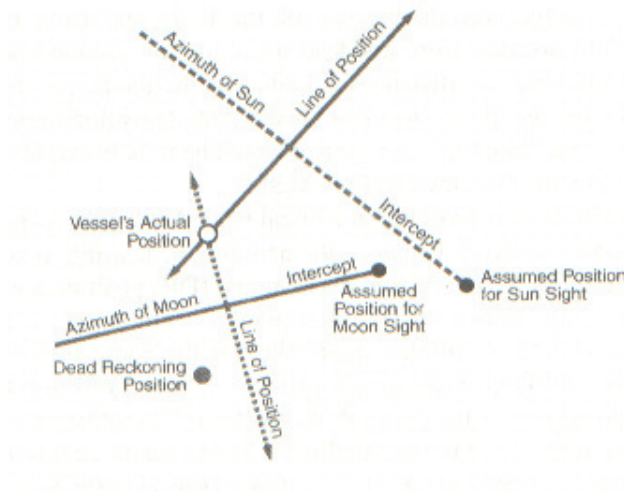# ASTRONOMICAL NAVIGATION

Basic terms

*astronomical navigation *compilation *astronomical tabels *celestial observations *solution of a sight * Sun/Moon/star sight *spherical trigonometry *PZX triangle *celestial pole *zenith *celestial body * Cosine Theory *Nautical Almanac *altitude *true zenith distance *assumed position *sextant *Aries *Equation of time *digital fix *Mercator Sailing *Parallel Sailing *Great Circle track *DR position *intercept *Greenwich Hour Angle (GHA) *Line of position (LOP) *actual position *celestial fix *Local Hour Angle (LHA) *declination *position line * point of intersection *angle of cut *astro-navigation *ocean navigation *position circle *Geographical Position (GP) *computation *index error * course made good *vertex *true wind direction

Until the compilation of new astronomical tables to assist the air navigator in obtaining a quick position by celestial observations, the solution of u Sun, Moon, or star sight, by which a position line on a chart could be obtained, required a knowledge of spherical trigonometry and the solving of what is known as the PZX triangle, where P is the position of the celestial pole, Z is the observer's zenith (i.e., the point in the sky directly overhead), and X is the celestial body. The triangle is solved by calculations on the lines of the Cosine Theory and involve extensive use of mathematical tables.

But the new air navigation tables, now in wide use by many navigators at sea, have made the solution very much simpler, and with these and a Nautical Almanac, a navigator can obtain his true position without the long calculations previously necessary. From his observed attitude of the celestial body a navigator obtains from the tables the true zenith distance of the body and from the Nautical Almanac the zenith distance from his dead reckoning or assumed position. The difference between these two distances is known as the intercept, and shows the navigator how far his real position is from his assumed position in one direction. He finds this direction from the exact time at which he took his sight which, from the tables, gives him the Greenwich Hour Angle.

His assumed longitude then gives him the Local Hour Angle and, using the body's declination from the Nautical Almanac, the azimuth, or bearing, is obtained. By drawing this bearing on the chart from his assumed (DR) position and measuring off the intercept, a line drawn through that point at right angles to the azimuth provides a position line. A similar sight taken at the same time of a second celestial body on a different bearing will provide a second position line and the observer's true position is at the point of intersection of these two position lines. An alternative method for use during daylight hours when the Sun is normally the only celestial body in sight is to take a second observation of the Sun some 3 or 4 hours later when its azimuth has altered sufficiently to provide a satisfactory angle of cut, which should never be less than 30 degrees.
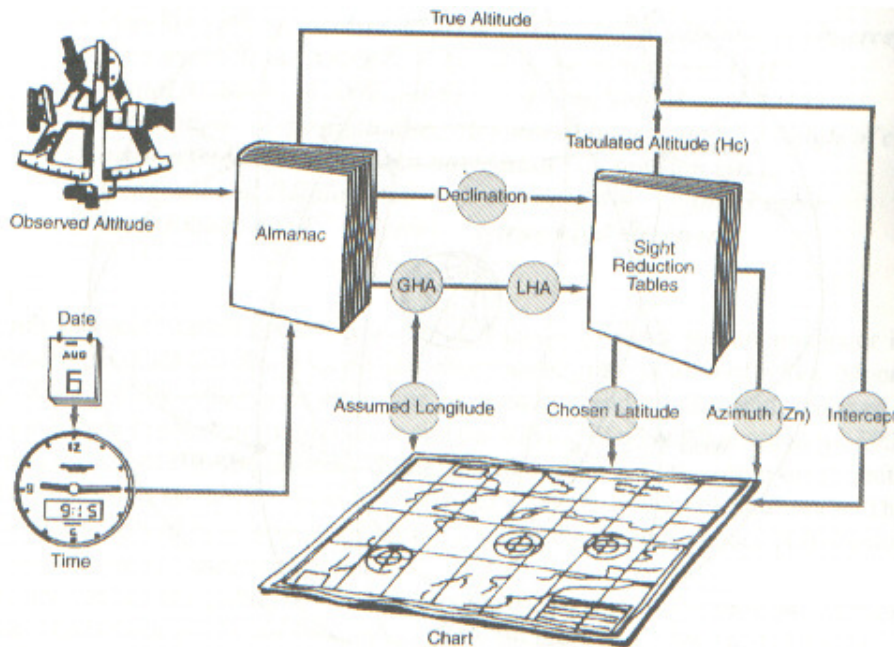
Celestial Fix Using Simultaneous Sights of Sun and Moon

Elements of the celestial sphere. The celestial horizon is the primary great circle (BOWDITCH, American Practical Navigator)
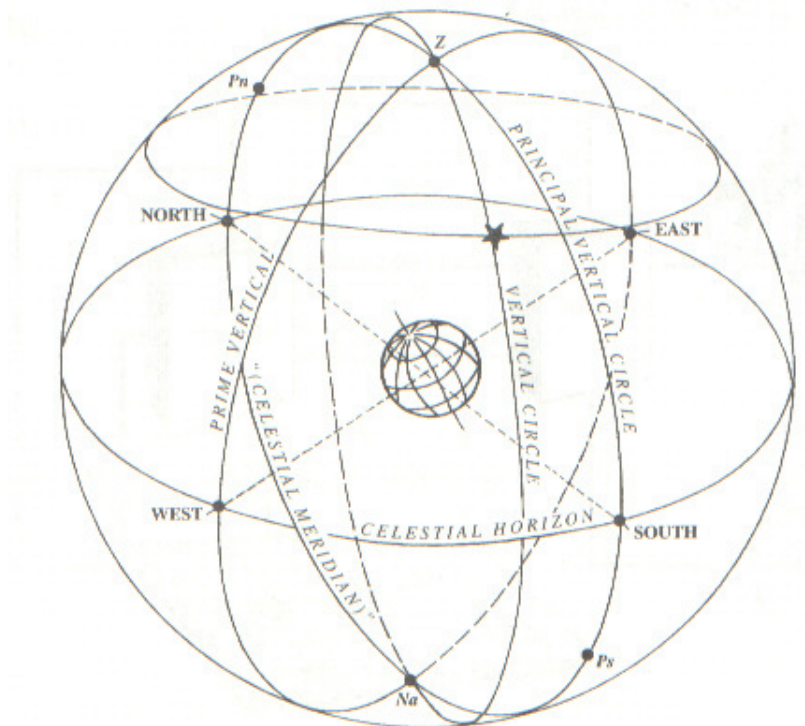
Astro-Nav Flow Diagram

A. Comprehension & vocabulary

A.1 Give an appropriate term for the following definitions:

1. The angle measured between our own ship's (local) meridian (i.e. our longitude) and that of the Sun or other heavenly body.
2. A point where an imaginary line drawn from the centre of the Earth towards a celestial body passes through the Earth's surface.
3. The point where a star or a heavenly body is directly overhead.
4. A circle with its centre in the GP.
5. A short section of a position circle in the region where it intersects with another.
6. A publication giving the time-tables of the heavenly bodies (i.e. ephemerides).

A.1 Supply the,following missing terms:
   *distance *ship's position *heavenly bodies *intersection *computatian *line of position *intersection *altitude *geographical position *Earth's surface *geographical position *position *position circle *chart *position circle

Obtaining a fix

When we know the distance from two points, the positions of which are already known, we can determine our 1._____ Suppose the 2._____ from our ship is 6 miles to Lighthouse A and 8 miles to Lighthouse B. Draw a circle with a radius of 6 miles and A as center. This is called a Position Circle because our ship must be somewhere on it. Now, draw another position circle with a radius of 8 miles and B as center. Obviously, the 3._____ of the two position circles is our ship's position. In Astro-Navigation, the same principle, 4._____ method, is used to determine the ship's position. Therefore, we must always have at least two known points, and instead of lighthouses we use 5._____ the Sun, Moon, planets and stars.

Then, how do we know the 6._____ of any of these heavenly bodies? We will express their position in terms of their 7._____ (GP). GP is the point where a line, drawn from the center of the heavenly body to the center of the Earth, would touch the 8._____ .

The next thing we must know is the distance from our ship to the GP. It can be determined by measuring the 9._____ of the heavenly body above the horizon. For instance, if we observed a star at an altitude of 40 degrees we can figure out the distance to its GP as 3,000 miles by 10._____ .

Now, if we drew a 11._____ with a radius of 3,000 miles and the GP as center, our ship must be somewhere on it. By drawing another position circle with another heavenly body whose 12._____ and distance are known we can determine our ship's position at their 13._____.

Since it is not feasible to draw a 3,000 miles radius position circle on a 14._____, only a necessary part of it is drawn as a straight line in the manner explained. This is called Position Line or 15._____ .

A.3 Define the following terms:
Declination _____
GHA _____
LHA _____
UTC _____
Geographical position _____
Sextant _____
Almanac _____
Index error _____

A.4 Say which of the astro- navigational terms is described below:

1._____: the east or west position of a celestial object measured by its angle from the zero or prime meridian.

2._____: the angle measured westwards between our own ship's meridian (our longitude) and that of the Sun or a star.

3._____: the point directly overhead, (i.e. latitude and longitude of a point on the

Earth's surface at which a given heavenly body would be in a zenith).

4._____: a small circle on the surface of the Earth and on the circumference of which is the observer's position.

5._____: a section of a position circle, (i.e. arcs of position circles).

B. Grammar

B.1 *Supply the right verb to complete the sentences below:*
     *obtain *note down *make *draw *measure *do *find

Drawing a Line Of Position (LOP)

To 1._____ a Position Line we must 2._____ the altitude and azimuth of a suitable body whose position in the sky is 3._____ from the Almanac, and to 4._____ that we must 5._____ the date and exact time of our observation. To 6._____ a position we must 7._____ at least two such observations.

B.2 *Supply the suitable adjective or adverb as required:*
     *clearly *celestial *possible *usually *still *short *quick *visible *easiest *overcast * temporary

Taking sights of a celestial body

Sights are 1._____ whenever we can 2._____ see the horizon at the same time as an identifiable 3._____ body. In practice we are 4._____ limited to taking Sunsights by day and all other sights during the 5._____ period of twilight at dawn when the horizon is just becoming 6._____ but the stars have not yet faded, and at dusk when the stars are coming out but we can 7._____ see the horizon. A partially 8._____ sky doesn't necessarily prevent us from taking a 9._____ sight during the 10**.**_____ break in cloud cover. The 11**.**_____ shot of all is to find our latitude by the Sun's altitude at noon.

B.3 *Fill in the right preposition:*
     *of *at *on *to *from *with *of *at *to *on *of *with *at *from *of *to *through

A running fix by astro

Suppose that 1._____ 0830 GMT 2._____ 21 June 1985 we are in DR position 49deg 40 min north, l5deg 00 min west.

We're making for the south west 3._____ Ireland 4._____ a course 5._____ 045deg true, speed 6 knots.

6._____ the Almanac and with a little interpolation we find that 7._____ 0830 the Sun's

dec- is 23deg 27min and its GHA is 307deg (ignoring decimals).

8._____ get the Sun's Local Hour we subtract our westerly longitude: l5deg 9._____ 307 gives a LHA 10._____ 292deg.

So now we know the three angles needed 11._____ enter the Sight Reduction Tables or to use 12._____ our calculator: LHA, dec and lat, and we find that the Sun's azimuth is 90deg and its calculated altitude Hc is 3ldeg 43 min.

Our corrected sextant altitude Ho 13._____ 0830 is compared 14._____ Hc 15._____ give us the intercept which we mark off along the 90deg line 16._____ azimuth drawn 17._____ our DR position.

B.4 *Fill in the suitable conjunctions:*
*if *so *and *which *where *while

A running fix by astro (continued)

Our 0830 position line is drawn at right angles to the azimuth, 1._____ in this instance it is a meridian of longitude, so we can, 2._____ necessary revise our DR long 3._____ still being uncertain of our true latitude.

4._____ we sail on, and just before local noon we prepare to find our latitude, using the method described earlier, 5._____ turns out to be 49deg 55min north, 6._____ the time is 1300 GMT.

7._____ now we have a longitude at 0830 and a latitude at 1300. To obtain our "fix" we have to "run-on" the 0830 position line.

We have been sailing 4 1/2 hours at 6 knots, a distance of 27 miles on a course of 045deg true 8._____ we now plot that bearing and distance from any point on the 0830 line we can draw our new 'run-on' position line parallel with the original through the end of the 27-mile line 9._____ this intersects with the latitude we have just obtained, there is our present position.

B.5 *Check the pronunciation of the following words and give their phonetic transcription equivalents:*

Astronomy _____

Astronomical _____

Sight _____

Spherical _____

Trigonometry _____

Triangle _____

Zenith _____
Cosine _____
Sine _____
Almanac _____
Altitude _____
Polaris _____
Aries _____

Declination _____
Equation _____
Horizon _____
Subtract _____
Latitude _____
Longitude _____
Intercept _____

C. Writing skills

C.1 Answer the foltowing questions:

l. What must be solved first in order to obtain a position line in astro-navigation?

2. What kind of knowledge was required in the past?

3. Why is it much easier to obtain a quick position today?

4. What is the PZX triangle?

5. How is the astronomical triangle solved?

6. What is the first step in astro-navigation?

7. Where is the true zenith distance of the celestial body obtained?

8. What is obtained from the Nautical Almanac?

9. What is the intercept?

10. What does it show?

1 I. How does the observer get his direction?

12. What is GHA and LHA?

13. How is the azimuth or bearing obtained?

14. How is the position line provided on the chart?

15. Why is a second position line needed?

16. How are daylight observations taken?