Celestial Navigation
What are the Options?

There are so many variations possible that we can not discuss them all. For example, it is even possible to do some sort of celestial navigation with sticks and bits of paper, but that's not what we're talking about here. People interested in such things should consult books like "Emergency Navigation" by David Burch.

For our purposes a minimum of three pieces of equipment will be required. A sextant (for measuring the angle of celestial objects above the horizon,) an accurate clock that can be read to hours, minutes and seconds (four seconds error can put you off a mile) and , finally, a copy of the "Nautical Almanac" for the current year. The almanac contains tables that you use to calculate the exact location of the sun, moon, planets or stars you have observed.

Of course, it is possible to do something with these three pieces of equipment taken singly or in pairs (six possibilities) but these options will not concern us at the moment.

The time honored "noon shot," where the navigator observes the sun while it is passing through its highest point for the day is a good place for us to start. The angle of the sun above the horizon at its highest point is measured with the sextant and easily (using the Nautical Almanac) converted to latitude. The time when the sun reaches its highest point is easily converted to longitude in the same way. So, if you stick to noon shoots, that's all there is to it. An hour or so of instruction, a few hours of practice, and you're on your way. I read somewhere that this is just about all the old-time navigators ever did. You can also measure the altitude (and time of observation) of the north star (Polaris) and calculate your latitude rather easily using tables in the Nautical Almanac.

You can measure the altitude (angle above the horizon) of the sun at other times during the day, or the moon, or (if you stick to brief periods around sunrise and sunset when both stars and horizon are visible) you can also measure the altitude of stars and planets. But this is where it starts to get more complicated. For many of you "celestial navigation" means stars, so let's forge on.

This is the heart of the matter. Assume you have measured the altitude (and time) for a number of celestial objects. What now? The standard approach (attributed to Marcq Saint Hilaire) is called the intercept method of sight reduction. In this approach you use the Nautical Almanac to look up the position of the object at the time of observation. Then you calculate the altitude (angle above the horizion) and azimuth (angle from true north) that the object should have had based on your assumed position. Comparison of the calculated and observed values of the altitude gives rise to a line of position (LOP) that helps you determine your true position. This is where it gets harder and there are many different ways of proceeding.

Just to be perfectly clear, let's backup and go over the procedure one more time, step by step:

1. You measure the altitude of an object (and the time.)
2. You calculate the position of the object at the time of observation using the Nautical Almanac.
3. You use your assumed position to calculate what the altitude should have been and what the azimuth (direction of the object) should have been.
4. Comparison of the altitude you measured with the one you calculated gives you an offset that can be plotted on a chart as a line of position (LOP).
5. A "fix" is then obtained by observing where a bunch of LOPs cross.

This is the process most people think of when they think of "celestial navigation". Getting it all to come out right requires a fair amount of instruction and practice.

At step (3) there are a number of options that we still need to discuss. To start with imagine the earth as a globe with three points marked on it. One point is your assumed position and another is the nearest pole (north or south.) The third point is the geographical position (GP) of the celestial object that you observed. This GP is the point on the earth directly below the object at the time of observation. You can look it up in the Nautical Almanac.

These three points form the "navigational triangle" and "sight reduction" or "solving the navigational triangle" is the process used to determine the altitude and azimuth the celestial object would have had if you had really been at your assumed position. One way of doing the sight reduction is with an inexpensive hand calculator (that has "sin" and "cos" keys) using two easy, one line formulas from spherical trigonometry (You can do it! Trust me.) These formulas can be found (for example) in the Nautical Almanac "Sight Reduction Procedures" section under the title "Methods and Formulae for Direct Computation." Another way to perform the sight reduction is to use tables of pre-calculated solutions such as the one given in the Nautical Almanac under the title "Use of Concise Sight Reduction Tables."

Some people find the "Concise Sight Reduction Table" difficult to use and prefer a more accurate and complete table known as HO-229. This government publication has the title "Sight Reduction Tables for Marine Navigation" and consists of six big, heavy volumes that are a serious problem to carry around. These people feel that "real" or "pure" celestial navigation requires that you use HO-229 for your sight reduction. They don't like hand calculators and feel that the tables in the Nautical Almanac are complicated and perhaps not sufficiently accurate. Most older text books use the HO-229 method. For example, my favorite, the well recommended, "Practical Celestial Navigation" by Susan P. Howell uses HO-229 as does "Celestial Navigation for Yachtsmen" by Mary Blewitt and "A Star to Steer Her By" by Edward J. Bergin. Just add HO-229 to the three items mentioned earlier (sextant, clock and Nautical Almanac) and you have everything you need for traditional celestial navigation.

These days there is another popular option in the form of HO-249, the "Sight Reduction Tables for Air Navigation." These tables are slightly less accurate than HO-229 and are an interesting hybrid. Volumes II & III are just like HO-229 but they are limited to celestial objects whose declination (angle above or

below the celestial equator) is less than 29 degrees. This is good enough for the sun, moon, planets and some stars. Volume I is something completely different. It has the sub-title "Selected Stars." Each day a changing set of seven stars (out of the 41 best navigation stars) are presented in a way that combines the functions of the almanac and sight reduction tables. It even suggests the 3 best stars in each case.

Most modern books on celestial navigation are based on the use of HO-249. Some good examples are "Celestial Navigation by HO-249" by John E. Milligan, "One-day Celestial Navigation" by Otis S. Brown or "Miranav" by Rosalind Miranda. Of course, if you have taken a course based on the traditional use of HO-229 it is easy to switch. I usually teach HO-229 because I have found that many people want to learn the most traditional possible form of the subject, but I'm thinking of switching to HO-249 because it is so similar (and there are fewer volumes to lug around).

Finally, let me mention my own favorite form of celestial navigation. The "Celesticomp V" hand calculator. This little jewel will run your DR (dead reckoning) track for you and use it as your assumed position. It contains the celestial object positions so no almanac is required. You just punch in your observations (object code, altitude and time) and out comes a LOP. It will even combine LOPs into a fix and then start your new DR track from the fix. It's great. I enjoy making the observations and plotting the results more than I enjoy all the paperwork of looking things up in the Nautical Almanac and Sight Reduction Tables, so this works great for me. Of course, the real fun is being able to do it all and knowing different ways to do each thing. For example, I sometimes use a hand calculator method called "Sumner's Lines" that gives a LOP from quite a different approach than the usual method.

The equipment I use consists of an Astra IIIB sextant, which is without question the best deal around considering its high quality and relatively low price. I have attached a small digital clock to the sextant and I carry the sextant in a small foam lined high impact plastic case that can take a ton of pressure or a 7 foot drop (and it floats). There is also space in the case for my Celesticomp V calculator, my hand calculator, an electronic handbearing compass and a copy of the current Nautical Almanac. With this arrangement there is a substantial amount of redundancy and everything is in one place.

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- The primary reason for this website is to provide a place for me to share material concerning my interests in sailing and celestial navigation.

- I'm retired now, but for about 35 years I worked at the Lawrence Berkeley Laboratory on a scientific program concerning the properties of nuclei.

- My wife Valerie and I have started a occasional newsletter to keep friends up to date on our adventures.

Valerie has also started her own web page.

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