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CELESTIAL NAVIGATION

ELEMENTARY ASTRONOMY

PILOTING

A text with 27 operative programs

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FUNCTIONS OF THE PROGRAMS

I N T R O D U C T I O N

1 - A text and an operative software

The book embodies three parts
- Celestial Navigation
- Elementary Astronomy
- Piloting

supported by an interactive software with 27 operative programs.

The outstanding feature in Celestial Navigation is a new method of immediately obtaining a fix (vessel position) by entering the sequences h - t of the sextant altitudes and chronometer time readings of at least two celestial bodies in a programmed computer. No need of tables like HO tables or similar, no graphical construction on a nautical chart. The computer immediately provides the fix and optionally provides course, distance and time to reach a destination point.
The procedure applies to any kind of celestial body: Sun, Moon, planets, stars.

A set of astronomical programs offers wide fields of application to astronomy hobbyists. Position of celestial bodies for any date, time and place. Times for an altitude or an azimuth. Solar System. Image of the sky. Diagrams of time lines of rising, meridian passage and setting of any celestial body in a point of the Earth for periods chosen from three days up to one year.
Validity of the data: two centuries from January 1st 1900, to December 31, 2100.

A set of piloting programs. Great circle routes and rhumb line routes. Plotting point by point a great circle route. Crossing point of the route for any longitude. Great Distances: route run along rhumb line legs. Plotting the grid of a Mercator nautical chart.

The programs of the three parts are tightly connected in many examples worked out in the book. But each part also covers kinds of application specific of that single part.

The text of the book has twenty chapters, structured as follows:
- relevant notions
- the program and its running
- examples, aimed to highlight possible fields of application.

The software includes 27 operative programs. See farther the table of the programs. Each program includes a **LOG BOOK** and a **HELP**.

The **LOG BOOK** is a list of all input and output data of the last application carried out. It can be reviewed by the user, printed and saved in a file with the function **LOG BOOK MANAGER**.

The **HELP** has three choices:
- a synthetic description of the matter dealt with in the called program and its running. To easy an overall view of the matters dealt with in the book, the texts of all 27 operative programs are summarized in the section **FUNCTIONS OF THE PROGRAMS** at the end of the book.
- information about the formats of the input and output quantities and automatic check of validity of the input quantities
- visualization of the **CHAPTER OF THE BOOK** related to the program.

The use of the programs is greatly facilitated by two **DATA BASE**:
- **DATA BASE of the celestial bodies**: 1241 celestial bodies, each with its name:
  - celestial coordinates of Sun, Moon, eight planets, 63 main stars
  - coordinates of 1044 minor stars and 24 non-stellar objects: galaxies, nebulas of the Messier Catalogue
- **DATA BASE of the places**: 60 terrestrial places of the five continents (coordinates and Standard Zone). Other 40 places at choice can be stored, substituted and cancelled.

2 - Forms and running of the programs - 27 operative programs

The software includes 27 operative programs:
- 5 main **CELESTIAL NAVIGATION PROGRAMS**
- 14 **ASTRONOMICAL PROGRAMS**, the first of them, **POSITION OF CELESTIAL BODIES,** is a main program based on 6 programs
- 8 **PILOTING PROGRAMS,** the first of them, **ROUTES,** is a main program based on 4 programs

- CELESTIAL NAV. PROGRAMS	☐ SEXTANT DATA REDUCTION ☐ INTERPOLATION OF SEXTANT READINGS ☐ TRUE LINE OF POSITION ☐ CIRCLE OF AZIMUTHS ☐ VESSEL POSITION - FIX
- ASTRONOMICAL PROGRAMS	☐ ARIES EPHEMERIDES ☐ POSITION OF CELESTIAL BODIES 6 PROGRAMS → ☐ SOLAR SYSTEM ☐ ALMANAC ☐ PLANETS ☐ DIURNAL ARCS ☐ IMAGE OF THE SKY ☐ MOTION OF THE CONSTELLATIONS ☐ STARS IDENTIFICATION
- PILOTING PROGRAMS	☐ ROUTES PROGRAMS 4 PROGRAMS → ☐ LEGS ☐ TACKS ☐ GREAT DISTANCES ☐ MERCATOR CHART
- AUXILIARY FUNCTIONS	☐ CALENDAR ☐ PLACES DATA BASE ☐ LOG BOOK MANAGER
- EXIT	

from the main program **POSITION OF CELESTIAL BODIES:**

-POS. CELESTIAL BODIES	☐ ALTITUDE AND AZIMUTH AT A TIME ☐ TIMES AND AZIMUTHS AT AN ALTITUDE ☐ TIMES AND ALTITUDES AT AN AZIMUTH ☐ RISING MERIDIAN PASSAGE SETTING ☐ TWILIGHTS ☐ REVERSE - TERRESTRIAL COORDINATES

from the main program **ROUTES**:

- ROUTES	☐ GREAT CIRCLE ROUTE - COURSE DISTANCE TIME ☐ GREAT CIRCLE ROUTE - DESTINATION POINT ☐ RHUMB LINE ROUTE - COURSE DISTANCE TIME ☐ RHUMB LINE ROUTE - DESTINATION POINT

3 - Data stored in the software

3.1 - Celestial bodies
How to deal with Sun and stars and with Moon and planets

The astronomical coordinates of 1240 celestial bodies are permanently stored with their names.

Sun and stars

Directly enter their name

- 1207 stars of the 88 constellations defined by the Astronomical Association, see the list in the table of the second following page:
  - 63 stars of 1st level (fig. 0.1)
  - 163 stars of 2nd level
  - 981 stars of 3rd level
- 24 non stellar objects of the Messier's catalogue (galaxies, nebulas), visible and not visible at the naked eye (fig. 0.2).

The astronomical data of the Sun and the 63 stars of 1st level are automatically corrected for the date within two centuries from January 1st, 1900 to December 31, 2100 .

Any other celestial body can be dealt with by entering its pair of celestial coordinates (Sidereal Hour Angle SHA$_\star$ or the equivalent Right Ascension R.A. and Declination δ [1]).

[1] THE NAUTICAL ALMANAC, United States Naval Observatory, The United Kingdom, Nautical Almanac Office, uses the coordinate Sidereal Hour Angle SHA$_\star$ for the stars and non stellar objects. THE ASTRONOMICAL ALMANAC uses the equivalent coordinate Right Ascension R.A. = (360° - SHA$_\star$) hh.mm.ss

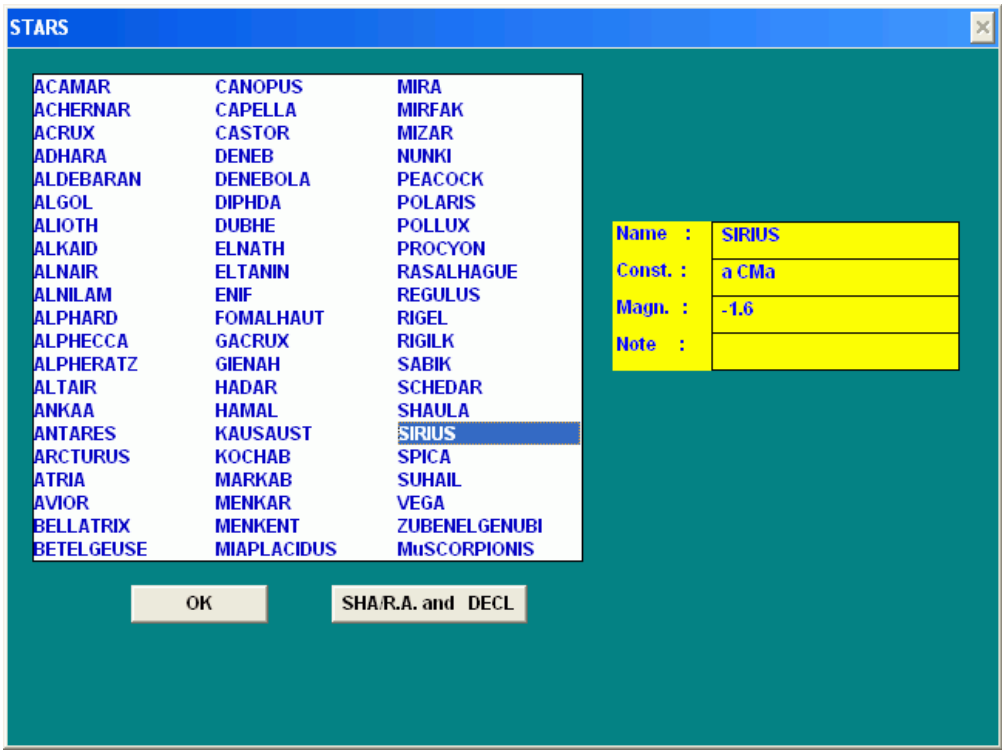

Fig. 0.1 - The 63 stars of 1st level permanently stored in the software with their coordinates (R.A. or SHA and Decl) and magnitude. To operate with a star, select it from the DATA BASE. Any other celestial body can be entered: press with the mouse on the box SHA/R.A. and Decl

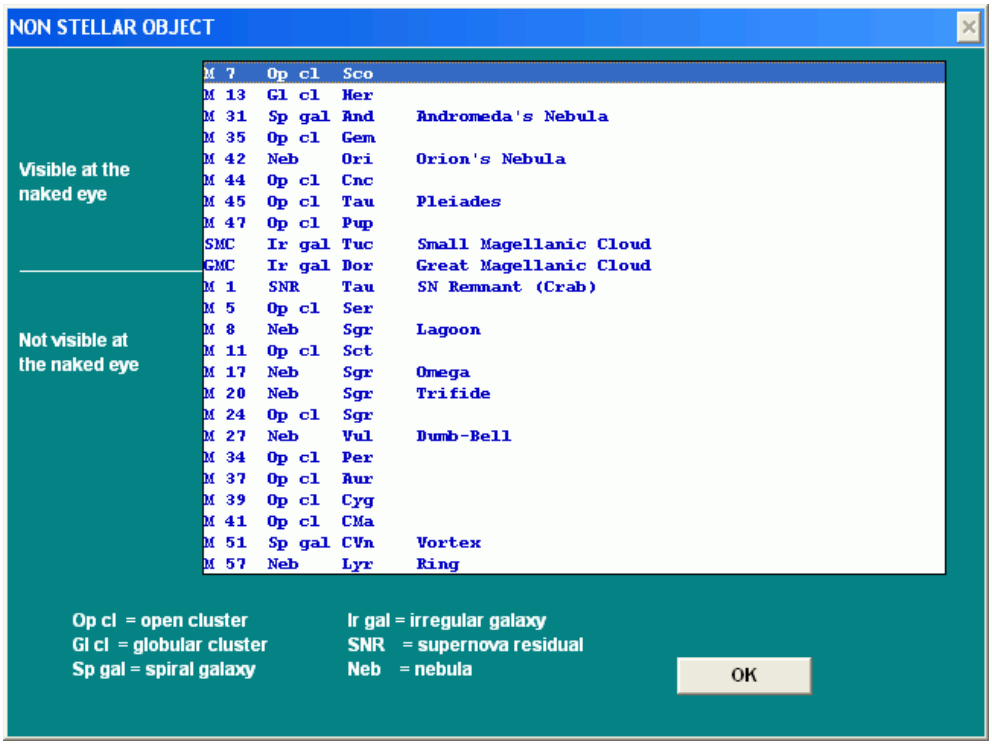

Fig. 0.2 - The 24 non stellar objects permanently stored in the software

The 88 constellations defined by the Astronomical Association								
	Latin name	main star		Latin name	main star		Latin name	main star
Ara	Ara		Del	Delphinus		Pav	Pavo	
And	Andromeda	Alpheratz	Dor	Doradus		Peg	Pegasus	Markab
Aqr	Aquarius		Dra	Draco		Per	Perseus	Mirfak
Aql	Aquila	Altair	Her	Hercules		PsA	Piscis Austr .	Fomalhaut
Ari	Aries	Hamal	Eri	Eridanus	Achernar	Vol	Volans	
Cet	Cetus	Menkar	Phe	Phoenix		Psc	Pisces	
Boo	Bootes	Arcturus	For	Fornax		Pic	Pictor	
Lib	Libra	Zubenelge.	Gem	Gemini	Pollux	Pup	Puppis	
Cae	Caelum		Cam	Chamaleon		Ret	Reticulum	
Pix	Pyxsis		Gru	Grus		Sge	Sagitta	
Cha	Chamaleon		Hya	Hydra	Alphard	Sgr	Sagittarius	Kaus Aust.
Cnc	Cancer		Hyi	Hydrus		Sco	Scorpius	Antares
CMa	Canis Major	Sirius	Ind	Indus		Sct	Scutum	
CMi	Canis Minor	Procyon	LMi	Leo Minor		Scl	Sculptor	
CVn	Canes Venatici		Leo	Leo	Regulus	Ser	Serpens	
Cap	Capricornus		Lep	Lepus		Sex	Sextans	
Car	Carina	Canopus	Lyn	Lynx		Nor	Norma	
Cas	Cassiopeia	Schedar	Lyr	Lyra	Vega	Crt	Craters	
Equ	Equuleus		Lac	Lacerta		Tel	Telescopium	
Cep	Cepheus		Lup	Lupus		Tau	Taurus	Aldebaran
Cen	Centaurus	Rigilk	Ant	Antlia.		TrA	Triang. Austr.	Atria
Com	Coma Berenic.		Men	Mensa		Tri	Triang. Bor.	
Cyg	Cygnus	Deneb	Mic	Microscopiu.		Tuc	Tucana	
Aur	Auriga	Capella	Mus	Musca		Aps	Apus	
Col	Columba		Oph	Ophiucus	Rasalhagu	Mon	Monoceros	
Cir	Circinus		Ori	Orion	Betelgeuse	Vel	Vela	Suhail
CrA	Corona Austr.		Hor	Horologium		Vir	Virgo	Spica
CrB	Corona Boreal.	Alphecca	UMa	Ursa Maior	Dubhe	Vul	Vulpecula	
Crv	Corvus	Gienah	UMi	Ursa Minor	Polaris			
Cru	Crux Australis	Acrux	Oct	Octans				
								.

Moon and planets (Mercury, Venus, Mars, Jupiter, Saturn, Uranus, Neptune)

Two procedures of calculation are available according to the required degree of precision.

- *Direct procedure.* Simply enter the name of the body, as for the Sun and the 1st level stars. The apparent semi-diameters of Sun and Moon, the parallax and the age of the Moon are directly provided by the program or can be read in the NAUTICAL ALMANAC.
  Results of good approximation are obtained, sufficient for many kinds of application, as the ones of the **GRAPHICAL PROGRAMS**: medium level of precision.
  Estimated precision of the data provided by the programs: altitude ±1' azimuth ±0.1°
- *Ephemerides procedure.* When a high precision is required, as in the calculations of Celestial Navigation: line of position and fix, the pair of the integer GHA and Dec values of the previous and following integer hour of the relevant fractional time must be taken from the daily pages of the NAUTICAL ALMANAC.
  Enter:
  Dec Hour -
  Dec Hour +
  GHA Hour -
  GHA Hour +
  The programs lead the operator step by step.

3.2 - Places

The latitude, longitude and Standard Zone of 60 places are permanently stored. 40 other places or Waypoints (WP) can be stored, cancelled and substituted (fig. 0.3).
When running a program, it is not necessary to use the **PLACES DATA BASE**. The place can be directly chosen in the input form of the program by shifting the mouse along the box of the places.
Any other terrestrial point can be dealt with by entering its latitude, longitude and Standard Zone.

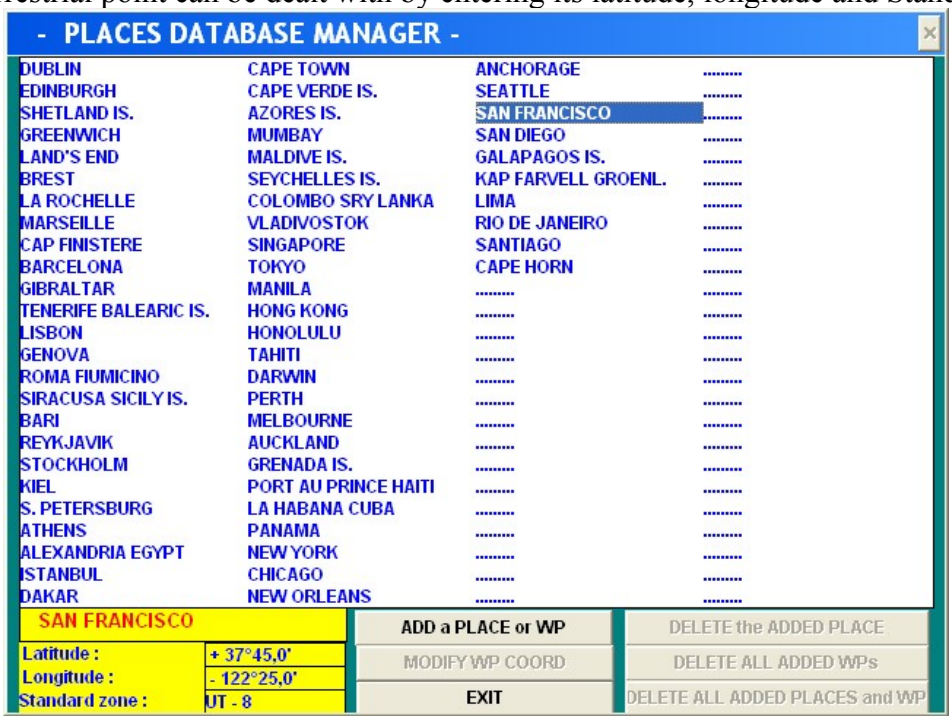

Fig. 0.3 - The 60 places permanently stored in the software with their latitude, longitude and Standard Zone. Other 40 places can be entered, named and cancelled. Any other terrestrial point can be entered with its coordinates and Standard Zone. The chosen place in the figure is San Francisco.

4 - LOG BOOK and LOG BOOK MANAGER

The **LOG BOOK** is a list of all the input and output data of the last application carried out. It can be saved and printed.
The **LOG BOOK MANAGER** function allows to list, view and delete each saved **LOG BOOK**.

5 - Format and check of the input and output quantities

General rule

When an input quantity contains fractional parts, any arbitrary number of fractional digits can be entered: decimal fraction of the last group of digits.
For instance: 21.0273 for an altitude 21 degrees, 2 minutes and 73 hundredths of a minute
345.593 for a distance 345 nautical miles and 593 thousandths of a mile
simply 23 for 23h00m00s
The whole entered figure is taken into account in the calculations, even if the figure displayed on the screen of the computer is rounded off according to a standard format of limited number of digits, as shown in the following examples of input/output formats. The **LOG BOOK** provided by the program shows the values of the entered quantities, last decimal parts included.

DATE
The current date set in the computer is taken as default by the software
Input format
The day and month are chosen by clicking on their lists with the mouse. The year is to be entered with four digits.
Output format
dd, name of the month, yyyy.
Input check
Only years between 1900 - 2100, months between 1-12, dates of days between 1 and 28, 29, 30 or 31 according to the month are accepted.

TIME
The current time set in the computer, expressed in hours, minutes and seconds, is taken as default.
Input time is expressed in UT
Output time is generally expressed both in UT and in ST (Standard or Zone Time) [2].
Input format
hh.mmss (e.g. 21.0735 for 21h07m35s).
Integer hours can be expressed without fractional digits (e.g. 21).
Output format
xxhxxmxxs (e.g. 21h07m35s).
Input check
Times less than 0 and equal to or more than 24 hours are not accepted
(instead of entering 24, enter 0 of the following day).
Values whose first fractional digit is higher than 5 are not accepted, being not compatible with the sexagesimal format.

[2] Daylight-saving time is not adopted, owing to the different dates in the years.

DURATION (of time)
Input format
hh.mmss
if greater than 24 hours, the days are to be converted in hours and added
e.g.: 3d08h45m34s → 80.4534
Output format
(xxd)xxhxxmxxs

DISTANCE
nautical miles (nm) and decimal fractions. In some cases kilometres (km)

SPEED
knots (kn) and decimal fractions.

LATITUDE and LONGITUDE
These are expressed in degrees, minutes and decimal fractions of a minute. South latitudes and West longitudes are conventionally expressed with the minus sign.
Input format
±xxx.xxx...(e.g. -12.023 for 12 degrees, 2 minutes and 3 tenths of a minute, South or West).
Alternatively, the name of a place can be chosen from the list of the PLACES DATE BASE (which already contains the latitude, longitude and Standard Zone correction).
Output format ±xx°xx.x'
Input check
Latitude less than -90° or greater than 90° and longitude less than -180° or greater than 180° are not accepted.
Values where the first digit of the fractional part is over 5 are not accepted.

ALTITUDE (of a celestial body)
This is expressed in degrees, minutes and decimal fractions of a minute . The minus sign indicates altitudes below the horizon.
Input format
±xx.xxx…(e.g. 71.0432 for 71 degrees, 4 minutes and 32 hundredths of a minute).
Output format
±xx°xx.x' . In some programs and for some celestial bodies only the integer degrees are displayed.
Input check
Altitudes greater than 90° or less than -20° (for the Sun) or less than -5° (for every other celestial body) are not accepted.
Values whose first fractional digit is higher than 5 are not accepted.

AZIMUTH
This is expressed in degrees and decimal fractions of a degree.
Input format
xxx.xx.... (e.g. 321.75 for 321 degrees and 75 hundredths of a degree).
Output format
xxx.x° . In some programs and for some celestial bodies, only integer degrees are displayed.
Input check
Values less than 0° or greater than 360° are not accepted.

DECLINATION OF A CELESTIAL BODY
This is expressed in degrees, minutes and decimal parts of a minute.
The minus sign conventionally indicates South declinations.
Input format
±xx.xx...(e.g.-7.0583 for 7 degrees, 5 minutes and 83 hundredths of a minute South).
Output format
±xx°xx.x'
Input check
Values equal to or lower than -90° and greater than or equal to 90° are not accepted.
Values whose first fractional digit is greater than 5 are not accepted.
HOUR ANGLES GHA, SHA, LHA,
are expressed in degrees, minutes and decimal parts of a minute.

RIGHT ASCENSION (R.A.), LOCAL SIDEREAL TIME (L.S.T.)
are expressed in hours, minutes and seconds.

6 - Precision of the output data

The calculations of all programs of the software work at medium level of precision.

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