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Celestial up in the air

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To the editor: While both mariners and aviators can use celestial navigation for position finding, celestial in the air is very different than surface celestial navigation.

First, since a bubble sextant is used, you can shoot stars anytime you want during the night and are not restricted to the limited time around twilight. On a boat you generally have to wait until twilight and shoot the stars and record the times of the observation, which are random, for your computations. In the air, you decide what time you want a fix and then schedule the times you want to take the sights and then take the sights at the preplanned times.

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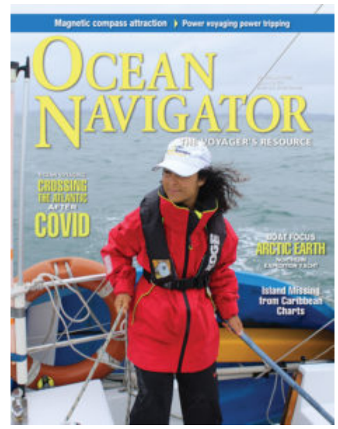
Second, you must come up with a fix rapidly. On a boat you can take the sights and then go below to start the computations, and you could wait until the next day to compute the fix. Since a plane is moving so quickly, a 10-minute delay in plotting the fix will mean the plane could be 100 nm from the fix by the time it's plotted. So airborne navigators use procedures to minimize the time between taking the shots and finishing the plot. This includes doing all the computations before taking any sights and this is what these MOB and MOO tables are used for.

Third, the level of accuracy achievable and the level of accuracy needed are much less than for marine navigation so it is perfectly acceptable to do the calculations to a lower order of precision, more quickly, and the fixes obtained will be within the achievable level of accuracy. As we say in the artillery, "it is a waste of time to polish the cannon ball." This is why H.O. 249 only gives the Hc to the minute, not the tenth of a minute as in H.O 229.

So here is an example of how it is done. First, you decide what time you want a fix, which is usually on the hour. The Air Almanac gives the data for every 10 minutes, so by choosing one of the listed times (usually on the hour) you don't need to do any interpolation of the data. You assume a longitude so that LHA Aries is a whole number and then go to H.O. 249, Volume 1 for selected stars and choose the stars that are well-spaced in azimuth. Since you are usually above the clouds you can shoot in any direction. You take the values of altitude and azimuth from H.O. 249 without any interpolation. These would be the Hcs if all the shots were taken at the planned fix time, which is not possible.

You usually plan to space the shots by four minutes since each shot takes two minutes for the use of the averager and this allows two minutes between shooting to write down the measured altitude (maybe actually to plot the LOP) and reset the sextant to get ready for the next star. A common shooting



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schedule would be to start the first shot at 51 minutes after the hour (assuming a planned fix time of on the hour).
You set up the sextant using the precomputed altitude and azimuth, and start tracking the body. Then you check your watch and trigger the averager on the sextant at H:51:00. You usually shoot the first star near the wing tip since advancing its LOP to the fix time will have little effect on its accuracy. You continue shooting until the shutter closes on the sextant, blocking the view, which tells you that two minutes have elapsed. You have, therefore, shot until 53, so that the midtime is 52, which is eight minutes before the fix time.

You use the next two minutes to reset the sextant and start tracking the second star and start the averager at 55:00 so the midtime of the second shot is 56:00, four minutes prior to fix time. You start the last shot at 59 and continue shooting until 01 after the hour, so the midtime of the third star is on the hour.
Every volume of H.O. 249 contains two tables for correction for the motion of the body (MOB) as well as tables for correction for the motion of the observer. The MOB tables show the change in altitude for both a one-minute interval and a four-minute interval, as well as an interpolation table for other time intervals based on the observer's latitude and the azimuth of the body.

The table for the motion of the observer (MOO) is used to adjust the Hc to allow for the motion of the observer between shots and is the equivalent of advancing the LOP to obtain a running fix. All fixes in the air are "running" since the plane moves a significant distance between the first and last shot, about 60 nm at 450 knots. (Some flight navigators use other methods to make these adjustments instead of the tables in H.O. 249.) Even though a boat is moving between shots its small amount of movement can usually be disregarded.

In order to be able to plot the fix as quickly as possible after shooting the last star, you precompute the expected altitudes so you can compare them immediately with the sextant altitudes (Hs) to determine the intercepts. So, using the MOO and MOB tables you adjust the tabulated Hc from H.O. 249 to allow for the two shots taken four and eight minutes before fix time. No correction is needed for the shot centered on 00. You look at the MOB table and take out the correction for four minutes (this is the reason for the four-minute table) without any interpolation, and add to it the four-minute correction from the MOO table. This will be the correction for these motions for the star shot at 56. You do the same for the first star but you multiply the sum by two for the total motions for the 52 shot. You add these motions to the Hc's obtained from H.O. 249. You also add the refraction correction (that's right, add) and add the index error (if any) so as to arrive at Hp (precomputed altitude). Since you have allowed for index error and refraction (no need for dip when using the bubble sextant) by applying them (with reversed sign) in computing the Hp you do not have to apply them to the Hs, so you can compare Hs directly with Hp to determine intercept. It is obvious that this procedure allows for the determination of intercept much more rapidly after the shot than in marine practice.

As part of the precomputation process you have plotted the assumed position on the chart (only one is needed with H.O. 249, Volume 1, after applying the correction for Coriolis effect, precession and nutation) and the azimuths so you can quickly plot the LOPs on the chart (or plotting board). You have completed the fix in one or two minutes after the last shot depending on if you had time to plot the first LOPs between shots. So you have a fix at 02 or 03 after the hour and can compute the winds encountered over the last hour and compute a new heading to destination. So by 06 you can give the pilot a new heading and a new ETA.

Another point, for those learning celestial, I think it is useful to use the sextant correction tables from the Air Almanac rather than those in the Nautical Almanac. In the Nautical Almanac many of the corrections are combined into one (e.g., refraction, semi-diameter and parallax in altitude are all combined in the moon correction table). Someone just learning will not see the pattern or where the various corrections come from. Using the Air Almanac you have separate corrections for refraction (for all bodies), dip (if using the natural horizon), semi-diameter (if using the moon or the sun), and parallax in altitude (if shooting the moon). This can give you a better grasp on what is going on rather than rote memorization of the process using the Nautical Almanac correction tables.

— Gary LaPook learned to fly in 1970 and has been an airline transport pilot since 1978. In the 1970s he ferried new airplanes from the factory to aircraft dealers, including crossing the Atlantic using celestial navigation to find the Azores. He started sailing in the 1960s and always brings his sextant along. He occasionally takes his sextants flying and shoots sights just to stay in practice.

By Ocean Navigator

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