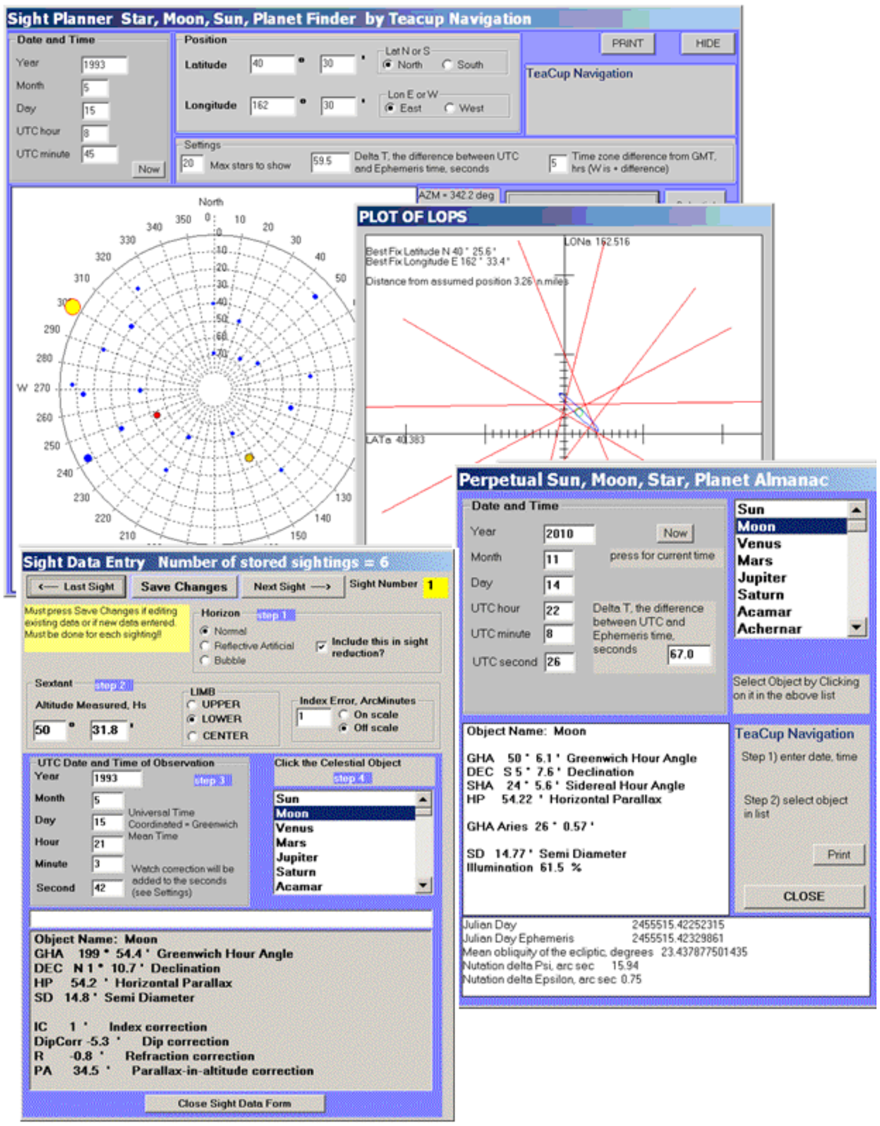
Manual and Documentation for “Teacup Celestial version 3.2f” Software revision 4



By Teacup Navigation

Rodger E. Farley

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1st Edition rev 4

My web site: http://www.teacupnavigation.net

TeaCupCELESTIAL version 3.2a by Teacup Navigation
This Celestial Navigation Software was developed by Rodger Farley 2002-2013

You can contact the author at milkyway99@verizon.net
Please visit my web site where you can download my book 'Celestial Navigation in a Teacup' at http://www.teacupnavigation.net

Equations for the celestial almanac are partly from Jean Meeus's book 'Astronomical Algorithms' 2nd edit. The ephemerides are calculated with an abridged set of VSOP87 periodic terms.

My thanks to Stan Klein of the USPS Offshore Navigation Committee who was kind enough to review this manual and Teacup Celestial software.

Introduction

This software can calculate and plot a single best fix for multiple target sightings from of any combination of Sun, Moon, planet, or stars taken with a sextant. It will accept up to 25 sights, though in practice 6 is more likely. The session can then be saved in a data file (that has the extension .NAV) so that it can be reopened in the future to relive it or to modify. The sightings are corrected with running fixes if underway, and the final new fix can be to any reference time you choose.

There is a very accurate built-in perpetual almanac for the Sun, Moon, 58 navigational stars, Venus, Mars, Jupiter, and Saturn using VSOP87 periodic terms and knowledge of DeltaT. One simply selects the object being recorded, and the internal computer almanac will supply the astronomical data.

This is the usual order of doing things:

1) Sight Planner from the top menu bar to plan your best objects to shoot

2) Shoot altitudes with sextant, record data on paper

3) Set up main form with fixed data (course, speed, etc..)

4) Transcribe altitudes and times and object details in the Sight Data Form

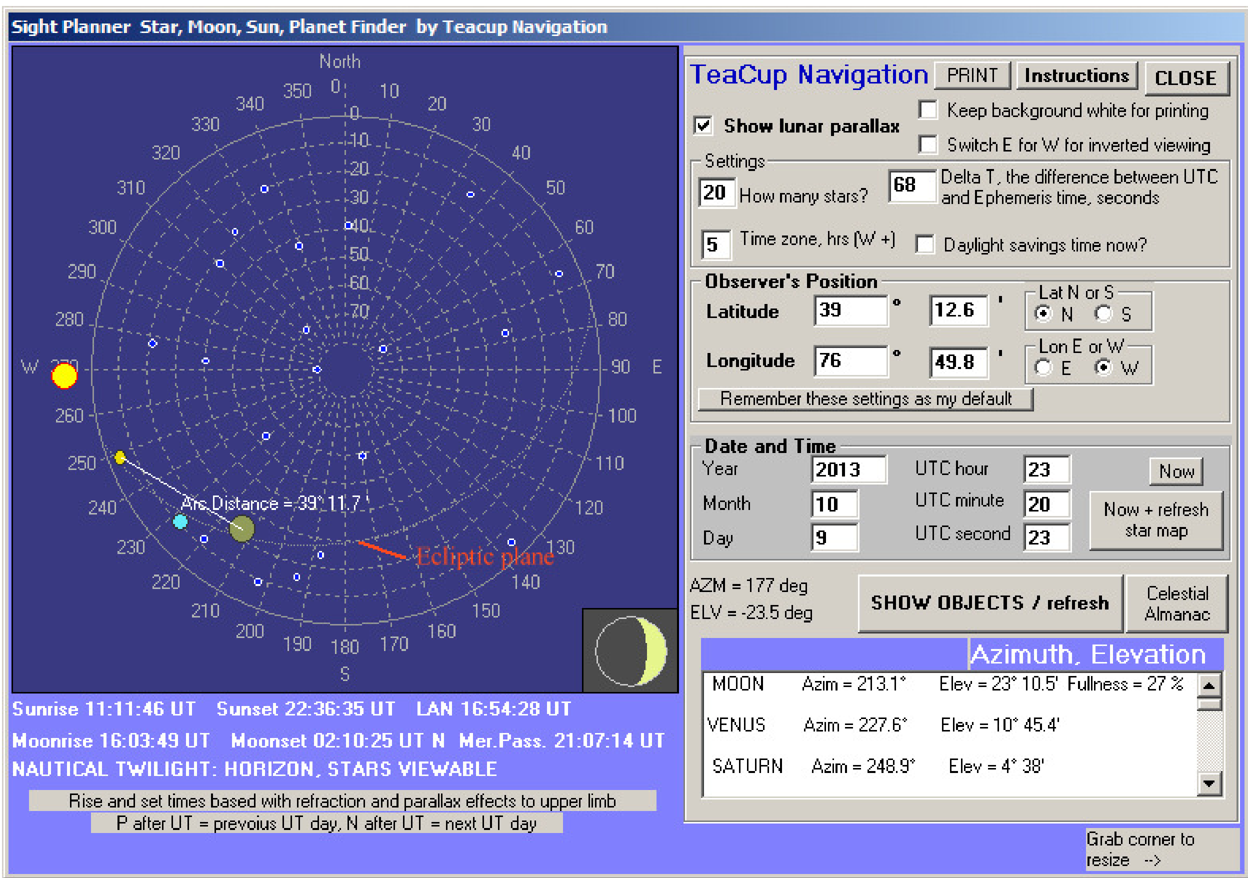
5) After saving the fixes individually, and saving the session with the FILE manager, close the Sight Data Form. Then on the Main Form press the 'Reduce Sight and Plot' button.

Note as to compatibility with older versions before 2.0

Unfortunately, if you had made data files with old versions, they will not carry over to this new version. The data being now simply a selection of the celestial object rather than a nautical almanac facsimile of GHA and DEC inputs, well it would have been too much trouble as the old method did not record the object. Sorry…

Sight Planner

One uses the sight planner to figure out what objects will be up and where. It's up to you determine the best combinations of celestial objects; briefly you will want to take sights of the brightest objects that have a 90° to 120° azimuth spread to cancel out systematic errors. For planning, you don't need a terribly accurate DeltaT, so just leave it at 67 sec. If you want to use the 'Now' button to load the present date and time, you need to have the nominal time zone difference from Greenwich (note the separate daylight savings time check box). This assumes your computer knows the correct local time.



As you can see, one can also get the arc distance between celestial objects. This is done by clicking the left mouse button over the 1st object, then (while still holding the button down) drag the cursor over to the 2nd object and release the mouse button. For doing lunars, while the 'show parallax effects' box is unchecked, this will give the lunar distance cleared from center to center. To see what the arc distance would be with actual parallax (as you would see it for real), check the box. Also shown is a note pointing to the ecliptic plane (earth's orbital plane) where the sun, moon and planets will be near. For lunars, picking a star or planet hovering near this line will give the greatest accuracy.

The steps 1-5 are listed on a help button on the planner.

Step 1) Modify the settings for your time zone, and the max number of stars to show
Step 2) Enter the date and UT time, or simply press the 'Now' button

Step 3) Enter the latitude and longitude, remembering to select the radio buttons for N, or S, and E, or W

Step 4) Press the Show Objects, or the Now-refresh button

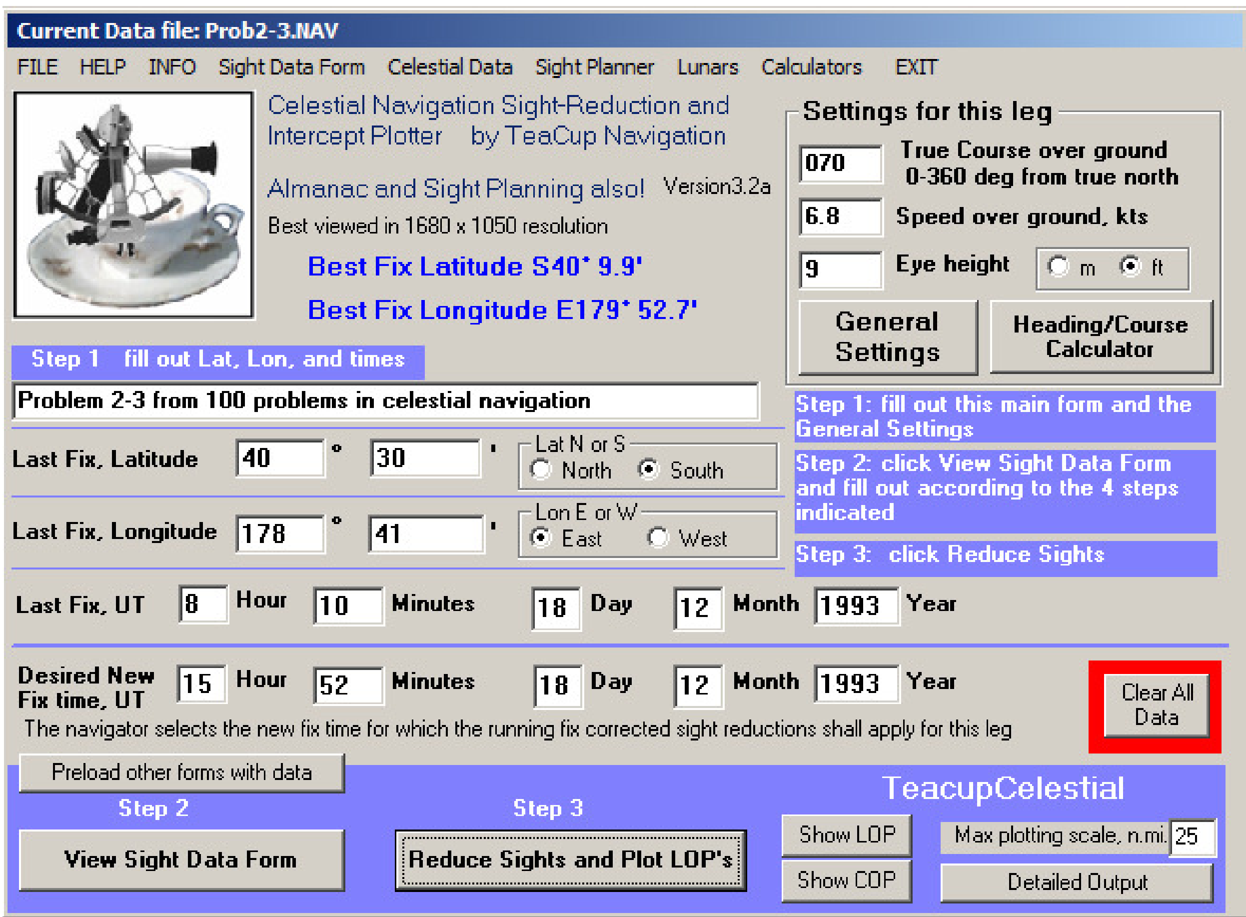
Step 5) View the objects. The moon goes from very dark to light cheese color to indicate fullness (there is also the lower right image to show phase). Stars have sizes according to their brightness magnitude. You can move the mouse cursor over the map to see the azimuth and elevation readout. When the cursor passes over an object of interest, its name appears in a side bar to the right. The parallax or non-parallax position of the moon can be observed according to the upper right check box. Rise/set and LAN for the Sun and meridian passage for the Moon are on the bottom bar. Sometimes after the UT there is a 'P', or an 'N' to indicate this event happened on the previous day (P), or will happen at the next UT day (N).

This planner can be used for sight reduction in its own right if you should be interested. Since you can put in UT time to the second, it will calculate and display the Hc (as Elevation Elev) for the assumed position you list under present latitude and longitude. Making your own index, dip, refraction, and semi diameter corrections to your sextant reading, you can determine the offset distance from the assumed position. By checking the 'Show Parallax Effects' checkbox, you won't have to calculate the parallax correction for the moon as it will already be reflected in the Elevation calculation as Hc – PA.

Your normal default settings for observer's position, time zone, deltaT, etc... can now be set with the "Remember these settings as my default" button. It makes a file called TeacupNav.nv1 which must be in the same folder as the executable file.
Inverse viewing is achieved by checking the Switch E for W box. Stretch the whole form larger by left-click grabbing the lower right corner, then refresh.

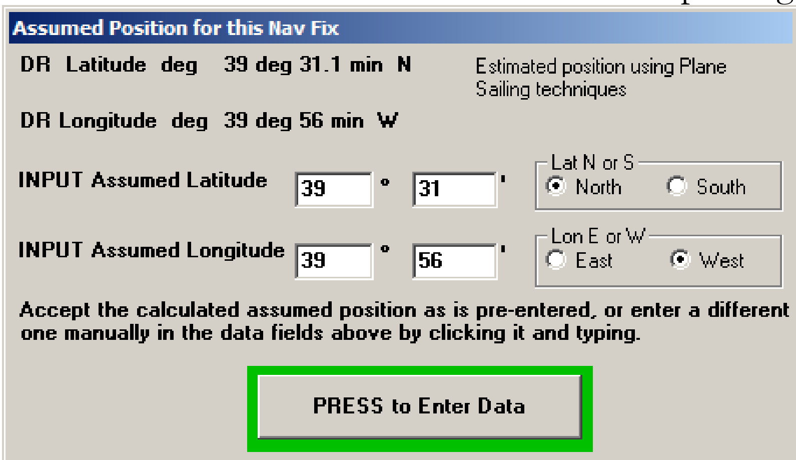
Main Form

Set up the main form with last fix, new fix time, eye height, true course and speed over ground, air temperature and barometer (you can leave it at the standard settings if you want), and any chronometer corrections. The chronometer correction compensates for watch error (this is under the General Settings form). The UTC in the sightings has this correction added to them to correct to actual UTC. It can be + or - . There is a comment box where you can type any descriptor you want, but don't use any commas! They will not be remembered.

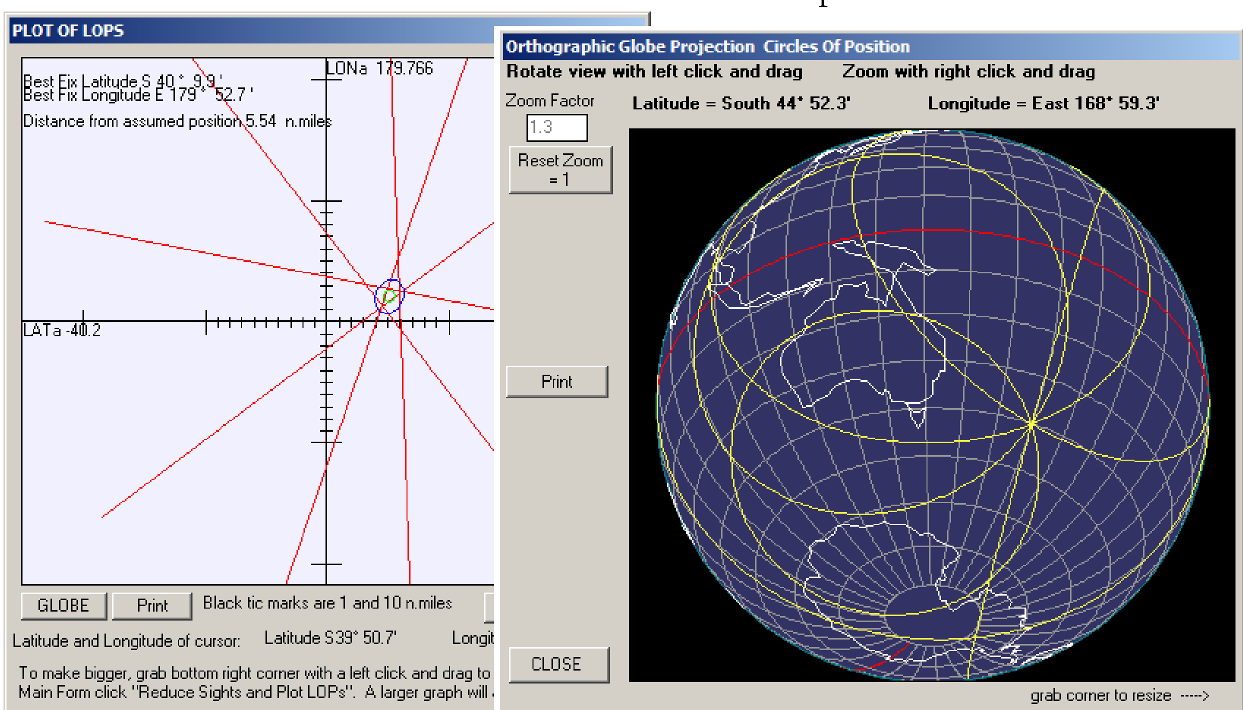


There is a calculator to convert your in-the-water speed and heading measurements into true course and true speed by compensating for current and leeway. Instructions for what to do next are on the main form. After the Sight Data Form has been filled out, close it to come back to the Main Form. Press 'Reduce Sights and Plot LOP's'. The dead reckoning position will show up in a small form, where you can change it if you don't like where the plane sailing calculation places it. For example, if you wish to set it at a whole or half degree instead of to the odd-ball arcminute.

If you agree with the recommended assumed position for the fix, the press the 'PRESS' button. The Main Form has the max plotting scale on lower right.

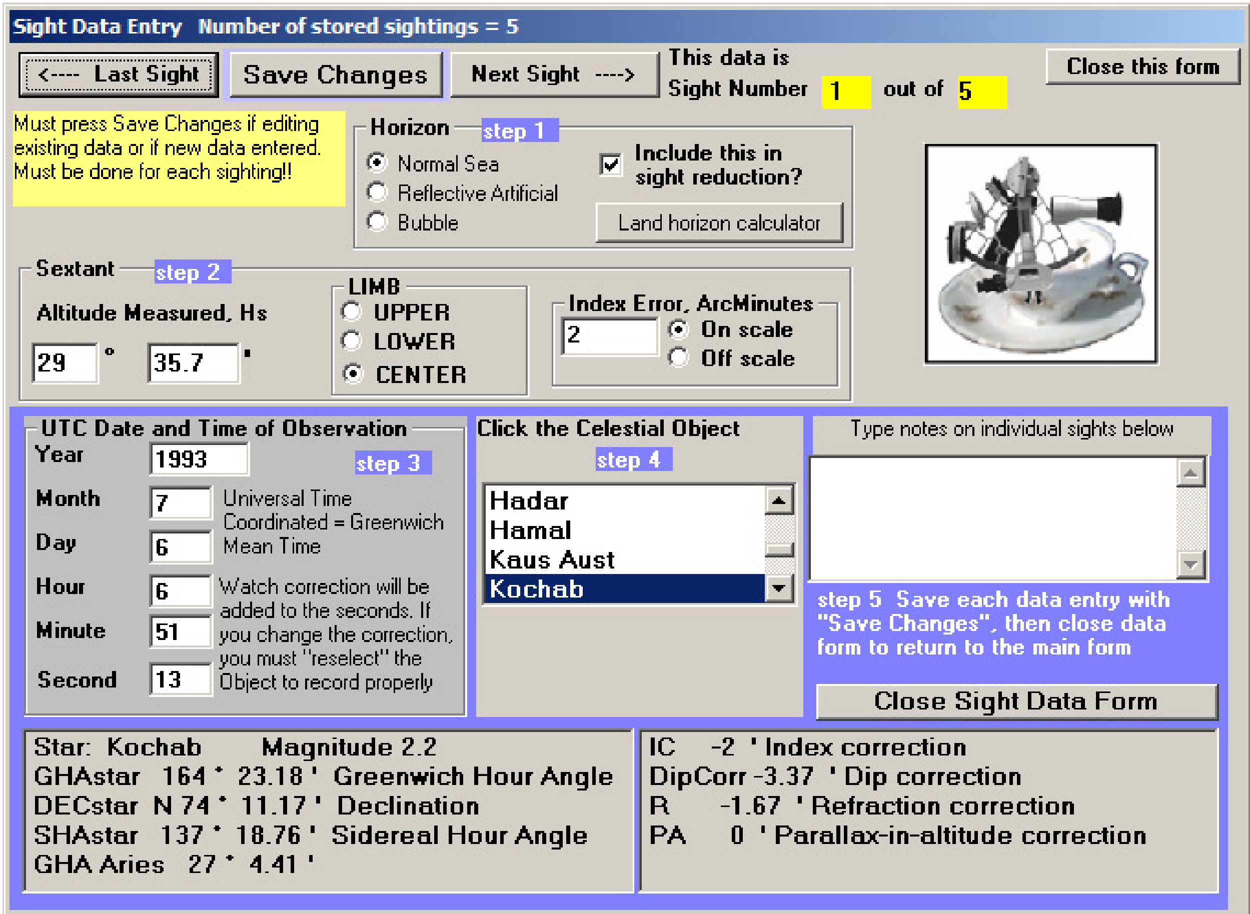


After pressing the button, this plot appears of the Line of Positions. The little green circle marks the best fix location. The blue ellipse marks the 95% confidence zone that the fix is somewhere within the ellipse.



A nice feature is the indication of Lat, Lon under the point of the mouse cursor which one can see at the bottom bar. A global plot of the circles of position is also shown.

Sight Data Form



This will carry the measured time, measured sextant angle, and celestial object selected with details. The steps to follow are conveniently on the form. When all the information regarding that shot is in, press the 'Save Changes" button which allows you to advance to the next blank sight form. After you have saved your sight data, you can advance forwards or backwards to review each one. Also, you should save the whole thing in the Main Form FILE menu button. Watch error correction for seconds inconsistent with UT will be added to the times recorded (from General Settings), but the times are still UT, not local clock time. The horizon can be either the sea (normal), or bubble, or there is a check use an artificial reflective horizon (mineral oil pan). The number of stored sights is listed across the top banner. Also the yellow boxes contain the sighting being viewed and the total saved shots. Unfortunately, there is no way to totally erase a saved shot (you can edit it and resave), but you can take it out of the calculations by un-checking the "Include in the Sight Reduction" check box.

Follow these steps:

Step1) select horizon type

Step2) enter altitude measured, select limb, and enter index error

Step3) enter UTC date and time of sighting knowing the watch correction will be applied internally to the seconds

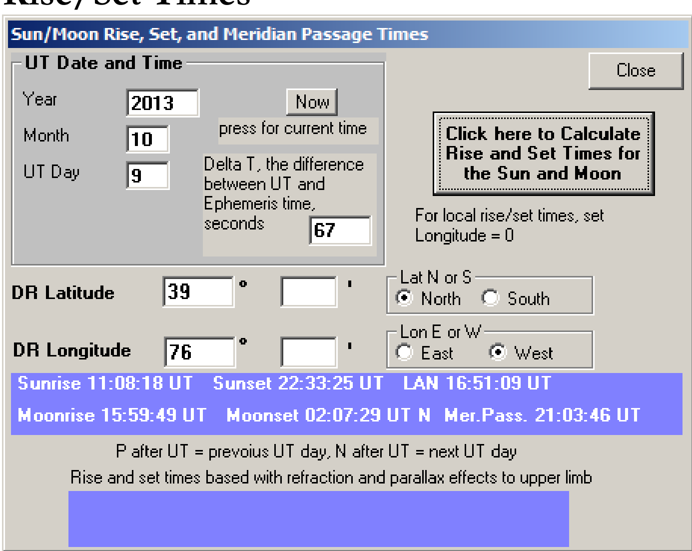
Step4) click on the celestial object in the list. Some details will appear in the bottom grey pane

Step5) click the Save Changes button on top

If you go back to Step 3 and change the time, you have repeat Step 4 again and reselect the celestial object. Otherwise it will have in its memory the GHA, DEC of the last time information when the object was previously selected.

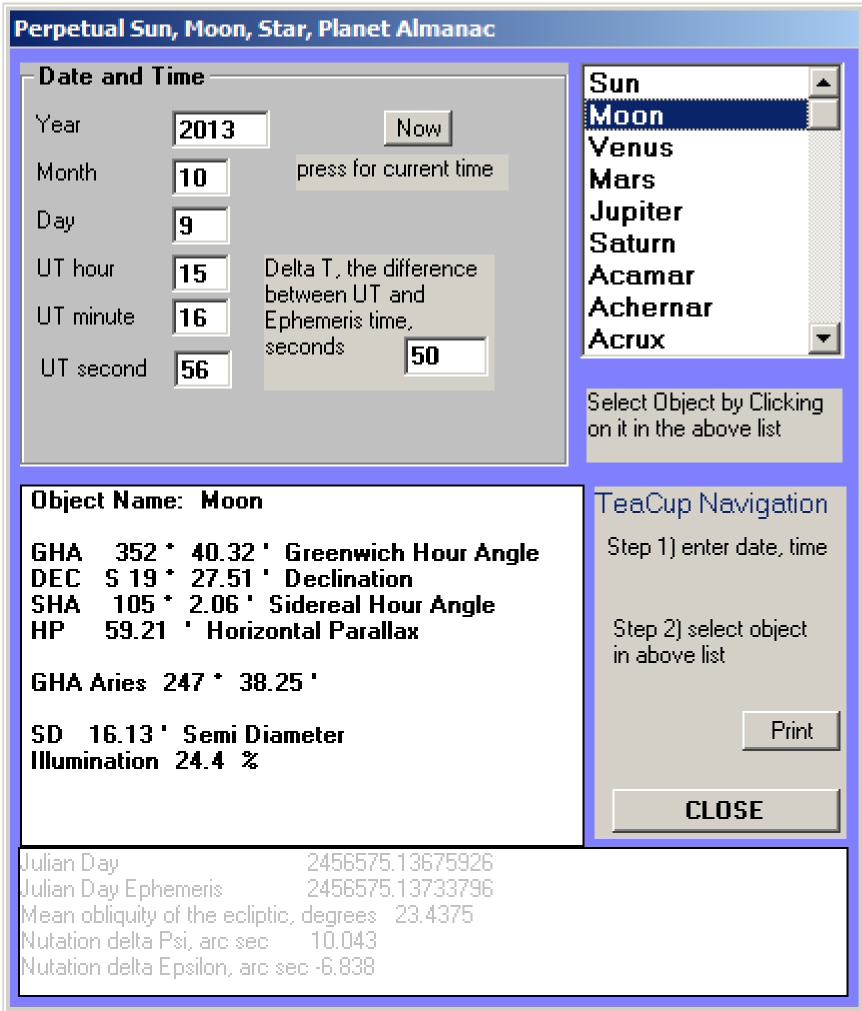
You can save typed notes for each shot by typing in the provided text box on the center right.

Rise/Set Times



Gets you the rise and set times of the Sun and Moon based on the optical position of the upper limb coincident with the horizon. It does this for your local day, so it might report times either in the present UT, or previous/next day UT.

Perpetual Almanac for Sun, Moon, Stars, and Planets



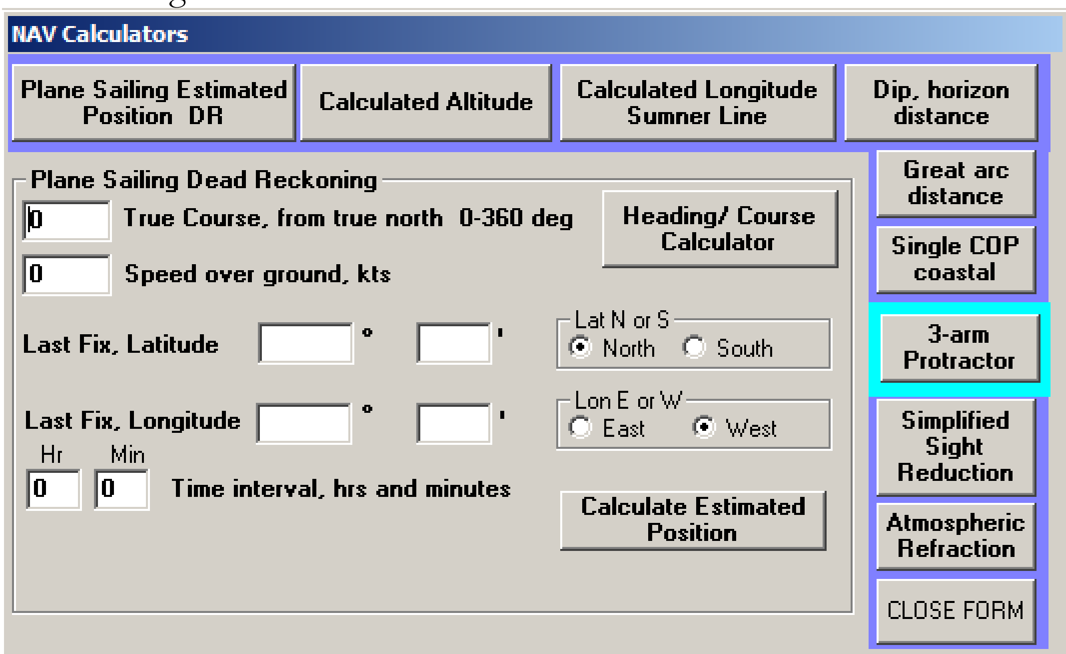
The 2 steps are listed on the form to get the instantaneous GHA and Declination for the object clicked. This is using the actual UT time typed in and does not have watch error included.

DeltaT is the difference between Dynamical Time and UT. It is set from the main form under General Settings. If this value is known then the ephemeris results from the internal celestial almanac will be accurate for perhaps centuries. The US naval observatory has DeltaT information at their web site http://maia.usno.navy.mil/. Look for 'Delta T values' on the web page. See appendix 1 for a list of DeltaT for different years.

Calculator Utilities

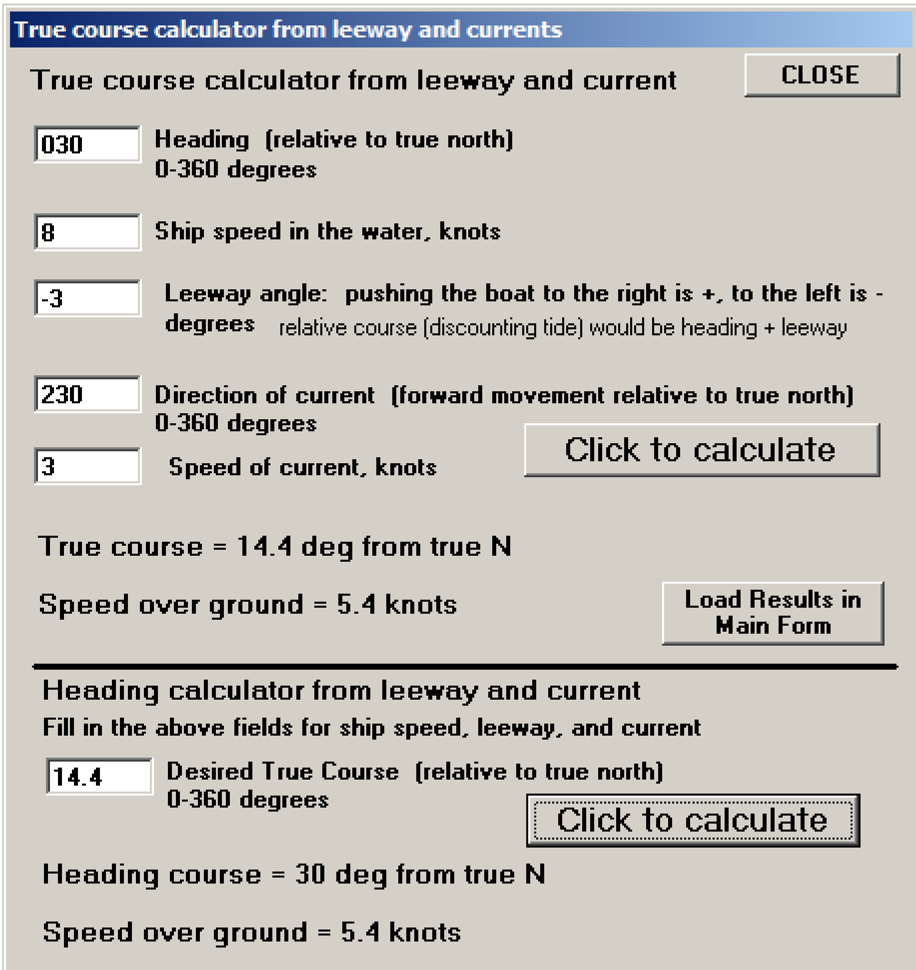
Along the top menu bar of the main form is an item labeled "Calculators". In all cases, fill in the text windows, then mouse click the button that says "Calculate…".

Plane Sailing



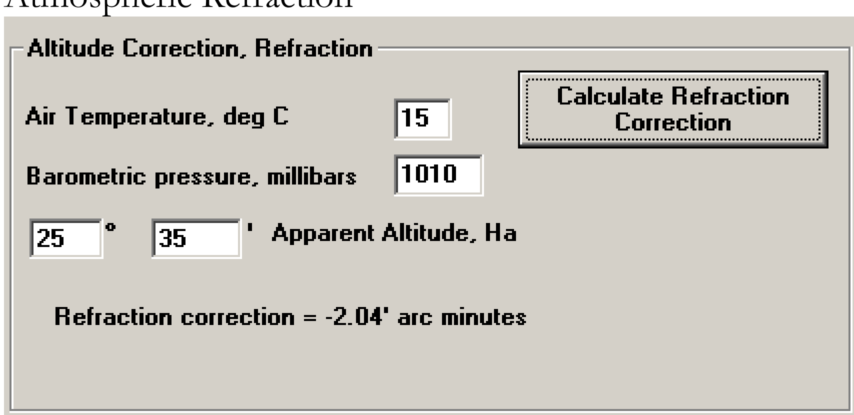
This should be self-explanatory. Use the Heading/ Course calculator to convert your heading, speed in the water, current and leeway into a true course and speed over ground. It also does the inverse, in that if you wanted a TC to steer by it will calculate the proper heading, accounting for leeway and current.

Current and Course



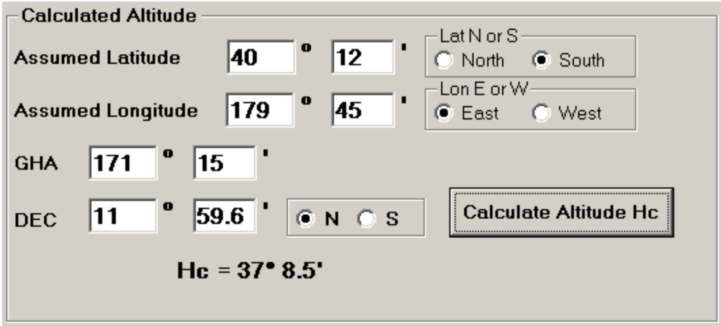
Current set is the direction the current is moving towards, whereas winds are noted for their origin, where they are coming from.

Atmospheric Refraction

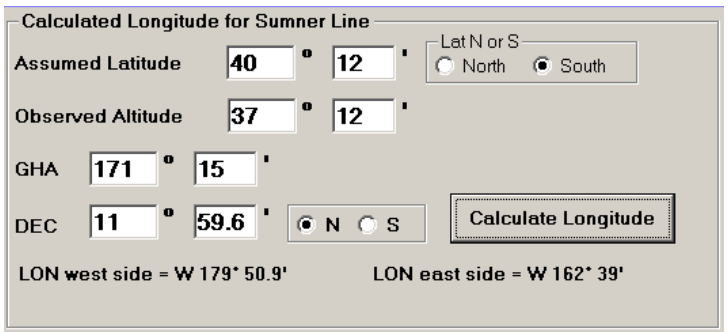


Altitude correction usually involves semidiameter and refraction, but for stars it's just refraction.

Calculated Altitude

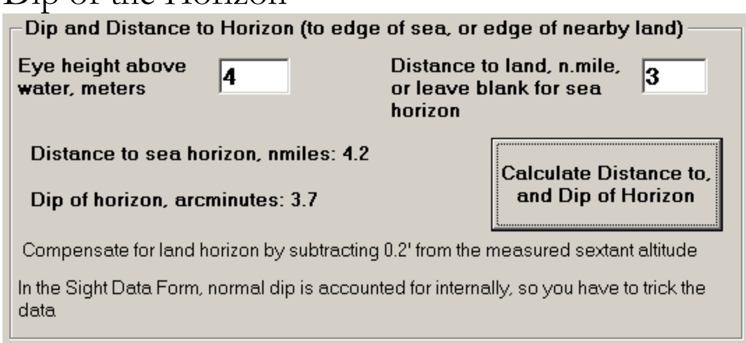


Sumner Line



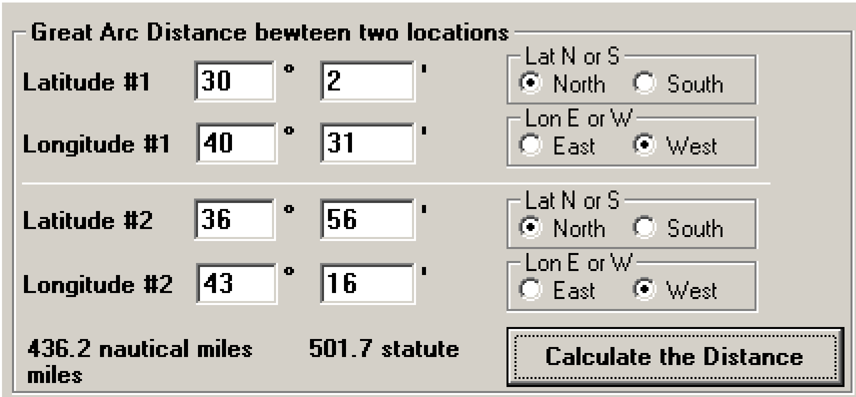
Make 2 calculations with slightly different assumed latitude and you will have two lat-lon points to create your Sumner LOP.

Dip of the Horizon



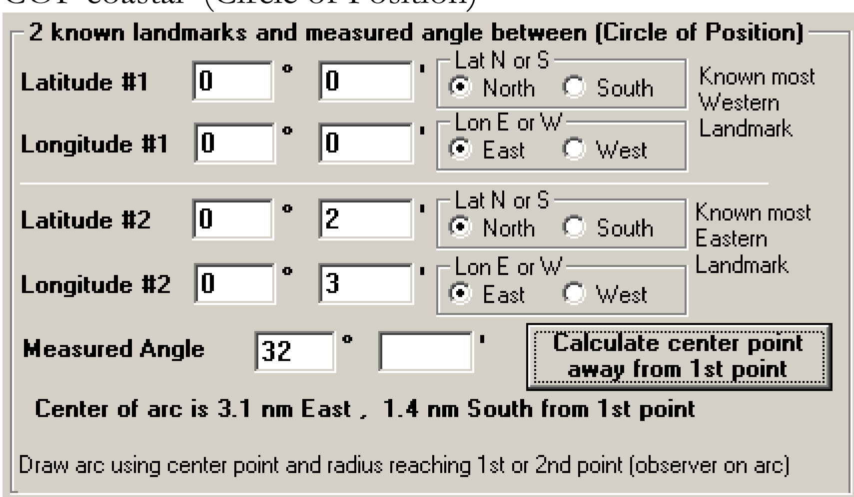
This tells you the dip angle and distance to the visible horizon. Also, if you use the shore edge of land this will tell you the dip angle to that. It also prints the difference in dip correction which can be added to the sextant measurement (normal dip is calculated internally to the software, so you have to “trick” it with additional correction if you want to use the beach edge of land as your horizon.

Great Arc Distance



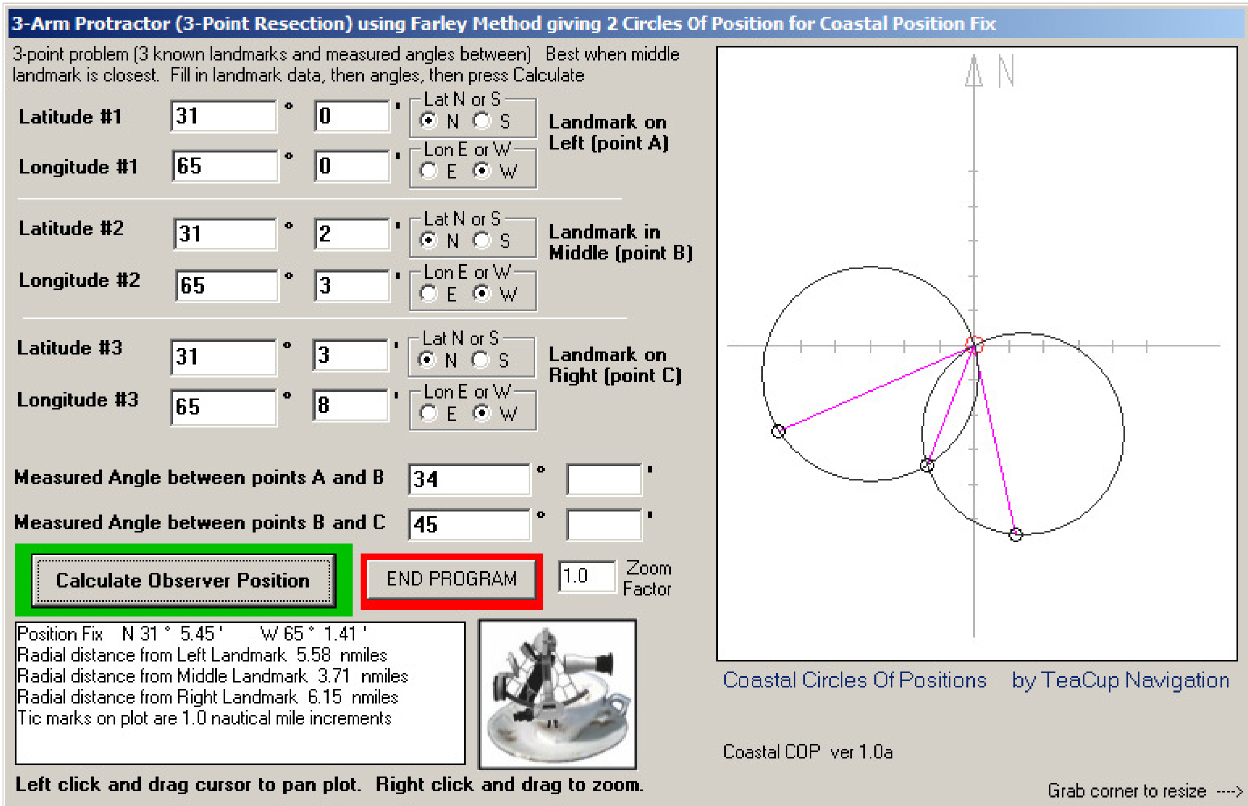
This should be self-explanatory.

COP coastal (Circle of Position)



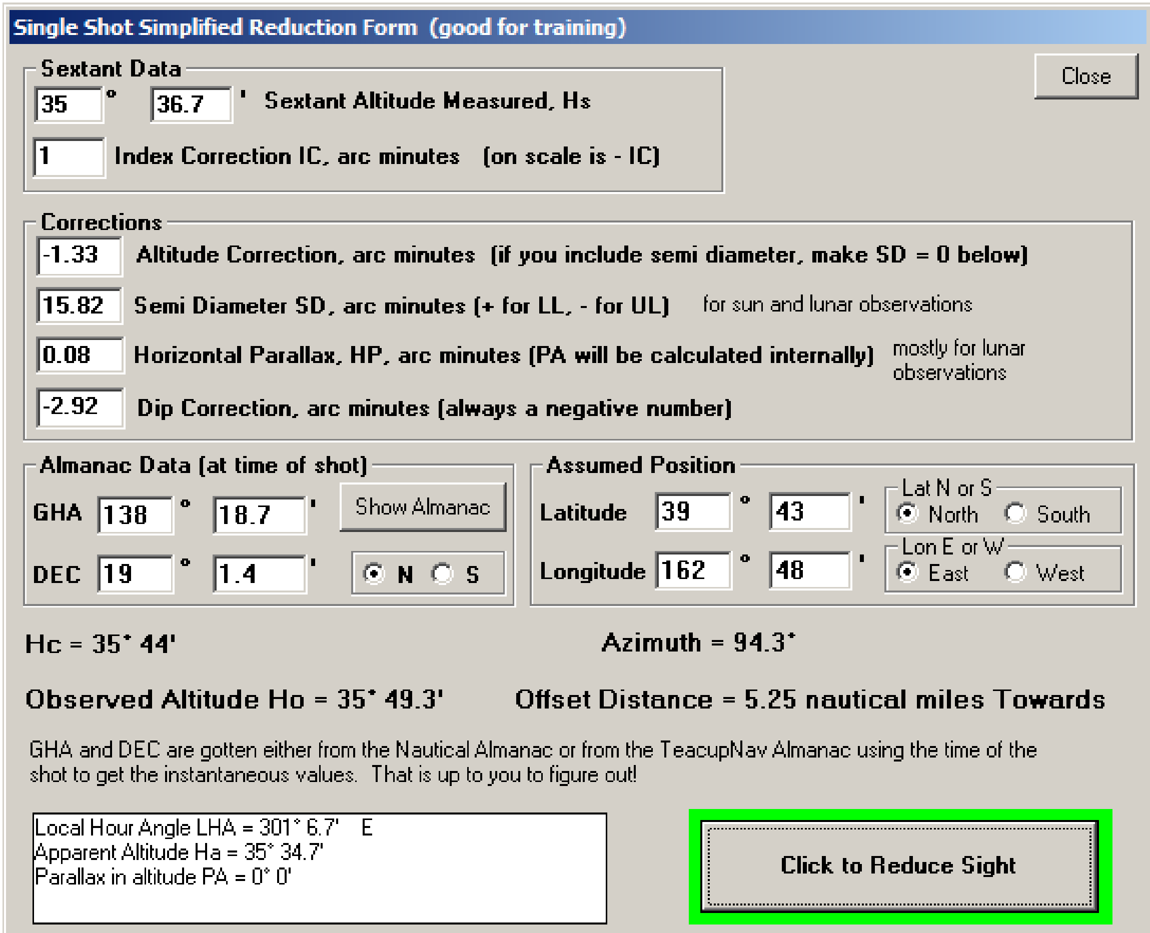
This gives the location of a circle's center where the arc passes thru both locations and the observer who measures the included angle. The location is in nautical miles away relative to the 1st location. You can then draw an arc on your chart with the given centerpoint, and the radius will be by stretching the compass to either the 1st or 2nd landmark on the chart. Do this this with a 3rd landmark (use 2nd and 3rd as inputs) to get another circle. Where the 2 intersect is you position fix.

3-arm Protractor (3-point resection in surveyor's parlance)



With 3 landmarks, this automates elements of the last calculator (COP coastal). This plots with N up, E to the right, but the definition of left, middle , right landmarks are all relative to **you** the observer which is marked as a red circle. The small black circles are the landmarks, and the large grey circles are the circles of position created with the two angle measurements. The radial distances between the position fix and the landmarks are graphically represented with the magenta lines.

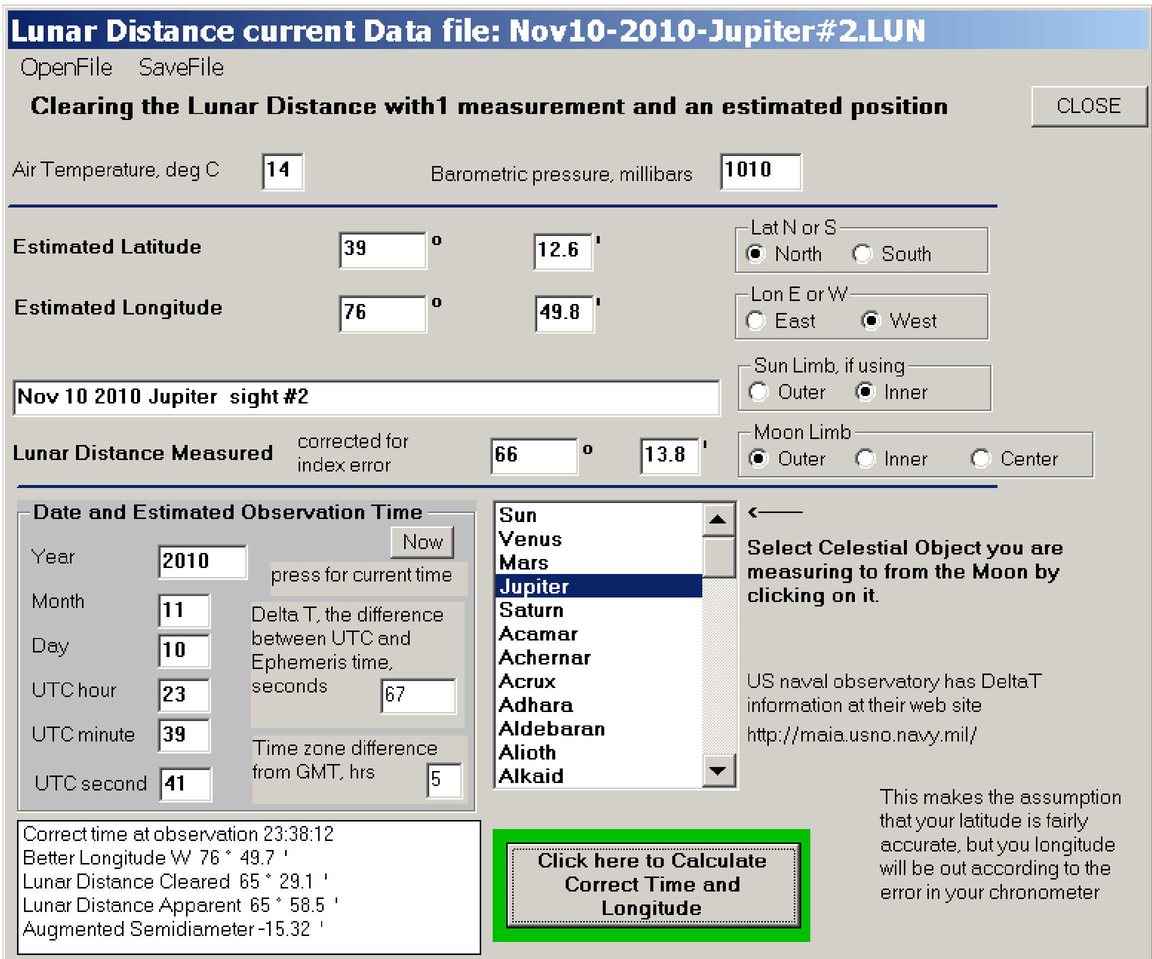
Simplified Sight Reduction



This lets you look up in the Nautical Almanac (or use the built-in Perpetual Almanac tool) the astronomical data, and manually enter all other data so you can excersise the line-by-line hand-shaping of the input data. This gets you an appreciation of whats involved before you even get to calculating altitudes and intercepts. This calculator does the last step of crunching out the altitudes, intercept and azimuth. For the most precise lunar LOPs, the SD should be the augmented SD. The SD as calculated in almanacs is based on being at the center of the Earth, which we of course are not. The higher the altitude measured, the closer you are to the moon (by a wee little bit) and it slightly enlargens the SD. The difference to your LOP will be measured in the tenths of miles.

Lunars

Step 1) Fill out the estimated latitude and longitude
Step 2) Enter the observed arc distance, date, and estimated time. The arc distance entered here should be corrected for index error.
Step 3) Select the object you were measuring to. Click to calculate!



Internally it is a good algorithm where the assumption is made that your latitude is accurate, but your longitude can be off due to the error in your clock. The altitudes are calculated according to the estimated time and position. It iterates with a new time and new longitude to converge to the proper time and longitude. It's amazing how small errors such as an incorrect index correction or a compromised reading because your arms were shaking holding the sextant in a weird position, can change the results quite a bit. You can use the arc distance function in the Sight Planner to verify the cleared arc distance. See page 5. As you can see, one may save new lunar files and open old ones.

File Management

This method only accesses and can save one leg at a time, not the entire voyage in a single file. You could easily manage that with the file names. For example, a trip from New Zealand to Tahiti could have individual files with saved names NZT-1.nav, NZT-2.nav, etc… The calculated new fix from the previous file becomes the inputted last fix for the next leg of the journey. This info you have to carry over manually, but that is not much of a burden in order to save unnecessary programming complexity. You can open as may windows of TeacupCelestial as you wish, and you can have one open from the last leg while you fill out the next leg info. The lunar distance files have the extension .LUN.

The settings file for the Sight Planner is called TeacupNav.nv1 and should always be in the same folder as the executable file. If you open a data file first and that data file is located in another folder, then it might expect to find a TeacupNav.nv1 file there instead. If one is not there then it will report that there is a problem and continue with blanks in the settings. You should arrange the program such that the executable file, the data files, and the TeacupNav.nv1 file are all in the same folder.

Appendix 1 Values for DeltaT, recent, future, and historical

Year	seconds for DeltaT
2013.00	66.907
2013.25	67.026
2013.50	67.121
2013.75	67.158
2014.00	67.267
2014.25	67.379
2014.50	67.7
2014.75	67.8
2015.00	67.9
2016.00	68.4
2017.00	69.
2018.00	69.
2019.00	70.
2020.00	70.
2021.00	71.
2022.00	71.
2023.00	72.

Recent Historical Values for DeltaT

1960	33.150
1961	33.584
1962	33.992
1963	34.466
1964	35.030
1965	35.738
1966	36.546
1967	37.429
1968	38.291
1969	39.204
1970	40.182
1971	41.170
1972	42.227
1973	43.373
1974	44.486
1975	45.477
1976	46.458
1977	47.521
1978	48.535
1979	49.589
1980	50.540
1981	51.382
1982	52.168
1983	52.957
1984	53.789
1984	53.7882
1985	54.3427
1986	54.8712
1987	55.3222
1988	55.8197
1989	56.3000
1990	56.8553
1991	57.5653
1992	58.3092

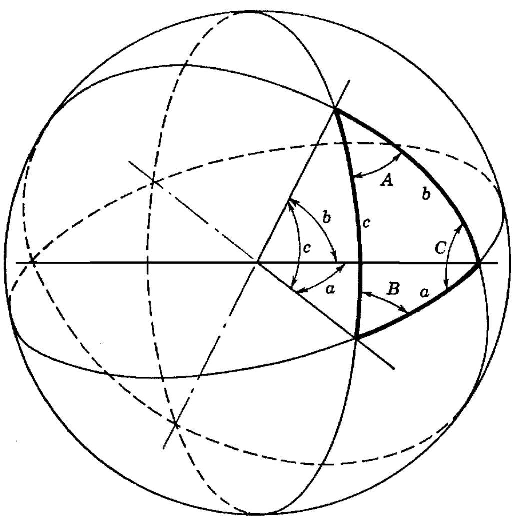
1993	59.1218
1994	59.9845
1995	60.7853
1996	61.6287
1997	62.2950
1998	62.9659
1999	63.4673
2000	63.8285
2002	64.2998
2003	64.4734
2004	64.5736
2005	64.6876
2006	64.8452
2007	65.1464
2008	65.4574
2009	65.7768
2008.00	65.457
2008.25	65.545
2008.50	65.60
2008.75	65.62
2009.00	65.70
2009.25	65.79
2009.50	66.2
2009.75	66.3
2010.00	66.5
2010.25	66.6
2010.50	66.8
2010.75	66.9
2011.00	67.1
2011.25	67.2
2011.50	67.
2011.75	67.
2012.00	68.
2012.25	68.
2012.50	68.
2012.75	68.

Appendix 2

Derivation of the equations used in clearing the lunar distance

Useful identities:
$\sin(\alpha) = \cos(\alpha - 90^\circ)$
$\cos(\alpha) = - \sin(\alpha - 90^\circ)$

Spherical Trigonometry



Three Great Circles on a sphere will intersect to form three solid corner angles a, b, c, and three surface angles A, B, C. Every intersecting pair of Great Circles is the same as having two intersecting planes. The angles between the intersecting planes are the same as the surface angles on the surface of the sphere. Relationships between the corner angles and surface angles have been worked out over the centuries, with the law of sines and the law of cosines being the most relevant to navigation.

Law of Sines: $\sin(a)/\sin(A) = \sin(b)/\sin(B) = \sin(c)/\sin(C)$

Law of Cosines: $\cos(a) = \cos(b) \cdot \cos(c) + \sin(b) \cdot \sin(c) \cdot \cos(A)$

(for spherical trigonometry; there are similar ones for plane trig)

Law of Cosines in terms of co-angles:
$\sin(90-a) = \sin(90-b) \cdot \sin(90-c) + \cos(90-b) \cdot \cos(90-c) \cdot \cos(A)$

$$S = s + R_s$$

$$M = m + R_m$$

$$d = d_{sextant} + IC + SD_{aug}$$

$$\cos(d) = \sin(s)\cdot\sin(m) + \cos(s)\cdot\cos(m)\cdot\cos(\delta)$$

$$\cos(D) = \sin(S)\cdot\sin(M) + \cos(S)\cdot\cos(M)\cdot\cos(\delta)$$

$$\cos(\delta) = \frac{\cos(d) - \sin(s)\cdot\sin(m)}{\cos(s)\cdot\cos(m)}$$

$$\cos(D) = \sin(S)\cdot\sin(M) + \cos(S)\cdot\cos(M)\cdot\left[\frac{\cos(d) - \sin(s)\cdot\sin(m)}{\cos(s)\cdot\cos(m)}\right]$$

$$\cos(D) = \sin(S)\cdot\sin(M) + \left(\cos(d) - \sin(s)\cdot\sin(m)\right)\cdot\left[\frac{\cos(S)\cdot\cos(M)}{\cos(s)\cdot\cos(m)}\right]$$

$$\sin(a)\cdot\sin(b) = -\cos(a+b)$$

$$C_{ratio} = \left[\frac{\cos(S)\cdot\cos(M)}{\cos(s)\cdot\cos(m)}\right]$$

$$\cos(D) = \left(\cos(d) + \cos(s+m)\right)\cdot C_{ratio} - \cos(S+M)$$

$$S = s + R_s$$

$$M = m + R_m$$

$$d = d_{sextant} + IC + SD_{aug}$$

$$\cos(d) = \sin(s)\cdot\sin(m) + \cos(s)\cdot\cos(m)\cdot\cos(\delta)$$

$$\cos(D) = \sin(S)\cdot\sin(M) + \cos(S)\cdot\cos(M)\cdot\cos(\delta)$$

$$\cos(\delta) = \frac{\cos(d) - \sin(s)\cdot\sin(m)}{\cos(s)\cdot\cos(m)}$$

$$\cos(D) = \sin(S)\cdot\sin(M) + \cos(S)\cdot\cos(M)\cdot\left[\frac{\cos(d) - \sin(s)\cdot\sin(m)}{\cos(s)\cdot\cos(m)}\right]$$

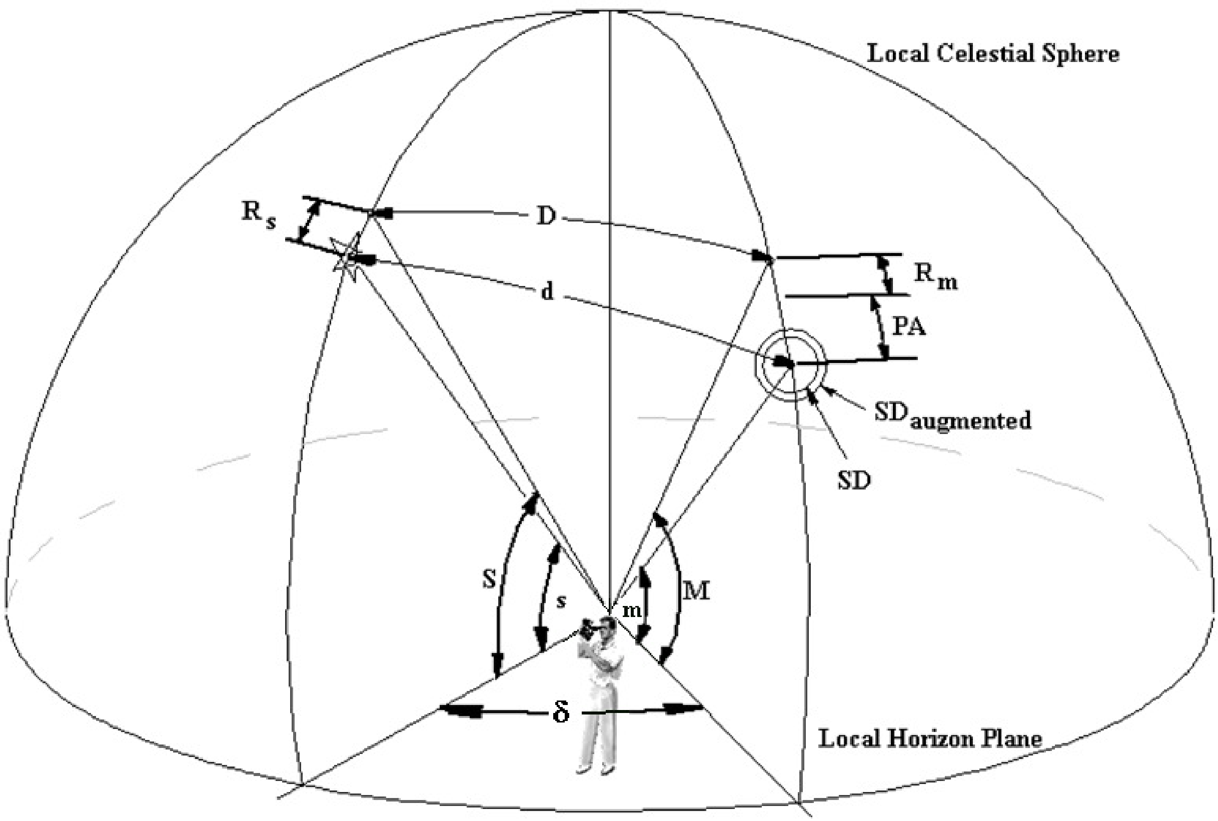
$$\cos(D) = \sin(S)\cdot\sin(M) + \left(\cos(d) - \sin(s)\cdot\sin(m)\right)\cdot\left[\frac{\cos(S)\cdot\cos(M)}{\cos(s)\cdot\cos(m)}\right]$$

$$\sin(a)\cdot\sin(b) = -\cos(a+b)$$

$$C_{ratio} = \left[\frac{\cos(S)\cdot\cos(M)}{\cos(s)\cdot\cos(m)} \right]$$

$$\cos(D) = \left(\cos(d) + \cos(s+m)\right)\cdot C_{ratio} - \cos(S+M)$$

$$D = arcCos\left[\left(\cos(d) + \cos(s+m)\right)\cdot C_{ratio} - \cos(S+M)\right]$$



The key to the problem is to realize that the parallax and refraction corrections only change the altitudes, not the 'wedge angle' δ. When the corrections are applied, and using the law of cosines, the equation with s, m can be related to S, M with the common angle δ. Even though refraction corrections are negative, the picture is drawn in the positive direction to establish a consistent sign convention.