Operational Level Celestial Sight Planning

A Resource for Senior Deck Cruise

Joey Simone

February 29, 2024

Introduction

A common stumbling block for cadets doing their Celestial Project on cruise is planning their required star fixes and sun fixes. This document is made from my personal experiences making over a hundred sight plans on my own senior cruise. This Document provides the format, steps, and examples required for producing sight plans quickly and accurately in a way yielding to high quality fixes and communicating the planning information to fellow cadets. It is only necessary for one person to create a sight plan if it is posted in the Nav Lab, and so other people can set their alarms based on that plan.

For Star Fixes, both Morning and Evening, steps will be laid out for establishing the most correct twilight time for observations of stars and planets, the DR position at the recommended fix time, the selection of appropriate stars, the altitude and relative position of the moon and navigational planets, and creating a table and visual diagram for showing the others.

For the Sun Run Sun fix, this paper shows an effective way to determine estimated Local Time of LAN and the most satisfactory times to shoot the morning sun line and afternoon sun line.

1 The Math

1.1 The Sailings

For the purpose of accuracy and rapid calculation, I like to use the sailings, and for this application I exclusively use the Mid Lat sailing. The additional accuracy rendered from the Mercator sailing is negligible on the short run of finding the morning position of the ship from the evening position. The "best" solution is to use the actual navigational chart, but you shouldn't do that if you're not on watch yourself, and the Nav Watch people will be doing this anyway. Universal Plotting Sheets are acceptable but they are the worst for this application. The margin of error in measurements of longitude is significant, it's not good to waste them on just making the sight plan, and you can do the sailings anywhere you can have your calculator and notebook. The mid lat sailing is accurate enough for the job, fast, and doesn't require tables or charts or plotting gear. With your TI-30xa and the most recent position slip (0800, NOON, or 2000), you can determine star time and vessel position. Here are the formulas you will use.

$$D = S \cdot T \qquad L_2 = L_1 + \ell \qquad \lambda_2 = \lambda_1 + DLo$$

$$L_m = \frac{L_1 + L_2}{2} \qquad \ell = D \cos C \qquad p = D \sin C$$

$$DLo = \frac{p}{\cos L_m} \iff DLo = \frac{D \sin C}{\cos L_m}$$

Remembering that C is Course Angle, the angle inside the triangle, not the angle clockwise from True North (Cn). To Convert from Cn to C, use the rules:

$$
\begin{aligned}
0 < Cn < 90 \rightarrow & \quad C = Cn \\
90 < Cn < 180 \rightarrow & \quad C = 180 - Cn \\
180 < Cn < 270 \rightarrow & \quad C = Cn - 180 \\
270 < Cn < 360 \rightarrow & \quad C = 360 - Cn
\end{aligned}
$$

1.2 Phenomena

For the Star Sights, you have to interpolate the twilight tables for your latitude to find the star time at the standard meridian, which then have to be adjusted for Longitude. The Meridian Passage is not sensitive to Latitude or Declination, and happens at the same time for the entire line of longitude, so the given times in the book must be adjusted for Longitude in the same way. There are two methods which are algebraically equivalent. Sam Pearson teaches the American method in class, I prefer the British method because it renders both the UT and the LT of the event, which you would need anyway.

$$\text{Almanac Time} +^{+W}_{-E} \frac{\lambda}{15°/\text{hr}} - \text{ZD} = \text{Local Time}$$

The British Method gives the Universal Time of the event first, then you get Local Time by applying minus Zone Description.

$$\text{Almanac Time} +^{+W}_{-E} \left(\lambda - \frac{\text{ZD} \times 15°}{1\text{hr}} \right) = \text{Local Time}$$

The American Method prioritizes finding the Local Time, then apply the zone description to get Universal Time. The last of the mathematics is to find the LHA of Aries, here LHA♈. The Almanac itself has instructions in the "Explanation" chapter.

2 Star Sight Planning

2.1 Establishing Time and Position

I have found that the most consistent way to organize the DR Positions in the AM and PM sight plan is with a table. Take the first line information from the position slip, for instance, when making the PM sight plan, use the Noon slip to get CSE, SPD, L_1, λ_1, ZD, and let T_1 be 1200hrs and D_1 be 0nm.

Time (hhmm)	Latitude	Longitude	Distance (nm)
T_1	L_1	λ_1	0
T_2	L_2	–	D_2
T_3	–	λ_3	D_3
T_4	L_4	λ_4	D_4

Table 1: Required Times, Positions, and Distances

All shots happen during Nautical Twilight, but some people are confused by the column to use. In the *morning*, Shooting Time begins at Nautical Twilight, as per the Nautical Almanac, this time is BMNT for "Begin Morning Nautical Almanac". Shooting Time ends at the interpolated and corrected time of Civil Twilight, or BMCT. In the *evening*, Shooting Time begins at the interpolated and corrected time in the Civil Twilight column, this time is End Evening Civil Twilight, EECT. Shooting time normally ends by End Evening Nautical Twilight

When selecting a time from the twilight column to be T2 for your table, select the earliest time in your pair of latitudes, so as to not overshoot. For instance, the date is Feb 07$^{\text{th}}$ 2024, the DR Latitude is 38N.

Lat	Naut	Civil
N40°	0603	0635
35°	0558	0628

Lat	Civil	Naut.
N40°	1754	1826
35°	1800	183

In the morning, the table on the left applies, and we choose the soonest time in the Nautical column that applies to the Latitudes we are between, in this case 0558. In the evening, the table on the right applies, and we choose the soonest time in the Civil column that applies to the Latitudes we are between, in this case 1754.

1. Adopt this time as T_2, DR out, and record L_2. Longitude is not needed in this step.
2. Use L_2 to interpolate the column and find a most accurate center meridian time of the phenomena. For Latitudes greater than 40 North or South, more accuracy may be had using the Table 1 in the back of the Almanac, near the Lunar Sight Correction tables, although it may be necessary to perform a double interpolation of that table. The interpolated time is T_3
3. DR to T_3 and record Longitude λ_3.
4. Use $T_3 +^{+W}_{-E} \frac{\lambda_3}{15\,\text{deg}/\text{hr}} - \text{ZD} = T_4$ or
5. DR to T_4 and record L_4 and λ_4

From here on, T_4 is the (ship) time at which you should plan to be out on the Nav Lab or Bridge Wing with your sextant, notebook and pen, accurate wristwatch, and your red colored flashlight. For Clarity, UT_4 is the Universal (GMT) Time that you use to enter the Nautical Almanac and Air Sight Reduction Table.

2.2 Writing the Sight Plan

The fastest and most accurate resource for sight planning is the *Sight Reduction Tables for Air Navigation, Vol. I*, sometimes called the Air Almanac by mariners, even though another book has that name. It can list the Name, Altitude, and Azimuth of the 7 best stars for shooting, and recommends 3 of them for a very good fix. All it wants is your (AP) Latitude and the LHA♈for the time and place you will shoot. The procedure for finding AP Lat is exactly the same as in Sight Reduction, simply round L_4 to the nearest whole number. Table 4 in the back of the book gives instructions and numbers for finding the GHA of Aries to the nearest minute of arc in a ten year period. The book labeled epoch 2025 is good for years 2021-2029. Use UT_4 to find GHA♈and then use $\text{GHA}\Upsilon^{+E}_{-W}\lambda_4 = \text{LHA}\Upsilon$ and round to the nearest whole number. Pages in the table are labeled by Latitude, and then find the row with the corresponding LHA♈.

LAT 38°N

LHA ♈	Hc	Zn	Hc	Zn	Hc	Zn	Hc	Zn	Hc	Zn	Hc	Zn	Hc	Zn
	♦Alpheratz		ALTAIR		Nunki		♦ANTARES		ARCTURUS		♦Alkaid		Kochab	
270	15°46′	065	51°32′	132	24°22′	166	22°13′	201	38°17′	265	44°30′	305	47°37′	343
271	16 28	065	52 07	133	24 33	167	21 55	202	37 30	266	43 51	306	47 23	342
272	17 12	066	52 41	134	24 43	168	21 37	203	36 43	266	43 13	306	47 09	342
273	17 55	067	53 14	136	24 53	169	21 18	204	35 56	267	42 34	306	46 54	342
274	18 38	067	53 47	137	25 02	170	20 58	205	35 09	268	41 56	306	46 39	342

Figure 1: Excerpt from Pub 249, Page for L38N

Stars listed in all upper case, such as SIRIUS, are among the twenty brightest stars, brighter than magnitude 1.5. On each line, three stars are marked with a diamond symbol ⧫. These are best suited, among the seven available, for a fast three-star fix with wide crossing angles among the resulting lines of position. Shoot those first unless clouds or viewing angle limitations rule them out.

If a two-star fix is preferred, ignore the diamonds, and choose the most convenient pair from the seven that are bright, easily-identified, and separated by at least 45° and not more than 135° in azimuth, preferably near 90° apart. For each star, the Main Table provides the un-refracted altitude above the true horizon, referred to in the intercept method as Hc, and also the true azimuth (non-magnetic compass direction) measured clockwise in degrees from true north, labeled Zn.

2.3 Use of the RUDE Star Finder

I find that my accuracy with the star finder is reduced for main stars like are covered in the Pub 249 table, but in situations where the Air Nav Table is not available, you can get much the same information, with less accuracy. The blue disks are reversible, with *5N on one side and *5S on the other. Each disk is good for 5 degrees on either side, so if your latitude is 38N, use the disk labeled 35N. Find the LHA♈from the Nautical Almanac in the usual way, and put the blue disk on the white disk so that the arrow points to the right number for LHA on the bottom. Look at the stars about 45 degrees up the disk (middle altitude) and find stars which are well distributed in azimuth, 120 degrees between them is ideal. Stars with big circles are brighter, stars with tiny dots are dimmer, and the peg at the center of the disk is Polaris (in the Northern Hemisphere)

Where the Star Finder shines is the ability to display the Minor Stars, the Navigational Planets, and the Moon. Use the red disk, the Right Ascension of the body (RA = 360° − SHA) and the Declination of the same body at UT_4. If you desire to use the moon, RA☾ = 360 − GHA☾ + GHA♈

Play around with this. Once you have drawn all the planets and moon on your star finder, you can scroll the blue disk back and forth to find, for instance, the LHA Aries associated with moonrise and moonset, or the meridian passage of a planet, then you can work backwards with your λ_4 and your almanac to find what time in UT and LT that will happen. It's like having the world's cheapest planetarium.

2.4 Putting it all together

Now that you know all of this stuff, the most helpful thing you can do is to distill it into a format that is understandable to your friends, and post it in the nav lab. If someone wants to know for what time they should set their alarm in the morning, the ship time and universal time of BMNT is posted on your sight plan. The ship's direction and speed from the position slip and the DR Lat and Long have to be on your plotting sheet anyway for your work to be counted, so include it on the sight plan. The most important thing is to include a brief table with the name, altitude and azimuth of each body.

June 26 AM Sight Plan
ZD=+9, CSE 042, SPD 15.2, Reckoned from 25 Jun 2023, 2000 POSN SLIP
UT BMNT 1342, LT BMNT 0442, 0442 DR Posn: L31° 26.4′N, λ146° 43′W

Symbol	Name	Hc	Zn
♦	Mirfak	30°16′	047
♦	FOMALHAUT	28°29′	168
♦	VEGA	46°01′	295
⋆	Hamal	37°31′	083
⋆	Diphda	28°54′	138
⋆	ALTAIR	50°41′	243
⋆	Kochab	24°25′	344
☽	MOON	NOT	AVAILABLE
♀	VENUS	NOT	AVAILABLE
♂	MARS	NOT	AVAILABLE
♃	JUPITER	30°	090
♄	SATURN	48°	171

Table 2: Created from a real sight plan I made on the TSGB

2.5 Example

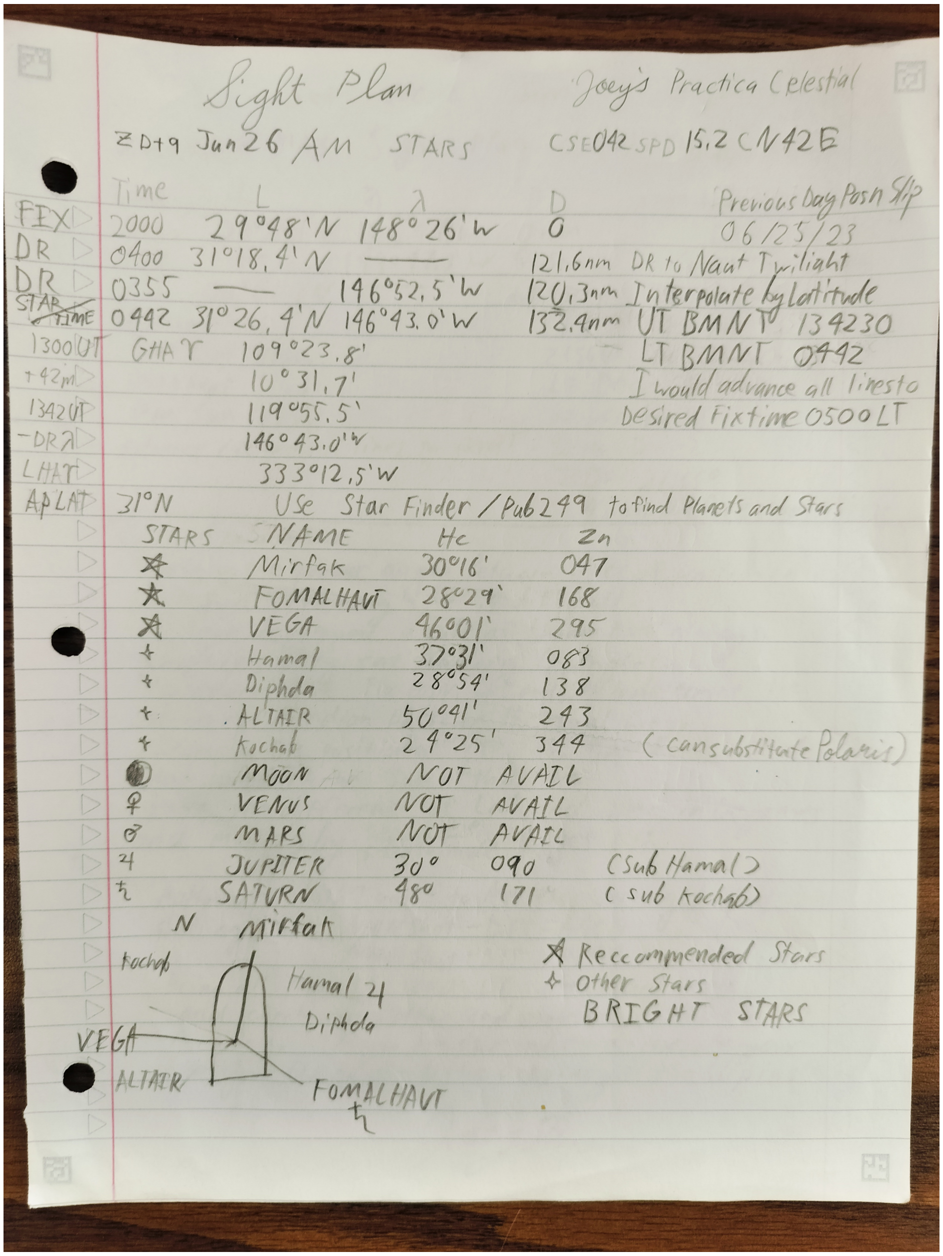

Figure 2: Handmade Sight Plan with all tables and drawings.

3 Daylight Fixes

3.1 Making the Plan

The process for creating good sight geometry in your daylight running fixes is much more brief, and you are already a little acquainted with the process from the second unit of Pearson's class. As before, we want to find the UT and LT of LAN using "Mer. Pass." from the Almanac and use the 0800 POSN slip to establish CSE, SPD, ZD, L_1, λ_1, and let T_1 be 0800 and D_1 be 0nm.

Create the table.

Time (hhmm)	Latitude	Longitude	Distance (nm)
T_1	L_1	λ_1	0
T_2	—	λ_2	D_2
T_3	L_3	—	D_3

Table 3: Required Times, Positions, and Distances

1. Set "Mer. Pass." from the correct day in the Almanac as T_2, DR to T_2 and record λ_2 only.
2. $T_2 +^{+W}_{-E} \frac{\lambda_2}{15°/\text{hr}} - \text{ZD} = \text{LT LAN}$
3. Let LT LAN be T_3. DR to T_3 and record L_3. LT LAN + ZD = UT LAN (UT_3)
4. Use UT_3 to find Dec $\odot$ (Sun)
5. Find the Absolute Difference of (Lat $\sim$ Dec), which is to say $L - D$ if Latitude and Declination are same hemisphere and $L + D$ if contrary hemispheres.
6. This is the same thing as your predicted co-alt[1], or 90 − Ho.
7. Multiply your co-alt in degrees by $\frac{4\text{min}}{1°}$ to get difference of time, which I'm calling ΔT
8. The best time to shoot your AM sun line is $T_3 - \Delta T$, and your PM sun line time is $T_3 + \Delta T$.

Then, a much shorter Sight Plan can be created, posted, shared with friends, and hastily copied down into pocket notebooks in the chow line.

Sun Noon Sun Sight Plan

ZD= +10, CSE 237 SPD 10, Reckoned from 0500 Star Fix in POSN L00°39.1′N, λ148°49′W

- Shoot AM sun line at 1030
- LAN occurs at 1156
- Shoot PM sun line at 1322

Recommend Advance/Retard all lines to 1200.

[1] Pearson calls it Zenith Distance, but I don't like that because it also abbreviates to ZD, like zone description.

3.2 Example

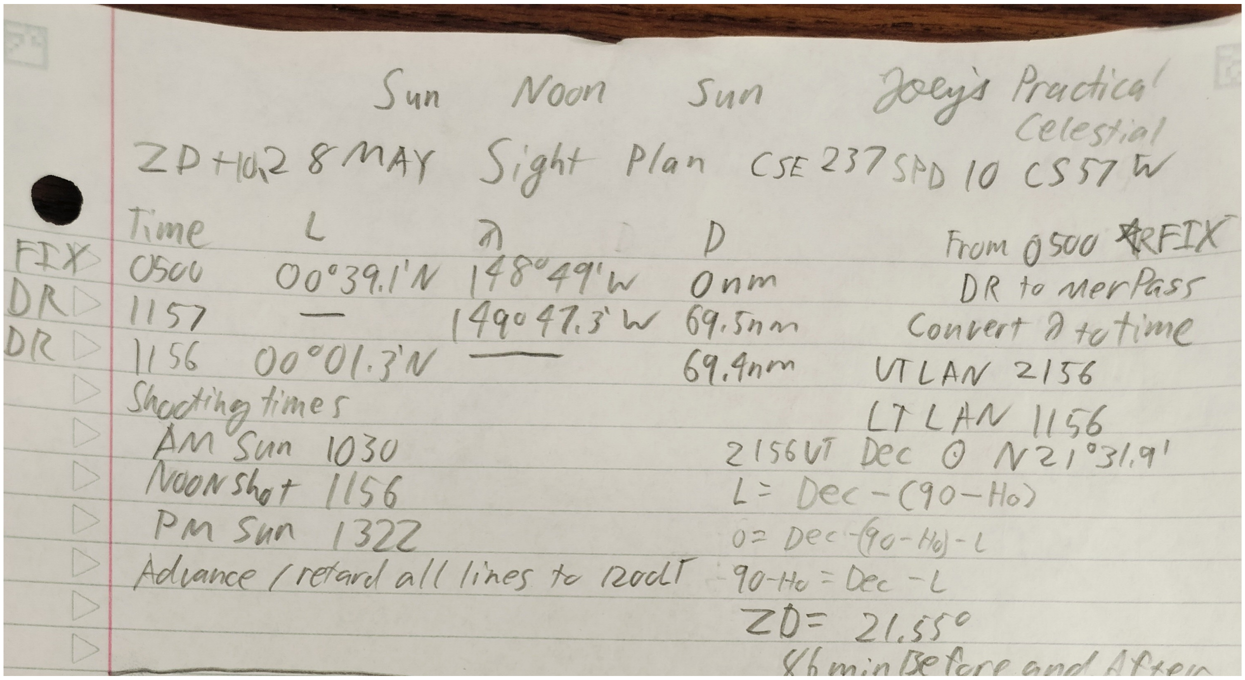

Figure 3: A recreated sight plan from when we crossed the equator going southwest at noon.

Conclusion

There is always more to be learned in the art of celestial navigation. Omitted from this handout are the instructions for the use of Tables 1 and 2 in the back of the almanac, instructions for calculation of Moonrise and Moonset, instructions on planning daylight three body fixes with the Moon, The Sun, and Venus all at once, the use of the Star Finder to precalculate Sun Azimuth for perfect 60-60-60 triangles, and the calculations in pub 249 that allow the navigator to advance and retard star LOPs non graphically. This paper is just for helping you get the Sun and Star fixes that the instructors want you to get, and for helping you formulate and communicate sight plans to your fellows in a productive and consistent way. Besides, if you're interested in the other stuff, trying to figure it out on your own is one of the most rewarding and exciting parts of this ancient discipline. Don't let me have all the fun.

Good Luck, happy shooting, don't get arrested in port.