBLc	Subroutine for rhumb line equations
188	2	
189	÷	
190	4	
191	5	
192	+	
193	TAN	
194	LN	
195	RTN	- - - - - - - - - - -
196	*LBLC	Compute worst-case error for 1′ error in h_{s1} or h_{s2}
197	SF2	
198	*LBLD	
199	P⇄S	
200	RCL7	
201	P⇄S	
202	RCL7	
203	+	
204	2	
205	÷	
206	F2?	Normalize Z
207	9	
208	0	
209	+	
210	COS	
211	COS⁻¹	
212	STOI	
213	RCL7	
214	-	
215	COS	
216	1/X	
217	ABS	
218	R/S	
219	RCLI	
220	RTN	

LABELS

A	B	C	D	E
A →L, λ	B	C →D, Z_D	D →ΔD′, Z_D′	E
a C↑S↑Δt	b	c	d	e →L, λ
0	1	2	3	4
5	6	7	8	9

FLAGS

0	
1	
2	
3	

SET STATUS

FLAGS	ON	OFF	TRIG		DISP	
0	☐	☒	DEG	☒	FIX	☒
1	☐	☒	GRAD	☐	SCI	☐
2	☐	☒	RAD	☐	ENG	☐
3	☐	☒			n	4

RADAR PLOTTING CLOSEST POINT OF APPROACH

Step	Key	Comment
001	*LBLb	
002	STOC	Store course and speed
003	X⇄Y	
004	STOB	
005	RTN	- - - - - - - - - - - -
006	*LBLc	
007	STOA	Store Miss Distance
008	RTN	- - - - - - - - - - - -
009	*LBLd	
010	DSP0	
011	P⇄S	Exchange data
012	F1?	IF flag 1
013	GTO1	THEN GTO 1
014	1	Display 1
015	SF1	
016	RTN	
017	*LBL1	
018	2	Display 2
019	CF1	
020	RTN	- - - - - - - - - - - -
021	*LBLa	
022	SF2	First time
023	*LBLA	
024	RCL8	
025	STO5	Range
026	R↓	
027	STO8	
028	R↓	
029	RCL7	
030	STO4	
031	R↓	
032	STO7	Bearing
033	R↓	
034	HMS→	
035	RCL6	
036	STO3	
037	R↓	
038	STO6	Time
039	F2?	Stop here first time
040	RTN	- - - - - - - - - - - -
041	RCL7	
042	RCL8	
043	→R	
044	RCL4	
045	RCL5	
046	→R	
047	X⇄Y	
048	R↓	
049	-	
050	R↓	
051	-	
052	R↑	
053	X⇄Y	
054	→P	
055	X⇄Y	
056	3	
057	6	
058	0	
059	X⇄Y	
060	X<0?	
061	+	
062	STO9	Bearing of CPA
063	RCL7	
064	-	
065	COS	
066	RCL8	
067	×	
068	→R	
069	→P	
070	STO0	Range of CPA
071	RCL7	
072	RCL8	
073	RCL4	
074	RCL5	
075	CHS	
076	GSB8	
077	RCL6	
078	RCL3	
079	-	
080	÷	
081	STO2	Relative speed
082	X⇄Y	
083	STO1	Relative course
084	RCLA	
085	RCL0	
086	X≤Y?	IF r_{CPA} ≤ MISS DIST
087	PSE	THEN blink display
088	X≤Y?	
089	PSE	
090	X≤Y?	
091	PSE	
092	DSP1	Display range of CPA
093	R/S	
094	DSP0	
095	RCL9	Display bearing of CPA
096	RTN	
097	*LBLB	
098	DSP0	His course
099	RCL1	
100	RCL2	
101	RCLB	
102	RCLC	
103	GSB8	
104	STOE	
105	X⇄Y	
106	3	
107	6	
108	0	
109	X⇄Y	
110	X<0?	
111	+	
112	STOD	

REGISTERS

0	1	2	3	4	5	6	7	8	9
r_{CPA}	h_r	rm	t_1	ϕ_1	D_1	t_2	ϕ_2	D_2	ϕ_{CPA}, θ

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
r_{CPA}	h_r	rm	t_1	ϕ_1	D_1	t_2	ϕ_2	D_2	ϕ_{CPA}, θ

A	B	C	D	E	I
MISS DIST	COURSE	SPEED	h	em	t_3

```
RTN
*LBLC        His speed
DSP1
GSBB
RCLE
RTN
*LBLe        t → New course, Left
DSP0
GSB0
-
GSB1
RTN
*LBLE        t → New course, Right
DSP0
GSB0
+
GSB1
RTN
*LBL0
HMS→
STOI
RCL1
RCL2
RCLI
RCL6
-
x
RCL7
RCL8
GSB8
X⇄Y
1
8
0
+
RCL1
-
STO9
X⇄Y
RCLA
÷
1/X
SIN⁻¹
RTN
*LBL1
RCL1
+
ENT↑
ENT↑
1
8
0
+
X⇄Y
RCLD
-
CHS
SIN
RCLE
x
RCLC
÷
SIN⁻¹
-
3
6
0
→R
→P
X⇄Y
X<0?
+
RTN
*LBL8
→R
R↓
R↓
→R
X⇄Y
R↓
+
R↓
+
R↑
→P
RTN
*LBLD        Time of CPA
DSP4
RCL9
RCL0
RCL7
RCL8
CHS
GSB8
RCL2
÷
RCL6
+
→HMS         Display time
RTN
```

LABELS				
A $t_2 \uparrow B_2 \uparrow R_2$	B → HIS Course	C → HIS speed	D t_{CPA}	E right turn
a $t_1 \uparrow B_1 \uparrow R_1$	b course↑speed	c MISS DIST	d TARGET?	e left turn
0	1	2	3	4
5	6	7	8	9

FLAGS	
0	
1	TARGET
2	first time
3	

SET STATUS

FLAGS	ON	OFF
0	☐	☒
1	☐	☒
2	☐	☒
3	☐	☒

TRIG	
DEG	☒
GRAD	☐
RAD	☐

DISP	
FIX	☒
SCI	☐
ENG	☐
n	0

DISTANCE BY HORIZON ANGLE

```
*LBLA
STO1        Store HE
RTN
-------------------------
*LBLB
STO2        Store H
RTN
-------------------------
*LBLC       Short of horizon
HMS→        hs → D
RCL1
√X
.
0
1
6
2
x
-
STO3
TAN
2
.
4
6
EEX
CHS
4
÷
CHS
ENT↑
ENT↑
x
RCL2
RCL1
-
.
7
4
7
3
6
÷
+
√X
+
RTN
-------------------------
*LBLa       Distance to horizon
RCL1
√X
1
.
1
4
4
x
RTN
-------------------------
*LBLb       Distance of visibility
RCL1
√X
RCL2
√X
+
1
.
1
4
4
x
RTN
-------------------------
*LBLD       Beyond horizon
HMS→        hs → D
STO4
RCL1
√X
.
0
1
6
2
x
+
STO4
TAN
RCL1
X⇄Y
÷
GTO0
-------------------------
*LBLe       H ↑ hs → D
HMS→
TAN
÷
GTO0
-------------------------
*LBLE       D ↑ hs → H
HMS→
TAN
x
6
0
7
6
x
*LBL0
R/S
6
0
7
6
÷
RTN
```

REGISTERS

0	1	2	3	4	5	6	7	8	9
	HE	H							

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A	B	C	D	E	I

LABELS					FLAGS
A HE	B H	C $h_s \rightarrow D$	D	E $D \uparrow h_s \rightarrow H$	0
a $\rightarrow D_{hor}$	b $\rightarrow D_{vis}$	c	d	e $H \uparrow h_s \rightarrow D$	1
0	1	2	3	4	2
5	6	7	8	9	3

SET STATUS		
FLAGS	TRIG	DISP
ON OFF 0 ☐ ☒ 1 ☐ ☒ 2 ☐ ☒ 3 ☐ ☒	DEG ☒ GRAD ☐ RAD ☐	FIX ☒ SCI ☐ ENG ☐ n 2

BEATING TO WINDWARD

```
*LBLA
SPC
R↓      Store Wa
STO9
R↓      Store S
STO8
R↓      Store Sa
STO7
R↓
COS
X²
STOA
RCL9
1       Correct Sa for angle of heel
→R
X²
X⇄Y
X²
RCLA
×
+
√X      Store new Sa
RCL7
X⇄Y
÷
STO7
- - - - - - - - - - - -
RCL9
X⇄Y
→R      Compute MW
RCL8
-
→P
STO5
DSP2
- - - - - - - - - - - -
PRTX
RCL7
X²
RCL8
X²
-       Compute Wt
RCL5
X²
-
2
÷
RCL8
÷
RCL5
÷
COS⁻¹
STO6
DSP1
- - - - - - - - - - - -
GTO5
*LBLB   Port Tack
SF1
GSB0
-
GSB9
STO3
RND
GTO5
- - - - - - - - - - - -
*LBLC   Stbd Tack
CF1
GSB0
+
GSB9
STO3
GTO5
- - - - - - - - - - - -
*LBL0   Subroutine
SPC
STO0    Store deviation
R↓
STO1
X⇄Y
STO2
R↑
+
+
GSB9
STOA
RCL6
RTN
- - - - - - - - - - - -
*LBL8   Subroutine to multiply
→R      complex numbers
R↓
R↓
→R
X⇄Y
R↓
+
R↓
+
R↑
→P
RTN
- - - - - - - - - - - -
*LBLD
STOI    Store Drift
X⇄Y
STO4
X⇄Y     Store Set
RCLA
RCL8
GSB8
DSP2
PRTX
STOB    SMG
X⇄Y
GSB9
PRTX
STOC    CMG
RCL3
RCL6
```

REGISTERS

0	1	2	3	4	5	6	7	8	9
Dev	Var	C_c	W_m	Set	MW	W_t	S_a	S	W_a

S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
C_m	D	t_{Lay}	t_{next}						Used

A	B	C	D	E	I
C_t	SMG (this tack)	CM (this tack)	SM (next tack)	CMG (next tack)	Drift

Step	Key	Comments
113	F1?	
114	CHS	
115	+	
116	GSB9	
117	STOE	
118	PRTX	C_t next tack
119	CF3	
120	SPC	
121	*LBL7	Wait loop
122	PSE	
123	F3?	Wait for new dev
124	GTO0	
125	GTO7	
126	*LBL0	
127	RCLE	
128	X⇄Y	
129	STO0	
130	-	
131	RCL1	
132	-	
133	GSB9	
134	PRTX	C_c next tack
135	RCLE	
136	RCL8	
137	RCL4	
138	RCLI	
139	GSB8	
140	DSP2	
141	PRTX	
142	STOD	SMG next tack
143	X⇄Y	
144	GSB9	
145	STOE	
146	GTO5	
147	*LBLE	CMG next tack
148	P⇄S	
149	STO1	
150	X⇄Y	Store D
151	STO0	
152	X⇄Y	Store C_m
153	RCLC	
154	RCLE	
155	-	
156	SIN	
157	÷	
158	STO9	
159	RCL0	
160	RCLC	
161	-	
162	SIN	
163	x	
164	ABS	
165	DSP2	
166	PRTX	Distance along lay line
167	RCLD	
168	÷	

Step	Key	Comments
169	STO2	
170	→HMS	
171	DSP4	
172	PRTX	Time along lay line
173	RCLE	
174	RCL0	
175	-	
176	SIN	
177	RCL9	
178	x	
179	ABS	
180	DSP2	
181	GSB5	Distance to lay line
182	RCLB	
183	÷	
184	STO3	
185	DSP4	
186	GSB4	Time to lay line
187	P⇄S	
188	SPC	
189	RTN	
190	*LBL4	Print subroutines
191	→HMS	
192	*LBL5	
193	PRTX	
194	RTN	
195	*LBLe	Compute C_m and D given time from start
196	P⇄S	
197	HMS→	
198	RCLB	
199	x	
200	RCLC	
201	X⇄Y	
202	CHS	
203	RCL0	
204	RCL1	
205	GSB8	
206	P⇄S	
207	DSP2	
208	PRTX	
209	X⇄Y	
210	GSB9	
211	PRTX	
212	RTN	
213	*LBL9	Subroutine to reduce angles to range $0 \leqslant \theta < 360$
214	DSP1	
215	3	
216	6	
217	0	
218	→R	
219	→P	
220	X⇄Y	
221	X<0?	
222	+	
223	RTN	

LABELS

A $S_a \uparrow S \uparrow W_a \uparrow i$	B PORT	C STBD	D $S_t \uparrow D$	E $C_m \uparrow D$
a	b	c	d	e $\Delta t \rightarrow C_m, D$
0	1	2	3	4
5	6	7	8	9

FLAGS

0
1
2
3

SET STATUS

FLAGS	ON	OFF
0	☐	☒
1	☐	☒
2	☐	☒
3	☐	☒

TRIG	
DEG	☒
GRAD	☐
RAD	☐

DISP	
FIX	☒
SCI	☐
ENG	☐
n	2

Notes

Notes

Notes

HEWLETT PACKARD

1000 N.E. Circle Blvd., Corvallis, OR 97330

00097-90174

● B C D E