MERLIN II
INSTRUCTION MANUAL

* Learn to use section
* Both broad outline and detailed description of each function
* Navigation functions illustrated by examples in context
* Around 70 celestial observations of all types in graded exercises
* Table of time signals, glossary of terms
* Theory, practice, sextant selection, emergencies and more

The handbook to the remarkable Merlin II . . .

Observations turned into position line in 5 seconds * Electronic almanacs from the Royal Greenwich Observatory for sun, moon and 59 stars to AD 2020 * Automatic altitude corrections * Automatic correction for passage of vessel * Automatic star position line without identification or bearing * Latitude and longitude from a single body * Rigorous, instantaneous fix and running fix from unlimited number of sights * Fix automatically upgraded with each sight * Fix accuracy displayed: reject or recompute any sight at any time * Advance or retire fix at will * Instant computed set and drift * Noon, Polaris and ex-meridian latitude * Star identification using bearing * Prediction of sextant settings * Prediction of meridian passage and twilights * Open access to computed almanac values every sight * Computed altitude and computed corrections accessible every sight * Instant dead reckoning using speed or sumlog * Automatic mercator and great circle * Speed for timed distance * Distance off by vertical angle * Current vector solution * Tide height interpolator * Numbers entered once and held indefinitely * Direct access to all numbers at all times for checking, changing and re-use . . .

. . . super fast, flexible, uniquely understandable.

MERLIN

MERLIN II

INSTRUCTION MANUAL

AND

CELESTIAL NAVIGATION REFERENCE

SHARP

MERLIN

SHA	dec	**No**	mag	SHA	dec	**No**	mag
13	15	**37**	2.6	182	14	**24**	2.2
15	-29	**30**	1.3	194	61	**26**	2.0
28	-47	**8**	2.2	208	12	**48**	1.3
34	9	**29**	2.5	218	-8	**10**	2.2
49	45	**23**	1.3	221	-69	**40**	1.8
53	-56	**43**	2.1	223	-43	**57**	2.2
62	8	**13**	0.9	234	-59	**18**	1.7
76	-26	**42**	2.1	243	28	**45**	1.2
80	38	**58**	0.1	245	5	**46**	0.5
84	-34	**35**	2.0	255	-29	**4**	1.6
90	51	**28**	2.4	258	-16	**55**	-1.6
96	12	**47**	2.1	264	-52	**21**	-0.9
96	-37	**53**	1.7	271	7	**20**	1.0
102	-15	**51**	2.6	276	-1	**9**	1.8
108	-69	**17**	1.9	278	28	**27**	1.8
112	-26	**15**	1.2	278	6	**19**	1.7
126	26	**11**	2.3	281	46	**22**	0.2
137	74	**36**	2.2	281	-8	**49**	0.3
137	-16	**59**	2.9	291	16	**5**	1.1
140	-60	**50**	0.1	309	49	**41**	1.9
146	19	**16**	0.2	314	4	**38**	2.8
148	-36	**39**	2.3	315	-40	**1**	3.1
149	-60	**33**	0.9	324	89	**44**	2.1
153	49	**7**	1.9	328	23	**34**	2.2
158	-11	**56**	1.2	335	-57	**2**	0.6
166	56	**6**	1.7	349	-18	**25**	2.2
172	-57	**31**	1.6	350	56	**52**	2.5
173	-63	**3**	1.1	353	-42	**14**	2.4
176	-17	**32**	2.8	358	29	**12**	2.2

1 Acamar
2 Achernar
3 Acrux
4 Adhara
5 Aldebaran
6 Alioth
7 Alkaid
8 Al Na'ir
9 Alnilam
10 Alphard
11 Alphecca
12 Alpheratz
13 Altair
14 Ankaa
15 Antares
16 Arcturus
17 Atria
18 Avior
19 Bellatrix
20 Betelgeuse
21 Canopus
22 Capella
23 Deneb
24 Denebola
25 Diphda
26 Dubhe
27 Elnath
28 Eltanin
29 Enif
30 Fomalhaut
31 Gacrux
32 Gienah
33 Hadar
34 Hamal
35 Kaus Aust.
36 Kochab
37 Markab
38 Menkar
39 Menkent
40 Miaplacidus
41 Mirfak
42 Nunki
43 Peacock
44 Polaris
45 Pollux
46 Procyon
47 Raselhague
48 Regulus
49 Rigel
50 Rigil Kent.
51 Sabik
52 Schedar
53 Shaula
54 Sigma Oct.
55 Sirius
56 Spica
57 Suhail
58 Vega
59 Zuben'ubi
60 Extra star
90 SunL
91 SunC
92 SunU
93 MoonL
94 MoonU
95 Planet

-1 Unknown star
-2 Unknown star

MERLIN II

OPERATING INSTRUCTIONS

AND

CELESTIAL NAVIGATION REFERENCE

MERLIN

Please turn to page 10 to learn how to use the Merlin II.
You do not need to refer to the Sharp PC 1248 manual.

Experiment as you wish but -

Don't ever type the word 'new'.
Don't touch the batteries till you've read page 94.

LINEPRINTER OPTION
Merlin II version MM will print to the Sharp CE-123P and CE-126P lineprinters. Learn to use your Merlin II (page 10) before trying the printer. Always switch off before connecting or disconnecting. Press DEF L to activate LinePrinter. To deactivate switch the computer off and on. Other DEF L functions are unaffected. To interrupt printing press the BRK/ON key on the computer.

CONTENTS MERLIN II INSTRUCTION MANUAL

PREFACE

This manual has two purposes:

1. to teach you, expert or novice, how to use Merlin II
2. to serve as a reference to each of its functions.

Initial users should turn directly to Example 1 on page 10. That will show you how to operate your Merlin II. If you are a novice then do Examples 2 and 3. If you are an experienced navigator the Outline on pages 4 to 7 will give you an overview of Merlin II. The extended exercise on page 59 shows how the navigation functions work together.

The computer cover carries a quick reference to most functions. The Outline gives a concise description of all the functions. For detailed information each function has its own chapter. In principle you should decide what you want to compute, select the corresponding function on Merlin II, and follow the displayed prompts. If you're not sure what to do, you may get some hints by looking at the functions provided.

You'll find answers to some of your questions on page 8. Some advice on navigational procedure and the role of the computer is set out on page 72. The reference section concentrates on topics which are popularly misunderstood or which textbooks tend to cover inadequately.

For the total beginner I suggest a 3-step plan: (1) do the examples in this manual to become proficient at operating your Merlin II, (2) take computer and sextant to the beach and there observe and compute sun sights till you are good at it, (3) study the theory.

The Merlin II has now been on sale for eight months. To date the instruction manual has been produced by photocopying which has permitted continuous refinement in response to user comment. The Merlin II itself has also undergone minor enhancements. This printed manual is appropriate to version LL onwards.

It is a source of some pride that the original Merlin has sold over 5000 units. Indications are that Merlin II will do as well. I'm sure it is the fastest and easiest-to-use computer that has ever been made for navigation but I do not claim it is perfect. Your opinion is invited. I answer all correspondence.

Thank you to the people who tested and criticised prototypes of the Merlin II. Thank you to the people who have commented on it and on the manual and to all those who have written or called over the last four years. Thanks, too, to the Sharp Corporation for their quality products and their marketing support. And thanks once again to my wife, Fran, who is the best critic and who looks after everything else allowing me to write computer programs and manuals.

Mike Pepperday, Perth, Western Australia, July, 1989.

PREFACE (second printing): In late 1989 I modified the Merlin II (version MM) to give an optional paper record. Otherwise this reprinting has required only very minor amendments and corrections.

MP, November, 1990.

OUTLINE INSTRUCTIONS / OVERVIEW

Learn to use Merlin II with the example on page 10

This outline is a quick reference. Pages in brackets refer to examples and full reference. Turn to page 10 to learn to use Merlin II.

DEF followed by a letter DEFines what you want the computer to do. ENTER tells the computer to carry on. Read the display and if in doubt press ENTER. If ERROR appears the red CL clears it.

Strict rule: The display MUST show a "?" for Merlin II to accept a number. You don't necessarily have to enter a number but Merlin II will not accept any input from you unless the display is showing you a question mark. When the computer shows you a question mark you have three options: (1) key in an appropriate number and press ENTER; (2) just press ENTER; (3) press **N** ENTER.

If the request was for a number and you just press ENTER the computer will continue without the requested number if logically possible. Try it to see. (If in doubt press ENTER.)
If the question was a yes/no option ENTER is "yes", **N** ENTER is "no".

Any DEF can be pressed at any time. Any time. You can do no harm nor create a situation not readily reversible or repeatable - with one important exception: when **START SIGHTS** shows, if you press ENTER the latest fix will be lost. This is the only time you might hesitate to press ENTER. The fix and adopted position and time are cleared by STARTing SIGHTS. You can use DEFined functions, inspect memories, do private calculations: nothing will be "lost" or "corrupted". And if you are not sure what you should do, press ENTER.

DEF A Astro and All data DEF Z Piloting data [Ex p.11 Ref p.22]
Use DEF A to check the "basic data" and change any which need changing. The display MUST show a question mark to enter a number into Merlin II. If you use DEF Z you'll access the list of data half-way through. The data set with DEF A or DEF Z are used by other DEFined functions. The data remain until you change them. You can select either LOG & LOG COR or DR.CLOCK with 6 DEF L. Use the minus sign for south and west; Merlin II puts on the S and W.

DEF S Start sights DEF C Continue sights [Ex p.12 Ref p.26]
Set data with DEF A then press DEF S to see **START SIGHTS**. Press ENTER to erase Merlin II's memory of the previous fix and see the prompt for observation No 1. Some body will be showing. Press ENTER to raise the question BODY OR TIME? and key in either a different body number or else the time of the first sight. The machine will then ask for SEXT ALT? . If you enter a sextant altitude you'll see azimuth and intercept. After taking note of the azimuth and intercept press ENTER to see the prompt for sight No 2.

For **prediction** ignore SEXT ALT? (ie just press ENTER) and you'll see the azimuth and Computed ALTitude. LHA Aries is in memory A (to view press A ENTER) now and after any sight except after body 95. Planets may be predicted with the aid of a current Nautical Almanac.

If you don't know the number of the star you may call it body -1. It will take nearly four minutes to reduce it. [Ex p.19 Ref p.28]

When azimuth and intercept are computed they are used to upgrade the fix and "Nearest Point". DEF C (Continue sights) is the same as DEF S except that the fix/NP (so far) is not erased. Thus you may interrupt the computations and later continue them. The interruption may be hours but a running fix is better computed with DEF S and DEF K [Ref p.40]. DEF C also restarts a sight: press it at any time.

When you have a new set of sights you must press DEF S, not DEF C. When you press ENTER with **START SIGHTS** showing, the computer adopts the DR.LAT and DR.LON as the point to compute intercepts from and prompts for sight No 1. When you press DEF C intercepts are computed from the DR position adopted when DEF S was used. Moreover altitudes are corrected for passage of the vessel since the time of sight No.1, the first sight after **START SIGHTS**.

DEF X Reject sight [Ex p.12 Ref p.33]
Every position line automatically contributes to the fix. Use DEF X to reject a line if you think it should not contribute. You may reject any line if you key **N** ENTER when asked REJect LAST SIGHT? .

DEF F Fix DEF N Nearest point [Ex p.10 to 19 Ref p.34]
When sights have been reduced using DEF S/C you may examine a fix or the "Nearest Point". A fix is appropriate where two or more sights differ by an appreciable amount in azimuth. If only one body was observed use DEF N to find the point on the (average) line nearest the DR position. If you wish you may look at the fix or NP (so far) at any time. It is automatically upgraded every time you compute azimuth and intercept.

DEF F or DEF N show the number of observations with the time for which the fix or NP is valid. Press ENTER to see: [Ex p.15]

- the lat and long.
- the precision in miles.
- a request for the time of previous fix (ignore with ENTER or enter time to see set and drift. Set & drift are held for use with DEF B.)
- a request for a time to advance the position to (ignore with ENTER or enter a time to see advanced position).
- a request to replace the DR (ENTER is "yes", **N** ENTER is "no".) (Set LOG or DR.CLOCK to match the new computed position.)

and then the computer goes into DEF G giving mercator and great circle information. You can look at the fix as often as you like.

DEF K Add a line (for running fix) [Ex & Ref p.40]
Adds azimuth and intercept directly. For running fix: DEF S for early sights, DEF N to replace DR with NP, DEF D for DR as required, DEF S for later sights, DEF K to add azimuth of earlier sights and zero intercept, DEF F to see running fix at time of later sights.

DEF H Star and planet identification [Ex & Ref p.42]
Set up with DEF A then press DEF H. Prompts request approximate time, then approximate altitude and azimuth for each required star. Accuracy to ten minutes time or a couple of degrees suffices. Compare the displayed SHA and dec with the star list to obtain the star's identification number. If the object was bright and the declination less than ±30° it may be a planet. The SHAs of planets are given in the lower right corner of the left side daily page of the Nautical Almanac. Then use DEF S or DEF C to compute the sights.

DEF M Meridian passage and twilights [Ex & Ref p.44]
Set date and rough position with DEF A and press DEF M for time and altitude at noon and time and LHA Aries of morning and evening civil twilights.

DEF D Dead reckoning update [Ex pp.46,51 Ref p.46]
DEF D asks for the log reading or it asks for a clock reading: you can set Merlin II to either DR by sumlog or DR by time and speed with the 6 DEF L switch. If DR.CLOCK is switched then LOG and LOG COR do not appear - and if LOG is set the DR.CLOCK does not exist. On entry of log or clock reading DEF D tells you the progress (distance and course) since the last update and then gives your new latitude and longitude.

DEF D uses and replaces the previous DR.LAT and DR.LON along with LOG or DR.CLOCK as the case may be. It also uses COURSE and either LOG COR or SPEED. DEF D continues into DEF G to give rhumb and great circle information. The changes to latitude and longitude do not affect sights later reduced with DEF C.

DEF G Great circle and rhumb line [Ex & Ref p.50]
DEF F/N and DEF D automatically go to DEF G without your having to do anything except continue pressing ENTER. You can also select DEF G on its own. Set your DR position, speed and destination using DEF Z and press DEF G to see: the course and distance by rhumb line (a straight line on a mercator chart), the time it will take to reach the destination (at present SPEED), the start course and distance by great circle, the time by great circle and then the latitude of the great circle at every whole 5° of longitude around the world.

DEF V Vertical Angle for distance off and Visibility [Ex & Ref p.52]
Requests height of object in metres (or feet *.3), displays the heights of eye and object and asks for sextant altitude. If sextant altitude is ignored visibility distance shows for your height of eye to that object. If sextant altitude is entered INDEX COR is applied and distance off shows. If you do no other computing height of object is held and you may ignore its prompt for further sights to that object.

DEF B Current [Ex & Ref p.54]
Requests set then drift. If ignored it shows presently held values (possibly left by DEF F or DEF N). Then asks for course and speed through water. Gives true course along with the effect the current had on the course then true speed along with the percentage effect of the current on the speed. The computer holds the set and drift as long as no DEFined astro functions are used.

DEF = Convert to d.mmm, DEF spc Convert to d.ddd [Ex & Ref p.55]
Put your angle in the display and then press DEF = or DEF spc.

0 DEF L Speed from timed distance [Ex and Ref p.51]
Put 0 or nothing in the display, press DEF L and follow the prompts. Accepts miles and h.mmss or feet or metres and seconds to give speed in knots. The two entered values are temporarily retained in N and M.

1 DEF L 2 DEF L 3 DEF L Spherical triangle solutions [Ref p.58]
Trigonometry solutions for those interested.

4 DEF L Merlin II computer check [Ref p.8]
Checks every Merlin II program step. After 3 minutes the computer will show 999. Anything else indicates the computer is faulty.

5 DEF L Tide interpolator: time of required height [Ex & Ref p.53]
Manually store time (h.mmss) & height in Q and W and the other time & height in Z and X then press 5 DEF L. The 4 tide values will be lost if you run any other Merlin II DEFined function (except 0 DEF L).

6 DEF L Switch: DR by log or DR by speed & time [Ex & Ref p.47]
Put 6 in the display and press DEF L and the computer will switch over between LOG and DR.CLOCK. The switch works both ways.

Memory access [Ex & Ref p.21 and p.56, list p.57]
The keyboard letters are memories. They may be viewed and numbers stored when no question mark shows. To inspect Q, put Q in the display and press ENTER. To store 12.34 into memory Q, key Q = 1 2 . 3 4 ENTER . If, when a question mark shows during a DEFined function, a memory is entered instead of a number, then the value in that memory will be used to carry on the computation.

QUESTIONS AND ANSWERS ABOUT MERLIN II

Learn to use Merlin II with the example on page 10.

How accurate is Merlin II?
The computer itself is, in effect, perfect, being good enough to compute position to an accuracy of one inch. Maximum errors for the Merlin II almanacs are 0'.5 for the sun and stars and 1' for the moon. These seldom occur. More than 0'.5 difference in intercept from some other method is suspicious. More than 1' difference must mean a mistake. The almanacs are nominally for 1980 to 2020 but they don't stop. They just decline in accuracy. You could use the Merlin II sun and star almanacs for at least 50 years either way without shipwreck.

Will there be future revisions of the Merlin II functions?
It's very unlikely now (Nov 90). Merlin II is a general purpose computer (Sharp PC-1248) loaded with navigation programs. There were minor enhancements through versions FF, GG, JJ, LLa, LLb, MM. The MM version, which has been on sale since late 1989, operates with the Sharp printers CE-123P and CE-126P. The capacity of the Sharp PC-1248 is completely occupied by the Merlin II programs.

Can I put in my own programs alongside the Merlin II programs?
No, you'd need another computer. The Sharp PC 1403 or EL 5500-III (they are the same) is handy for mathematical programming.

Can I check the Merlin II?
Yes. Switch off then on, key 4 into the display and press DEF L. Your Merlin II will check itself and after nearly 3 minutes will show 999 or 993. If 4 DEF L yields anything other than 999 or 993 the computer is not to be trusted - and if you do get 999 or 993 then it is definitely in order. This check is for Merlin II version JJ and later.

Can the Merlin II programs be lost?
It's unlikely. The programs are password protected so they cannot be corrupted (or copied). It is possible to lose them by entering a special key sequence. That can't happen accidentally. Power is required to maintain the programs and if the batteries are out for more than about a minute they will go and ERROR 4 will show when you try to operate DEFined functions. If you do lose the programs, airmail the computer, without manuals, to Merlin Navigation Pty Ltd, PO Box 1264, Booragoon, WA 6154, Australia, with an explanatory note. Please send the equivalent of $US15 to cover costs.

How often should I replace batteries?
Replace when the display is dim even with the contrast fully up. The machine must be OFF and you must be prompt - see page 94. Carry a spare pair of type CR-2032 batteries on extended voyages. The life-span of unused lithium batteries is many, many years. In the computer the batteries are in use all the time but the drain is so low they would last at least five years if you never did any computing.

Can the computer be made waterproof?
It is best to keep wet hands away. The keyboard is impervious but the back certainly isn't. You can wrap the computer in clear plastic. It would surely be a good idea to tape up the socket on the left end.

What does it really mean when ERROR shows?
It just means you have tried the impossible. The Merlin II DEFined functions do hundreds of operations on the data you give them. Data faulty in a way that makes a function try the impossible (eg, dividing by zero) will cause ERROR. Look through your data (with DEF A) to see what needs fixing up. Feasible data will not produce an error message. If you see BREAK it is because you pressed the ON button when the computer was already on. It is harmless.

What should I do if my Merlin II gives incorrect results?
If it was a position line (azimuth and intercept) the first thing is to cross it out with DEF X so that it doesn't influence the fix. To find the problem examine your data. Be careful of the clock correction - see page 23 for a blunt warning. Make sure the plus or minus signs on clock and index corrections are right and all N/S and E/W are correct.

If you get erroneous results and you cannot see why (after checking everything and reading the appropriate chapter in this manual), write to us. Give the exact values and the buttons you pressed. Give the serial number but it would be best not to send the computer. (If you do think you should send it, please use airmail, do not include any manuals and mark the outside of the package "calculator returned for repair".) If you had a puzzle which you solved and feel that by sharing it you might save others frustration, please let us know.

Can I check whether I entered a sight correctly?
Yes. The last clock time and sextant altitude you entered are in memories T and H so you can look at them directly. For previous sights the actual observations are not held and nor are the azimuths and intercepts, but you can nevertheless check such a sight. You simply recompute it. If you get the same azimuth and intercept as previously then everything's okay: press DEF X ENTER to remove this check computation from the computed fix. If you get a different answer from the first time then the original must have been incorrect. (But inspect T and H to ensure you didn't bungle the recomputation.) Press DEF X and reject the original, erroneous, values of azimuth and intercept by entering them when prompted (see DEF X chapter).

I keep getting answers different from a textbook. Why?
You have a data error. Whenever you get the wrong answer, there is one reason, and one only: a mistake in your data. Most textbook solutions are by inspection tables that require an "assumed" position, not the DR. It doesn't affect the position line but to compute the same intercept you must set Merlin II's DR to this assumed position. The assumed longitude will be different for each observation.

What happens to a number entered when there is no question mark?
The Merlin II navigation functions have no interest in such a number. If no question mark shows you can use the computer as you wish, even in the middle of a DEFined function. You can do private calculations, examine memories or store numbers into memories and when you are finished you can press ENTER (once more) to continue the function.

EXAMPLE 1 INTRODUCTORY: SUN SIGHTS

Setting data - Sight reduction - Lat and long - Optional extras

Put the printer, if any, aside: first learn to use without a printer. Switch on the computer. ON and OFF are top right on the keyboard.

There are two "action buttons", **DEF** and **ENTER** . DEF is to DEFine (choose) what you want the computer to do and ENTER is to tell it to get on with it. Generally if you press ENTER the computer will guide you. Watch the display. If in doubt press ENTER.

You won't accidentally harm the computer by pressing keys. In fact you'll best learn by trying things. If the display ever says ERROR press the red CL button to get rid of it. If you mis-key when putting a number in also press CL. There are numerous other features: if you want a reference to the keyboard it is on page 20.

Setting the "basic data"

Press **DEF** and you'll see a tiny DEF showing in the top of the display. See it? Press **A** . **DEF A** stands for **A**stro and **A**ll data. You'll see MO.YEAR followed by some numbers representing the month and year.

Now press ENTER and you'll see "?" . This is your chance to set the month and year. Note well:

You can only enter numbers when Merlin II shows you a question mark in the display.

Suppose it is now February, 1988. You must enter a number for the month, follow it by a decimal point, and then put the year as four digits, that is key 2 . 1 9 8 8 ENTER. You'll see

MO.YEAR 2.1988

If your display shows this it means the computer is set to February 1988. If it shows anything else try again . . . press DEF A, press ENTER to raise the "?" for the month/year and key them in correctly.

The rule is strict: The display must be showing a ? in order to enter numbers. Merlin II will **NOT** accept a number if it is not displaying a "?".

When the display confirms that the month and year are correct press ENTER **twice** and you'll see the next item of data which is DAY , ie the day of the month. Press ENTER to see the question mark for changing the day. Keep pressing ENTER and you'll see a list of

items. Press it about 20 times and get the feel of it. The values of "basic data" you see are the ones the computer happens to be holding at present. After each item a question mark appears for changing it.

Use DEF A and the ENTER button to set the following "basic data". Only key in numbers and, where appropriate, the minus sign: no letters or other symbols. If you see ERROR press the red CL (then ENTER). Reminder: there must be a ? showing to enter anything.

MO.YEAR 2.1988	This is, by now, in the computer.
DAY 22	The machine is set to February 22, 1988.
CLCOR -0.0006	Correction for a clock 6 sec fast on GMT.
EYE 1.9 M	for height of eye 1.9 metres above water.
INDEX COR -1	So 1' will be taken off sextant altitudes.
DR.LAT N 40.170	Enter 40.17 (40° 17'.0), the computer sets the N automatically. (For South you key a minus sign before the number)
DR.LON E 163.460	Enter 163.46 (for 163° 46'.0) and the E is automatic. (W would be with a "-" sign.) You are in the North Pacific.
**LOG 111	Log reading is for DR - not used for astro.
**LOG COR -15 %	Correction to a log recording 15% too high.
COURSE 70	Course and speed are used by Merlin II to
SPEED 6.5	allow for boat's passage during observing.
DEST. N 48.220	Destination is Cape Flattery (Vancouver).
DEST. W-124.420	Enter - (minus sign). Merlin II puts the W.

Have you understood the system? DEF A shows the current value, then it offers you a question mark to change it. If you don't change it the computer shows you the **next item.** If you do change it the computer confirms the change by showing both name and number. Then it offers you the question mark again and you may change the number again. You can change the number as many times as you like, and the moment you don't change it - ie just press ENTER at the question mark - Merlin II moves to the next item.

If you continue to press ENTER after the destination longitude, you'll start again at MO.YEAR etc. Flip through now and check your values. In particular **make sure you have the minus sign attached to CLCOR** and other places where a minus belongs. These minus signs are vital. To inspect data you don't necessarily have to go through the whole list. Try DEF Z and you'll be able to view them from the middle. Later you will learn other short cuts.

** If you see, not LOG and LOG COR but DR.CLOCK, do this: switch off then on, put 6 in the display, press DEF and press L. Your Merlin II will switch over and DEF A will function as above.

Having set the "basic data", your Merlin II is ready to compute sights at this particular date and place. It will remain set with these numbers until you change them.

Sight Reduction

Suppose on the above date at the above place you took three sights to the sun's lower limb, as follows:

Body	#	Clock time	Sextant alt	Az	Int
Sun LL	1	23h 26m 53s	33° 04'		
"	2	23h 28m 08s	33° 11'		
"	3	23h 29m 52s	33° 22'		

Your immediate aim is to turn each time and altitude into azimuth and intercept. [The intercept may be regarded as the error in your DR position. The azimuth is the true bearing of that error.]

Press DEF S and you'll see **START SIGHTS**. If you press ENTER you will wipe the computer's memory of the previous fix (if any).

This is what you want so press ENTER. You'll see 1: and some other information. Press ENTER to see BODY OR TIME? The body number for the sun's lower limb is 90 (see lists of body numbers in this manual and on the computer case) so key in 90 ENTER and you'll see 1:BODY 90 SUNL meaning Merlin II is ready for the first sight which will be to the sun's lower limb. Key ENTER to see BODY OR TIME? again. You can change the body again if you wish - as many times as you like. Press ENTER a few times and see what happens (nothing much). (You must have the "?" to enter anything.)

To compute the first sunsight let BODY OR TIME? show and key in the time as 23.2653 (that is with the minutes and seconds separated from the hours by the decimal point) followed by ENTER. After a few seconds SEXT ALT? is requested so key in 33.04 ENTER. The display shows 147 INT A -2.1 (You see something else? See box below.) which means the azimuth is 147° and the intercept is

If you did not agree with the above azimuth and intercept it means your computer is holding some incorrect information. There's a swift remedy: press DEF **X** to see REJect LAST SIGHT? and press ENTER. The blunder has now been struck from the record. Naturally, to get the right answer you have to fix up that incorrect information: press DEF A to view the values and replace any incorrect one. Press DEF **C** to **C**ontinue sights from where you left off (not DEF S).

2.1 miles "Away". That's it; the first sight is computed. Copy the *azimuth and intercept into the columns provided (write either "A" for* Away or a minus sign, whichever you prefer).

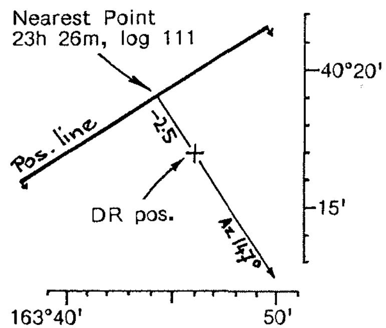
Press ENTER to see 2:BODY 90 SUNL which means the computer is ready for sight No 2 which it expects will be to the sun's lower limb.

Press ENTER to see the question BODY OR TIME? , enter the time and then the altitude to see an azimuth of 147° and an intercept of -3.0. The third sight yields azimuth 147° and intercept 2.8 away.

So you have:

Body	#	Clock time	Sextant alt	Az	Int
Sun LL	1	23h 26m 53s	33° 04'	147°	-2.1
"	2	23h 28m 08s	33° 11'	147°	-3.0
"	3	23h 29m 52s	33° 22'	147°	-2.8

These are consistent results and you may plot the position line in the traditional manner adopting, say, -2.5 as an average intercept. [If you could observe perfectly all intercepts would be identical. When intercepts agree with each other to a couple of miles they may be considered satisfactory - especially if they were taken from a small boat.]



Computing the Nearest Point (a fix is similar)

Sights to a single body cannot give a fix but you may examine the point on the line nearest your estimated position - that is the point where the position line meets the azimuth line. Press DEF N and you'll see the message 3 OBS, NP 23.26 meaning that 3 observations have been used to compute the Nearest Point valid for the time of 23h 26m (which is the time of observation No 1, Merlin II having corrected for the progress of the vessel during observations).

Press ENTER and the display will show the latitude and longitude of the point, 40° 19'.2 N, 163° 44'.1 E. (You know it's East not only from common sense but because it would show a minus sign if it were West.) The NP depends on the DR but the position line does not. Plot the NP on the chart and draw the position line through it at right angles to the azimuth. (That's convenient, isn't it?)

Now press ENTER again and you'll see NP PREC. 2.6 which is an indicator of precision of the computed NP. In the case of an NP it is a sort of average intercept (regarding intercepts as unsigned). [PRECision is also given for a FIX where it has more meaning. See Examples 2 and 3 and the discussion in the DEF F / DEF N chapter.]

Now you have done all the hard work your Merlin II has a lot of extra knowledge it is anxious to impart . . .

Optional extras after latitude and longitude are found

Press ENTER and to see the question TIME PREVious FIX? You could ignore it by simply pressing ENTER but let us suppose there was a fix a few hours ago about 20h 30m. So key in 20.30 ENTER and you'll see SET 326 DRI 0.8 which is the set and drift that affected the vessel since 20h 30m. This is computed from the difference between the DR and the fix/NP. [In theory, if there were no current you would have zero intercepts because your DR would be perfect.]

Press ENTER and you'll be asked ADVANCE TO? which allows you to advance the NP (at the course and speed set with DEF A) to any time. To ignore this request you'd press ENTER but let us advance the NP, which was for 23h 26m, to, say, 24h. Key in 24 ENTER (0 ENTER will do just as well) and see the position at 24h of 40° 20'.4 N, 163° 48'.5 E.

Press ENTER and see REPLACE DR POS? . This is a yes/no question and ENTER means "yes", **N** ENTER means "no". The question is: Should the computer replace DR.LAT and DR.LON with this newly computed NP? If you are satisfied with the observations, you would replace the DR. If you strike ENTER a message **DR REPLACED** will flash and it's done.

The purpose of navigation is not so much to find out where you are as to find where to go. Press ENTER (or N ENTER) and after the flashed message (or not) you'll see 81 RHUMB 3097.4 which means that the rhumb line course and distance to the destination are 81° and 3097.4 miles. A further ENTER shows the duration of the voyage following the rhumb line at present speed (6.5 knots), namely 19 days 20h 32m.

Another ENTER for great circle course & distance: 55°, 2991.9 miles. Another ENTER shows the great circle will take 19 days 4h 18m.

If you press ENTER again you see 165 E 40.571 N which is a point on the great circle track. You can keep pressing ENTER and see the latitude of the great circle at every whole 5° of longitude. Use this to plot the great circle on a mercator chart. The function doesn't stop: it goes around the world as long as you keep pressing ENTER.

Key:	**See:**	
DEF N	3 OBS, NP 23.26	Nearest Point from 3 sights at 23h 26m (time of sight No 1).
ENTER	40.192 N 163.441	NP is 40° 19'.2 N 163° 44'.1 E
ENTER	NP PREC 2.6	Precision: in the case of an NP it is a sort of average intercept
ENTER	TIME PREV FIX?	for finding (extra) set and drift
20.3 ENTER	SET 326 DRI 0.8	current for last three hours
ENTER	ADVANCE TO?	advance the NP to what time?
24 ENTER	40.204 N 163.485	ship's position at 24h
ENTER	REPLACE DR POS?	NP to replace DR lat and long?
ENTER	flash **DR REPLACED**	or **N** ENTER (no flash)
	81 RHUMB 3097.4	81° for 3097.4 miles to dest.
ENTER	19 DAYS 20.32	Rhumb duration 19d 20h 32m
ENTER	55 GCIRC 2991.9	Great circle course and distance
ENTER	19 DAYS 4.18	GC time to destination.
ENTER	165 E 40.571 N	GC 1st point 165° E 40°57'.1 N
ENTER	170 E 43.166 N	GC 2nd point
ENTER	175 E 45.140 N	etc every 5° of longitude.

For practice repeat some of this example, eg press DEF N to see the NP etc again (you'll get slightly different rhumb and GC values if you advance to a different time) or DEF X to cross out the last sight followed by DEF C to re-enter it. Merlin II has many capabilities. The Quick Reference on the case might be enough for you to try your hand at the various functions. Use a little thought and two rules:

- no data entry without a question mark
- if in doubt press ENTER

General operations summary

- Set up "Basic data" with DEF A (or DEF Z).
- DEFine the task you want computed and follow the display.
- You may press any DEF any time. For example you can interrupt calculations to check data (DEF A), or examine a fix (DEF F) with some sights, continue the sights (DEF C) then re-examine the fix.
- If in doubt press ENTER. You may need to press it twice. As a rule with Merlin II something will happen if you press ENTER. (If nothing does use a DEF.) ENTER means yes/go/get-on-with-it.
- There is only one possibility on Merlin II to press something you could regret: if you were to start sights when you really wanted to continue sights. After DEF S the message **START SIGHTS** is a reminder: press ENTER and you erase the computer's memory of previous fix along with its adopted time and position. Other than this instance there is nothing you can do that is not immediately reversible or repeatable.
- For a new group of sights you must use DEF S (not DEF C).
- If you see ERROR in the display press the red CL (then ENTER to carry on). A computer error is caused by impossible data.

EXAMPLE 2 SUN MOON FIX

Learn to use your Merlin II by working through the Introductory Example 1 from page 10. This Example 2 follows from it.

You would regard this example, with its short interval between the sun and the moon observations, as a running fix. Strictly speaking, all fixes on Merlin II are running fixes unless you set SPEED to zero.

If you have not already done so, use DEF A to set the computer with the data of page 11 and use DEF S to compute the three sunsights of page 13. If you were to compute the sights below without at least the first sun sight, you'd get different figures because the computer corrects altitudes for the passage of the vessel since (or to go till) the time of sight No 1, the first entered after **START SIGHTS** . All intercepts refer to the DR lat and long adopted when sight No 1 was computed and are for the time of sight No 1.

The computed fix is the position of the vessel at the time of sight No 1. You can bring it up to, or back to, any desired time with the ADVANCE TO? facility. So the fix <u>for a given time</u> does not depend on the computer. (It depends on your skill.) Nor does the fix depend on the DR, provided it is within a hundred miles or so. A different DR will give different intercepts, since intercepts are errors in the DR, but these will be the same lines and they'll give the same fix.

Sight Reduction

Shortly after the sun sights, readings to the moon's upper limb were:

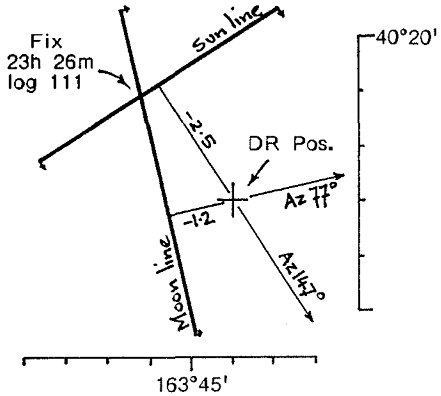
Body	#	Clock time	Sextant alt	Az	Int
Moon UL	4	23h 58m 00s	15° 18'		
"	5	23h 59m 34s	15° 35'		
"	6	24h 01m 47s	15° 59'		

Press DEF C and ENTER to raise the prompt BODY OR TIME? Key in 94 which is the code number for the moon's upper limb and press ENTER. The computer will confirm with 4:BODY 94 MOONU. Compute the moon sights and fill in the azimuths and intercepts in the appropriate columns. They are 76°, -0.9; 77°, -1.1; 77°, -1.5.

[If you were doing this by tables each sight would take, if you are practised, 10 or 15 minutes of figuring. On Merlin II the first sight to the moon takes 16 seconds. Further sights take five seconds.]

If you disagree with any azimuth or intercept reject the sight with DEF X and do it again. For the third sight 24.0147 or 0.0147 will both work. (During computations leave the day set to 22.)

Fix



Press DEF F to see 6 OBS @ 23.26 meaning that the fix is from six observations referred to 23h 26m which is the time of the first sunsight. Press ENTER to see the fix: 40° 19' N 163° 43'.7 E. Press ENTER to see the precision of 0.3 miles which is the low sort of figure we should expect. [We have only two bodies which is the minimum for a fix. See discussion in the DEF F / DEF N chapter.]

Press ENTER to be asked for the time of the previous fix. Say (as in Example 1), it was at 20h 30m. Enter 20.30 to see a set 319°, and a drift of 0.9 knot. This current is in addition to whatever was allowed for in setting COURSE and SPEED. Press ENTER and the computer will ask you you to put in a time to advance to. If you enter 24 (or 0) the position 40° 20'.2 N, 163° 48'.1 E shows.

You are then asked whether you want this fix to replace the DR.LAT and DR.LON. ENTER is "yes" and **N** ENTER is "no". If you say "yes" the message **DR REPLACED** will flash. Keep pressing ENTER and the computer will then give rhumb and great circle information. From the fix as advanced to 24h you will find:

81°	RHUMB	3097.8 nautical miles
19	DAYS	20h 35m at present speed
55°	GCIRC	2992.3 nm
19	DAYS	4h 21m
165° E	40° 57'.2 N	point on GC track
170° E	43° 16'.6 N	next point etc.

The minimum requirement for a fix is two observations in two different directions. The quality of the fix depends on, among other things, the angle of intersection ("cut") of the two position lines. The optimum is 90°. The angle is the same as the difference in the azimuths of the two observations. If the difference in direction of the bodies is less than about 30° the fix is going to be less reliable.

The fact that the fix is a computed one - the computer draws no actual lines - is irrelevant: the quality of a fix depends directly on the difference in azimuth between the two sights.

Where you have sights to make a fix there is no NP - pressing DEF N is nonsense. Use NP when the azimuths are all more or less in the one direction - which is normally to a single body over a short period.

EXAMPLE 3 STAR FIX

Learn to use your Merlin II by working through the Introductory Example 1 from page 10.

Example 3 is of four stars observed during evening twilight. It is the same day as the sun and moon sights of Examples 1 and 2 but this Example 3 does not depend on the previous examples.

Merlin II will compute stars where they are not known but in this example the stars are known. That is to say the navigator:

- **knew** their numbers because the same stars had been observed on previous evenings, or
- **knew** their names from long experience and looked up their numbers in the list in this manual, or
- **identified** the stars systematically from compass bearings to them and with the help of DEF H.

These observations are to four stars in four evenly spaced azimuths which is the ideal configuration.

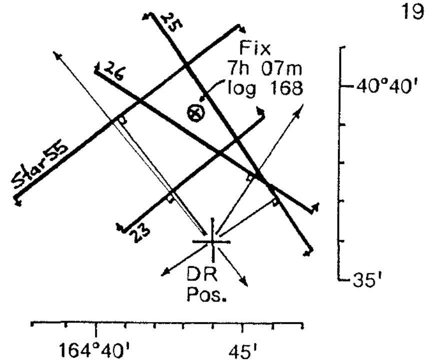
Many of the basic data remain as in Examples 1 and 2:

Date February 23, 1988
Index cor -1' Clock cor to Greenwich -6s (stored as -0.0006)
DR lat: 40° 36' N DR long: 164° 44' E Height of eye 1.9 metres
Log 168 Log cor -15% Course 70° True Speed 6.5 knots True
Destination 48° 22' N, 124° 42' W.

Body	#	Clock time h m s	Sextant alt ° '	Az °	Int nm
Star 55	1	7 07 24	23 07		
"	2	7 08 15	23 14		
"	3	7 08 54	23 18		
Star 26	4	7 11 33	30 35		
"	5	7 12 41	30 40		
"	6	7 14 02	30 50		
Star 23	7	7 19 04	12 59		
"	8	7 20 21	12 50		
"	9	7 22 08	12 37		
Star 25	10	7 26 47	10 27		
"	11	7 28 42	10 09		
"	12	7 30 04	9 55		

After setting the basic data with DEF A compute the sights with DEF S, entering each azimuth and intercept in the above columns. You'll find the answers listed opposite.

After computing the sights DEF F shows 12 OBS,FIX 7.07 and the fix is 40° 39'.3 N 164° 43'.5 E. Fix precision shows as 1.3 miles which, given the number of sights, their disposition in all directions and the consistency of the intercepts, indicates that the fix is very reliable.



[It is not impossible for it to be wrong: what if your clock error is not what you think it is? A clock error of one minute of time would cause a longitude error of 15' which is 15 miles at the equator and 11½ miles at latitude 40°. The fix would appear to be good in every respect but it would be displaced 15' to the east or west. Longitude depends on time absolutely and no computer check is possible. It is up to you to get the time signal right. It doesn't have to be closer than a few seconds but don't make major blunders. If the clock was right then it may be said, definitely insofar as a cautious navigator will be definite, that at 7h 07m this vessel was within a mile or so of the computed fix. The DEF F / DEF N chapter has more.]

Pressing ENTER . . . If the time of the previous fix was 0h then the set and drift will show as 354° at 0.4 knots. If you advance to 7h 30m (the time of the last sight) the position becomes 40° 40'.2 N 164° 46'.6 E. In practice you would certainly replace the DR position. For DR purposes, do not forget to set the LOG (or DR.CLOCK) value to what the log or DR clock actually read at 7h 30m or whatever time you have advanced the fix to - ie to make the computer's record of LOG (or DR.CLOCK) match its record of DR.LAT/DR.LON.

The rhumb and great circle values follow as usual. From the 7h 30m position: 81° RHUMB 3045.6, 19d 12h 33m, 55° GCIRC 2944.3, 18d 20h 58m, 165° E 40° 47' N, 170° E 43° 07'.5 etc.

If the star's number is unknown call it -1 (minus one). Enter the time and sextant altitude as usual to see azimuth and intercept. The star's actual number is revealed on the next press of ENTER.

Try it for one of these stars. (Use DEF C.) It takes nearly four minutes. The computer will beep when it has finished.

Azimuths and intercepts from Example 3
55: Az 141, Int: -4.7, -3.8, -4.5 **26:** Az 33, Int: +3.0, +1.0, +2.5
23: Az 320, Int: +1.1, +1.5, +1.6 **25:** Az 235-6, Int: -1.7, -1.6, -2.7
When plotting do NOT calculate averages. Celestial navigation is only good for a mile or so and careful adding and dividing invites mistakes to no purpose. Just take -4, 2½, 1½, -2.

MERLIN II KEYBOARD

Even large fingers will work the buttons if you press centrally. And, if you press centrally, it only takes a light touch. You can use the back of a pencil to press the keys if you think it necessary though it would probably be a good idea if it is rubber-tipped.

SHIFT MODE DEF
When you press these buttons little signals in the display go on and off. (Try them out.) The MODE key you never need and the dot must be over RUN for the computer to work at all.

CL
Use the red CL key to clear the word ERROR out of the display and when you mis-key a number (see also the back arrow, <, below).

Contrast
Display contrast is given by a wheel to the right of the OFF button.

Programming jargon
Preceded by SHIFT the letters on the keyboard put programmer's terms into the display. They are of absolutely no use to you. They won't hurt the Merlin II but could possibly corrupt your navigation data. If you ever get a persistent ERROR recheck your DR.LAT.

ERROR
Clear ERROR with CL. ERROR 4 showing whenever you try to operate DEFined functions would mean your computer has entirely lost its Merlin II programs. Program loss only occurs through extended battery removal or through typing a special key sequence. It may be that strong electrical signals in close proximity would disturb or destroy the Merlin II functions. No actual evidence exists of this.

Low batteries
When the display begins to fade even with the contrast fully up it means the batteries are running down. Batteries may be replaced without disturbing the programs if they are swapped reasonably smartly and with the calculator <u>off</u>; see instructions elsewhere in this manual.

Use as a calculator
The number keys work like any calculator but the ENTER button must be used where you would normally use an equals key. (The "=" on the keyboard is only for storing values in memories.) The button marked / is the divide key. The one marked * is the multiply key. If you wish you can do calculations in the middle of operating a DEFined function - just as long as no question mark was showing. You don't need to do any calculations for navigation with Merlin II.

Back arrow
The diamond shape is four keys. The pattern represents four arrows. Two are up/down arrows which are of no use and must be left alone when using the machine for navigation; the other two are left and right arrows. Example: Key in 1236 and press < (the left arrow key, ie the one with DEL on it) and you can change the 6 or any digit you set the flashing "cursor" over. To erase digits, back up with < and type spaces with the SPC key. You can even use the arrows after a calculation, eg press 6 * 7 ENTER and see 42; now press > or < to see the 6 * 7 again.

SHIFT
The SHIFT key might be used if you want to operate something printed in yellow on the keyboard.

Reset
Reset can be pressed with a ball point pen. According to the Sharp book you press this if the computer jams and the CL does not clear the problem. It is probably for programming rather than computing and the problem must be very rare. Try OFF and ON before Reset (chances are you have accidentally pressed the mode button).

Transcendental functions
You can use the letters to spell mathematical functions (sin, cos, etc) if you have a use for them.

Memories
Apart from occasionally pressing N for "no" (any letter, not only N, will do), the only time you actually need to press a letter is as a DEFined function. But the letters are also memories and are very convenient:

<u>To inspect a memory</u>

Press A ENTER and you will see whatever number is currently stored in memory A. After sights A holds LHA Aries, T holds the clock time, H holds the sextant altitude. There is a list of Merlin II memory allocations in this manual.

You can inspect a memory anytime as long as Merlin II is not showing you a "?". After inspection if you then press ENTER whatever DEFined function you were using will just carry on. If there is a question mark showing and you key a memory then, instead of showing you its contents, whatever value is in that memory will be used by Merlin II as input for the next stage.

<u>To store a number in a memory</u>

To store 3.7 into memory E (E holds height of EYE) key in E = 3.7 ENTER and E will hold 3.7 till you change it. This is an occasional alternative to operating DEF A or DEF Z. (If you use DEF A to check you will find the EYE is indeed now 3.7 metres.)

All of the memories are used for data storage by Merlin II's DEFined navigation functions. You must therefore be circumspect about using them for other purposes. If you are doing private calculations and want a few memories to hold some numbers temporarily use V, W, X, Y, or Z - that will not affect the navigation. Don't expect your numbers to still be there after operating a DEFined function.

Unusual displays
The functions discussed above cover those useful for navigation. Small as it is your Merlin II is nevertheless a comprehensive general purpose digital computer and now and again you will accidentally press some unusual key combination and see something odd in the display. Just press OFF then ON and it will be gone. If you want to know more about the keyboard see the Sharp PC-1248 Manual.

DEF A ASTRO AND ALL DATA
DEF Z PILOTING DATA

Purpose: DEF A and DEF Z are for inspecting and entering "basic data" - numbers which are used by the other DEFined functions to give answers to various problems. When you use DEF A/DEF Z Merlin II shows the name of the item and what value it is currently holding for it. You can change it or you can leave it as it is.

DEF A provides access to all basic data whereas DEF Z gives access only to the piloting (DR etc) items of the data. That is:

DEF A	month, year, day, height of eye, index cor,	[Astro]
DEF A] **DEF Z**]	DR lat and long, log, log cor, true course, speed, destination lat and long.	[DR]

Press DEF A to check all data, or DEF Z to check DR position and the subsequent items. Press DEF A and DEF Z at any time. Instead of log & log cor you can have DR.CLOCK by switching with 6 DEF L.

Example: For typical values see the introductory Example 1, page 11.

The current value of each item is displayed in turn:

To **change** the value press ENTER to see a "?" , key in the new value and press ENTER to see it accepted.
To **leave** the value as it is press ENTER **twice** to see the next item.

You can't enter a number into DEF A/DEF Z (or any other DEFined function) unless there is a "?" showing. You never have to enter any letters or other symbols: only numbers and perhaps a minus sign are keyed in. (On other functions you might key an occasional N for "no", though any letter, not only N, will do for "no".)

An incorrect value will cause an incorrect answer (indeed, an incorrect value is the **only** cause of an incorrect answer). When you get an answer which is clearly wrong check your data with DEF A or DEF Z.

If you enter an impossible value your Merlin II may reduce it to zero. Examples are a day exceeding 31, or a clock correction greater than 13 hours. So if you get a value showing zero immediately after you entered it, it means you attempted to enter something impossible. The computer cannot, of course, foresee all mistakes.

If you are keying in, say, a longitude, and you overlook a minus sign you can save re-entering, or backtracking with <, by pressing * - 1 ENTER which multiplies by -1 (thus putting a minus sign on).

The memories where values are stored are given below for reference purposes. Memories are for people who would like a deeper insight into Merlin II. You can ignore them if you wish.

MO.YEAR (memory F)
Example: April 1994 is entered as 4.1994 where the month and year must be separated by a decimal point. The year must be entered in the four digit manner: 1994, not 94. Your Merlin II's electronic

almanacs are accurate nominally from 1980 to 2020. The almanacs may be used for many years before and after these dates, as they decline only gradually in accuracy. [For sun and stars the error is less than 0'.5 and seldom exceeds 0'.3. The moon almanac's error should not exceed 1' and will seldom exceed 0'.5].

DAY (memory D)
Day of the month. This is the date of your clock. If you keep GMT on your clock it is Greenwich date. When observations span midnight (24h on your clock) do not change the day. (See Example 2 page 16.)

CLCOR (memory K)
The clock correction means total correction to GMT. It is in hours minutes and seconds whereby the hours are separated from the rest by a decimal point. The minutes and seconds must each be **two digits,** for example 3h 4m 19s must be entered as 3.0419 and the "0" must not be omitted.

A clock that is fast requires a minus correction, a slow one has a positive correction (though you don't actually have to enter the "+"). For a clock 7 seconds ahead of GMT a clock correction of -.0007 is to be entered. You can have any correction up to 13 hours. You may put -9.0007 for a clock 7 seconds fast on a local time which is 9 hours ahead of GMT. You'd put 5.5953 for a clock that was 7 seconds fast on a local time that was 6 hours behind GMT. Don't forget: you have to set the day that applies to your clock.

It is very, very advisable to keep clocks set to GMT directly. All other times are superfluous. The introduction of a time other than GMT (more properly called UT or UTC, meaning Universal Time or Universal Coordinated Time) must be the most common cause of blunders in celestial navigation. If you keep only GMT there are no conversions or corrections. None whatever. Yes, that even applies if you are in a jet flying west faster than the sun or sailing zig-zag up and down the International Date Line on the 29th of February. GMT is GMT and where you are has nothing to do with it. GMT would be valid if you were exploring on the surface of Mars. (Merlin II is not suitable for navigation on Mars.) Keep GMT and Greenwich date and you need consider no local time, no zone time - no discussion of time. CLCOR will do whatever you want but the wise course is only to use CLCOR for accommodating a few seconds correction. If your clock is off GMT by a few seconds you will conveniently cope with it using CLCOR but if you introduce a few hours you will make mistakes.

Celestial navigation requires timing to an accuracy of a few seconds. A 4 second timing error will cause an error of 1' in longitude which is, at most, 1 mile. A timing error does not affect latitude.

EYE (memory E)
The height of eye is in metres. You may enter the height in feet with *.3 after it (which means it is multiplied by 0.3) and it will be converted to metres. The height of eye is measured from sea level to your eye and should be accurate to half a metre for values under 4 metres and less accurate for higher positions. 10% error is negligible. The height of eye is used, when computing sights, to compute a "dip correction" to the sextant altitude.

Take sights from a small boat when it is on the top of a wave while there is a view to the distant horizon - which consists of similar wave tops. For artificial horizon (and bubble and theodolite) sights set EYE to zero (see Land Navigation article in reference section).

If you wish to practise in a "dip short" situation, here is a way of saving some manual figuring. Look up the dip short in ' (minutes) for your circumstances and enter it multiplied by itself and by .31. For example, if your table gives the dip short as 12'.5 then key 12.5 * 12.5 * .31 ENTER to see EYE 48.4375. Dip correction will now be correctly applied when you enter sextant altitude. You would get better results with an artificial horizon than "dip short".

INDEX COR (memory I)
The index correction is the amount, in ' (minutes of arc), that must be applied to the sextant reading to make it correct. Check it every time you use the instrument, using a distant (at least 1.5 miles away) target such as the horizon or a star. Any calibration correction may be included in the index correction.

For artificial horizon (reflection off level surface) sights the sextant altitude must be manually halved. You must then set INDEX COR to **half** the measured correction. (See Land Navigation article).

DR.LAT DR.LON
Example: an East longitude of 145° 3'.4 is entered as 145.034 with the decimal point being used to divide the minutes from the degrees. It will be displayed by DEF A or DEF Z as E 145.034 with the E being placed automatically. Note that the whole number of minutes must be two digits, ie you must not omit that 0 after the decimal point in front of the 3.

For South and West put a minus [-] sign in front of the value; Merlin II will automatically put the S or W. This design with the minus key is used to save searching the keyboard for N, E, S, W keys. (You don't need to enter + for N or E.)

The DR.LAT and DR.LON may be changed by other DEF functions. Like all the other values DR.LAT and DR.LON are set by you, using DEF A/Z but unlike all the others except LOG they may also be reset by other DEFined functions (namely DEF D, DEF N, DEF F). The computer advises you when this happens or is about to happen.

When DEF S is operated DR.LAT and DR.LON are adopted as the position from which intercepts apply. You can change DR.LAT and DR.LON in the middle of sight computation without it affecting the sights. (DEF S function retains the adopted position in memories L and O in d.ddd. You cannot access the DR.LAT and DR.LON memories.)

LOG (memory R)
This is the value, in nautical miles, you take from the vessel's sumlog. It plays no role in the celestial navigation. It is only for keeping the DR record. The value held as the log reading will be changed (as will DR position) if DEF D, the DR function, is used.

LOG COR
This is the percentage correction to apply to the log. It is negative if the log reads high. Whether the log correction is necessitated by the instrument or by current is not so important as long as you apply it. Comparison of the DR with successive fixes allows you to check and improve your estimate of the log correction. (The memory holding LOG COR is not accessible.)

DR.CLOCK (memory R)
DR.CLOCK is an alternative to LOG and LOG COR. You can choose whether you want to keep DR by sumlog or by speed and time by switching with 6 DEF L (see DEF D chapter). The DR.CLOCK value is quite separate from the times the Merlin II keeps for astro (clock time, clock cor, GMT). The value held under DR.CLOCK will change when you operate DEF D. SPEED is used with DR.CLOCK for DR.

COURSE (memory C)
This is the true course over the bottom. The true course consists of the compass heading with allowance for compass deviation, magnetic variation, leeway and local current. **You** make these allowances. The reason these items are not entered into the Merlin II is because the navigator must know the true course anyway. Deviation may be found with the help of azimuths from DEF S/C; variation you take from the chart; leeway is a matter of experience and sailing conditions; DEF F will compute current and DEF B will show the effects of a known current on course and speed.

Course is used by both sight computations and DR update. It is not critical for sights. For DR, course accuracy is important because it will usually apply over a considerable distance.

SPEED (memory S)
This is the speed of the vessel in knots. It is true speed - speed over the bottom, as best you know it.

SPEED is used along with the course to adjust the observed altitudes for the progress of the vessel. Intercepts are corrected to the time of sight No 1, the sight which you first entered after DEF S and **START SIGHTS**. For sight reduction SPEED is not critical. If you are stationary, eg becalmed or on land, set SPEED to zero.

If you enter sights in the sequence they were observed they are all "retired" to the position of the first sight. If you entered the last sight first all sights would be "advanced" to this time. The computer doesn't care which you do but you should develop a habit and stick to it. You will probably find it more convenient to enter sights in order of observation. Later the position may be readily moved up using the ADVANCE TO? after the fix, or using the DR update, DEF D.

For dead reckoning, if you have switched (with 6 DEF L) to LOG then SPEED does not play a role when updating the DR with DEF D. If you are switched to DR.TIME, SPEED is, of course, fundamental.

DESTination latitude and longitude
The same system for entering the destination applies as for DR lat and long. Destination is for rhumb and great circle computations.

DEF S START SIGHTS
DEF C CONTINUE SIGHTS

uses:
MO.YEAR DAY CLCOR EYE INDEX COR (DEF C does not
DR.LAT DR.LON COURSE SPEED use DR.LAT/LON)

requests:
BODY(number)
(clock)TIME?
SEXT ALT?

yields:
[azimuth Comp.ALTitude]
azimuth INTercept

Purpose: Marcq St. Hilaire sight reduction to all bodies, known and unknown. Prediction of all bodies. Fix computation or recomputation.
Example: Introductory Example 1 on page 10; Ex. 2 and 3 page 16.

Weather permitting, take four to six sights to each body. A formal booking sheet will help keep order and prevent forgetting to record something. You should keep your notes until you have arrived.

To compute the sights enter the appropriate basic data with DEF A or DEF Z and then press DEF S. You'll see **START SIGHTS** and then, if you press ENTER , the computer will:-

1. **clear** its memory of the previous fix,
2. **adopt** the current values of DR.LAT and DR.LON - ie store them away separately - from which intercepts will be found,
3. **reset** the count of sights to zero. The time of sight No 1 will be adopted as the fix time to which all sights are retired or advanced.

These things do not occur when you press DEF C.

If the body showing in the display is not the one you shot, then at the prompt BODY OR TIME? enter the code number (there are lists on the computer case and in this manual) and press ENTER. The machine will confirm your entry. Press ENTER to see the prompt again and key in the time of the observation.

The same prompt is for entering either body number or clock time. How does the computer distinguish? By the fact that body numbers are whole numbers, ie have nothing after the decimal point. If a clock time did happen to be exactly a whole hour, add .00001 (or so) to it. The likelihood of this occurring is once every 3600 sights.

When you enter time, Merlin II computes GMT, calculates azimuth and computed altitude for that body at that instant (except Bodies -1, -2, 60, and 95), then prompts for SEXT ALT? . Enter the sextant altitude to see azimuth and intercept. Record these two values. The fix has been automatically upgraded (or its computation begun) and may be viewed with DEF F (or DEF N). Press ENTER for another sight.

When the sextant altitude is entered Merlin II computes corrections for index, dip (height of eye), refraction, passage (the course and speed since sight No 1) and parallax. This total correction is applied to the sextant reading from which the computed altitude (which is already corrected for any semidiameter) is subtracted to give the intercept.

DEF C
Suppose you compute 3 sights and are interrupted. Later you come back to the computer. Press DEF C and you will see the prompt for sight number 4 as the computer Continues sights where it left off, the adopted position, time and the fix so far all being retained. Suppose you enter a time for sight No 6 and then realise it was wrong: just press DEF C to restart No 6. Only use DEF C when you really are continuing sights. When you have a new group of sights use DEF S so that the previous fix is cleared, the latest DR position adopted, and a new time of sight No 1 recorded to which altitudes will be corrected.

Reject and check
Just before showing you the azimuth and intercept Merlin II uses them to upgrade the fix (and NP). If you don't want this latest position line to contribute to the fix, press DEF X and then ENTER to reject it. If you decide to remove an earlier line (not the latest), DEF X will reject it too: just do the logical thing or see the DEF X chapter.

If you'd like to check what time or sextant value you entered to see if you might have mis-keyed, you'll find the time in memory T and the sextant altitude in memory H. [To inspect T press T ENTER.] To check a previous sight just compute it again. If you get the same result reject it with DEF X, if not, use DEF X to reject the earlier answers. Don't try to inspect a memory if "?" is showing - if you do, Merlin II will accept the contents of the memory as input.

Prediction
When SEXT ALT? shows you don't have to enter an altitude. If you ignore it - ie just press ENTER - the computer will show the azimuth and the **computed** (ie predicted) altitude. This goes for any body, including Body 60 (extra star) and Body 95 (planet). This computed altitude has had semidiameter correction, if any, applied. A negative computed altitude means the body is below the horizon. A further ENTER will cause the computer to invite you once more to enter a sextant altitude and a further ignoring ENTER will put you back to the beginning prompt - with no sight recorded.

If you are familiar with celestial navigation you will see that Merlin II is doing what you've always done: using the time and DR position to find the azimuth and computed altitude, then subtracting the computed altitude from the observed one to give an intercept. At the same time as Merlin II finds the intercept, it upgrades the fix (and NP).

The computed azimuth and altitude may be used to predict the sextant setting and the direction of the body. A negative altitude means the body is below the horizon. You can use it for stars, if you know which you want, or for the sun so that you don't miss an opportunity in poor weather, or for the moon when it is difficult to make out in bright daylight. You can predict a planet as long as you have a current edition of the Nautical Almanac. (Try it: it only takes a few *moments to see where the four planets will be at civil twilight.)*

Noon latitude
If you like to take noon latitude it is given (after entering your sights with DEF S) by DEF N ENTER. There is no need to observe precisely

at noon: DEF N ENTER will still give the latitude. This is known as an ex-meridian sight and not restricted to the sun, of course.

Stars
If you know the star by name (or wish to learn the stars) there is a list in this manual. Otherwise it suffices to refer to them by number. Stars 1 to 59 are the standard 57 plus two pole stars (the southern one, Star 54 Sigma Octantis, is for surveyors; it is not visible to navigators). If you specify a number between 1 and 59 the azimuth and intercept will be found in 5 seconds. Star 60 is a provision for using extra stars from an external list. Star -1 is an unknown star.

Latitude from sights to Star 44 Polaris (or any body which is near the meridian) is given with DEF N ENTER , just as for noon latitude.

Star 60, Extra star
You probably won't use any extra stars but Star 60 is there if you do. When Star 60 is selected the computer asks for the time, as usual, and then for the SHA? followed by the DEC? . These must come from a current edition of the Nautical Almanac where 173 stars are on pages 268 to 273. Declination must be entered with a minus sign if it is south. Merlin II adds the SHA to the LHA Aries then finds the azimuth, computed altitude and intercept as usual. For further sights to the same star there is no need to re-enter SHA and dec and you may ignore the prompts for them (ie just press ENTER).

Star -1, Unknown star
It is not necessary to know the identity of the star. Your Merlin II allows you, for the first time in over 200 years of modern celestial navigation, to reduce a sight to an unidentified body.

Key in Star -1 (a 1 with a minus sign) and, after usual entry of clock time and sextant altitude, azimuth and intercept will be displayed. You record them and, as usual, press ENTER for the first prompt of the next sight. The display will reveal which star it was.

Body -1 is like any sight computation except that it takes nearly 4 minutes to give the result. It works by computing the altitude of every one of the 59 stars held internally and comparing them with the corrected sextant altitude. The smallest difference (intercept) is assumed by Merlin II to be the star observed.

It could occur that the computer chooses the wrong star if there happens to be, by coincidence at that time, one that has a computed altitude nearer the observed altitude than the one you actually shot. This ought to be obvious from the azimuth which will, in all likelihood, be in an entirely different direction than the real star. In such a case press DEF X to reject the sight and then compute Star -2. Now the computer will give the azimuth and intercept of the second closest star. This only takes a moment for the computer is holding this star in reserve, having found it while it was looking for the closest as body -1. (No, there is no Star -3.)

In the extraordinary circumstance of the wrong star having a plausible azimuth, that is to say after using body -1 you are under the mistaken impression that the computation is correct, you will find when

computing subsequent sights to it that the intercepts won't make sense. Body -2 is still waiting in reserve. Get rid of the faulty lines from the fix by using DEF X or start again with DEF S.

The most straightforward approach to star sights is to go on deck when the stars come out and take all the observations without being concerned about their identities. At least do that at the beginning of a voyage. Given clear weather, on subsequent twilights you will generally be using the same ones so you will have their numbers.

As an alternative to computing Star -1, you can identify stars in the conventional manner with DEF H if you take approximate azimuths to them by compass. DEF H is very quick.

It is very unlikely that you would shoot a star not included in the 59 held by Merlin II. If you think you have shot another you should double check for at twilight it is next to impossible. (It's probably a planet.) It is possible, and occasionally convenient, to shoot fainter stars by moonlight. Use Star 60 then.

Body 95, Planet
You may compute planets if you have the current Nautical Almanac. **Example A:** Set CLCOR to zero, press DEF S, specify Body 95 and then enter the time 21.3456. Merlin II shows ALMANAC 21.0000 which is telling you you have to open up the almanac on the correct date and look to the line of figures at 21 hours. Press ENTER and see GHA? enter the GHA of the planet at 21h and see DEC? which you enter (with a minus sign if it is south) and see V? which is the v correction and is at the bottom of the column. Enter the v just as given including any minus sign (eg -1.4). Merlin II now finds azimuth and computed altitude and asks for SEXT ALT? as usual.

This procedure tells the computer the position of the planet on the hour (21.0000 in this case) and gives it the variation in the change in GHA (the v) and so it can work out the position for the actual sight time (here 34m 56s). For further sights you can ignore (press ENTER) the request for GHA? You can ignore it even if the hour changes.

Example B: Set CLCOR to +12, select Body 95, enter a time of 21.3456 and you'll see ALMANAC 33.0000 telling you to look up the next day at 9h in the Almanac. Similarly, a large negative clock correction might require you to look up a negative time - meaning the previous day. There is no need to use such clock corrections.

Provided you have the current Nautical Almanac planets are readily computed. They are identified and predicted just as easily.

Notes on DEF S and DEF C
The time you enter is corrected by adding the value held as CLCOR. The result is the GMT and is held in memory G in h.mmss. If you get mixed up (because, despite advice above and elsewhere in this manual, you set your watch to a time other than Universal Time) you can directly check the GMT in G.

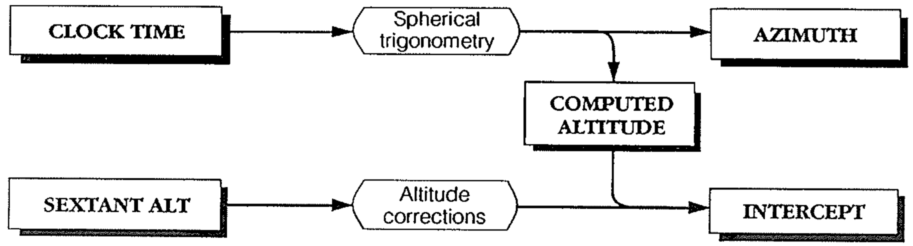
While computing sights you can press any other DEFined function and then press DEF C to continue entering the series of sights. For

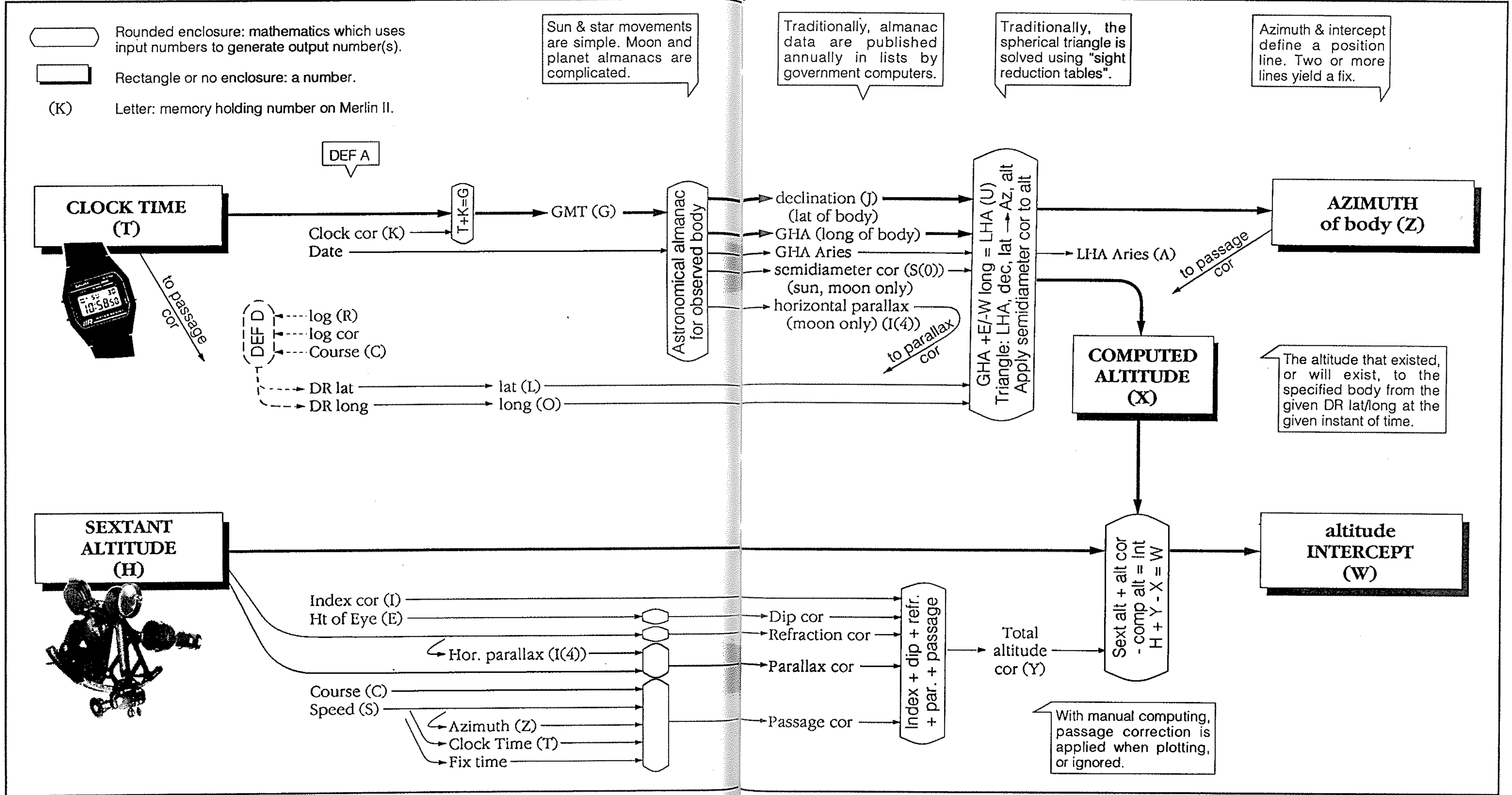
MARCQ ST HILAIRE "SIGHT REDUCTION"

First published in 1875 and now in universal use. In summary:

1. Specify Greenwich date and time and compute the azimuth and altitude from your estimated position to the body.
2. Compare this computed altitude with the altitude you observed. The difference—the "altitude intercept"—indicates error in your estimated position. The azimuth is the direction of that error (and of the body).

On Merlin II this sight reduction is performed by DEF S/DEF C which also calculates the fix if there are two or more observations.





example you can examine the fix so far with DEF F, or update the DR position with DEF D, or identify a star with DEF H, or inspect the data with DEF A or Z, and so on.

Since the intercepts are corrected for passage of the vessel it is important to use DEF S before beginning a series of sights - if you use DEF C they will be "run back" to sight No 1 of whenever you last used the computer. This could be puzzling if it is not intended.

The sight computation uses the data you put in with DEF A or Z. You can change these data any time but as a rule you wouldn't be altering values in the middle of a series of sights. An exception might be your height of eye: if it varied you would re-set the computer. (The fast way is direct to memory E, eg if the height of eye is 4 metres, key E = 4 ENTER .)

The other exceptions are the DR.LAT, DR.LON, and LOG. Your Merlin II is at once both astrocomputer and independent DR computer. You may change the DR position during sight computations and it will **not** affect the computation of further sights, because when DEF S is initiated with **START SIGHTS** the computer adopts the DR.LAT and DR.LON at that time and keeps them separately (in memories L and O in d.ddd). It uses this adopted position until **START SIGHTS** is operated again. So you can change DR position as you like and as you carry on computing sights, or continue with DEF C, the intercepts still refer to the position originally adopted.

Leave the DAY alone except when you are STARTing SIGHTS with DEF S. If a series of sights spans clock midnight and goes into the following day the computer will cope and it doesn't matter whether you put 0h or 24h. (If you put 0, the computer adds 24.)

How does the computer know? It compares each sight with the time of sight No 1. If this sight is less than 12 hours earlier it corrects the altitude to advance this sight to the time of sight No 1, but if it appears to be more than 12 hours earlier it presumes you mean the next day and so adds 24 hours. Thus Merlin II permits sights to extend back (from sight No 1) for up to 12 hours, or forwards for up to 12 hours into the next day. (Normally, of course, sights do not extend over more than half an hour or so.)

But don't try to extend the sights backwards through clock midnight. The computer might get confused if you make your No 1 sight after midnight and then enter observations taken before 2400 hours. You shouldn't really want to do this: it is just as easy to enter sights in simple order of observation then advance the fix to the time required.

Precise azimuth
After time is entered and DEF S/C operated, azimuth is left in memory Z. To see it in d.ddd key Z ENTER . To see it in d.mmm key Z DEF = . To see it in d.mmss key D M S Z ENTER . For survey purposes the maximum effect of almanac error may be examined by varying longitude by 0'.5 and latitude by 0'.3 (to simulate error in GHA and declination), these being the maximum errors from the Merlin II almanacs of the sun and stars. Correction to azimuth for semidiameter (in memory S(0)) is given by S.D./cos alt.

DEF X REJECT SIGHT

uses:
the latest fix or NP prepared by DEF S/DEF C, and memories L & O.

requests:	**yields:**
REJect LAST SIGHT?	returns to sight reduction
AZ?	
INT?	returns to sight reduction

Purpose: To remove a (faulty) position line from influencing the computed fix or Nearest Point.
Example: Use DEF X in the Introductory Example 1 on page 10.

At the same time as the function DEF S/DEF C shows the position line (azimuth and intercept) it automatically uses it to upgrade the fix and Nearest Point. If you do not want a line to contribute to the fix - you consider it unreliable or superfluous - reject it using DEF X.

Press DEF X and see REJ LAST SIGHT? . If that is what you want press ENTER (meaning "yes") and *REJECTED* will flash. The display will then show the prompt for further sight computation. The LAST SIGHT at any time is the last azimuth and intercept displayed.

If some other, previously computed, sight is to be rejected then, when REJ LAST SIGHT? shows, press N ENTER (for "no"). You'll see AZ? Key in the unwanted azimuth, press ENTER, see INT? Key in the unwanted intercept (with a minus sign if it is Away), press ENTER, *REJECTED* will flash and the computer will await further sights.

It may help understanding to imagine the computer plotting, on an internal chart, each position line as the azimuth and intercept are computed. DEF X erases lines. If the last line is rejected it is lifted from the chart without leaving a mark - as if it had never existed. For a previous line, where you enter the unwanted azimuth and intercept, the line you specify is erased - and if you were to make a mistake entering the azimuth and intercept the eraser would miss.

Note: The record of the last sight is held until you compute another sight. Thus you may do other calculations and then decide to reject the last sight. You may do that - the computer can cope. However if you don't like an answer it is best to get rid of it while it is on your mind. You can then seek the cause, if you are interested, and perhaps recompute. Note your findings on your worksheet. It helps if you number sights on the worksheet corresponding to the computer's running count.

When seeking the cause of a mistake you can inspect the time and altitude in memories T and H as long as there is no question mark showing. (For how to access memories, see the Keyboard chapter.)

X

You can check your computation of any sight by recomputing it with DEF C and then, if AZ/INT are the same as on the original occasion, operating DEF X to remove this check computation from the fix. If they are not the same, make DEF X reject the original AZ/INT.

DEF F FIX
DEF N NEAREST POINT

uses:
the latest fix or NP prepared by DEF S/DEF C, and memories L & O.

requests:	**yields:**
-	No obs, time of fix/NP
-	lat and long of fix or NP
-	FIX or NP PRECision
TIME PREVious FIX?	SET DRIft
ADVANCE TO? (time)	advanced lat and long
REPLACE DR?	course RHUMB distance
-	etc, as per DEF G:

Purpose: Display the fix or "Nearest Point" from position lines
Example: Examples 1, 2, 3 from page 10.

After sights have been computed with DEF S/C, press DEF F in the case of two or more bodies, or DEF N if there is only one. The display will show how many sights have been computed and the time when the fix or nearest point is valid. The time is that of sight No 1, ie the first computed after DEF S and STARTing SIGHTS.

Press ENTER; the fix or NP will show as lat and long. ENTER again will show "PRECision" in nautical miles. A further ENTER and the computer will ask TIME PREVious FIX? If you are not interested in the current ignore this by pressing ENTER otherwise enter a time and see the set and drift. (See the end of this chapter for more details.)

A further ENTER and the computer will ask ADVANCE TO? If you don't want to advance the fix, ignore it. If you want to bring the fix up to a later time (or back earlier) key in the desired moment (hours decimal point minutes seconds as always), press ENTER and see the appropriate lat and long. The computation uses COURSE and SPEED.

Another ENTER and the machine will ask REPLACE DR POS? and you may replace the DR.LAT and DR.LON with the new position if you wish. ENTER is "yes"; N ENTER is "no". If you replace, then the values presently held as DR.LAT and DR.LON are, naturally, gone. (They should be written down in your deck log.)

Whether or not you replaced the DR position, the computer continues into DEF G automatically to compute, from the new, (possibly advanced) fix or NP, the rhumb and great circle information.

You can add sights to the fix with DEF C or DEF K or reject them with DEF X and DEF F or DEF N will show you the new fix or NP. You may alter the DR.LAT and DR.LON (by using DEF D or replacing them with the fix) without this affecting re-computation of fix or NP.

FIX PREC can be a useful indicator of the fix's reliability - see discussion below. The "precision" given for a Nearest Point is just an overall measure of the intercepts. For practical purposes you may regard it as an average. Technically it is the root mean square.

Nearest Point
The Nearest Point is not a fix. It is the nearest point of the line to your adopted DR (the DR position as at sight No 1). The NP depends on that adopted DR. It is the place where the azimuth line meets the position line. For plotting a single line the NP is very convenient since you don't have to plot the DR or the azimuth or measure the intercept: instead plot the computed NP and draw the line through it at right angles to the azimuth (turn the protractor through 90°, thus avoiding mental arithmetic). Usually, but not necessarily, the NP would be your best estimate of position on the line.

[Sometimes this Nearest Point is called the "most probable position". It is not a good name because it is not necessarily the most probable and because the term "most probable position" more properly refers to statistical probability. The least squares fix found by DEF F is a genuine MPP computation.]

The NP is the latitude from the noon sun or Polaris. It is ex-meridian latitude so it is not necessary to observe precisely at noon.

DEF F or DEF N?
If you have bodies in two or more different directions use DEF F. In such a case DEF N is meaningless. Conversely, with bodies in the same direction DEF N will show a realistic value and DEF F will not.

There is no absolute definition distinguishing between sights in the "same" direction and sights in "different" directions. 30° is sometimes given as the angle where a fix has a good enough "cut". DEF N would be more appropriate when differences are well under 10°. If you need to use borderline cases you should plot lines on the chart and make decisions taking nearby dangers into account.

Running fix - either DEF D with DEF K or DEF C
Position lines computed with DEF S/C are automatically retired ("run back") or advanced ("run up") to the time of sight No 1. Thus all sights are running sights. You may use this to form a running fix over several hours but it presumes a constant course and speed.

It is better to use DEF K. Dead reckon from the earlier position line (with DEF D if you wish), compute the later sights with DEF S, then use DEF K to introduce the earlier line. DEF F will show the running fix. Traditional practice has been to plot running fixes from sights to the morning sun, noon sun, and afternoon sun. To do this on Merlin II:

Compute morning sun sights with DEF S. Use DEF N to see the NP and to replace the DR lat and long. (Or plot the line and replace the DR position with some preferred point on it.) Keep the vessel's dead reckoning position with DEF D up to midday and compute midday sights with DEF S. Then press DEF K and for AZ? enter the morning sun azimuth, and for INT? enter zero. DEF F will show the running fix at the time of midday sight No 1.

To carry on: use DEF F to replace the DR with the new midday fix, continue the DR with DEF D, use DEF S to compute the afternoon sights. Then, with DEF K, enter the azimuth of the midday sights and zero intercept, and DEF F will show the afternoon running fix.

This afternoon fix is the intersection of midday and afternoon lines taking into account the vessel's movements between them. If you wish to include the morning line - which you normally wouldn't because it means advancing it a rather long way - just use DEF K to enter its azimuth and zero intercept. Then inspect the fix with DEF F.

DEF K "draws" the earlier line through the later DR position just as you would with a pencil on a chart. The reason you put zero for the intercept is that the earlier DR was taken **on** the earlier line. There is an example of a running fix in the DEF K chapter.

You may also compute a running fix with DEF C if the speed and course of the vessel were constant between the two sets of sights. Example 2 on page 16 is such a fix. Position lines computed with DEF S/C are automatically retired or advanced to the time of sight No 1. That is to say each altitude is corrected, using COURSE and SPEED, for the passage of the vessel since (or to go till) the first sight computed after DEF S and START SIGHTS.

Normally you should maintain a careful DR and use DEF K to form a running fix. Over short periods, such as Example 2 on page 16, or where the sun is extremely high, this DEF C running fix may be more convenient. For a running fix of the sun: compute the morning sights, then compute the later sights using DEF C. DEF F will show the fix retired to the time of the No 1 morning sight and ADVANCE TO? may be used to advance it to the later time. When computing the later sights the computer assumes that COURSE and SPEED in memories C and S apply since the time of sight No 1.

You should restrict such a fix to a short interval but Merlin II will cope with a time interval up to 12 hours. Don't try to make it go backwards through midnight, ie don't make sight No 1 after 2400 hours and then enter sights earlier than 2400. During the period between the two sets of sights you may change DR.LAT and DR.LON without affecting the fix, that is, you may continue to use Merlin II for DR.

It is instructive to plot running fixes and novices in particular are advised to do it. The practice of sun-run-sun fixes came about partly because of inconveniences of navigating with moon and stars. Merlin II obviates most of those inconveniences. Stars, or the sun with the moon, give a fix largely independent of the passage of the vessel.

Basis for fix and computed fix

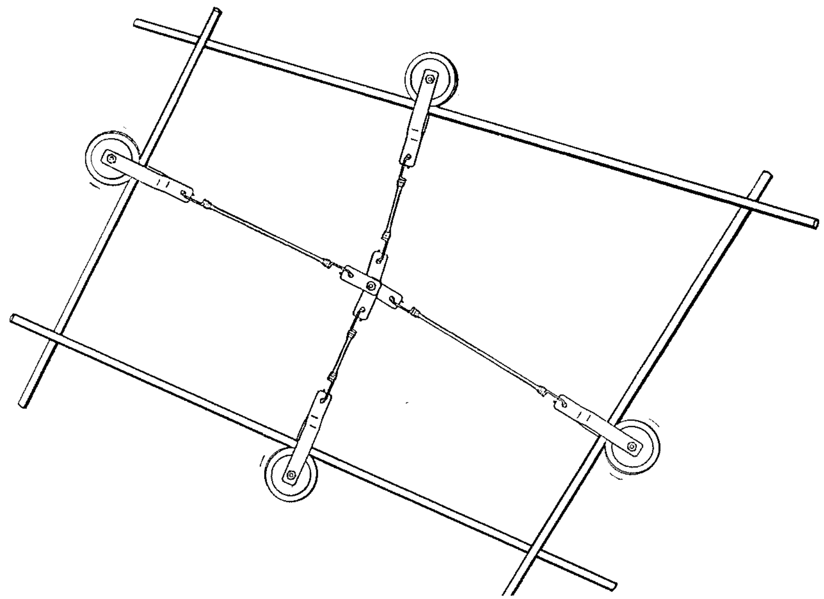
A sight to a celestial body yields a position line, not a position. The position line is a line on the chart (a line on the ocean) which the observer was on at the time of taking the sight. Navigators anywhere on the position line would all have observed the same altitude to that particular body at that particular instant.

A fix may be found when there are two or more sights. Two sights yield two lines and an observer who is on both must be at the point where they intersect. The two bodies must be in two significantly different directions in order to achieve a reliable "cut", 90° being optimal. Several sights to one body at about the same time yield nearly parallel lines (which would all be exactly on top of each other if observing were perfect) and so do not provide a useful intersection.

If there is a sufficient time interval between sights to one body then its azimuth will change and a fix - a running fix - may be obtained.

In the case of three or more observations in various directions the position lines will generally not all intersect at the same point owing to small errors in the observing. The fix in this case is the "best fit" - a compromise. Learners should plot the lines to appreciate the situation. Plotting is also a good check: it only takes a few moments to draw a quick sketch to make sure you agree with the position the computer has found. The form in this manual has provision for such a sketch. If intercepts are very long, plot carefully on the chart.

DEF F shows the fix computed according to the principle of "least squares". It may be imagined that the computer draws the lines and then selects as the fix a point as near as possible to all the lines at once. Physically this is the equivalent of a point attached by bands of stretched elastic to sliding points on all the position lines.



Technically the "least squares" fix is the point where the sum of the squares of the distances to the position lines is the minimum possible. These distances are then "errors".

Errors are not intercepts. The accuracy is not affected by large intercepts which could even be 100 miles without significant effect. Errors are the amounts that the lines disagree with the fix and are caused by the mutual disagreement of the lines. They are the lengths of stretched elastic: the distances from the fix to each line.

The computer fix will be the same as the one you would find by manual plotting **provided that:**

> the errors are small (one mile) **or:**
> the sights are very evenly distributed in azimuth.

If the sights are not evenly distributed the computed fix will be the same as a plotted fix if the errors are small. If the errors are large the computed fix would still be the same as the plotted one **if** the distribution of sights around the horizon is **very even.**

Merlin II gives you an indication of the size of the errors. FIX PREC is the overall measure - a sort of average error - in nautical miles. (Technically it is a standard deviation.) If FIX PRECision is small the FIX will agree with the plot and if there were plenty of sights a small PRECision also indicates reliability. For a small number of sights FIX PRECision is less useful. In the case of two sights it will be 0 because there are no errors, the fix being where the lines cross. This obviously doesn't mean your sights are perfect - though such a computed fix is, of course, the same as you would plot. For sights numerous and well-distributed around the horizon, a low PRECision makes the FIX a certainty, provided you have no mistake with time.

A large value for FIX PRECision requires explanation. If sights were few, look for a mistake. If you have a lot of sights and a large fix precision it does not necessarily mean the fix is poor - but it is quite suspect. The plot of such lines will show whether the errors are consistent. If they are not you have a blunder somewhere. If they are consistent - all of the same sign and about the same amount - it means there was a systematic error in your altitudes. This may be height of eye error, index error, sextant calibration error, a personal tendency always to measure too high or too low, or perhaps unusual refraction occurred. Where observations include large systematic error the computed fix may differ, by a couple of miles, from the plotted fix unless the sights are very evenly distributed in azimuth.

To illustrate: Example 3, page 19. The precision is a low figure, sights are plenty and well distributed so the computed fix is good. If the errors had been large, for example if the precision had come to five miles (owing to one or more of the above systematic causes) then the computed fix would differ noticeably (though not dangerously) from the plotted middle point because the sights are imperfectly distributed in azimuth. The azimuth distribution of Example 3 would normally be entirely adequate.

[Aside 1. It may be seen from the sketch of Example 3, page 19, that such errors as there are, are of the same sign. That is, if the fix was the real place from where the observations were taken, each star shows the observer to be further from its geographical position than it should. Expressed another way: the altitudes were all in error the same way (too low). In this instance the errors are so small that no importance should be attached to them.]

[Aside 2. Unusual atmospheric refraction may affect the ray of light from the horizon. The refraction of the ray from the body will always be properly accounted for unless altitude is exceedingly low (say, under 5°, and mostly even then). The horizon ray to a ship's

bridge can be bent a couple of minutes in calm conditions. At a height of eye of two or three metres measurable error is unlikely. The problem is said to be caused by temperature inversion. Blaming refraction is a last resort.]

What all this discussion about fixes boils down to

> Select four stars in four directions about 90° apart around the horizon. Take four to six shots to each.

You don't necessarily have to compute them all: if three sights to a star give consistent intercepts you are not going to learn anything by computing more. Avoid computing four sights to one star and two to another unless you intend the former to have twice the influence on the computed fix. (Think of those bands of stretched elastic.)

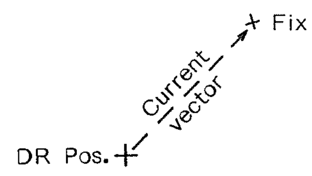
Occasionally it is not possible to find four stars in four directions 90° apart but if the weather is good, mostly you can. Unless it seems necessary for even distribution in azimuth, which is always desirable, there is no point in taking more than four stars. There is much value in taking four rather than the traditional three, because with four you do not need to interpret a triangle of error and a mistake may be resolved as well as revealed. Where you only observe one or two bodies, such as the sun and moon, you will not expose systematic error - so double check index correction and height of eye in the computer.

Do a rough plot - at least do a plot until you have seen lots of situations and are at ease with the computed fix - and remember: no computational check on time is possible. Every 1 minute mistake with your clock is a 15' mistake in your longitude.

Computed set and drift

Assuming that you have carried your DR from a previous fix, then, if your DR were perfect, and if your sights were perfect, intercepts would be zero and there'd be no difference between DR position and fix. The computer knows the bearing and distance between the adopted DR and the computed fix/NP. Assuming the difference is due to current, the bearing is the set. If you tell the computer when you had a previous fix Merlin II divides the distance by the time interval since then and calls it the drift. This set and drift is in addition to any current you may already have allowed for in your dead reckoning.

Your heading, your speed, and where the previous fix might have been, are irrelevant here. Only the time elapsed since a previous fix and the difference between adopted DR position and the fix/NP play a role.



To see the effect of the current on your heading use DEF B (no numbers need to be entered because this current calculation leaves the set and drift waiting in memories U and J: see the DEF B chapter).

Of course, the difference is probably not entirely due to current: it is also due to inaccuracies in the course (owing to leeway and helming errors) and to your observational errors in determining the fix itself.

DEF K ADD A LINE (RUNNING FIX)

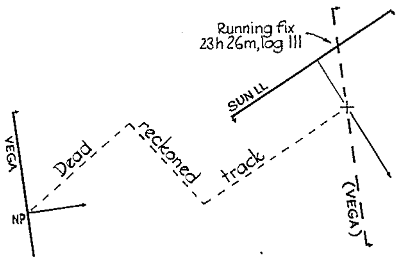
uses:
the latest fix or NP prepared by DEF S/DEF C, and memories L & O.

requests:	**yields:**
AZ?	
INT?	repeats DEF K

Purpose: To add a position line to a fix directly - mainly to include an earlier line for a running fix. DEF K does the opposite to DEF X.

Example: Suppose, on the 22nd of February 1988, in a cloudy pre-dawn several hours before the sunsights of Example 1, you obtained sights to a single bright star. It was Vega at an azimuth of 82°. Satisfied with the sights, you adopted the NP (or some other point on the position line) as DR position and from it dead-reckoned until the DR position is now 40°17'.0 N, 163°46'.0 E at 23h 26m, as per Example 1.

You dead reckoned from a specific lat and long but all you really knew, was that you were on the Vega position line - somewhere. Hence you must now be somewhere on that line shifted according to your dead reckoning. In other words you are now on a line, parallel to the Vega position line, through the present supposed DR position.



Set the data of page 11 and compute the sun sights with DEF S to obtain the results of page 13. You now need to "run up" the Vega line, ie "draw" it through the present DR position. Press DEF K. At AZ? enter 82 which was the azimuth of the earlier line. At INT? enter 0 because you want the line through the DR position. The computer asks for a further azimuth which you do not have. Press DEF F, see 4 OBServations for a FIX at 23h 26m and press ENTER to see the fix of 40°19'.9 N, 163°45'.4 E. The FIX PRECision of 0.4 miles reflects the slight disagreement within the sun sights.

You may use the NP or any point on the earlier line from which to keep the DR. (If there was danger nearby you might adopt a point nearer the danger.) If you ignored the earlier line, ie did not take a point on it at all but kept up the existing DR, then when you operate DEF K later you would enter azimuth and the average intercept, not zero. (Or you could enter all the Vega azimuths and intercepts.)

It is immaterial whether you kept the DR with DEF D or by plotting on your chart. (A cautious navigator might do both.)

Example: The following example illustrates DEF K in conjunction with DEF D. Read the DEF D chapter before doing it. You'll need to be comfortable with the concept of the running fix to understand the example. The way to learn about running fixes is to plot them.

Suppose (there having been no Vega sight) you take morning sun sights as per the introductory example on page 10 and you adopt the NP. Then it clouds over hiding the moon. You hold the course of 70° and maintain dead reckoning by sumlog. At log 121 you alter course to 55° true; speed drops to 5.7 knots. (Speed plays no role in this DR. Speed is only used for the DR if you have your Merlin II switched over to DR.CLOCK instead of sumlog. If you wish, later, to do this example by speed, the change to 55°, 5.7 knots occurs at 0h 44m.) At log 133 you manage to obtain two sights to the centre of a hazy sun. The clock times and sextant altitudes are 2h 32m 09s, 36° 37' and 2h 35m 44s, 36° 22'. What is the running fix at 2h 32m?

Set the data of page 11 and compute the three sunsights of page 12. Operate DEF N to see the Nearest Point (as page 13 but don't advance it) and, when asked REPLACE DR POS?, press ENTER to replace the DR with this NP. The DR.LAT and DR.LON are now 40° 19'.2 N and 163° 44'.1 E. You make this replacement because you are satisfied that the NP is the best estimate of position at this time (namely 23h 26m, log 111). You could plot the line and select a different point on it if you wished.

You sail on and at log 121 you alter course to 55°. Press DEF D and enter the log of 121. Press ENTER to see the DR position update to 40° 22'.1 N, 163° 54'.5 E. Now reset COURSE to 55° using DEF Z or just C = 55 ENTER. You sail on and at log 133 you take sights. Use DEF D to update the DR to log 133. The new DR position is 40° 27'.9 N, 164° 05'.5 E. Now compute the two sun sights with DEF S (note: body 91, not 90, and don't overlook the date which is now the 23rd of February) to see azimuths and intercepts of 203°, +2.1 miles and 204°, +3.7 miles. You can look at the NP if you wish (40° 25'.2 N, 164° 03'.9 E) but the requirement is to advance the morning sights to cross these afternoon sun lines.

Press DEF K and for AZ? enter 147 (the morning azimuth, see page 13) and for INT? enter zero. The intercept is zero because you did, at the time, adopt a point on the (average) morning line as the point from which to keep DR. (If you had not adopted the NP from the morning sights - ie ignored it and carried on with the then DR position - you could now enter the morning azimuths and intercepts with DEF K.) You'll see the flash *ADDED* and the machine will ask for more sights. Press DEF F. The display reminds you that there is a total of three observations (two afternoon and one morning) to give the fix at 2h 32m. The fix is 40° 26' N, 164° 01'.5 E.

The PRECision of 1.1 reflects the disagreement between the two afternoon sights. (If the sun came out you could go on deck, take a couple more shots, compute them with DEF C and see an improved fix with DEF F.) There's not much point in looking for the current as computed values will not be valid because the running fix has itself been influenced by current to an unknown extent.

DEF K may be used to restore a line previously rejected with DEF X - which can also be done by recomputing with time and altitude. DEF K could be used to find a fix from lines taken from a textbook. If you try this note that all intercepts must refer to the **same DR position** - which they probably won't do in the textbook.

K

DEF H STAR AND PLANET IDENTIFICATION

uses:
MO.YEAR DAY CLCOR EYE INDEX COR
DR.LAT DR.LON

requests:	**yields:**
APPROX TIME?	
APPROX AZ?	
(approx)SEXT ALT?	SHA DEC

Purpose: To find out which star you shot.
Example: See below.

This is an alternative to computing Body -1 with DEF S or DEF C.

Provided you took a rough azimuth of an observed star with a compass you can use DEF H to identify it. (You would like to know why it isn't DEF I? You'll have to ask the Sharp Corporation: the letter I is not available as a DEFinable function. Haitch for Hidentify?)

Press DEF H and Merlin II will ask for APPROX TIME? . Time within ten minutes will do. Enter it and the computer will want APPROX AZ? Enter the approximate azimuth and it asks for SEXT ALT? which you can put in to the nearest degree. Merlin II then shows the approximate SHA and DEC. Keep pressing ENTER for successive star identifications.

Example. Stars of Example 3 on page 18 were observed and rough azimuths were taken. Set with DEF A the data for Example 3. The azimuths to these unknown stars were about 140°, 30°, 320° and 240°.

Press DEF H see APPROX TIME? By inspection (page 18) the mean is about 7h 20m so key 7.20 ENTER and see APPROX AZ? For the first star this was 140° so key 140 ENTER and see SEXT ALT? which was about 23°. Enter this and see SHA 255 DEC -17. Now look to the list at the front of this manual for the nearest SHA and dec to these values. The nearest is 258 -16 for star 55.

Having identified the first star press ENTER to see the prompts for the next one. Enter 30 (Az) and 30 (alt) and see SHA 189 DEC 63 for which the nearest values are 194 and 61 for Star 26.

Keep going for the other two stars: Enter 320 and 12 to see SHA 50 DEC 44 which has to be Star 23 and enter 240 and 10 to see SHA 355 DEC -16 which must be Star 25.

Sidereal hour angle (SHA) and declination (DEC) are star coordinates. If that has no meaning for you, don't worry about it. You can be very approximate - several degrees error usually doesn't matter for identification purposes. When you have noted the identity numbers of your stars, use DEF C or DEF S to compute the sights to them.

That other column of figures is magnitude, which means brightness. The lower the magnitude, the brighter. It may aid identification. If there are two stars on the list that appear to fit the computed SHA and dec, presume the brighter. If it is wrong it will be obvious when you compute the sight: the intercept will be huge. Use DEF X to reject that sight then use the other star instead.

The practical approach to star sights is to observe them first and find out which ones they were later. It is the only way in cloudy weather and the efficient way in all circumstances. You can call a star Body -1 or else you can identify with DEF H. DEF H is faster. You note approximate azimuths at the time of shooting, set up the basic data with DEF A, press DEF H and identify them. It's done in moments. For convenience paste a copy of the list of coordinates to a bulkhead or to the clipboard used to hold booking sheets.

You only need to put the time in once for a series of identifications if you enter a rough average time. It will be good enough if your stars were all shot within about twenty minutes or half an hour. If the sights to unknown stars span a longer period press DEF H and put in a new time. You don't have to do them all at once: you may interrupt the series of sight reductions for an identification then continue the reductions with DEF C.

Planets
If there is no matching DEC and SHA and the declination is under, say, 30° (plus or minus) you have probably observed a planet. Planets are usually much brighter than stars. You will find the approximate SHAs of the planets in the bottom right hand corner of the left hand daily page of the Nautical Almanac.

Extra star
It is possible to observe a star not among the 59 listed. It is very unlikely and at twilight it won't happen accidentally in years of sailing. Identify such a star from the 173 stars on pages 268 to 273 of the Nautical Almanac. You compute it as Star 60.

Notes on DEF H
What happens with identification is that Merlin II finds LHA Aries for the specified date and time and then, knowing where you are and the direction and altitude to the star, it calculates what coordinates it must have had. If you have a star finder you do the same thing: you set the dial with LHA Aries and read off the stars at the observed directions and altitudes. LHA Aries (find it in memory A after any sight except body 95) is the measure of the position of the sky and its constellations in relation to your longitude at a given instant.

When you use DEF H the sextant altitude is not corrected for passage of the vessel. For surface craft this is academic.

DEF M MERIDIAN PASSAGE, CIVIL TWILIGHTS

uses:
MO.YEAR DAY CLCOR
DR.LAT DR.LON

requests:	**yields:**
-	NOON TIME
-	NOON ALTitude
-	CIVil TWIlight M orning
-	ARIES M orning
-	CIVil TWIlight E vening
-	ARIES E vening

Purpose: To forecast the time and altitude of noon (meridian passage of the sun) and the times, solar and sidereal, of twilight.
Example: Set with DEF A:

MO.YEAR 2.1989
DAY 13
CLCOR 0

DR.LAT S -35.400
DR.LON W-104.55

Press DEF M and then ENTER several times. You will see the time of noon at this longitude is 19h 13m and the noon altitude of the sun at this latitude will be 67° 30'. Morning civil twilight will be at 12h 04m, the LHA Aries at that time will be 219° 53', the evening twilight occurs at 2h 23m and the evening LHA Aries is 74° 48'. More ENTER pressing will repeat morning and evening alternately.

The times are for your clock (as always on Merlin II). The noon altitude is to the centre of the sun with no altitude corrections.

Civil twilight is when the sun is 6° below the horizon and is about when star observations may be taken (when both horizon and stars are visible). LHA Aries (local hour angle of the First Point of Aries or local sidereal time) is what you set on a star finder. The LHA Aries given by DEF M is accurate to a few minutes of arc.

In extreme latitudes the sun may not rise (thus the noon altitude will be negative, ie below the horizon) or may not set. In such cases where the time of civil twilight does not occur the computer shows ERROR . If you are using Merlin II in such a place please write and tell us about it.

Strictly speaking you should set the latitude and longitude where you expect to be at required noon or twilight. In practice a degree or two - a hundred miles or so - is immaterial for prediction purposes.

Taking noon sights can be a lengthy process so knowing the time noon will occur may speed up the observations. Sights at noon permit extensive short cuts with the calculations. This is of no consequence to a computer but some people continue to take the traditional noon latitude. Merlin II's Nearest Point calculation (DEF N) gives noon

latitude directly. In fact there is no need to observe the sun's actual peak altitude as DEF N is also an ex-meridian latitude.

Noon sights for latitude (and for longitude too) are a primary backup in case of computer failure. See the reference section for a perpetual sun almanac and instructions on taking noon sights.

The twilight information is for planning or identifying stars with a star finder. Select the appropriate latitude template, place it, right way up, on the appropriate side of the star base and turn its arrow to LHA Aries on the perimeter. For identification read off the names of the stars at the observed azimuths and altitudes. For planning read off the approximate azimuths and altitudes of the stars visible from that place at that time.

A star finder is interesting and instructive, however the planning of twilight stars is superfluous and for identification your Merlin II's DEF H is easier. There is no advantage in knowing stars' identities before observing. Instead of "planning", simply take sights when the stars or horizon appear. For approximate sextant settings turn the instrument upside down in the left hand or use values from the previous day. See the reference section for detailed information on observing at sea.

LHA Aries may be found for any time at all by computing any body (except body 95) for the desired time with DEF S or DEF C. You will them find LHA Aries in memory A.

MERLIN II
NAVIGATION COMPUTER

DEF **A** Astro and All data
DEF **Z** Piloting data

DEF **S** Start sights
DEF **C** Continue sights
DEF **X** Reject sight
DEF **F** Fix
DEF **N** Nearest point, Noon lat.
DEF **K** Add a line (running fix)
DEF **H** Identify (SHA, dec)
DEF **M** Mer.pass, twilights

DEF **D** DR update
DEF **B** Current (effect)
DEF **G** GC & rhumb to Go
DEF **V** Visibility, Vertical angle

Body **1-59** Stars
Body **-1** Unknown star
Body **-2** Unknown star
Body **60** Extra star
Body **90** SUNL
Body **91** SUNC
Body **92** SUNU
Body **93** MOONL
Body **94** MOONU
Body **95** PLANET

A LHA Aries d.ddd
H Sextant alt °.'
T Clock time

0 DEF L Speed calc.
4 DEF L Check 999
5 DEF L Tide interp.
6 DEF L DR switch

DEF = d.ddd to °.'
DEF spc °.' to d.ddd

Times h.mmss eg 13.5406
Angles ±d.mmm eg -56.075
(For S, W put -)
Month/year M.YYYY eg 7.1989
Index cor ±m.m eg -2.5
Ht of eye metres (or feet*.3)

DEFine function. **ENTER** means yes/execute/go.
At ? key number (or ignore) and press ENTER.
Only numbers entered after ? will be accepted.
Where ? is yes/no, ENTER = yes; N ENTER = no.

DEF D DEAD RECKONING UPDATE

uses:
DR.LAT DR.LON LOG LOG COR COURSE
(or DR.CLOCK & SPEED instead of LOG & LOG COR)

requests:	**yields:**
LOG? (or DR.CLOCK?)	progress (dist, course)
-	DR.LAT DR.LON
-	course RHUMB distance
-	etc as per DEF G.

Purpose: To maintain dead reckoning position at sea.
Example: Use DEF Z to set

DR.LAT	S -35.250	(Off Montevideo)
DR.LON	W -55.180	
LOG	38	
LOG COR	-10%	
COURSE	120	

If you see DR.CLOCK instead of LOG and LOG COR, put 6 in the display, and press DEF L to switch the computer to the log option.

Suppose those figures represent the situation a couple of hours ago. Suppose the log now reads 52 and your course has been 120° true since the log read 38. You would like to know your position.

Press DEF D and see LOG? . Key in 52 ENTER . The display shows 14 -10% @ 120 T , telling you that it is about to update the DR position by 14 miles less 10% in the direction of 120°. Since this is right, press ENTER. (If it is not right fix whatever is wrong with DEF Z or re-start DEF D.) The message **DR REPLACED** flashes and the display shows the updated position: 35° 31'.3 S, 55° 04'.6 W. If you look with DEF Z you'll see that this new position is now held as the DR and that the log reading is now 52.

Whenever you wish you may pick up the computer, key DEF D, enter the log reading and see your latest latitude and longitude. The purpose in displaying the distance and course is to keep you informed and enable you to catch any blunders: you see what the computer is going to do and if necessary you can stop and fix up anything that is not right using DEF Z. At a change of course you update the DR before putting in the new course with DEF Z (or simply put the new course into memory C). For a further example see page 41.

After the new position is displayed if you press ENTER the computer will continue automatically with DEF G to give rhumb and great circle courses, distances and times to the destination.

SPEED does not play a role in this DR update by log. You have the option to switch your Merlin II to compute DR using time and speed (see opposite). The percentage correction to your log is something you learn by comparing DR with fixes. The set and drift computed after an astrofix will help to infer this correction.

DEF D works backwards, which allows you to reverse an erroneous DR update: just enter the previous reading and the DR will be reset to the previous position. In this example, press DEF D, enter 38 for the log reading, and the position will be back to 35° 25' S, 55° 18' W.

DEF D is very effective. The extended exercise (page 59) contains many examples of its use. To take full advantage of it keep your Merlin II by the deck log handy to the helmsman. You can anticipate damp fingers by wrapping it in self-sticking clear plastic foil.

Deck log
A suggested layout for a deck log is given overleaf. Keep it on a clipboard or in a folder with a pencil on a string. Fill it in every hour and change of course or whenever something occurs worth recording. The columns to the left of the Remarks column are for readings while those to the right are for deduced quantities.

6 DEF L Switch between LOG + LOG COR and DR.CLOCK

On powered vessels it is usually preferred to keep dead reckoning with speed and time rather than a sumlog. Put 6 in the display and press DEF L to switch your Merlin II over to this option. 6 DEF L switches both ways. (If you ever accidentally switch it, just switch it again - no harm done.)

When so switched, instead of asking for log reading, DEF A/Z and DEF D will ask for DR.CLOCK? . As far as Merlin II is concerned, the DR.CLOCK is purely for DR and has nothing to do with astro or any other time. DEF D operates practically the same as described above for log readings. Speed is now important. At any change of course or speed you first update the DR and then reset COURSE and SPEED with DEF Z (or else store them in memories C and S directly). DEF D still works backwards though you can't go backwards through clock midnight. Use a 24 hour clock!

Example: Use DEF Z to set DR lat, long, course as at the top of page 46 and speed to 6.5. Set DR.CLOCK to 22 (ie 2200 hours). Press DEF D, enter a clock reading of 23.56, see 12.5 miles at 120° T. The DR position is 35° 31'.2 S, 55° 04'.6 W.

Example: Press DEF D for a later update at 2h 42m, see an advance of 17.9 miles at 120° T to a position of 35° 40'.2 S, 54° 45'.4 W.

If you need to estimate boatspeed, 0 DEF L will assist: see page 51.

DECK LOG

TIME	LOG	COM PASS	SPEED	APP. WIND	BARO.	REMARKS	CRS °T	DIST.	LAT.	LONG.	

DEF G GREAT CIRCLE AND RHUMB LINE

uses:
DR.LAT DR.LON SPEED DEST.lat DEST.lon

requests:	**yields:**
-	course RHUMB distance
-	days, hours mins to dest.
-	course GCIRC distance
-	days, hours mins to dest.
-	long lat on great circle
-	long lat on great circle
-	. . . . . . etc

Purpose: To find mercator and great circle routes.
Example: Use DEF Z to set:

DR.LAT S -35.250] DR.LON W -55.180]		These are the same values as in the above DEF D example.
SPEED 6.5 DEST. S -34.000 DEST. E 18.000		(Note: you don't have to enter these trailing zeros.)

Press DEF G and the rhumb line course and distance will appear: 88° for 3616.2 miles. Press ENTER and you will see that the rhumb line will take you 23 days 4 hours and 20 minutes at present speed.

Press ENTER again and the great circle will show: start course 111° and the total distance will be 3527.2 miles. ENTER will tell you that this great circle to Capetown takes 22 days 14h 39m.

Another press of ENTER and Merlin II will show you the track of the great circle. The latitude is given every whole 5° of longitude. The first one is at 55° W and the latitude there is 35° 30'.8 S. The next is 50° W, 36° 59'.6 S and so on. You may use these to plot the great circle on a mercator chart and to infer the vertices. Keep pressing ENTER and it will take you around the world without end.

You can press DEF G any time to find the particulars of a route from a DR position to a destination, but mostly you use it without actually pressing DEF G as DEF F, DEF N and DEF D automatically go into DEF G. After DEF F or N, the computation refers to the newly computed (possibly advanced) fix or NP, whether or not you have replaced the DR position with the newly computed one.

Rhumb and GC distances computed by Merlin II may be legitimately compared to see what the GC saves. For sailing vessels the great circle is irrelevant. The above example, perhaps the most plausible on the planet, only saves 90 miles and goes into iceberg territory.

Accuracy
For purposes of both rhumb and great circle, Merlin II considers the Earth a sphere with one minute being one mile. Technically the Earth is a spheroid and the International Nautical Mile (INM) is defined as exactly 1852 metres. To convert Merlin II's rhumb and GC distances

to INM on the spheroid, add 2 miles per thousand up to latitude 30° and 3 miles per thousand in latitudes from 30° to 45°. Thus the above distance would become 3627 and 3538 INM. (The actual values are 3626.7 and 3537.5 INM. It makes no difference which of the various "official" spheroids are adopted.)

A word to the wise: If you are making comparisons, rhumb line distances from some well-known formulae, and from some calculators, are too large by 5 miles per thousand at latitude 0°, reducing to 3 miles per thousand at 25°, reducing to zero in the forties. These supposedly spheroidal formulae thus yield a less accurate rhumb line distance than that found by simply considering the planet to be a sphere. The errors are of no consequence in practice, and have gone unnoticed, but comparing such a rhumb line distance with the great circle distance computed on a sphere, will give an exaggerated impression of the value of the great circle.

For GC or rhumb line course to greater accuracy inspect memory Q.

There is no function on Merlin II directly yielding all the courses and distances of theoretical great circle chords. A GC computation is out of date within one day so such a function is of no value. The instant **actual** GC course to the destination is always available with DEF G.

---

0 DEF L SPEED FROM TIMED DISTANCE

uses: no basic data

requests:	**yields:**
MILES? or FEET? or METRES?	
H.MMSS? or S.S?	boatspeed

Purpose: To find speed from a timed passage over a known distance.
Example: **1.** A distance scaled from the chart of 14.7 miles is sailed in 2h 09m 30s. What was the average boatspeed? With the display showing zero or nothing at all press DEF L to see MILES?. Enter 14.7 to see H.MMSS? and enter 2.0930 to see 6.81 KNOTS.
2. A scrap of paper is timed as it passes the length of a vessel which is 38 feet long. The time is 4.2 seconds. What is the boatspeed? With zero or a blank display press DEF L and press ENTER till FEET? shows. Enter 38 to see S.S? and enter 4.2 to see 5.36 KNOTS.

Note: Time from speed and distance as well as distance from time and speed are also provided by Merlin II. They are displayed when needed and no special effort or input is required. Time from speed and distance is given by DEF G (including via DEF F, DEF N, DEF D). Distance from speed and time is given by DEF D when Merlin II is switched to DR.CLOCK (see 6 DEF L).

DEF V VISIBILITY, DISTANCE OFF BY VERTICAL ANGLE

uses:
EYE INDEX COR

requests:	yields:
HT OBJ? in metres (or feet*.3)	EYE height OBJ height
SEXT ALT?	DISTance off
or, if sext alt zero	VISIBILity distance

Purpose: To find distance to an object of known height.
Example: You observe the vertical angle to the top of a hill given on the chart as 107 metres above sea level. The sextant reads 0° 38'.5 and has a +2'.5 index correction. The height of eye is 1.9 metres.

Set with DEF A:
EYE 1.9
INDEX COR + 2.5

Press DEF V see HT OBJ? enter 107, see EYE 1.9 OBJ 107 which is right so key ENTER and see SEXT ALT?, enter .385 and see DIST 4.8 which means that you are 4.8 miles from the hill (not from the shore but from the hilltop itself). Press ENTER to see the prompt for SEXT ALT? again.

If you press ENTER without putting a sextant altitude the computer assumes you haven't got one and you want to know the visibility distance. If you press ENTER in this case you'll see that the hill is VISIBLE 24.3 miles. This is the maximum distance it is above the horizon for your height of eye. (You'd get the same with a zero altitude - that is zero after index correction is applied.)

This visibility distance is sometimes known as the "dipping distance" - where a light appears to "dip" into the waves from the observer's point of view. At night (when you cannot measure a vertical sextant angle) knowing the visibility distance is very valuable.

Example: A beacon is charted as 7 metres high and the tide is about 1 m below high water. A crewman in the ratlines whose eye is about 23 feet above the water sees it "dipping". How far is the the light? (To set the height of eye enter 23 * .3 to turn it into 6.9 metres.)

Put 8 m for the object. (Chart heights are above highwater; depths are below low water) to find the yacht is 11.3 miles away.

How far away will it be when the helmsman, who is 1.8 metres above sea level, first sees it? It will be 8.6 miles away (if the beacon is still 8 m above the water).

You can experiment to see the effect of changing the height of eye. The action of adjusting height of eye to the point where a light is barely visible is also known a "bobbing a light". From a small boat it is often difficult to tell bobbing and dipping from flashing for it commonly occurs that the crests of waves interfere in a regular way with the view of the light and give it an apparent sequence - which may lead to incorrect identification.

On charts the "m" is the abbreviation for metres; the "M" refers to the number of miles away the light will be seen in reasonable conditions - ie it is a measure of the brightness of the light. Older English language charts - where depths are in fathoms - give heights in feet (ft) so you have to stay alert for the old ones will be in use for many years. On Merlin II enter the feet value with *.3 to convert it to metres. You may have to adjust the height for the state of the tide.

As long as you only operate DEF V, the height of object will stay put (it's in memory P) and you can ignore the prompt for it for repeated computations of distance.

To find the distance to the sea horizon for your height of eye, put zero for object height and ignore the prompt for sextant altitude.

---

5 DEF L TIDE TIME FOR A REQUIRED HEIGHT

This is the standard cosine interpolation to find the time a given height occurs between the high and low values taken from tide tables. This function is provided at the particular request of "mud skippers" of transport vessels working the big tides along northern Australia.

To use it you store the high and low values directly into memories Q & W and Z & X, thus:

Q = time W = height ◂ high tide

Z = time X = height ◂ low tide

These buttons are together on the top and bottom of the left end of the keyboard. The values will stay in these memories as long as you don't run any other Merlin II DEFined functions.

Example:
Low tide is at 14h 27m, height 2.74
High tide is at 21h 06m, height 6.23
The draft necessitates a tide height of 4.4

Key Q = 21.06 ENTER W = 6.23 ENTER
Z = 14.27 ENTER X = 2.74 ENTER

V

Key 5 DEF L and see REQ.HT? so key in the required height of 4.4 and press ENTER to see 4.40 @ 17.40 , meaning that the height of 4.4 will occur at the time of 17h 40m. Another press of ENTER will show REQ.HT? again. If you demand an impossible height you'll see ERROR in the display. If you ever want the height at a required time you can get it in two or three guesses.

(Actually, it doesn't matter if you set Q & W low and Z & X high.)

DEF B CURRENT

uses:
set and drift found by the fix, if desired.

requests:	**yields:**
SET?-	
DRIFT?	SET DRIft
CRS?	
SPD?	True CouRSe : effect on course
-	True SPeeD : effect on speed

Purpose: to see the effect of a current on apparent course and speed.
Example: According to the chart you have a current setting toward 180° with a drift of 2 knots. At the moment you are apparently on a course of 110° at 6.9 knots. What will be the true course and speed?

	Key	See	
	DEF B	SET?	Where the current flows toward
180	ENTER	DRIFT?	Speed of current in knots
2	ENTER	SET 180 DRI 2	(these stay in memories U & J)
	ENTER	CRS?	
110	ENTER	SPD?	
6.9	ENTER	T CRS 124 : +14	True course 124° (increased 14°)
	ENTER	T SPD 7.8 : +13%	True speed 7.8 knots (incr. 13%)

Suppose you actually want to go in the direction of 110°. The current is pushing you 14° to starboard. You alter course to, say, 95° (the nearest round 5° is probably a lot better than you know the current) and see if that does the trick:

	DEF B	SET?	This time you may ignore it
	ENTER	SET 180 DRI 2	Reminding and confirming
	ENTER	CRS?	
95	ENTER	SPD?	
6.9	ENTER	T CRS 111 : +16	which is near enough to 110°
	ENTER	T SPD 7.3 : +6%	

Finer points:

The set and drift are in memories U and G and they'll stay there as long as you don't do any astro computations (when these two memories will be taken over by LHA and GMT). When you do a fix or NP and then compute set and drift the two values are left in U and G so if you want to apply them you don't have to enter them at all.

The CRS and SPD here are apparent values you enter to see what the true course and speed might be. They are entirely separate from, and have no effect on, the COURSE and SPEED as stored by DEF A/Z and held in memories C and S. If you wish, when CRS? and SPD? are requested you may key C and S respectively to see the effect of the current on the values presently held as COURSE and SPEED.

DEF = CONVERT TO °.'
DEF spc CONVERT TO d.ddd

Input and output to Merlin II is in the navigator's usual format of degrees and minutes and tenths. The computations are actually performed on angles in decimal degrees. The internal functions which convert between the two formats are provided for the convenience of users who may wish to do their own calculations.

Example: Put 22.5 into the display.

Press DEF = and you will see 22.300, ie 22° 30'.0
Press DEF spc and you will see 22.500, ie 22°.500

Example: The GHA is given by subtracting longitude from LHA. The longitude for sights is in memory O and the LHA is in U so

Press U - O ENTER	and the GHA will show in d.ddd.
Press DEF =	to see it in degrees and minutes.

When you operate these two functions any other DEFined function is interrupted. They both make use of memories V and W.

The PC-1248 has DEG and DMS functions built in: see the Sharp manual.

TRUE WIND AND VMG USING DEF B

DEF B is a vector solution and may be adapted to find true wind. For:

SET?	enter	apparent wind angle off the bow
DRIFT?	enter	apparent wind speed in knots
CRS?	enter	zero
SPD?	enter	negative boat's speed; this **must** be negative.
T CRS	read	true wind angle off bow
T SPD	read	true wind speed

Example: A close hauled sailboat with the wind 30° off the bow and blowing an apparent 16 knots, is doing 6 knots. Press DEF B, enter 30 for SET? and 16 for DRIFT? . Put 0 for CRS? then -6 for speed. Read true wind angle of 46° and a true wind speed of 11.2 knots. Ignore the figures after the colon and don't forget the minus sign in front of the boatspeed - unless your vessel is going backwards.

To find velocity made good (VMG), multiply the cosine of the true wind angle by the boatspeed. The calculation leaves the true wind angle in memory Z, so key in C O S Z * 6 ENTER to see 4.2 knots. This VMG will be optimistic since leeway is not being taken into account. If you estimate the leeway at 5° that would make the true wind angle 51°. Key C O S 5 1 * 6 ENTER to see 3.8 knots. The VMG is negative if you are going downwind.

If you think it's easier, for SET?, CRS?, and T CRS you may use wind direction, boat's heading, and true wind direction respectively.

DIRECT ACCESS TO MEMORIES

The functions DEF A and DEF Z are not the only access to data. You can look at most of them directly. For example to see what the SPEED is, press S ENTER . Do this anytime as long as there is no question mark showing. Having looked at it, if you press ENTER whatever DEFined function you were operating will simply continue.

If you don't like what you see you can change it. If you decide you want, say, 5.5 as the speed then key in S = 5.5 ENTER and it is done. Another press of ENTER and any DEFined function carries on.

What happens if a question mark is showing? Merlin II expects some input in this case. If you put a letter and then press ENTER then you will be entering the contents of that memory. This is useful. For example if you want to re-run a sight you can put T instead of re-entering the time. You can do this because T holds the last clock time you put in. The same goes for the sextant reading with H.

T and H would be the most useful memories. If you get a funny answer to a sight reject it with DEF X (straight away before you forget) and then see if perhaps you mis-entered the time or altitude: press T ENTER and H ENTER. If they are all right the fault is elsewhere. Look for it with DEF A. If you find it, fix it and then when you are ready to run the sight again T and H will be waiting.

Use DEF A and DEF Z to check systematically but if you only want one number, and you know its memory, you can go straight to it. The simple allocation of S to speed, T to time, etc, has its limits: there are only so many letters.

Memories in the list opposite which are without any remark are not specifically allocated but are used by various Merlin II DEFined functions. You can use them and memories V W X Y Z for personal calculations without risk of disturbing any navigation data you are holding in the machine for later work. Your private numbers won't stay there once you start running DEFined functions.

To convert d.ddd into °.' use DEF =.
To see LHA Aries in degrees and minutes key A DEF =
To see SHA of body key U - A ENTER DEF =
To see GHA Aries key A - O ENTER DEF =
To see GHA body key U - O ENTER DEF =

Often these will not be within the range of 0° to 360°. Add or subtract 360° or 720° (perhaps more) as required. If you use the machine for adding 360s to a negative quantity, the quantity must be in d.ddd. Convert with DEF = after adding the 360s.

To see semidiameter in minutes key S (0) * 6 0 ENTER [The brackets are shifted buttons 1 and 2.] SUNC semidiameter is zero.

Numbers you entered are as you put them in. Numbers the computer found are usually in degrees decimal (d.ddd). Note, though, that GMT is not decimalised and course is decimal (course is not that accurate).

MEMORY ALLOCATIONS

A	LHA Aries in d.ddd at time entered into DEF S/C (not body 95)
B	Body number eg 1-59 stars; 90 SunL; 93 MoonL; 95 Planet
C	Course true in d.d
D	Day of the month
E	Height of eye in metres
F	Month.year as mm.yyyy
G	GMT of latest sight in h.mmss G=T+K (G is d.ddd during calcs)
	Current drift in knots (for DEF B)
H	Sextant altitude in °.'
I	Index correction in ' (minutes of arc)
J	Declination in d.ddd ~~Current drift in knots (for DEF B)~~
K	Clock correction (to astro clock) in h.mmss
L	Adopted latitude preserved by START SIGHTS in d.ddd
M	Time for 0 DEF L
N	Distance for 0 DEF L
O	Adopted longitude held by START SIGHTS in d.ddd
P	Height of object in metres (for DEF V)
Q	Rhumb course or GC course in d.d
R	Log reading in nautical miles or DR.CLOCK in h.mmss
S	Speed of boat over bottom in knots
T	Clock time of latest astro sight in h.mmss
U	Latest LHA body in d.ddd Current set in d.d
V	
W	Intercept in d.ddd . . . To view in minutes key W*60 ENTER
X	Usually the second of a double display eg CALT or fix long
Y	Total altitude correction after AZ and INT show. Includes index, dip (ht of eye), refraction, passage since first observation, parallax (moon), but no semidiameter. In d.ddd . . . To view in minutes key Y*60 ENTER.
Z	Usually the first of a double display eg AZ or fix lat in d.ddd

MEM

I(4)	Horizontal parallax after moon calculation in d.ddd
S(0)	Semidiameter correction in d.ddd

For 5 DEF L tide interpolator	Q = time h.mm	W = height
(memories set manually)	Z = time h.mm	X = height

All memories are used by Merlin II's various DEFined functions. If you try to inspect a memory and see ERROR it just means it is holding non-numeric data.

For private calculations use memories V W X Y Z.

1 2 3 DEF L SPHERICAL TRIANGLE SOLUTIONS

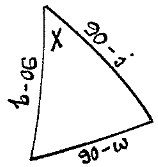
For mathematicians

Three spherical solutions numbered 1, 2, 3 are available. They are all that Merlin II applies.

To use these functions decide which solution you want, set the appropriate memories with the known quantities, key 1 or 2 or 3 into the display and press DEF L. Inspect the appropriate memory for the answer. All values must be in decimal degrees. Southerly latitude and declination may be marked negative in which case Napier's rules and the south pole are redundant. No rules are required concerning quadrants or hemispheres.

On the computer memories are represented only in upper case. For readability below, lower case letters indicate sides and upper case angles. The case has no meaning to the machine (ie q is memory Q).

1 Angle from three sides; *result is <180°*



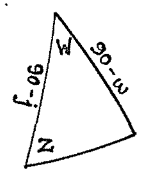
X = arccos[(sin w - sin j sin q)/(cos j cos q)]

To use set memories W, J, Q and press 1 DEF L
Then inspect memory X for the solution.

For instance:

LHA = arccos[(sin alt-sin dec sin lat)/(cos dec cos lat)]

2 Side from two angles and included side; result is < 180°.

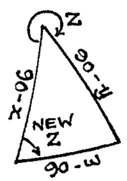


w = arctan[tan j cos W - sin W / (cos j tan Z)]
(the angle in memory W is replaced by the side)

For instance:

lat2 = arctan[tan lat1 cos dlong - sin dlong / (cos lat1 tan Az)]

3 Side from two sides and included angle
incl angle is of any magnitude clockwise from side (90 - x); result is < 180°; **then**
Angle from three sides; result is 0 to 360°



(This is the general transformation for most cases).

w = arcsin(sin x sin y + cos x cos y cos Z)
and having found w, memory Z is replaced by:
new Z = arccos[(sin x sin w - sin y)/(cos x cos w)] sign(sin Z) + 180°
where sign(sin Z) will equal -1 if 180° < Z < 360°

For instance:

alt = arcsin(sin lat sin dec + cos lat cos dec cos LHA)
Az = arccos[(sin lat sin alt-sin dec)/(cos lat cos alt)] sign(sin LHA) + 180°

EXTENDED EXERCISE WITH MERLIN II

Learn to use your Merlin II with the examples from page 10.

The story of a day's navigation is told, in detail, over the next few pages. The vessel might be a 35 foot monohull. It is bound for Fremantle in contrary winds. Owing to the wind, there is limited choice of the boat's course so the navigator's task is mainly to keep track of position. Equip yourself, therefore, with some sextant worksheets, and a ruled-up deck log. Fill them out as you follow the story. As you proceed, compare your figures with the completed deck log and sight computations presented here.

The navigator's general approach might be to consider the situation, decide what must be computed, consult the quick reference on the Merlin II cover for an appropriate DEFined function, press it and follow its prompts.

The specific approach to computing celestial observations consists of the same basic steps as celestial navigators have always followed:

Update the DR, etc.	Use DEF D. Check other data with DEF A/Z.
Identify unknown stars.	Use DEF H and an approximate time.
Compute the sights.	Use DEF S (and DEF C if interrupted).
	Use DEF K to include an earlier line in the fix.
Examine the fix.	Use DEF F (or DEF N for the NP of a single line).

Examine the fix precision and current with DEF F/N. See the effect of the current with DEF B. Replace the DR with DEF F/N. Adjust log correction, course, and speed with DEF Z. Cross out any bad sights with DEF X.

In the worked solutions the position lines are all sketched. This isn't necessary in practice, though it's valuable for enhancing understanding. Take the centre of the compass rose on the form as the DR position and sketch the azimuths and intercepts to a convenient rough scale. To convert east-west miles to minutes of longitude, multiply by the factor for the latitude given on the form as 1/cosine.

Footnotes contain non-essential discussion. You may find it beneficial to work through the exercise more than once, perhaps ignoring the footnotes the first time.

For planet sights the relevant 1989 Nautical Almanac page is reproduced.

The exercise makes some small departures from realism:

- For practice purposes the twilight bodies are not known. Normally at this advanced stage of a voyage they would be known. Approximate azimuths are given in all cases for identification. Identification is not required if you have the patience to use star "-1" (except for planets).

- For clarity explicit consideration of compass corrections is omitted.

- Numbers are given to 0'.1 which is unnecessarily precise. There is a reason for this. If you do the exercise straight through, with the computer applying figures already held from a previous task to the next one, you will compute exactly the same numbers as given. But you don't have to follow the story from beginning to end. You can do any part of the exercise by setting the DR lat, long, log, etc from the deck log and carrying on from that point (and that is what you do if you make a mistake). Because the given figures are so precise, starting in the middle will only incur slight errors (perhaps 0'.1 or 0'.2) from rounding discrepancies.

Reminder: Pressing ENTER when **START SIGHTS** is showing erases the last fix from the computer along with its adopted DR and fix time. Apart from this, you cannot "lose" any data and you can always reverse or negate a mistake. You need have no fear of "pressing the wrong button".

Dawn sights, log 1066

The boat is presently on starboard tack fighting a 15 knot south-easter. DR has been kept by sumlog since a fix the previous dusk at GMT 11h 30m.

Date: 27th November, 1989. Clock is 4 seconds slow on Greenwich. Height of eye is 3.1 metres. Index correction is -3'.5. At the time of the first sight the log read 1066 and the DR position is 31°26' S, 105°08' E. Log correction is set to zero. Course and speed are presently 80° and 5.5 knots. Destination is 32° S, 115°30' E. Four unknown bodies are observed, four sights each. Times and altitudes, with approximate azimuths, are:

	h m s	° '		h m s	° '
150°	20 43 42	23 56	220°	21 02 14	58 55
	20 45 08	24 06		21 03 22	58 47
	20 46 15	24 14		21 04 55	58 34
	20 47 39	24 23		21 05 41	58 27
60°	20 51 56	22 04	330°	21 12 08	28 51
	20 53 02	22 15		21 13 12	28 44
	20 54 44	22 24		21 14 06	28 37
	20 57 09	23 00		21 15 21	28 30

Set the data with DEF A, identify the stars with DEF H (or use body -1). Reminder: the SHA of planets is printed in the lower right corner of the daily page of the almanac. Compute the sights starting with DEF S. The fix is automatically recomputed with every azimuth and intercept - view it at any stage with DEF F (then continue sights with DEF C). Planet data need be entered only once for sight reduction. If you get a silly answer reject it while you are looking at it. You can reject it later if you wrote it down - DEF X rejects at any stage. Nobody is their best at this hour, especially with 15 knots on the nose, and you'll find one sight was actually misread.

The result, with one sight deleted, from 15 OBServations at 20h 43m is a FIX of 31°22'.2 S, 105°03'.0 E with a FIX PRECision of 1.1 miles. The current since the PREVious FIX at 11h 30m shows as set 311°, drift 0.6 kn - which is plausible given the wind direction, though it could also be an indication of leeway not allowed for. DEF B shows this current would be pushing the present course (memory C) off 5° to 75° and reducing the speed (memory S) to 5.1 kn, a loss of 7%. [Note: it is irrelevant to these current calculations whether the DR since the dusk fix had been kept using the Merlin II or by plotting.]

Since the dawn fix is satisfactory replace the 20h 43m DR position with it (use DEF F and press ENTER when it asks REPLACE DR?). The rhumb line course and distance to destination show as 94° for 534.8 miles which would take 4 days (at the 5.5 kn) if the boat could point that way.

Accepting the effect from current, reset COURSE to 75 and LOG COR to -7%. SPEED might as well be set to 5.1 though it plays no role in the DR and such a small change will make no meaningful difference to the passage correction. Use DEF D to update the DR on the hour at log readings 1067.6 and 1072.0.

Footnote 1: Up and down the DR

Change course, log 1075.2

The boat is tacked at 23h 35m, log reading 1075.2, to take advantage of a backing wind. Update the DR to get 31°20' S, 105°12'.7 E.

After taking deviation, variation and leeway into account the navigator decides that the course would now be about 145° and the speed through the water is still apparently about 5.5 kn. If the effect of the presumed current (311°, 0.6 kn) is examined with DEF B it would cut the speed by 11% to 4.9 kn. The effect on the course (to 147°) is negligible for a sailboat. Reset LOG COR to -11% and SPEED to 4.9. The DR is updated at 24h 00m with the log reading 1077.5 and is 31°21'.7 S, 105°14'.0 E.

Morning sun sights, log 1082.5

At 24h 55m - ie 0h 55m on the 28th - at log 1082.5, five sights are taken to the sun's lower limb:

0h 55m 20s 37°37' 0h 56m 31s 37°53' 0h 58m 08s 38°14'
1h 00m 12s 38°40' 1h 01m 44s 38°59'

The DR position is 31°25'.4 S, 105°17'.0 E. Compute the sights with DEF S. With only one body, DEF F has no meaning. DEF N gives the NP as 31°25'.3 S, 105°16'.2 E. Since DR has been carried from the previous fix at 20h 43m the current could be examined - set 273°, drift 0.1 kn - but the intercepts are so small that computing current is not reliable. Although the small difference between the DR and NP is insignificant, the navigator uses DEF N to replace the DR with the new NP. The DR is updated on the hour at log readings 1088.5, 1094.1, 1099.8, until -

Midday sun sights, log 1104.4

Four observations of the sun's lower limb:

4h 48m 24s 79°25' 4h 50m 32s 79°23' 4h 51m 56s 79°20'
4h 53m 22s 79°18'

The DR position is 31°41'.3 S, 105°29'.3 E. Compute the sights with DEF S.

Footnote 2: Noon and ex-meridian latitudes

To form a running fix the morning position line must be "run up" to the present DR. Press DEF K. At AZ? enter the morning azimuth of 94° (a degree or two isn't critical) and at INT? enter zero (since the DR was kept from a point on the morning line). Press DEF F to see the fix for 5 OBServations at 4h 48m of 31°42'.6 S, 105°29'.2 E. [Note: it is irrelevant to DEF K that the DR since the morning line was kept on Merlin II - the DR could just as validly have been kept by plot.]

Footnote 3: Current speculations

The navigator adopts the running fix at 4h 48m of 31°42'.6 S, 105°29'.2 E as the point from which to keep DR - ie, use DEF F to replace DR.LAT and DR.LON with this position. The display says there are 510.5 miles to go at 91°. Continue dead reckoning on this tack with updates on the hour at log 1105.5 and 1111.2 until -

Afternoon sun sights, log 1112.6

The skipper has a daily radio sked on which the 6h 30m GMT position is to be reported. To be able to give the best possible value sights are taken to the sun's lower limb:

6h 15m 41s 67°14' 6h 16m 35s 67°03' 6h 17m 31s 66°52'
6h 18m 40s 66°39'

The DR position is 31°48'.5 S, 105°34'.1 E. Compute with DEF S and use DEF K to add the midday line with azimuth 354°, intercept zero, to give a running FIX for 5 OBServations at 6h 15m of 31°48'.8 S, 105°31'.0 E. Then ADVANCE TO the required 6h 30m to see 31°49'.8 S, 105°31'.8 E.

Pressing DEF F again for another look: since it is only an hour and a half since the earlier line there would be little influence from current on this 6h 15m running fix. The morning line was about parallel to this afternoon line, so let us tell the computer that 0h 55m was the TIME of PREVious FIX. It responds with a set of 263 and drift of 0.5 which would seem to indicate that there has been more leeway than the course of 145° allows. DEF B shows that this alleged set and drift have been adding 5° to the course to make it 150° and reducing the speed by 5% to 4.7 knots.

Accepting this, the navigator lets the 6h 15m value replace DR.LAT and DR.LON and adjusts LOG COR, COURSE and SPEED. If speed is affected by 5% then so is the log. Thus LOG COR needs adjusting by a further 5% which means it should now be reset at -16%. Reset COURSE to 150 and SPEED to 4.7. [The purpose of holding this unattractive tack is to gain southing in the hope of finding south-westerly winds.]

The data with DEF A should now be: 11.1989, 28, +0.0004, 3.1 M, -3.5, -31.488, 105.310, 1112.6, -16%, 150, 4.7, -32.000, 115.300.

Update the DR on the deck log on the hour at log readings 1116.8 and 1121.5. The wind lightens and at about 8h 45m, log 1123.6, it fades altogether. The navigator takes the opportunity to adjust the sextant index correction to zero. A radio time check shows the clock to be now 5 seconds slow on GMT. It is a digital watch, so adjusting it is complicated and the navigator leaves it, putting the 5 seconds as a correction into the Merlin II.

Change course, log 1123.6

After a period of calm at about 9h 30m a breeze comes from the southwest. Course for the destination is 90° but the navigator decides to take the opportunity to edge a little further south and course is steered to make 100° true. Speed is about 4 knots. From the various considerations through the day it is still not clear whether there was a current or the differences were all due to leeway. With no leeway on this new heading, the navigator decides to allow something for contrary current and sets LOG COR at -5%.

The data with DEF A should be (at 9h 30m): 11.1989, 28, +0.0005, 3.1 M, 0, -31.568, 105.364, 1123.6, -5%, 100, 4, -32.000, 115.300. Update the log at 10h when it reads 1125.5.

Late afternoon sun sights, log 1127.6

Clouds build up and at about 10h 30m the navigator, concerned that stars will not be available, takes more sun sights. The clouds are a problem and for two of the sights the upper limb is observed:

LL	10h 30m 06s	13°59'	UL	10h 34m 21s	13°40'
UL	10h 36m 04s	13°18'	LL	10h 43m 53s	11°12'

The running fix with the earlier afternoon line of azimuth 292° is 31°55'.7 S, 105°41'.7 E which is a little north of the DR. A northerly set? The navigator decides simply to replace the 10h 30m DR with this running fix. The log reading at 11h is 1129.8.

Evening stars, log 1131.8

The clouds disappear and stars are observed at log 1131.8 in ideal conditions.

	h m s	° '		h m s	° '
150°	11 35 14	54 07	350°	11 53 40	42 37
	11 36 20	54 15		11 55 33	42 33
	11 37 02	54 19		11 57 50	42 29
	11 37 59	54 27		11 59 42	42 26
70°	11 43 13	25 30	260°	12 03 55	37 11
	11 45 10	25 53		12 04 40	37 01
	11 46 51	26 13		12 05 41	36 48
	11 49 02	26 39		12 06 27	36 38.5

The fourth body is not star 42; it is Venus. Venus, blazing with a magnitude of -4.2, has been by far the brightest object in the night sky for the whole trip. The 11h 35m fix from 16 observations is 31°59'.4 S, 105°44'.6 E and the FIX PRECision is 1.1 miles. **Footnote 4: Systematic error**

The fix may replace the DR position and become the point from which dead reckoning will be kept through the night.

FOOTNOTES TO EXTENDED EXERCISE

Footnote 1: Up and down the DR

Given a certain course (and log cor) you can put in any log reading that occurred, or will occur, and see the corresponding DR. For example, the first leg of the day goes from log 1066 to log 1075.2 so you may enter any value between these and see what the DR position was, or will be, at that stage. You may reverse a mistaken update this way.

Log is held in memory R. You may press DEF D and enter R at the LOG? prompt to see the present lat and long. Try it - it is quite harmless and a convenient alternative to pressing DEF Z. If you want to see where you will be in, say, 5 miles time you can key in R + 5 at LOG? - and then you can reverse this again by entering R - 5. Similar flexibility applies when the Merlin II is switched over to keeping DR by clock instead of sumlog.

Footnote 2: Noon and ex-meridian latitudes

While the purpose of the midday sights was to make a running fix using the morning sights, noon and ex-meridian latitudes are also available. To see them the earlier line must not (yet) have been brought in with DEF K - if it has been then remove it with DEF X.

From the declining sextant altitudes we see that the observations were taken after local noon but since the azimuths are near 0°, not long after.

The NP of the 4 OBServations at 4h 48m is 31°42'.5 S, 105°29'.5 E. As a sketch will show, the position line is practically east-west so the NP latitude is the latitude of the observer. The longitude of the NP is effectively the DR longitude as the sights are almost in the direction of the meridian. (They are "ex-meridian" sights.)

This NP at 4h 48m is the ex-meridian latitude. It is not quite the noon latitude. When did noon ("meridian passage") occur? Press DEF M to show noon time at this longitude to be 4h 45m. [Aside: DEF M shows a predicted noon altitude of 79°36'. This is to the centre of the sun.]

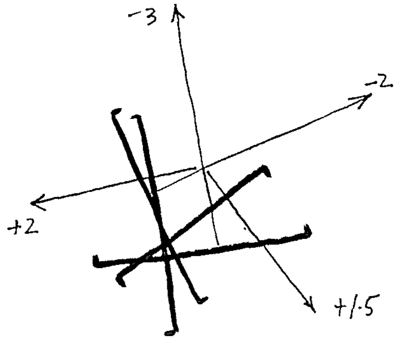
On ships it has been standard practice, and company regulations often require, that noon latitude be recorded. The ex-meridian latitude can be converted to a noon latitude by pressing DEF N to see the NP and, when

ADVANCE TO? shows, entering the noon time of 4.45. The computer adjusts the position according to SPEED and COURSE and the noon latitude shows as 31°42'.5 S (and the longitude displayed is the DR long at 4h 45m).

Footnote 3: Current speculations
With a running fix *it is not generally legitimate to compute current* by entering a time of previous fix because the running fix is, by its nature, influenced by current in an unknown way. Still, you can try putting 0h 55m, which was the time of the morning sights, and the computer will give a current of 184° at 0.3 knots. This is in the opposite direction to the previously presumed northwesterly set. In so far as any trust is to be placed in such small values, a current which appears to flow to port on a starboard tack and to starboard on a port tack would really mean that the yacht is making more leeway than the navigator had allowed.

Footnote 4: Systematic error
This fix is very satisfactory. And yet, given the excellent observing conditions, the FIX PRECision of 1.1 miles is not insignificant. From a sketch of the position lines we see that the error in each line is about a mile (as FIX PREC says) and is consistent. In this case each line is a mile behind the actual position of the observer, ie all lines are one mile further "away" from the body than they should be. The error is "systematic".

If all observed altitudes were increased by 1', the error would virtually disappear because increasing the altitudes by 1' will increase the intercepts by +1' and all the lines will move 1 mile towards their respective bodies. The plot would show all lines passing through practically the same point.



The navigator was supposed to have adjusted the sextant to zero during the period when becalmed but it appears, from the systematic error in this fix, that an index correction of +1' ought to have applied.

If that is so, what if the late afternoon sun sights are also adjusted for a 1' correction? This would **shift the line** 1 mile toward the sun, putting it pretty nearly through the then DR position. This would make the running fix itself at the DR position and not 2 miles further north as it appeared. If that running fix is two miles south then the DR at the time of star sights becomes two miles further south - which would make the star intercepts smaller, ie the star fix would more closely agree with the DR. It really does appear that a +1' correction should apply to the sextant.

These considerations may be clearer if you re-work the exercise from the late afternoon sun sights with a +1 index correction.

A one mile index error will not noticeably affect this fix, because in this fix the sights are fairly distributed around the horizon and the error is thus substantially self-cancelling. Error in DR position, even gross error, will not affect a fix from astronomical observations.

* * *

DECK LOG Extended exercise with Merlin II.

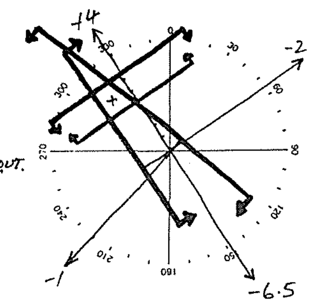
TIME	LOG	COMPASS	SPEED	APP. WIND	BARO.	27 Nov 89 REMARKS	CRS °T	DIST.	LAT.	LONG.	
20 43	1066		5·5	SE 15		Dawn starfix. Current 311° 0·6 kn.	80		22·2 31 26	03·0 105 08	FIX DR.
22 00	1067·6					5·1 15° 0·6 5·5	75°	1·6 -7%	31 21·9	105 04·7	
23 00	1072·0						"	4·4 "	31 20·8	105 09·3	
23 35	1075·2			E 15		TACK.	75 145	3·2 "	31 20·0	105 12·7	
24 00	1077·5		4·9			28 NOV 89	145	2·3 -11%	31 21·7	105 14·0	
0 55	1082·5					Morning sun sights		5·0 "	3 31 25·4	16·2 105 17·0	N.P. DR.
2 00	1088·5							6·0 "	31 29·7	105 19·8	
3 00	1094·1							5·6 "	31 33·8	105 23·1	
4 00	1099·8							5·7 "	31 37·9	105 26·6	
4 48	1104·4					Midday sun sights		4·6 "	42·6 31 43	2 105 29·3	R.FIX DR.
5 00	1105·5							1·1 "	31 43·4	105 29·9	
6 00	1111·2							5·7 -	31 47·5	105 33·3	
6 15	1112·6					Afternoon sun sights		1·4 -	48·8 31 48·5	31·0 105 34·1	R.FIX DR.
7 00	1116·8		4·7				150	4·2 -16%	31 51·9	105 33·1	
8 00	1121·5							4·7 -	31 55·3	105 35·4	
8 45	1123·6		Ø	nil		Becalmed		2·1 "	31 56·8	105 36·4	
9 30	1123·6		4	SW 5			100	— -5%		"	
10 00	1125·5							1·9 "	31 57·1	105 38·5	
10 30	1127·6					Late afternoon sun sights		2·1 -	55·7 31 57·5	41·3 105 40·8	R.FIX DR.
11 00	1129·8							2·2 "	31 56·0	105 44·1	
11 35	1131·8					Evening starfix		2·0 -	59·4 31 56·4	44·6 105 46·3	FIX DR.

MERLIN II **DAWN STARS**

Log: 1066 DR lat: 31°26'S DR long: 105°08'E Day: 27 Month: Nov 19 89

Course (°T): 80 Speed (kn): 5.5 Ht of eye (m): 3.1 Index cor (±'): −3'.5 Clock cor: +0.0004

Body No./name (approx. Az)	#	Clock time h m s	Sextant alt. ° '	Azimuth °	Intercept T+/A- nm
150°		20 43 42	23 56	148	-6.6
(SHA 134, dec -63)		45 08	24 06	"	-6.4
Star 50.		46 15	24 14	"	-6.1
		47 39	24 23	"	-6.7
60°		20 51 56	22 04	56	-2.1
(177, 11)		53 02	22 15	55	-2.8
Star 24		~~54 40~~	~~22 24~~	~~"~~	~~-4.8~~ OUT.
		57 09	23 00	"	-1.3
220°		21 02 14	58 55	218	-1.1
(265, -52)		03 22	58 47	"	-0.1
Star 21.		04 55	58 34	"	-0.7
		05 41	58 27	"	-1.6
330°		21 12 08	28 51	329	+4.0
(261, 23)		13 12	28 44	328	+4.2
JUPITER 281°30'.8 22°54'.9 v=2.7		14 06	28 37	"	+3.3
		15 21	28 30	"	+4.8
[APPROX TIME: 21 00]					



15 OBS FIX at 20 43
31°22'.2 105°03'.0
(PREC. = 1.1 MILES)
PREV. FIX 11 30 →
SET 311° DRIFT 0.6
DEF B: T CRS 75°, -5°
T SPD 51, -7%

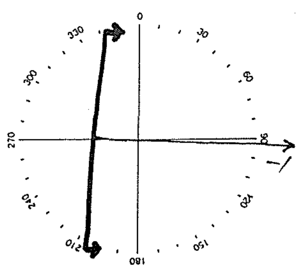
MERLIN II **MORNING SUN**

Log: 1082.5 DR lat: −31°25'.4 DR long: 105° 17'.0 Day: 28 Month: 11 19 89

Course (°T): 145 Speed (kn): 4.9 Ht of eye (m): 3.1 Index cor (±'): −3'.5 Clock cor: +.0004

Body No./name (approx. Az)	#	Clock time h m s	Sextant alt. ° '	Azimuth °	Intercept T+/A- nm
SUN LL.		0 55 20	37 37	94	-1.2
		56 31	37 53	"	-0.3
		58 08	38 14	93	-0.1
		1 00 12	38 40	"	-0.5
		1 01 44	38 59		-1.2

5 OBS NP at 0 55
31°25'.3 105°16'.2
SET 273° DRIFT 0.1 kn.



Latitude: 0° 25° 34° 44° 51° 56° 60°
1/cosine: 1.0 1.1 1.2 1.4 1.6 1.8 2.0

MERLIN II **MIDDAY SUN**

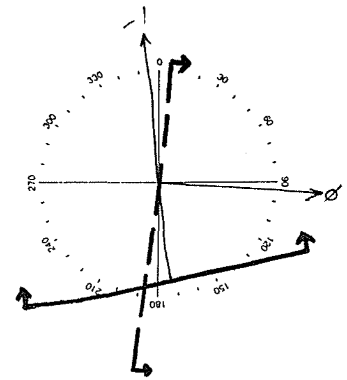
Log: 1104.4 DR lat: 31°41'.3 S DR long: 105° 29'.3 Day: 28 Month: NOV 19 89

Course (°T): 145 Speed (kn): 4.9 Ht of eye (m): 3.1 Index cor (±'): −3'.5 Clock cor: +.0004

Body No./name (approx. Az)	#	Clock time h m s	Sextant alt. ° '	Azimuth °	Intercept T+/A- nm
SUN LL.		4 48 24	79 25	357	-1.3
		50 32	79 23	354	-1.0
		51 56	79 20	352	-1.7
		53 22	79 18	350	-0.9

+ DEF K AZ = 94, INT = Ø

5 OBS FIX at 4 48
31°42'.6 105°29'.2
PREC = 0.3 miles



MERLIN II **AFTERNOON SUN**

Log: 1112.6 DR lat: −31°48'.5 DR long: 105° 34'.1 Day: 28 Month: NOV 19 89

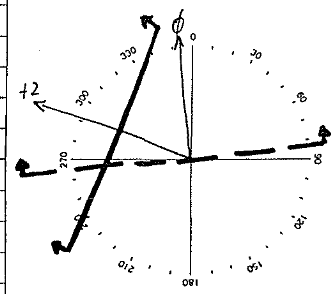
Course (°T): 145 Speed (kn): 4.9 Ht of eye (m): 3.1 Index cor (±'): −3.5 Clock cor: +.0004

Body No./name (approx. Az)	#	Clock time h m s	Sextant alt. ° '	Azimuth °	Intercept T+/A- nm
SUN LL.		6 15 41	67 14	292	+2.3
		16 35	67 03	"	+2.0
		17 31	66 52	291	+2.1
		18 40	66 39	"	+2.9

+ DEF K AZ = 354, INT = Ø

5 OBS. FIX at 6 15
31° 48'.8 105 31'.0
PREC = 0.3 miles

ADVANCE TO 6 30 = 31°49'.8 105°31'.8
(Current 263°, 0.5 kn ?)
DEF B: T CRS 150°
T SPD 4.7 -5%



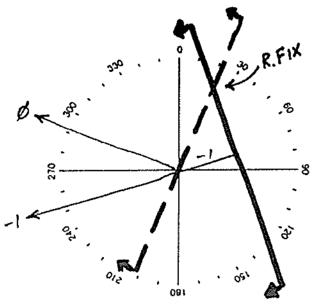
Latitude: 0° 25° 34° 44° 51° 56° 60°
1/cosine: 1.0 1.1 1.2 1.4 1.6 1.8 2.0

MERLIN II LATE AFTERNOON SUN

Log: 1127.6 DR lat: −31° 57'.5 DR long: 105° 40'.8 Day: 28 Month: 11 19 89

Course (°T): 100 Speed (kn): 4 Ht of eye (m): 3.1 Index cor (±'): Ø Clock cor: + .0005

Body No./name (approx. Az) #	Clock time h m s	Sextant alt. ° '	Azimuth °	Intercept T+/A− nm
SUN L.	10 30 06	13 59	253	−1.1
" U.	34 21	13 40	253	−0.8
" U.	36 04	13 18	253	−1.9
" L.	43 53	11 12	252	−1.0
	+ DEF K	AZ = 292, INT = Ø		
	5 OBS FIX at 10 30			
	31° 55'.7	105° 41'.7		
	PREC = 0.5 miles			

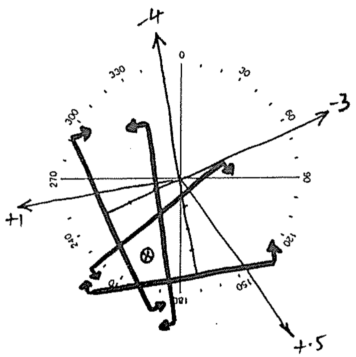


MERLIN II EVENING STARS

Log: 1131.8 DR lat: −31° 56'.4 DR long: + 105° 46'.3 Day: 28 Month: NOV 19 89

Course (°T): 100 Speed (kn): 4 Ht. of eye (m): 3.1 Index cor (±'): Ø Clock cor: + .0005

Body No./name (approx. Az) #	Clock time h m s	Sextant alt. ° '	Azimuth °	Intercept T+/A− nm
150°	11 35 14	54 07	146	+0.4
(SHA 334, dec −60)	36 20	54 15	"	+0.6
Star 2.	37 02	54 19	"	−0.3
	37 59	54 27	"	+0.8
70°	11 43 13	25 30	67	−3.3
(311, 2)	45 10	25 53	"	−3.3
Star 38.	46 51	26 13	66	−3.1
	49 02	26 39	"	−2.7
350°	11 53 40	42 37	353	−3.5
(17, 15)	55 33	42 33	352	−4.3
Star 37.	57 50	42 29	351	−4.1
	59 42	42 26	"	−3.3
260°	12 03 55	37 11	262	+1.2
(70, −26)	04 40	37.01	261	+0.7
VENUS.	05 41	36 48	"	+0.5
313°31'.8 −24° 47'.1 v = 0.3	06 27	36 38.5	"	+0.7
[APPROX TIME: 11 50]				



16 OBS FIX at 11 35
31° 59'.4 105° 44'.6
PREC = 1.1 miles
(TO 60: 4964 at 90°)

Latitude: 0° 25° 34° 44° 51° 56° 60°
1/cosine: 1.0 1.1 1.2 1.4 1.6 1.8 2.0

1989 NOVEMBER 27, 28, 29 (MON., TUES., WED.)

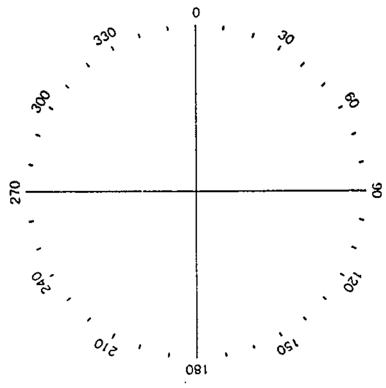
UT (GMT) d h	ARIES G.H.A. ° '	VENUS −4.6 G.H.A. ° '	VENUS Dec. ° '	MARS +1.7 G.H.A. ° '	MARS Dec. ° '	JUPITER −2.7 G.H.A. ° '	JUPITER Dec. ° '	SATURN +0.6 G.H.A. ° '	SATURN Dec. ° '	STARS Name	S.H.A. ° '	Dec. ° '
27 00	65 53.3	133 23.1	S25 03.5	202 51.8	S16 08.5	325 33.8	N22 54.5	143 14.0	S22 35.4	Acamar	315 31.2	S40 20.6
01	80 55.8	148 23.3	03.1	217 52.6	09.0	340 36.5	54.5	158 16.2	35.3	Achernar	335 39.2	S57 17.3
02	95 58.2	163 23.6	02.6	232 53.4	09.6	355 39.2	54.5	173 18.4	35.3	Acrux	173 29.9	S63 02.4
03	111 00.7	178 23.8	· · 02.2	247 54.1	· · 10.1	10 41.9	· · 54.5	188 20.6	· · 35.3	Adhara	255 26.1	S28 57.2
04	126 03.2	193 24.0	01.7	262 54.9	10.6	25 44.6	54.5	203 22.8	35.3	Aldebaran	291 09.4	N16 29.6
05	141 05.6	208 24.2	01.3	277 55.7	11.1	40 47.3	54.6	218 25.0	35.3			
06	156 08.1	223 24.4	S25 00.9	292 56.5	S16 11.6	55 50.1	N22 54.6	233 27.2	S22 35.3	Alioth	166 36.3	N56 00.6
07	171 10.6	238 24.6	00.4	307 57.2	12.1	70 52.8	54.6	248 29.4	35.2	Alkaid	153 13.0	N49 21.6
08	186 13.0	253 24.9	25 00.0	322 58.0	12.7	85 55.5	54.6	263 31.5	35.2	Al Na'ir	28 05.8	S47 00.8
M 09	201 15.5	268 25.1	24 59.5	337 58.8	· · 13.2	100 58.2	· · 54.7	278 33.7	· · 35.2	Alnilam	276 04.0	S 1 12.3
O 10	216 18.0	283 25.3	59.1	352 59.5	13.7	116 00.9	54.7	293 35.9	35.2	Alphard	218 13.4	S 8 36.8
N 11	231 20.4	298 25.5	58.6	8 00.3	14.2	131 03.6	54.7	308 38.1	35.2			
D 12	246 22.9	313 25.8	S24 58.2	23 01.1	S16 14.7	146 06.3	N22 54.7	323 40.3	S22 35.1	Alphecca	126 26.3	N26 44.8
A 13	261 25.4	328 26.0	57.7	38 01.8	15.2	161 09.1	54.7	338 42.5	35.1	Alpheratz	358 01.8	N29 02.4
Y 14	276 27.8	343 26.2	57.3	53 02.6	15.8	176 11.8	54.8	353 44.7	35.1	Altair	62 25.7	N 8 50.5
15	291 30.3	358 26.5	· · 56.8	68 03.4	· · 16.3	191 14.5	· · 54.8	8 46.8	· · 35.1	Ankaa	353 32.7	S42 21.7
16	306 32.7	13 26.7	56.3	83 04.1	16.8	206 17.2	54.8	23 49.0	35.1	Antares	112 48.4	S26 24.7
17	321 35.2	28 26.9	55.9	98 04.9	17.3	221 19.9	54.8	38 51.2	35.1			
18	336 37.7	43 27.2	S24 55.4	113 05.7	S16 17.8	236 22.6	N22 54.8	53 53.4	S22 35.0	Arcturus	146 12.1	N19 14.0
19	351 40.1	58 27.4	55.0	128 06.4	18.3	251 25.4	54.9	68 55.6	35.0	Atria	108 06.9	S69 00.7
20	6 42.6	73 27.7	54.5	143 07.2	18.8	266 28.1	54.9	83 57.8	35.0	Avior	234 25.1	S59 28.3
21	21 45.1	88 27.9	· · 54.1	158 08.0	· · 19.4	281 30.8	· · 54.9	99 00.0	· · 35.0	Bellatrix	278 50.7	N 6 20.6
22	36 47.5	103 28.2	53.6	173 08.7	19.9	296 33.5	54.9	114 02.1	35.0	Betelgeuse	271 20.1	N 7 24.5
23	51 50.0	118 28.4	53.1	188 09.5	20.4	311 36.2	55.0	129 04.3	34.9			
28 00	66 52.5	133 28.7	S24 52.7	203 10.3	S16 20.9	326 39.0	N22 55.0	144 06.5	S22 34.9	Canopus	264 03.5	S52 41.1
01	81 54.9	148 28.9	52.2	218 11.0	21.4	341 41.7	55.0	159 08.7	34.9	Capella	281 00.2	N45 59.4
02	96 57.4	163 29.2	51.8	233 11.8	21.9	356 44.4	55.0	174 10.9	34.9	Deneb	49 43.9	N45 14.8
03	111 59.9	178 29.4	· · 51.3	248 12.6	· · 22.4	11 47.1	· · 55.0	189 13.1	· · 34.9	Denebola	182 51.8	N14 37.6
04	127 02.3	193 29.7	50.8	263 13.3	23.0	26 49.8	55.1	204 15.3	34.8	Diphda	349 13.4	S18 02.5
05	142 04.8	208 30.0	50.4	278 14.1	23.5	41 52.5	55.1	219 17.4	34.8			
06	157 07.2	223 30.2	S24 49.9	293 14.9	S16 24.0	56 55.3	N22 55.1	234 19.6	S22 34.8	Dubhe	194 13.0	N61 48.0
07	172 09.7	238 30.5	49.5	308 15.6	24.5	71 58.0	55.1	249 21.8	34.8	Elnath	278 34.6	N28 36.1
T 08	187 12.2	253 30.8	49.0	323 16.4	25.0	87 00.7	55.1	264 24.0	34.8	Eltanin	90 54.9	N51 29.4
U 09	202 14.6	268 31.0	· · 48.5	338 17.2	· · 25.5	102 03.4	· · 55.2	279 26.2	· · 34.7	Enif	34 04.6	N 9 49.8
E 10	217 17.1	283 31.3	48.1	353 17.9	26.0	117 06.2	55.2	294 28.4	34.7	Fomalhaut	15 43.3	S29 40.6
S 11	232 19.6	298 31.6	47.6	8 18.7	26.5	132 08.9	55.2	309 30.6	34.7			
D 12	247 22.0	313 31.8	S24 47.1	23 19.5	S16 27.0	147 11.6	N22 55.2	324 32.7	S22 34.7	Gacrux	172 21.3	S57 03.2
A 13	262 24.5	328 32.1	46.7	38 20.2	27.6	162 14.3	55.3	339 34.9	34.7	Gienah	176 10.8	S17 29.1
Y 14	277 27.0	343 32.4	46.2	53 21.0	28.1	177 17.0	55.3	354 37.1	34.7	Hadar	149 13.9	S60 19.4
15	292 29.4	358 32.7	· · 45.7	68 21.7	· · 28.6	192 19.8	· · 55.3	9 39.3	· · 34.6	Hamal	328 20.5	N23 25.1
16	307 31.9	13 33.0	45.2	83 22.5	29.1	207 22.5	55.3	24 41.5	34.6	Kaus Aust.	84 07.6	S34 23.6
17	322 34.3	28 33.2	44.8	98 23.3	29.6	222 25.2	55.3	39 43.7	34.6			
18	337 36.8	43 33.5	S24 44.3	113 24.0	S16 30.1	237 27.9	N22 55.4	54 45.8	S22 34.6	Kochab	137 19.9	N74 11.6
19	352 39.3	58 33.8	43.8	128 24.8	30.6	252 30.7	55.4	69 48.0	34.6	Markab	13 56.0	N15 09.2
20	7 41.7	73 34.1	43.4	143 25.6	31.1	267 33.4	55.4	84 50.2	34.5	Menkar	314 33.3	N 4 03.2
21	22 44.2	88 34.4	· · 42.9	158 26.3	· · 31.6	282 36.1	· · 55.4	99 52.4	· · 34.5	Menkent	148 28.9	S36 19.2
22	37 46.7	103 34.7	42.4	173 27.1	32.1	297 38.8	55.4	114 54.6	34.5	Miaplacidus	221 43.4	S69 40.2
23	52 49.1	118 35.0	41.9	188 27.8	32.7	312 41.6	55.5	129 56.8	34.5			
29 00	67 51.6	133 35.3	S24 41.5	203 28.6	S16 33.2	327 44.3	N22 55.5	144 59.0	S22 34.5	Mirfak	309 05.4	N49 49.8
01	82 54.1	148 35.6	41.0	218 29.4	33.7	342 47.0	55.5	160 01.1	34.4	Nunki	76 20.5	S26 18.7
02	97 56.5	163 35.9	40.5	233 30.1	34.2	357 49.7	55.5	175 03.3	34.4	Peacock	53 47.2	S56 46.3
03	112 59.0	178 36.2	· · 40.0	248 30.9	· · 34.7	12 52.5	· · 55.6	190 05.5	· · 34.4	Pollux	243 49.0	N28 03.1
04	128 01.5	193 36.5	39.5	263 31.7	35.2	27 55.2	55.6	205 07.7	34.4	Procyon	245 18.0	N 5 15.2
05	143 03.9	208 36.8	39.1	278 32.4	35.7	42 57.9	55.6	220 09.9	34.4			
06	158 06.4	223 37.1	S24 38.6	293 33.2	S16 36.2	58 00.6	N22 55.6	235 12.1	S22 34.3	Rasalhague	96 23.2	N12 34.0
W 07	173 08.8	238 37.4	38.1	308 33.9	36.7	73 03.4	55.6	250 14.2	34.3	Regulus	208 02.3	N12 01.0
E 08	188 11.3	253 37.7	37.6	323 34.7	37.2	88 06.1	55.7	265 16.4	34.3	Rigel	281 28.7	S 8 12.6
D 09	203 13.8	268 38.0	· · 37.1	338 35.5	· · 37.7	103 08.8	· · 55.7	280 18.6	· · 34.3	Rigil Kent.	140 16.8	S60 47.5
N 10	218 16.2	283 38.4	36.7	353 36.2	38.2	118 11.6	55.7	295 20.8	34.3	Sabik	102 33.2	S15 42.9
E 11	233 18.7	298 38.7	36.2	8 37.0	38.7	133 14.3	55.7	310 23.0	34.2			
S 12	248 21.2	313 39.0	S24 35.7	23 37.7	S16 39.2	148 17.0	N22 55.7	325 25.1	S22 34.2	Schedar	350 00.7	N56 29.3
D 13	263 23.6	328 39.3	35.2	38 38.5	39.8	163 19.7	55.8	340 27.3	34.2	Shaula	96 46.4	S37 06.0
A 14	278 26.1	343 39.6	34.7	53 39.2	40.3	178 22.5	55.8	355 29.5	34.2	Sirius	258 49.0	S16 41.9
Y 15	293 28.6	358 40.0	· · 34.2	68 40.0	· · 40.8	193 25.2	· · 55.8	10 31.7	· · 34.2	Spica	158 50.2	S11 06.5
16	308 31.0	13 40.3	33.8	83 40.8	41.3	208 27.9	55.8	25 33.9	34.1	Suhail	223 05.4	S43 23.2
17	323 33.5	28 40.6	33.3	98 41.5	41.8	223 30.7	55.9	40 36.1	34.1			
18	338 36.0	43 41.0	S24 32.8	113 42.3	S16 42.3	238 33.4	N22 55.9	55 38.2	S22 34.1	Vega	80 51.3	N38 46.5
19	353 38.4	58 41.3	32.3	128 43.0	42.8	253 36.1	55.9	70 40.4	34.1	Zuben'ubi	137 25.4	S16 00.0
20	8 40.9	73 41.6	31.8	143 43.8	43.3	268 38.9	55.9	85 42.6	34.1		S.H.A.	Mer. Pass.
21	23 43.3	88 42.0	· · 31.3	158 44.5	· · 43.8	283 41.6	· · 55.9	100 44.8	· · 34.0		° '	h m
22	38 45.8	103 42.3	30.8	173 45.3	44.3	298 44.3	56.0	115 47.0	34.0	Venus	66 36.2	15 06
23	53 48.3	118 42.6	30.3	188 46.1	44.8	313 47.1	56.0	130 49.2	34.0	Mars	136 17.8	10 27
	h m									Jupiter	259 46.5	2 13
Mer. Pass.	19 29.3	v 0.3	d 0.5	v 0.8	d 0.5	v 2.7	d 0.0	v 2.2	d 0.0	Saturn	77 14.1	14 21

MERLIN II

Log:__________ DR lat:__________ DR long:__________ Day:______ Month:__________ 19______

Course (°T):________ Speed (kn):________ Ht of eye (m):______ Index cor (±'):________ Clock cor:__________

Body No./name (approx. Az) #	Clock time h m s	Sextant alt. ° '	Azimuth °	Intercept T+/A- nm

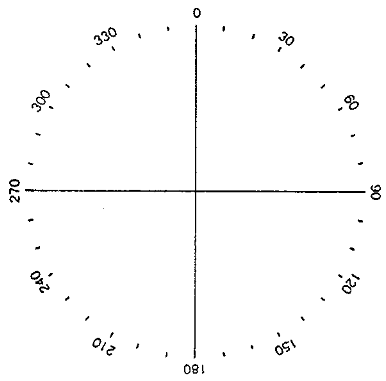


MERLIN II

Log:__________ DR lat:__________ DR long:__________ Day:______ Month:__________ 19______

Course (°T):________ Speed (kn):________ Ht of eye (m):______ Index cor (±'):________ Clock cor:__________

Body No./name (approx. Az) #	Clock time h m s	Sextant alt. ° '	Azimuth °	Intercept T+/A- nm



Latitude:	0°	25°	34°	44°	51°	56°	60°
1/cosine:	1.0	1.1	1.2	1.4	1.6	1.8	2.0

TO CELESTIAL NAVIGATORS

Four years ago when we introduced the original Merlin celestial navigation computer it was a fairly radical venture. Navigation has an awesome history and modern sextant navigation has been practised for over two centuries. At the time I hesitated, as an amateur, to tell people how to navigate. I offered the computer and felt that it was up to the user to apply it.

To some extent that is still my attitude. But after four years of customer contact I think I had better be more forthcoming. Though the need for sextant navigation is declining on ships there is a boom in offshore yachting. Proper practice is important and the amateur environment is different from that of the last two hundred years.

Celestial navigation is reputed to be fearsomely difficult. It has this reputation because (a) every book or article on it insists repeatedly that it is simple; (b) even experts have only a sketchy understanding of how it works; (c) those who can do it are visibly proud of their achievement; (d) it is always put at the end of courses of instruction, sometimes looming over students' heads for years.

A computer makes it easier. There is a degree of reluctance to accept computers by professional mariners. Radar, loran and satnav are welcome aboard but a navigation computer is suspect. Perhaps it is too easy. All you have to do is observe and the computer gives the answer. Is the computer trivialising that hard-earned knowledge?

The hard part is using those tables. The tables are printed by a computer. They are not deliberately made hard to use, but celestial mathematics is complicated and the tables are an attempt to provide every possible answer to every possible situation. To the extent they succeed they are ingenious but, unavoidably, they are very clumsy.

The navigator who personally operates the computer is working at a more fundamental level. For example, if you use the computer to find the position of a body, you find the position at the instant observed and not, as a tabular almanac, on the hour, every hour. And while you are at it you find azimuth and altitude. You never were interested in declination and GHA - they were just a means to an end.

Articles about navigation computers usually include an admonition to carry and be able to use tables. The sentiment may be sincere but the advice is unrealistic. Of the hundred-odd students I have taught celestial navigation over the last couple of years, as far as I know not one has bothered to learn how to use tables. This is despite (a) having learnt the use of the Nautical Almanac, (b) my teaching the precepts of inspection tables and, (c) my giving away sight reduction tables, with a set of instructions, to students who express interest.

The tables were not designed as a backup to an electronic computer and for most people they are not suitable. Hence the information on noon sights in this manual. It is an emergency method that requires no preparation. It can be learnt and applied if needed. That is realistic.

It may reassure those concerned about the computer's reliability to reflect that when lunar tables were discontinued in 1912, the device which replaced them, the chronometer, was much more delicate than today's pocket computer.

The various amateur associations require candidates for certificates to use tables. As a result a minority becomes believers in celestial navigation while the majority is driven to find renewed faith in the loran or satnav. If computers were an option celestial navigation would be more popular and it would be understood, rather than learnt by rote according to one tabular procedure. The calibre of the exams could be improved and the standard of navigation would rise.

Because of the historic context of navigation the special problems of the small boat sailor are not always appreciated. The professional navigator is trained within a formidable career structure and functions within a military, or quasi-military, heirarchy. His colleagues are professionals, his skills are duplicated on ship and he has a comfortable bridge with good equipment in redundant supply. In case of doubt the manpower is available to maintain a good lookout.

The amateur is two metres above the water, the horizon is lumpy, he or she learnt celestial at night school and there is no-one else on board who can navigate. Resources are such that sextant navigation is essential. The satnav, if any, will certainly fail one day.

One occasionally reads that this or that military or civilian institution is still teaching celestial navigation. It is meant to reassure but I detect a note of righteousness. Perhaps it is being taught because, like training on a square-rigger, it is character-building.

With exceptions, I find the schools of instruction disappointing. In other professions we look to the educational institutions to be innovators, sending out their students as the agents of change. But navigation schools seem to be actively resisting change. It is over fifteen years since calculators swept the books of tables from the shelves of other professions. In navigation, methods are still taught which were out of date even before pocket calculators came along.

By default the research is in the hands of individual amateurs - such as mine. Our motivation is commercial and it is understandable if our products are viewed with caution by professional seamen. That is as it should be. One might have looked for a different approach from the schools yet, in the main, instead of the staff informing students, it is the students who introduce teaching staff to computer navigation.

There are schools using examples and almanacs from as far back as 1968. What must the students think, using tables printed before they were born? Some of these institutions are high-profile and taxpayer funded. We know about them because the students write to us asking how to make the Merlin I work for such dates.

Not only are they out of date but the emphasis is sometimes on methods more suited to the safe conduct of ships. It is not unknown for lecturing staff to lack yachting experience.

I therefore have some blunt advice for the navigator who depends on the sextant.

Take stars. Star sights make for easy, confident navigation. The sun and moon are all right but precision and near foolproof reliability come with stars. If the weather is clear little can go wrong with them: they give an overdetermined fix which does not depend on the vessel's progress and blunders are self-revealing (except a clock error). **Take four stars in four directions and take four to six shots on each.**

If you can't see properly, clean the optics and if you still can't see remove the telescope.

Four stars, no more no less (not three, not seven); in two opposed pairs as in Example 3, page 18. That eliminates most systematic error. Systematic error is your big potential error source and it is not revealed when doing a two body (eg sun-moon or sun-run-sun) fix. (Systematic errors include unknown sextant error, personal error and refraction of the ray from the horizon.) If the Merlin II "precision" exceeds two miles an explanation is called for. As a rule plot or sketch to confirm the computed fix.

About five sights each. Don't worry too much if one didn't "feel" like a good shot: the intercept will tell you later whether it was good or not and one sight is neither here nor there. Record to the nearest minute and shoot again. If the star is to the north or south it won't be moving and you'll get nearly identical readings. There's no point in reading the same thing more than three times but do make sure you are not misreading three times. When computing, if three intercepts are substantially the same there is nothing to be gained by computing any more to that star.

Never take any reading only once. This hasn't anything to do with computers. It has always been correct practice and demonstrably so ever since Gauss explained how errors work, nearly 200 years ago. If he and I and common sense are not convincing enough, heed the foremost authorities in the language: the British Admiralty Manual says to take three to five observations and average them, while Bowditch (1977) says to take at least ten and average for high accuracy and if there are only three sights, then individually compute them.

It seems astounding that taking only one sight should even be considered, yet apparently the practice of taking a single sight has been quite widespread. On a ship the navigator might get away with it but the amateur sailor does not have that organisational support.

Averaging times and altitudes. Don't. It's wrong. There wasn't much choice with tables but never average observations when you've got a computer - it is a likely way to conceal a blunder.

Planning stars may be educational but it is superfluous to navigation. It would be harmless if it were so presented to the student but it has been added to the list of "simple" things done by the "proper" celestial navigator. The idea is relatively recent. The 1935 Bowditch doesn't mention it. I think it must have started with the air navigation tables which are simultaneously predicter and reducer. Perhaps it made sense on aircraft which were not limited to twilight and were above the weather. At any rate for the sailor it is needless fuss.

Noon sights, ex-meridian and Polaris latitudes are short cuts exploiting special situations. They serve no purpose while the computer is working. The noon sight looms large in the thinking of the traditional navigator but its value is as a backup in case of computer failure.

[The planet is covered in an imaginary grid of latitude and longitude but in principle lines that run north-south or east-west have no particular merit over lines in other directions. In fact a single position line is usually most useful if it is either parallel with your course or at right angles to it. A line is also useful parallel to a coast since it tells you your offing.]

Plotting sheets are a potential source of mistakes. They are not required when all sights are computed from a single DR position, as they are with a computer. Plot on the chart if the intercepts are big enough to see. If they are not there is no work to do: either you are at your DR or on a line through the DR. For fixes do a rough sketch on your worksheet to give yourself a picture of the situation and satisfy yourself that the computed fix is the same as the plotted one.

* * *

The hardest part of sextant navigation is taking sights from a moving deck. Weather permitting, celestial navigation is straightforward, no-nonsense routine.

MP July 1989

SELECTED SHORT WAVE RADIO TIME SIGNALS

Call sign	Frequency MHz	Power kW	s-pulse (ms)	m-pulse (ms)	Transmission times (GMT) and remarks
ATA New Delhi India	5 10 15	8 8 8	5 5 5	100 100 100	1230 - 0330 24 hours 0330 - 1230
CHU Ottawa Canada	3.330 7.335 14.670	3 10 3	300	500	24 hours, 29s pulse omitted and 51s to 59s voice time (GMT - 5h). Hour pulse is 1s.
JJY Sanwa Japan	2.5,5,8 10,15	2	8	8	24 hours. Silence 35m to 39m past each hour. Minute warning marker of 655ms during 59s each minute.
LOL Buenos Aires, Argentina	5,10,15	2	5	5	11h-12h, 14h-15h, 17h-18h, 20h-21h, 23h-24h. 59s silent.
MSF Rugby, England	2.5,5,10	5	5	100	24 hours, 5 mins on, 5 mins silence, alternating from 0h.
RWM Moscow	5, 10 15	5 8	100	500	24 hours, each hour from 10m to 20m and 40m to 50m.
WWV Ft Collins USA	2.5 5,10,15 20	2.5 10 2.5	5	800	24 hours. 29s and 59s silent. Male voice every minute. Atlantic storm info during 8m and 9m. Pacific info in 10m.
WWVH Hawaii USA	2.5 5,10,15	5 10	5	800	24 hours. 29s and 59s silent. Female voice every minute. Pacific storm info during 48m, 49m, 50m, 51m.
Y3S Nauen, Germany	4.525	5	100	500	24 hours except 0815 to 0945
YVTO Caracas, Venezuela	6.1	10	100	500	24 hours. 30s silent. Time & identity each min in Spanish.
ZUO S. Africa	2.5 5	4 4	5 5	500 500	18h to 04h. 24 hours.

s-pulse, m-pulse = second marker pulse, minute marker pulse. ms = millisecond

Extracted from the Admiralty List of Radio Signals, Volume 5, 1988. Silences during parts of a minute occur in some signals at times. Long range reception is most likely at 7 to 15 MHz. Power is of secondary importance. The "pips" from the BBC, Radio Australia, Voice of America, etc. may also be used.

PRINCIPLES OF NAVIGATIONAL ASTRONOMY

Learners might read this several times.

Celestial movement and position

The heavenly bodies rise in the east and set in the west. All of them do this every day. The cause is the Earth spinning but for our purposes we may consider the Earth to be stationary and the heavens to be in motion.

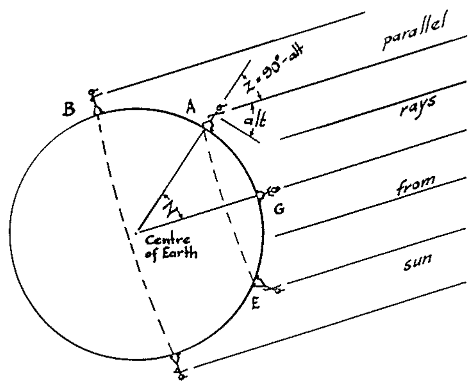
If a line be imagined from a body to the centre of the Earth, the point where the line pierces the Earth's surface is called the body's **geographical position.** An observer at the GP would find the body to be exactly overhead, though only for an instant because, of course, the GP is constantly moving. It moves westward, once around the planet every 24 hours, more or less.

It is the function of an almanac to give the location of the GP for a nominated body at a nominated moment of time. The almanac gives **declination** and **Greenwich hour angle.** Declination is the latitude of the GP; GHA is the longitude of the GP except that GHA is measured positive west from Greenwich. Longitude, at least in this volume, is considered positive east of Greenwich. Since the GP moves westward its latitude (the declination) will not change much. The GHA, on the other hand, is constantly increasing going from 0° to 360° every day.

When you take an observation you note the time carefully. Providing you know which body it was and you are equipped with an almanac for that body, then you can find its declination and GHA for that instant of time.

Relationship of observer to a heavenly body

The figure represents the Earth illuminated by the sun. The sun is so far away that rays from it may be considered parallel. One observer, G, is at the geographical position, ie. on the line from the Earth's centre to the sun. For him the sun is exactly overhead. For observer B, however, the sun is on the horizon.



In terms of altitude, G would find the sun to be 90° up from the horizontal, whereas for B the altitude is 0°. For an observer A, the sun's altitude is perhaps 50°, and we can see that A's altitude is the measure of his distance from the GP. The higher the altitude, the less the distance.

TIME

The reason for this effect is the elementary fact that the Earth is round and, naturally, it holds for any heavenly body, not just the sun. This fact, that altitude indicates distance from the GP, is the central concept of navigational astronomy. If you grasp it clearly, the rest will follow.

Now the distance from A to G (and indeed any great circle distance) may be reckoned in terms of the angle it makes at the centre of the Earth. This angle is marked Z on the sketch and, from fundamental properties of parallel lines, it is equal to the angle between observer A's zenith and the sun. This angle is known as the **zenith distance** and is the difference between the altitude and 90°.

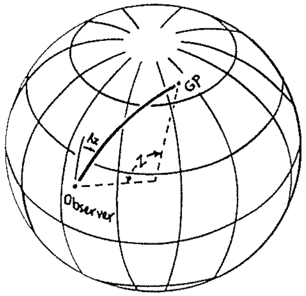
All this means that when a navigator, using a sextant, determines an altitude, he has only to subtract the altitude from 90° to find how far he is from the body's GP. In the sketch, if A found an altitude of 50° then his distance from G was 40°.

Providing A noted the time of his altitude observation he could find the location of the GP from an almanac. But, though he knows how far from the GP he is, he cannot actually find his position. As the sketch shows, an observer, E, would have the same altitude, and anyone situated on the circle centred on G and passing through A and E would observe that same altitude at that particular moment of time. So, without further information all A could say after taking an observation would be that he is somewhere on a circle. It is a fact that an observation of altitude and time to a single body does not yield position; all it yields is a **position circle.**

Since the navigator always has some idea of his location, only a small segment of the circle is of interest. However, even that cannot be drawn by plotting the GP and using a pair of compasses for the circle is too big. In this example, Z is 40°. Each degree represents 60 nautical miles so that A's position circle is 2400 miles in radius.

Marcq St. Hilaire sight reduction
The need is to plot the short section of the circle that is of interest. There are at least three approaches but the procedure which is practically universal nowadays is the **Marcq St. Hilaire** or **altitude intercept** method.

The navigator knows (via time and almanac) the position of the GP. He makes an **estimate,** normally by dead reckoning, of his own latitude and longitude. If you took a global model of the Earth you could mark these two points on it. If you stretched a string or tape between the points you would be able to measure the distance between them and, with the aid of a protractor, you could read off the bearing of this line at the observer's end. The bearing is known as the **azimuth** of the body. "Azimuth" is another word for "true bearing".



Navigators do not use globes. They are too inaccurate. Instead they use a portable computer or books of tables to compute, using appropriate mathematical formulae, the azimuth and distance from the observer to the GP. This distance is not reckoned in miles but in degrees and, in fact, it is not the zenith distance but the zenith distance subtracted from 90°. This makes it the **computed altitude.** That is to say, it is the altitude the observer __would have__ observed __if__ he had been at his estimated position.

Of course a real altitude was observed. Chances are it will not be the same as the computed altitude - which means that the observer was not where he thought. The difference is known as the **intercept.** For example, if the computed altitude was 28° 34' and the observed (corrected) altitude was 28° 37' then the observer was 3' - ie. 3 miles - nearer the GP than his estimated position. That is 3 miles in the direction of the azimuth. The actual location must be nearer to the GP because the actual observed altitude was greater.

To draw the small piece of position circle, the estimated position may be plotted and a line drawn through it in the direction (azimuth) of the body. The intercept is measured off from the estimated position towards or away from the body as appropriate, and the point marked (on Merlin II this is called the "Nearest Point"). A line drawn through this point at right angles to the azimuth is the **position line.** It is the required segment of the position circle and is drawn as a straight line because the circle is so large.

A position line is a line somewhere upon which the observer must be (or have been at the time of sight). A second sight may be taken to another body and the position line corresponding to it also plotted. The observer lies somewhere on this line too. The only way he can be on both lines is to be where they intersect. Thus a fix is given by two lines in different directions.

If more than two lines are plotted, it will doubtless occur that they do not all pass through the same point. Providing there have been no blunders the cause is small errors in measuring the sextant altitude and possibly in the precision of sextant manufacture. Examples showing such errors are to be found in this manual.

Other computational methods.
The above is a minimal description of how the St. Hilaire approach is realised on a computer. The determination of position given time, altitude and almanac data - solving the spherical triangle - has been a unique mathematical and practical problem, a problem which has played a central role in the history of modern times.

Accurate navigation was made possible by the invention of accurate time-keepers two centuries ago (accurate almanacs had long been available) but the calculations, which were well understood by astronomers, proved to be something of a burden to seamen. The concept of celestial position line was explained by Thomas Sumner in 1837. St. Hilaire explained the altitude intercept in 1875. Both mathematically and practically, the St. Hilaire method is the optimal approach and with the development of inspection tables and pressure from air navigation during the second world war it became standard.

Inspection tables consist of lists of pre-computed answers (ie azimuth and computed altitude) to possible situations. The number of possible combinations of observer's position and heavenly position is infinite, so the tables give solutions for combinations involving whole degrees. This would mean a lot of painful interpolating were it not that instead of using DR position the navigator **assumes** a position which may be written with whole numbers. The assumed position consists of the nearest whole degree of latitude and such a longitude that the difference between GHA and longitude (the local hour angle) is a whole number.

Use of tables for ocean navigation is still widely taught though most celestial navigation at sea is probably done using a computer. In the next few years we may expect the "sight reduction tables" to vanish, not only because of navigation computers, but because of computerised electronic positioning equipment. Air navigation is long since exclusively electronic.

Use of such positioning equipment will increase and it remains to be seen if the availability of navigation computers will prevent sextant navigation from vanishing along with the tables.

Obviously, celestial navigation computers do rather more than just solve the spherical triangle. Yet there is still quite a lot of room for improvement. With a suitable display a computer could draw the position lines. It could also find and reject faulty observations. On a computer substantially larger than the Merlin II a fix could be determined without knowledge of either DR position or the names of the bodies observed.

* * *

SELECTING A MARINE SEXTANT
From $30 to $3000.

These remarks refer to features affecting practical navigation.

Construction
Traditionally made of brass, sextants are nowadays often of aluminium. Its lightness is a benefit, especially for women and when sights are difficult. An aluminium instrument can also be made stronger than brass. Aluminium sextants will usually have brass parts which, at sea, are a potential source of electrolytic corrosion. With ordinary care, either type will last generations.

Plastic sextants are extremely light and do not corrode. They flex somewhat and may be affected by temperature changes. They require fairly frequent adjustment. The well-known brands are the British Ebbco and the American Davis. The Davis Mark 3 and the slightly better Ebbco are not toys and will get you out of trouble if used with skill and circumspection. The Ebbco may be stiffened by bolting it to a piece of rigid material. The Davis Mark 15, Mark 20 and Mark 25 are structurally the same and relatively elaborate.

Iron is not desirable on a sextant but the springs retaining the mirrors usually seem to have some iron content. Test for it with a small magnet.

Accuracy
Accuracy is expensive and in part accounts for the large range in prices. In principle, the more accurate the better, but for practical navigation a sextant with intrinsic error under 0'.5 may be considered error-free.

Metal sextants are manufactured to specified standards and modern full-size ones are always within 0'.5. Reduced-size "yacht" sextants may have slightly larger errors and be accompanied by a list of corrections. In practice it will probably never matter if these small corrections are ignored.

It is not so easy to state the accuracy of the plastic models. The manufacturers do not. The Davis Mark 3 under ideal conditions might show random errors around 5 to 8 miles. The Ebbco should be better. In good conditions the Davis Mark 15 etc show fair consistency and without filters the angular accuracy also seems reasonably good. Evidently the filters are not optically flat for they can cause up to 5' error. If this can be allowed for, better angles may be expected, but determining the error is not a trivial task.

To check accuracy measure angles between stars. Be wary of published values of interstellar angles for they change with the time of year. Instead borrow a reliable, quality sextant and measure them. Take many readings.

Scales
The most readable markings seem to be white on a black background. The micrometer - a worm gear meshing with teeth along the arc - has long since superseded the vernier. A vernier is, given practice, just as effective and if the price is right, the inconvenience is tolerable.

Telescope
In principle you need a high magnification for accuracy and a large objective (front) lens to let in plenty of light. In practice a magnification beyond 4 times causes unsteadiness of the image to become disturbing and an objective larger than 40 millimetres (about 1½ inches) diameter would cause structural problems. 4 x 40 is usual on the full size instruments.

It used to be held that sunsights are more accurate if a telescope of 6 times or 7 times is used. There is theoretical support for this but there appears

to be no actual evidence that it improves accuracy in any circumstances. It makes observing more difficult in all circumstances.

Magnification may be checked by looking through the telescope at something like a brick wall with both eyes open. The number of brick-lengths seen with the naked eye, which appear to fit into one brick-length as seen with the telescope eye, is the magnification.

Stars cannot be magnified - by any telescope at all. Stars can be made brighter by a large objective lens. A 40 mm lens gathers four times the light of a 20 mm lens and 16 times the light of a 10 mm lens. At twilight, when a speck of light has to be set to the line dividing a grey sea from a grey sky, a big lens increases the number of observable stars and lengthens the period the horizon is visible. For sun sights objective size doesn't matter but a big lens demands care as even a brief flash from the unfiltered sun could cause eye damage.

Where the lens is small the scope may be removed altogether. Accuracy will suffer (errors of perhaps 3') but star sights can at least be obtained.

Lenses on metal sextants will give a sharp image and modern ones will be coated to maximise light transmission. Lenses on the plastic sextants range from nonexistent to indifferent.

Mirrors
Mirrors have to be big and optically flat. Small mirrors restrict the field of view, making it difficult to "find" the body. Modern sextants all seem to be satisfactory in this respect. The mirrors must be adjustable to remove normal instrument error and removable for occasional drying and eventual resilvering. On one "pocket sextant" sold in the UK they are glued in place.

In recent years the "whole horizon mirror" (or "beam converger") has appeared. It has not superseded the split mirror but is offered as an option. Instead of the horizon mirror being half clear and half silvered, it has a special coating over its whole surface to allow light to both pass through and be reflected. This significantly increases the field of view and makes aiming easier, especially for beginners. Claims that the coating makes a vertical line disappear are misleading as focussing, even with the naked eye, blurs the edge of the split mirror and allows the two images to be superimposed. The disadvantage of the whole horizon mirror is that you cannot vary the relative brightness of star and horizon by sliding the telescope mount left or right or by pointing a little to the left or right.

Illumination
Battery illumination of the scales is not essential but is a fine convenience.

Case
As a precision instrument the sextant requires a robust carrying case. For convenience the sextant should fit into the case with the telescope mounted and the filters in any position.

Conclusion
The ideal practical sextant is of lightweight metal, is non-corroding, is accurate to within 0'.5, has a telescope of 40 mm diameter with a magnification of 3 or 4 times, is read by illuminated micrometer with white markings on black, and comes in a strong box.

Sextants are expensive. A popular strategy is to navigate with a metal sextant and carry a less costly plastic one as a backup.

SEXTANT OBSERVATIONS AT SEA

Practical suggestions

Learning to use the sextant
If possible, begin learning to use your sextant on the beach where you are not distracted by the movement of a boat. On a small boat try to position yourself so that the lower half of your body is supported and the upper half is free to sway to counteract the boat's movements. In a rough sea it is not easy and a sextant takes two hands. It is simpler to begin with the sun, rather than the stars.

Ensure your watch is correct. It helps to have a companion to book for you. It helps even more if you have a teacher, for using a sextant is a skill better communicated by demonstration than by this printed page. Select a filter by holding the filters up in front of the sun. Guess the altitude and set this on the arc, aim at the horizon down the path of maximum glare off the water and move the index arm a little. The sun will appear. Focus sharply and set the sun on the horizon. Rock the sextant laterally ("swing the arc") to find the low point, adjust the micrometer and call the instant.

Record half a dozen times and altitudes and compute them. Knowing your position, you are looking for a zero intercept. After a couple of series even a complete beginner should obtain satisfactory sights. In good conditions with a quality metal sextant you should be within a mile on most shots.

Learn, through experimentation, the significance of swinging the arc, focussing sharply, and having clean optics. Remove the telescope entirely and see what difference it makes to your sights.

Don't forget to check the sextant errors. It is up to you, not an instrument technician, to adjust your sextant's three main errors. As a reminder:

1. Check the index mirror perpendicularity to the arc by reflection test.
2. Check horizon mirror perpendicularity (side error) by seeing that the direct and reflected images of a star pass through each other.
3. When direct and reflected images of a distant object (star or horizon) are superimposed the reading should be zero. The amount needed to be added or subtracted to make zero is the index correction.

Adjust them in sequence. Index correction is much the most important.

Star sights
Taking the sun is quickly learnt. For star sights you have to be organised.

Observe two rules contrary to popular teaching:

1. Do not do any predicting or planning.
2. Do not use a stopwatch for celestial navigation.

Carefully clean the glass surfaces of the sextant. If the objective (front) lens of the telescope is less than 30mm in diameter remove the scope. If you are keeping the scope make sure the eye lens is spotlessly clean. At twilight go on deck with the sextant, watch, flashlight, booking sheet and pencil. Choose a bright star and **either** hold the sextant upside down in the left hand, point directly up at the star and with the right hand on the clamp bring the horizon up to it, **or** preset the sextant to yesterday's figures. With the sextant approximately set (and right way up) point at the horizon, find the star in the field of view, and take about five sights.

Repeat for three more stars as nearly as possible in azimuths 90° apart. Note their approximate azimuths as an extra rough check. Take several observations to determine the sextant index correction.

If you are observing and recording alone:
Attach the watch to your right wrist or the clipboard so you can illuminate it with a light in your left hand.
Count (aloud) the seconds between the sight and the reading of the watch and mentally subtract the count.
Sextants are all made left-handed, so if you are right-handed then after reading the time put the flashlight in your mouth, carefully transfer the sextant to your left hand, fish the pencil out of your pocket and write down the time. Do not fall overboard or bump the sextant.
Read the sextant altitude and write it down.

Notes
- Do not accept the focussing. Re-focus whenever you take up the sextant.
- The ideal clock is a digital watch set to GMT in 24 hour mode. Given a Merlin II, mis-adjusting your clock is the most likely source of a blunder.
- Timing to a few seconds is appropriate. Finer timing will not improve accuracy. Repeat: will not. To improve accuracy take more sights.
- For convenience use a clipboard with the booking form on it. If necessary have a protective piece of plastic over it.
- If it is rough have a tissue in your pocket to keep wiping glass surfaces.
- Preserve night vision by using one eye to look in the telescope and the other to read the sextant scale.
- If you need spectacles to see the stars (eg short-sighted) wear them. If that means you can't read the sextant scale remove the lens from the other eye. If you need spectacles to read the sextant but not the stars you can look at the sky over the top of the lenses.
- Avoid stars below 10° altitude if possible.
- High stars become more awkward but good results may be obtained up to 90°. At extreme altitudes swinging the arc becomes sweeping the horizon. The greater the altitude, the more important is swinging the arc.
- From a small vessel sights are to be made when it is on the top of a wave and there is a distant view. When concentrating on the sextant at twilight it may help if someone warns you as the opportunity approaches.
- Stars may be observed by moonlight. Optics have to be clean. Results will be good in clear weather. Avoid observing the moon itself except in daylight or twilight. In the night the horizon below it may look all right yet give false answers. (You can demonstrate this yourself by trying it.)
- When the moon is nearly full look carefully to make sure you are using the limb which is whole.
- In cloudy weather sit in wait for the sun with sextant in hand. Predict the altitude so a chance is not missed. Sights to the centre of a hazy sun will yield quite useful results.
- On plastic sextants the filters sometimes cause large errors - up to 5'. This will make the index correction different for stars and for sun.
- Do not leave a wet sextant in its case. The main secret for long-lived silvering is to keep the mirrors dry and ventilated.
- If possible avoid climbing a companionway with the sextant in hand. You will make life easier if you mount the sextant, in or out of its case, to a bulkhead where it may be conveniently reached.
- In case of sextant damage, useful position lines may be obtained by timing the rise and set of the sun (both limbs) and moon. The observed altitude is simply zero. Allow for a couple of miles error due to unknown refraction. The rise or set of any body could be used but the atmosphere is seldom clear enough to see stars or planets on the horizon.
- For plotting on a yacht use a square protractor, not a parallel ruler. The parallel ruler takes two hands and you need to see the compass rose. A five inch (not bigger) square protractor is itself a compass rose that can be readily oriented anywhere on the chart.

NOON SIGHTS FOR LATITUDE AND LONGITUDE

In case of computer break-down.

Local noon (or "meridian passage" of the sun) is the instant when the sun stops rising and starts setting. It is exactly due north or due south of the observer at this moment. In principle the meridian passage of any body may be used to take such sights except that the moon should not be used for longitude as its declination changes too rapidly. Naturally, sights can only be taken when the horizon is visible.

For latitude you need a sextant, altitude correction tables for dip and refraction and an almanac. For longitude you need a sextant, a clock and an almanac. An almanac for the sun is printed here along with dip and refraction correction tables.

LATITUDE

As noon approaches, keep reading the sun's altitude, watching it slowly increase. When noon occurs, the altitude appears to stay the same for a while before beginning to decrease. Note the sextant reading at noon and the approximate GMT.

The altitude must be corrected for index, dip (height of eye), refraction and semidiameter. The semidiameter correction for the sun is ±16'. Dip and refraction corrections may be taken from tables.

After correcting the altitude subtract it from 90° to give the zenith distance, Z. This Z is the angle from your zenith to the sun and it indicates how far you are north of, or south of, the sun's geographic position. Z may be regarded as a sort of latitude with respect to the sun instead of the equator. Since the sun's declination is its latitude, if you add Z to it you will get your latitude.

Example 1: In the northern hemisphere you observe the sun to the south at noon. The corrected alt is 70°. So Z is (90 - 70) = 20°. An almanac gives the sun's declination at that time as 10°N. So your latitude is 30°N.

In strictly algebraic terms: latitude = Z + sun's dec.

where latitude is negative if south
declination is negative if south
Z is negative if you were south of the sun (ie looking north).

Example 2: Sun to the north, corrected alt = 85° 32' thus Z = -4° 28'. The almanac gives dec as 15° 45' S.

lat = -4° 28' -15° 45' = -20° 13' ie 20° 13' S

Example 3: Sun to the south, corrected alt = 78° 04' thus Z = 11° 56'. The sun's dec is 21° 27' S

lat = 11° 56' -21° 27' = -9° 31' ie 9° 31' S.

LONGITUDE

At the instant of local noon you and the sun have the same longitude. Since the sun's longitude is its GHA, if you can find the GMT of local noon it is only necessary to look up the GHA to find your longitude. However the GMT of noon can't be read directly because with a sextant you can't pick the exact moment.

The procedure, in principle, is to measure the altitude 20 minutes to an hour (or more) before the time you expect noon to occur, noting the GMT. After noon is past set the sextant to the same altitude and keep watching the sun

until it descends to that altitude. Note the GMT of that moment. The average of the two GMT's is the GMT of local noon. An almanac will yield the sun's GHA for that instant. This is your longitude west. There is no need to apply any altitude corrections as they should be the same before and after noon.

Example 4:
Sun's GHA at GMT of local noon = 47° 38' so longitude = 47° 38' W.

Example 5: Sun's GHA at GMT of local noon = 256° 31'.5. Longitude is thus 256° 31'.5 west but longitude is only measured to 180°, so subtract the value from 360° and call it east: 360° - 256° 31'.5 = 103° 28'.5 E.

In practice one sight before and after meridian passage is not satisfactory. Instead take half a dozen before noon, spread over half an hour or so. After noon has occurred set the sextant to the highest of the forenoon readings and note the time when the sun descends to this altitude. Do the same for the rest of the observations. You then have half a dozen pairs you can average. Of course they should all give the same answer for GMT noon but they won't so take a new average of them and look up your longitude.

The reasons for this procedure are (a) the equal altitudes method of finding longitude does not always give really good results and it is improved by taking averages of several sights; (b) if you only took one sight cloud might obscure the sun at the critical moment when you want the second one. The more you take the better.

You don't necessarily have to take the same altitudes before and after noon. You can just take random altitudes and graph them, time against altitude, and put a smooth curve through the values. The GMT of noon is at the centre of the curve. It is handy to have some squared paper and for accuracy you should draw it so that it takes up nearly the whole page.

Latitude at noon is as accurate as any other sextant position line - right up to altitudes near 90° too. But longitude may be good or it might not. There is an important reservation with longitude as well: your vessel must not be moving north-south during the period between the forenoon and afternoon sights. If you move east-west (parallel with the movement of the sun) there is no error. Record the log so the noon log can be inferred.

ALTITUDE CORRECTIONS

Ht eye	Dip cor
1.3m	-2'
3 m	-3'
5 m	-4'
8 m	-5'
12 m	-6'

Altitude	Refr cor
90°	0
44°	-1'
26°	-2'
18°	-3'
13°	-4'
9°	-6'
6°	-8'
5°	-10'
1°40'	-20'
0°	-34'

Example 6: The lower limb of the sun is observed. The sextant altitude is 33° 14'. The sextant requires an index correction of -2' and the height of eye is 2.8 m. Find the corrected altitude.

Index correction	-2	may be + or -
Dip correction for 2.8m	-3	always negative
Refraction correction for 33°	-1.5	always negative
Semidiameter correction for LL	+16	LL is +16', UL is -16'
Total altitude correction	+9'.5	and the corrected altitude 33° 23'.5

PERPETUAL SUN ALMANAC

This almanac lists the declination and GHA of the sun for 0h GMT for each day of the year. The maximum error in it for the rest of this century is 2'. To use it first roughly adjust the GMT of the observation according to the kind of year, viz:

In a year preceding a leap year	make the adjusted time	6 hours	earlier
In a leap year in Jan and Feb	" " " "	12 hours	"
In a leap year in March to Dec	" " " "	12 hours	later
In a year after a leap year	" " " "	6 hours	"

In even numbered non-leap years the adjusted time is the same as the GMT. Leap years are the Olympic Games years: 1988, 1992, 1996, 2000, 2004, etc.

For declination: Interpolate (ie, work out by proportion) the value for the adjusted time from the almanac.

For GHA: Interpolate a "datum GHA" from the almanac using adjusted time. Convert the actual GMT to arc by multiplying by 15. Add this arc to the datum GHA.

Example 7: Find the sun's dec and GHA at GMT 19h 55m 17s on September 27 1992. It's a leap year; here add 12h so adjusted time becomes 8h on September 28.

For dec: dec at 0h Sept 28 = -1° 50'
dec at 0h Sept 29 = -2° 13'
difference = 23'

23 x 8/24 = 8

dec = -1° 50' - 8' = **-1°58'**

For GHA:
The interpolation can be done by eye. On September the 28th, the GHA is at 0h is 182° 17'. At 24h (ie 0h on the 29th) it is 182° 22' so at 8h it would be 182° 19'. Converting 19h 55m 17s to arc gives 298° 49' 15". If you have a calculator use the >DEG button to express the time in decimal hours, multiply by 15 then change back with >DMS. Otherwise multiply manually as below or use an arc-to-time conversion table such as on the first tinted page of the Nautical Almanac.

```
   19          55        4 )17
 x 15        x 15        -----
   --          ---         4'.25
   95          275
  190          550
  ---          ---
  285°         825' = 13°45' (arc is 298° 49'.25)
```

datum GHA = 182° 19'
arc = 298° 49'
481° 08'

GHA = **121° 08'**

NOON SIGHTS SUMMARY

To find position at noon start taking sights an hour or so before. Note GMTs and sextant altitudes. At noon keep reading the sextant to determine the peak altitude. Apply the altitude corrections to the peak altitude, subtract the corrected altitude from 90° to give Z. Sign Z (+ or -) and algebraically add it to the sun's declination to give your latitude. Preset the sextant to the highest of the forenoon readings and note the GMT when the sun drops to that sextant altitude. Repeat for the other forenoon altitudes. Average each pair of GMTs and average the averages to give the GMT of noon. Look up the GHA of the sun at that time. It is your west longitude.

Do not change your latitude (move north or south) during the period.

SUN'S DECLINATION AT 0h GMT IN DEGREES AND MINUTES

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	-23 2	-17 14	-7 46	4 21	14 56	21 59	23 8	18 8	8 27	-2 60	-14 16	-21 44	1
2	-22 57	-16 57	-7 23	4 44	15 14	22 7	23. 4	17 53	8 6	-3 23	-14 36	-21 53	2
3	-22 52	-16 40	-7 0	5 8	15 32	22 15	22 60	17 38	7 44	-3 46	-14 55	-22 2	3
4	-22 46	-16 22	-6 37	5 31	15 50	22 23	22 55	17 22	7 22	-4 10	-15 13	-22 10	4
5	-22 40	-16 4	-6 14	5 53	16 7	22 30	22 50	17 6	6 60	-4 33	-15 32	-22 18	5
6	-22 33	-15 46	-5 51	6 16	16 24	22 36	22 44	16 50	6 37	-4 56	-15 50	-22 26	6
7	-22 26	-15 27	-5 28	6 39	16 41	22 42	22 38	16 33	6 15	-5 19	-16 8	-22 33	7
8	-22 18	-15 8	-5 4	7 1	16 57	22 48	22 32	16 17	5 52	-5 42	-16 26	-22 40	8
9	-22 10	-14 49	-4 41	7 24	17 14	22 53	22 25	15 60	5 30	-6 5	-16 43	-22 46	9
10	-22 2	-14 30	-4 18	7 46	17 30	22 58	22 18	15 42	5 7	-6 28	-17 0	-22 52	10
11	-21 53	-14 11	-3 54	8 8	17 45	23 3	22 10	15 25	4 45	-6 50	-17 17	-22 57	11
12	-21 43	-13 51	-3 30	8 30	18 1	23 7	22 2	15 7	4 22	-7 13	-17 34	-23 2	12
13	-21 33	-13 31	-3 7	8 52	18 16	23 11	21 54	14 49	3 59	-7 35	-17 50	-23 7	13
14	-21 23	-13 11	-2 43	9 14	18 31	23 14	21 45	14 31	3 36	-7 58	-18 6	-23 11	14
15	-21 13	-12 50	-2 20	9 36	18 45	23 17	21 36	14 12	3 13	-8 20	-18 22	-23 15	15
16	-21 2	-12 30	-1 56	9 57	18 59	23 20	21 27	13 53	2 50	-8 42	-18 37	-23 18	16
17	-20 50	-12 9	-1 32	10 18	19 13	23 22	21 17	13 34	2 27	-9 5	-18 52	-23 20	17
18	-20 38	-11 48	-1 8	10 39	19 27	23 24	21 7	13 15	2 3	-9 26	-19 7	-23 22	18
19	-20 26	-11 27	-0 45	11 0	19 40	23 25	20 56	12 56	1 40	-9 48	-19 21	-23 24	19
20	-20 13	-11 5	-0 21	11 21	19 53	23 26	20 45	12 36	1 17	-10 10	-19 35	-23 25	20
21	-20 0	-10 44	0 3	11 42	20 5	23 26	20 34	12 17	0 54	-10 31	-19 48	-23 26	21
22	-19 47	-10 22	0 26	12 2	20 17	23 26	20 22	11 57	0 30	-10 53	-20 2	-23 26	22
23	-19 33	-10 0	0 50	12 22	20 29	23 26	20 10	11 36	0 7	-11 14	-20 15	-23 26	23
24	-19 19	-9 38	1 14	12 42	20 41	23 25	19 58	11 16	-0 16	-11 35	-20 27	-23 26	24
25	-19 5	-9 16	1 37	13 2	20 52	23 24	19 45	10 56	-0 40	-11 56	-20 39	-23 25	25
26	-18 50	-8 54	2 1	13 22	21 3	23 23	19 33	10 35	-1 3	-12 17	-20 51	-23 23	26
27	-18 35	-8 31	2 25	13 41	21 13	23 21	19 19	10 14	-1 27	-12 37	-21 2	-23 21	27
28	-18 19	-8 9	2 48	13 60	21 23	23 18	19 6	9 53	-1 50	-12 57	-21 13	-23 18	28
29	-18 3	-7 46	3 11	14 19	21 33	23 15	18 52	9 32	-2 13	-13 17	-21 24	-23 15	29
30	-17 47	-7 23	3 35	14 37	21 42	23 12	18 38	9 10	-2 37	-13 37	-21 34	-23 12	30
31	-17 31		3 58	14 56	21 51	23 8	18 23	8 49	-2 60	-13 57	-21 44	-23 8	31
32	-17 14		4 21		21 59		18 8	8 27		-14 16		-23 4	32

SUN'S "DATUM GHA" AT 0h GMT IN DEGREES AND MINUTES

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	
1	179 11	176 37	176 52	178 59	180 43	180 35	179 5	178 25	179 57	182 32	184 5	182 48	1
2	179 3	176 35	176 55	179 3	180 44	180 33	179 2	178 26	180 2	182 36	184 6	182 42	2
3	178 56	176 33	176 58	179 7	180 46	180 30	178 59	178 27	180 6	182 41	184 6	182 37	3
4	178 50	176 32	177 2	179 12	180 48	180 28	178 56	178 28	180 11	182 46	184 6	182 31	4
5	178 43	176 30	177 5	179 16	180 49	180 25	178 54	178 29	180 16	182 50	184 6	182 25	5
6	178 36	176 29	177 8	179 21	180 50	180 23	178 51	178 31	180 21	182 55	184 5	182 18	6
7	178 29	176 28	177 12	179 25	180 52	180 20	178 49	178 33	180 26	182 59	184 5	182 12	7
8	178 23	176 27	177 15	179 29	180 53	180 17	178 46	178 34	180 31	183 4	184 4	182 6	8
9	178 17	176 27	177 19	179 33	180 53	180 14	178 44	178 36	180 37	183 8	184 3	181 59	9
10	178 10	176 26	177 23	179 37	180 54	180 11	178 42	178 39	180 42	183 12	184 2	181 52	10
11	178 4	176 26	177 27	179 41	180 55	180 8	178 40	178 41	180 47	183 16	184 0	181 46	11
12	177 58	176 26	177 30	179 45	180 55	180 5	178 38	178 43	180 52	183 20	183 59	181 39	12
13	177 53	176 26	177 35	179 49	180 55	180 2	178 36	178 46	180 58	183 24	183 57	181 32	13
14	177 47	176 27	177 39	179 53	180 56	179 59	178 34	178 48	181 3	183 27	183 55	181 25	14
15	177 42	176 27	177 43	179 57	180 56	179 56	178 32	178 51	181 8	183 31	183 52	181 17	15
16	177 36	176 28	177 47	180 1	180 55	179 53	178 31	178 54	181 14	183 34	183 50	181 10	16
17	177 31	176 29	177 51	180 4	180 55	179 50	178 29	178 57	181 19	183 37	183 47	181 3	17
18	177 26	176 30	177 56	180 8	180 55	179 46	178 28	179 0	181 24	183 40	183 44	180 56	18
19	177 22	176 31	177 60	180 11	180 54	179 43	178 27	179 4	181 30	183 43	183 41	180 48	19
20	177 17	176 33	178 4	180 14	180 53	179 40	178 26	179 7	181 35	183 46	183 38	180 41	20
21	177 13	176 34	178 9	180 17	180 53	179 36	178 25	179 11	181 40	183 49	183 34	180 33	21
22	177 8	176 36	178 13	180 20	180 52	179 33	178 24	179 14	181 46	183 51	183 30	180 26	22
23	177 4	176 38	178 18	180 23	180 50	179 30	178 24	179 18	181 51	183 53	183 26	180 19	23
24	177 0	176 40	178 22	180 26	180 49	179 27	178 23	179 22	181 56	183 55	183 22	180 11	24
25	176 57	176 42	178 27	180 29	180 48	179 24	178 23	179 26	182 1	183 57	183 18	180 4	25
26	176 53	176 44	178 31	180 31	180 46	179 20	178 23	179 30	182 6	183 59	183 13	179 56	26
27	176 50	176 47	178 36	180 34	180 45	179 17	178 23	179 34	182 12	184 1	183 9	179 49	27
28	176 47	176 50	178 40	180 36	180 43	179 14	178 23	179 39	182 17	184 2	183 4	179 41	28
29	176 44	176 52	178 45	180 39	180 41	179 11	178 23	179 43	182 22	184 3	182 59	179 34	29
30	176 42	176 55	178 50	180 41	180 39	179 8	178 24	179 48	182 27	184 4	182 53	179 27	30
31	176 39		178 54	180 43	180 37	179 5	178 24	179 52	182 32	184 5	182 48	179 19	31
32	176 37		178 59		180 35		178 25	179 57		184 5		179 12	32

CELESTIAL NAVIGATION ON LAND

In the desert or the backyard.

Equipment

In general the appropriate instrument is a marine sextant with an artificial horizon. However, there are some other possibilities.

In skilled hands a theodolite is convenient. A theodolite and a quality metal sextant are constructed to comparable precision but the theodolite telescope is of much higher magnification. This permits greater pointing accuracy and better determination of index error. The instrument is levelled on a tripod and the horizon is, in effect, built in. For altitudes greater than about 35 degrees special eyepieces are needed.

A theodolite is around five times the cost, weight and bulk of a sextant. Moreover, in use there are traps for the inexperienced. If you have to carry a theodolite for other survey purposes then use it for position finding. Otherwise, even if you are competent, you would probably be better off with a marine sextant. By taking observations to opposed pairs of stars you will, in good conditions, obtain a fix to the same precision as with a theodolite.

A bubble (aircraft) sextant is less useful. These instruments have a circular bubble built into the optics. To take a reading the body is made to appear in the centre of the bubble. The trouble is that the bubble indicates not the true local horizontal but the resultant of gravity and accelerations from the observer's unsteady hand. The errors are unacceptable. They would be improved by setting the instrument on a camera tripod. The bubble sextant's advantage is independence of the natural horizon and no limits to altitude.

Marine sextants are readily available and are quite portable. There is a "pocket" type, with lower accuracy, which might be appropriate if weight is critical. With a marine sextant and artificial horizon altitudes cannot exceed 60°. This is not serious as 87% of the visible sky is below 60°.

An artificial horizon is a level reflecting surface. Traditionally this is a dish of mercury. For sunsights a pan of water succeeds if there is no breeze. Engine oil is steadier and the smaller the pan the quicker it will settle between puffs. Water and oil work for star sights but only the brightest stars are satisfactorily reflected. (Use a pan with a blackened interior surface.) To keep the wind from ruffling the surface, a cover could be used but its glass would have to be optically flat. Stretching clear plastic food wrapper over the pan works with oil but fogs with water and at night the film gives a stronger reflection than the liquid.

An alternative to liquid is a levelled mirror. It can be set horizontal using three wooden wedges and a spirit level. A carpenter's line level is just barely good enough. The mirror is the best system for backyard practice but unflatness and mislevellment cause systematic error in position. For navigation the glass must be truly flat and a precision level used.

The celestial navigator needs maps showing latitude and longitude. Suitable maps are published by governments to scales between 1 to 100 000 and 1 to 1 000 000. Air navigation charts may also be available. Topographic maps usually carry a reference grid of squares which is not useful. Latitude and longitude are indicated by edge ticks. You need a ruler to connect them. You also need a protractor, a clock, a short wave radio and a compass.

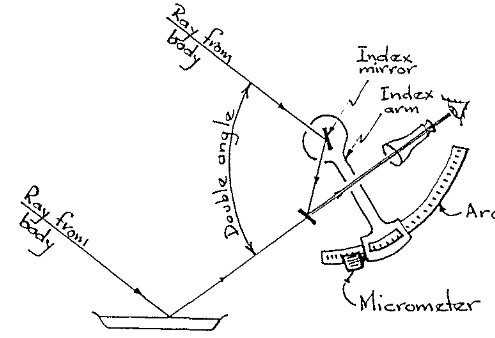
Observations

Learners will find it much easier to start with the sun rather than stars. Set the pan (artificial horizon) on the ground or on a box or a stump. Place yourself so you can see the sun's reflection in the liquid - dazzling you.

Select some suitable filters on the sextant and sight the image in the pan. Release the index arm and slide it forward until a second image of the sun appears in the telescope. If this does not happen - assuming the upper filter is not too dark - it will be because you are not holding the instrument vertical or you are pointing it too much to the right and thus looking too much through the horizon glass and not seeing enough of the silvered part.

The remedy is to ROTATE the instrument about the telescope axis and WAVE it from right to left. At the same time you have to move the index arm back and forth and the whole time you have to keep the pan image in view. The sketch shows what you are aiming for.

Most people find it quite difficult at first. Read the last paragraph again. Persist. After a while you'll get the knack. When both images are in the field of view clamp the arm. Experiment a little by ROTATING the sextant about the telescope axis and WAVING it left and right. Use the micrometer knob to superimpose the two images.



For star sights make sure the optics are clean. Stand comfortably so that you can see the reflection in the pan (or mirror). Set the sextant arc near zero, look up and sight the star in the sky through the telescope. There will be two images close together.

Unclamp the arm and slide it forward while simultaneously lowering the sextant. You have to keep one image in view all the time. Continue lowering the sextant until you see the image in the pan as well. This procedure is known as "bringing down" the star. It is often recommended for sailors but only works well in calm conditions. On land you have to use it in order to make sure the star you see via the index mirror is the same one you see in the pan. You can't afford to lose sight of it on the way down.

Superimpose the two images and note the time. For repeat sights leave the sextant set and look into the pan: the two images will still be there, as long as not too much time has passed, and after rotating and waving to find them, can be brought into coincidence again.

With practice observing with an artificial horizon is not a problem. It is easier than conventional observing from a small boat and more accurate too. Heat waves bend light so don't look over a car body or a campfire.

Reduction

Manually halve the sextant reading and halve the index correction (or apply the whole index correction and then halve the result). Set height of eye to zero for there is no dip correction. In good conditions with good equipment you should be able to achieve a consistency around half a mile in the intercepts of multiple sights.

LIMITATIONS ON THE ACCURACY OF CELESTIAL NAVIGATION

Chart
It is not unusual for a reef to be a mile or two away from the charted position. In such cases there is little point in knowing latitude and longitude to within a fraction of a mile.

Refraction
The bending of the ray from the body will be properly accounted for by the standard correction, at least for sights higher than 5° or 10°. The ray from the horizon can be bent a couple of minutes in calm weather and, according to Bowditch, in the arctic it can be bent several degrees. Presumably in the overwhelming majority of cases it is a small fraction of a minute.

Almanac
The printed Nautical Almanac published by the British and US Hydrographic Offices has a maximum error of 0'.25 for the GHA sun and 0'.3 for the GHA moon. Merlin II has maxima of 0'.5 for GHA of sun and stars and 1' for the moon. Other computers have other errors; the largest published is the Hewlett Packard module which has 1' for the sun and 5' for the moon.

Deviation of the vertical
In some places gravity does not pull exactly towards the centre of the Earth. This means that the sea horizon is higher or lower than it ought to be. In rare cases the error exceeds 1'. This is on land. To what extent the vertical deviates in the oceans is probably not known.

Human limits
Human measurements are subject to small random errors. In good conditions, from the shore, an experienced observer with a quality sextant might make a dozen sun sights agree within one mile of each other. That is, a consistency of 1' might be achieved. At sea this will generally not be possible.

It will not improve the accuracy to read the sextant to a tenth of a minute, or to record the time to a fraction of a second, or to carry out calculations to extreme precision. With a given sextant in given conditions the only way an observer can improve the accuracy is by taking more sights. If the expected random error of a single sight is 2' then the expected error in the average of four sights will be 1'. There is no point in taking more because halving the expected error again (to 0'.5) would require sixteen sights - and to halve it again (to 0'.25) would require 64 sights.

In sum
Except for taking multiple readings and perhaps for the almanac, the above sources of error are beyond the control of the navigator. In any instance they could add up to several miles - or they could be mutually cancelling. Research by the Royal Institute of Navigation on 4000 observations taken from ships showed that for a single sextant sight the average professional seaman had a 10% chance of being 2'.4 in error and a 5% chance of being 3'.1 in error.

Perhaps we might estimate that from a small boat in "ordinary" conditions a fix from a set of star sights evenly distributed around the horizon might have 70% chance of being within a mile of the truth and perhaps a 95% chance of being within two miles.

Putting it another way: we may reasonably hope for an accuracy of a mile or two but if a celestial position were to indicate a danger within five miles we should be concerned.

GLOSSARY OF SELECTED CELESTIAL NAVIGATION TERMS

Advance If the observer was on a line drawn on a chart at a given instant then the line may be moved according to the passage of the vessel. A line moved to an earlier position is "retired", to a later position "advanced".

Almanac is a book or computer function giving the position of a heavenly body. The Nautical Almanac published annually by the US and UK hydrographic offices contains almanacs for the sun, moon, four planets, Aries and 173 stars. Merlin II contains almanacs for sun, moon, Aries and 59 stars.

Altitude is the angle up from the horizontal to a heavenly body. The horizontal is an imaginary plane at right angles to local gravity.
Computed altitude of a given body is the theoretical altitude to it from a given place at a given time. Computed altitude is predicted altitude.
Sextant altitude is the value shown by the sextant. It requires correcting.
Corrected altitude is the sextant altitude after the altitude corrections have been applied. It is widely, and confusingly, known as the observed altitude.

Altitude corrections are applied to the sextant altitude to give corrected altitude. They are index, dip, refraction, passage, parallax and semidiameter corrections. (See individual entries below.)

Aries or the First Point of Aries is a sort of "Greenwich in the sky": the point from which the SHA of stars is measured. An almanac finds the GHA of Aries and the SHA of the star and adds them to give the GHA star.

Artificial horizon is a level reflecting surface which permits a double altitude to be found by measuring the angle from the image in the artificial horizon to the body in the sky. It is used for land navigation.

Azimuth is another word for true bearing. It is a general term and not limited to astronomical bodies.

Bearing is direction measured as an angle clockwise from north. Magnetic bearing refers to magnetic north; true bearing refers to true north.

Correction is an amount which has to be applied to a value to make the value correct. A correction may be positive or negative.

Dip correction The sextant is used to measure the angle up to the body from the sea horizon. Dip correction takes into account the height of the observer's eye above sea level thus converting the angle up from the horizon into the angle up from the horizontal.

Declination is the latitude of the geographical position of a heavenly body.

Ephemeris and ephemerides are alternative words for almanac.

Error is a known or unknown deviation from a true value. Where it is known and is to be allowed for (such as instrument error) it is clearer to think of a correction rather than an error.

Filters or shades on a sextant reduce the light from the sun.

Fix An astrofix is the latitude and longitude where two (or more) celestial position lines cross. A fix may also be obtained by non-celestial means.

GHA Greenwich hour angle of a body is the longitude of its geographical position measured westwards from the Greenwich meridian. (GHA goes 0° to

360° west, not 0° to 180° both east and west like longitude.) GHAs of all bodies increase from 0° to 360°, more or less, every day as the Earth turns.

GMT Greenwich Mean Time, proper name Universal Time (UT) or Universal Coordinated Time (UTC). This is the time of the time signals. It applies universally and the only time required by the celestial navigator.

Geographical position or ground position or sub-stellar point of a heavenly body is that point on the Earth's surface where a ray from the body to the centre of the Earth would pierce the Earth's surface. The geographical position moves westward as the Earth turns.

Index correction is the sextant zero correction applied to account for maladjustment of the sextant. It should be re-determined, using the horizon or a star, every time the sextant is used.

Index mirror is the top mirror of the sextant.

Index arm is the swinging arm of the sextant with the index mirror on it and carrying the mark or "index" against which the arc is read.

Intercept is an expression of the error in your estimate of position. The intercept is the difference between the corrected sextant altitude and the computed altitude which existed from the estimated (DR) position. If the DR is correct the intercept will be zero but if the intercept is zero it does not necessarily mean the DR is correct. Every arcminute of intercept is one nautical mile. An intercept is said to be either Towards or Away, meaning that it is measured from the DR position along the azimuth toward the body, or else in the opposite direction away from the body.

Latitude of a point is the measure of how far north or south of the equator it is. Latitude goes from zero at the equator to 90°N at the north pole or 90°S at the south pole. A minute of latitude is a nautical mile, thus there are 5400 nautical miles from equator to pole.

LHA Local hour angle of a body is the hour angle (longitude of geographical position) measured westward from the observer's (not the Greenwich) meridian. LHA = GHA + E long or GHA - W long. The LHA of Aries is required to set a star finder.

Limb The lower limb and upper limb are the lower and upper edges of the sun or moon. Conventionally the lower limb of the sun is observed but the upper is just as good. Except when it is full there is only one limb of the moon available. The arc of a sextant is also known as its "limb".

Longitude of a point indicates how far east or west of Greenwich it is. It is 0° on the Greenwich meridian increasing east to 180°E and west to 180°W. (180°E is the same as 180°W and is about New Zealand.) At the equator a degree of longitude is 60 nautical miles but at other latitudes it is less than this being 30 miles at latitude 60° and zero at the poles where the meridians, like quarters of an orange, converge to a point.

Magnitude of a star or planet is its apparent brightness. The lower the magnitude, the brighter. It is an aid to identification.

Meridian is a north-south line on the Earth from pole to pole.

Meridian passage of a body occurs when the body is on the observer's meridian which is when it is precisely north or south of the observer. It is the moment when the body ceases to rise and begins to set - ie is at its maximum altitude. At meridian passage a body's LHA is zero. Meridian passage for the sun is known as noon. Meridian passage altitudes are largely

independent of time and, providing an almanac is available, yield latitude without complicated calculation.

Nautical mile is the length subtended at the Earth's surface by an angle of one minute at the Earth's centre. A minute of latitude is one mile. A minute of longitude is a mile only at the equator; elsewhere it is less.

Noon is meridian passage of the sun.

Parallax correction accounts for the body not being at infinity but closer to the Earth. The only body for which parallax matters is the moon where the horizontal parallax (parallax when the altitude is zero) can exceed 1°.

Parallel is an east-west line of constant latitude. Parallels of latitude cross meridians at right angles.

Passage correction Allows for progress of the craft during sights. Using COURSE and SPEED, altitudes are corrected on Merlin II for the distance travelled towards or away from the body since, or to go till, the time of the first sight computed (sight No. 1). Thus the fix or NP is valid for this time.

Position line is a line drawn on the chart upon which the observer lies. A celestial position line is a short segment of the position circle which is a circle centered on the geographical position of the body. The position circle is the locus of all points from where the particular sextant altitude would have been observed to that particular body at that instant of time. A position line may be considered to exist even if it is not actually drawn.

Program a computer program is a predetermined calculation the machine performs using data (numbers) you feed into it. The correctness of the calculated answer depends on the validity of your input data.

Reduce Sights are said to be "reduced" when they are computed. It is nowadays unclear whether "sight reduction" means both almanac and the solution for azimuth and intercept or just the azimuth and intercept part.

Refraction correction is to account for the bending of a light ray when it passes through media of varying densities. Light from heavenly bodies passes through a vacuum and the atmosphere. Light from the horizon passes through various densities of air just above the water surface. See remarks on refraction in the DEF F / DEF N chapter.

Retire See Advance.

Semidiameter is the apparent radius of the sun or moon in angular measure. It depends on the distance of the body from the Earth. The distances vary. Semidiameter correction allows for altitudes taken to the upper or lower limb. Merlin II applies semidiameter correction to the computed altitude.

SHA Sidereal hour angle of a star is the longitude difference between it and Aries. The SHA of each star is more or less constant and all the stars move together. The GHA of one point, Aries, is found and the GHA of the desired star is obtained by adding its SHA to the GHA Aries.

Zenith is the point vertically above the observer's head - ie the upwards direction of local gravity.

Zenith distance is the angle from the vertical to the heavenly body. It is altitude subtracted from 90°. The zenith distance, in minutes of arc, equals the distance in miles from the body's geographical position to the observer.

CHANGING BATTERIES

The batteries are lithium cells type CR-2032.

If the display becomes dim and difficult to read even when the contrast is at maximum setting, the cells need replacing. If there is no display at all, the batteries are too flat to drive it. In such a case the procedure here will revive it and, depending how long it has been in that state, the Merlin II functions as well.

Before beginning, read this page right through.

Computer OFF
Ensure the new batteries are clean and lay them out, correct sides upwards, ready to slip into the computer.

Make quite certain the computer is OFF.

Remove the plastic compartment lid.

Metal cover off
The batteries are spring loaded against the metal cell cover. With the stopper held down, a little pressure will help the cover slide and then lift free.

In 30 seconds . . .
Tip out the old batteries, place in the new ones (correct sides up!) and reset the metal cover. You have at least 30 seconds from the time you take off the metal cover to the time you replace it.

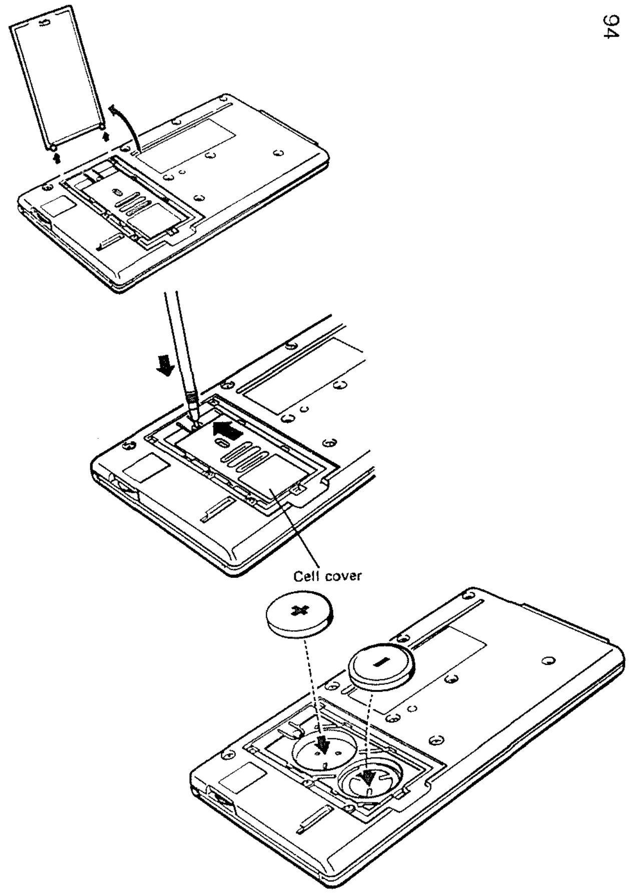
Metal cover on
Again, a little pressure on the batteries lets the metal cover slide home easily. Put back the plastic cover.

* * *

Neither programs nor data will be lost: your computer was tested when programmed.

<u>**Don't**</u> go entering 'new' as the Sharp manual says.

Set 4 in the display then press DEF L to check. After nearly three minutes the computer must show 999.



USER REGISTRATION FORM

Merlin II serial No:________ Purchase date:________

If you return the registration form your name will be added to our mailing list. Registered users will be notified of any improvement to Merlin II, possibly informed of other celestial navigation products, and receive an occasional *Merlin Navigator's News*. Interested non-users will be added to the mailing list on request.

MERLIN II - USER REGISTRATION

Merlin II serial No: ________

Name: ________

Address: ________

My Merlin II was bought:
_In a shop _By mail order
_Other: ________

I heard about Merlin from:

My main application is:
_Yachting _Land navigation
_Navy _Merchant marine
_Armchair _Academic
_Other: ________

Comments:

MERLIN II
NAVIGATION COMPUTER

DEF **A** Astro and All data
DEF Z Piloting data

DEF S Start sights
DEF **C** Continue sights
DEF **X** Reject sight
DEF F Fix
DEF **N** Nearest point, Noon lat.
DEF K Add a line (running fix)
DEF H Identify (SHA, dec)
DEF **M** Mer.pass, twilights

DEF **D** DR update
DEF **B** Current (effect)
DEF **G** GC & rhumb to Go
DEF **V** Visibility, Vertical angle

Body **1-59** Stars
Body **-1** Unknown star
Body **-2** Unknown star
Body **60** Extra star
Body **90** SUNL
Body **91** SUNC
Body **92** SUNU
Body **93** MOONL
Body **94** MOONU
Body **95** PLANET

A LHA Aries d.ddd
H Sextant alt °.'
T Clock time

0 DEF L Speed calc.
4 DEF L Check 999
5 DEF L Tide interp.
6 DEF L DR switch

DEF = d.ddd to °.'
DEF **spc** °.' to d.ddd

Times h.mmss eg 13.5406
Angles ±d.mmm eg -56.075 (For S, W put -)
Month/year M.YYYY eg 7.1989
Index cor ±m.m eg -2.5
Ht of eye metres (or feet*.3)

DEFine function. **ENTER** means yes/execute/go.
At ? key number (or ignore) and press ENTER.
Only numbers entered after ? will be accepted.
Where ? is yes/no, ENTER = yes; **N** ENTER = no.