knowledge of time or longitude; near the Solstices the result will be accurate to within a few miles.

Task: Find accurate latitude without accurate time or longitude

Discussion: Unlike the sun, whose declination varies from day to day, stars circle the globe over essentially fixed latitudes equal to their declinations. Hence a normal twilight star fix will yield a correct latitude even though the longitude will be wrong if the watch times of the sights were wrong.

Solution: Assume your watch has correct time and proceed with normal star sights: 3 or 4 sights each of 3 stars near 120° apart, chosen from Sight Planner. Use Plot fix or USNO fix method to determine a fix from this data. The resulting latitude will be your correct latitude, but the longitude will be in error in direct proportion to the watch error — each 1 minute of watch error will cause a longitude error of 15'. If you believe your watch is correct to within, say, ± 3 minutes, then the longitude you found is uncertain by ± 45'.

Task: How to figure the number of miles per 1° of longitude at a given latitude.

Discussion: 1° of latitude = 60 nautical miles at any latitude, but since longitude lines (meridians) converge at the poles, the number of miles per degree of longitude gets smaller with increasing latitude. In an emergency we may be working without a chart but still determining positions in Lat/Lon, hence it is helpful to keep this scaling factor in mind.

Solution: The actual conversion factor is given by [miles per 1° of longitude] = 60 nm x cos(Lat), which can be computed on the TI-86 by exiting the StarPilot program, [2nd] [QUIT], and just typing in the question, i.e., at latitude 48, type 60 [x] cos48 [enter]. Alternatively, just do a Rhumb line computation from, say, 48 N, 120 W to 48 N, 121 W and you will get the same answer from within StarPilot. You can use any two longitudes 1° apart. Compare to 0 N, 120 W, to 0 N, 121 W which will be 60 nm.

Task: How to find GMT from lunar altitudes.

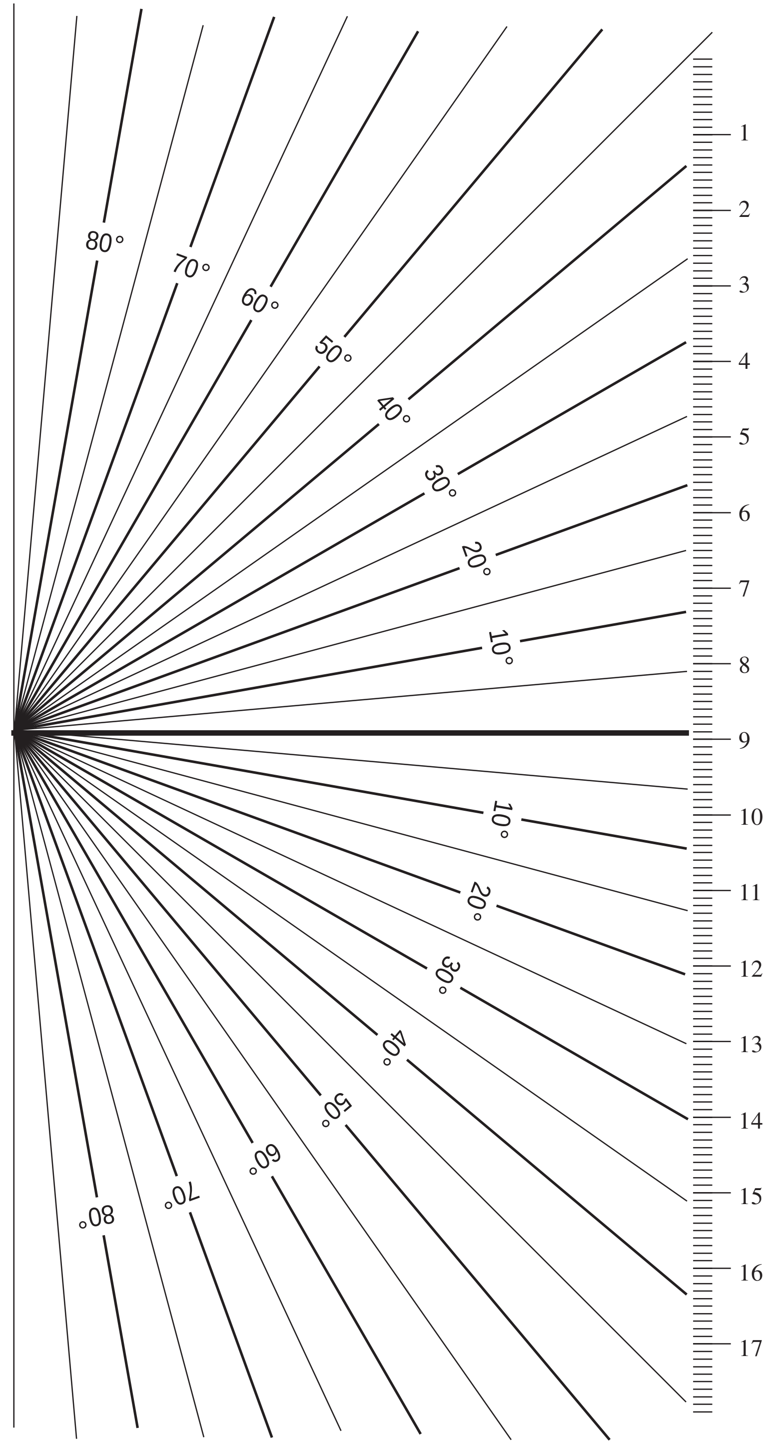
Discussion: This method is not as versatile as lunar distance method below, but when it can be done it is easier and uses only standard sight procedures. This method requires a moon bearing near east or west.

Solution: Using a hack watch for the relative times of these sights. Find 2 stars bearing some 40° to 90° apart which we use with the near east- or west-bearing moon. Take very careful standard sextant sights in this sequence: star1, star2, moon, then repeat 3 or 4 times. Enter the data into StarPilot and do a Fix by plotting using a fix time about halfway through your data set. Unless your watch was right to begin with, the moon LOP will not go through the intersection of the two star lines. This discrepancy is due to your watch error. If the moon line is east of the intersection, your watch is slow. Now guess a new watch time that is faster, by about 2 min for each 1' of longitude discrepancy. Keep guessing and plotting till all three lines intersect at the same point. The resulting time is your GMT at the time of the sight. With best of conditions and sight data accurate to 0.1', the resulting time can be accurate to 1 to 2 minutes.

Task: How to find GMT from lunar distance

Discussion: This is an easy sight to analyze since StarPilot has a special function for it, but the lunar distance sight is non standard. Accuracy is about the same as above, but the actual lunar distance sight is more difficult.

Solution: Choose a nearby planet or the sun, or use a bright star inline with the moon's path. Holding the sextant tilted to the side, very carefully measure the distance from moon's edge to the body. Enter the data in celestial utility 6, and compute



STARPATH.

StarPilot Emergency Navigation

StarPilot is a powerful aid to navigation, in routine work and perhaps especially so in an emergency. In an emergency, you can use it to determine your position from celestial observations — with or without conventional instruments — and from there compute the proper course to a chosen destination. It can then tell you the bearings to celestial bodies throughout the day and night from which you can set the course to guide you there. In the presence of current, it can tell you how much you will be set, or alternatively how much to adjust a course to correct for the set.

These notes outline the emergency procedures. For best preparation, study the StarPilot *User's Guide* and the book *Emergency Navigation* by David Burch. And most important, use your StarPilot to practice these exercises before you need them. These descriptions are very brief and intended only as reminders of techniques that you have practiced and learned ahead of time.

The basic tools of ocean navigation are watch, compass, and sextant. The basic data are present position, destination position, and GMT. The basic reference materials are nautical almanac, sight reduction tables, and plotting sheets. StarPilot performs all the functions of the basic reference materials precisely and completely, so if you have the basic tools and basic data and a StarPilot you can navigate in the normal manner, the loss of any or all of the reference materials does not constitute an emergency — other than the obvious requirement of being more careful whenever we lose any of our standard resources.

First we list a few tips on being prepared for navigation emergencies, followed by specific how-to procedures using the StarPilot.

Know where you are going, (i.e. Lat and Lon of your destination). We can find out where we are from looking at the sky but we cannot find out where we want to go. Destination can be stored in StarPilot and it is a good idea to do so, but beyond that, it is valuable to know these coordinates by heart yourself and to discuss it with others so they know it as well.

Wear a watch with known watch rate and encourage others to do so as well. That is, know how to figure GMT from your watch time. Knowing GMT alone takes most of the sting out of emergency navigation.

Keep your DR updated in your StarPilot and, the best you can, in your mind as well. It can be convenient to know the magnetic variation where you are and at your destination, and roughly how it varies between the two, but this is not strictly crucial as we can check this from the sun and stars with the StarPilot. In short, keep the basic data up to date and our job as navigator in an emergency will be easier.

— How to —

- Do low-angle "sextant sights" with a kamal
- Get LOPs from sunrise and sunset
- Find course and distance to destination
- Find magnetic variation
- Check or calibrate the compass
- Find the time from a known position
- Find proper date, from approx. position and time
- Find approx. Lat without time or accurate Lon
- Find accurate Lat without accurate time or Lon
- Figure the number of miles per 1° of Lon
- Find GMT from lunar altitudes
- Find GMT from lunar distances

Task: How to do low-angle "sextant sights" with a *kamal*
Discussion: If we know GMT and have a StarPilot we can essentially navigate as normal even without a sextant. The trick is to use bodies low in the sky (< 15° or so above the horizon), because the height of these can be measured to within about ±

0.1° using a simple millimeter scale.
Solution: When a millimeter ruler is held 57 cm from the eye (fig. 1), each 1 cm on the ruler spans about 1° of arc. To use the ruler as a makeshift *kamal* (ancient Arabic navigation tool used for measuring angles), hold the ruler at that distance from the eye, and line up the top with the body and note where the horizon crosses the scale as shown in fig 2. A star that is, for example, 6.7 cm above the horizon has a sextant altitude Hs of 6.7° or 6° 42'. Any one measurement of this type is not likely to be accurate to the precision it can be read, but the average of multiple readings should be accurate to at least ± 0.2', which would translate very roughly into some ± 12miles in an LOP. Sights are best done by measuring 57 cm along a string or stick to use as a guide in maintaining the proper eye-to-scale spacing.

Fig 1

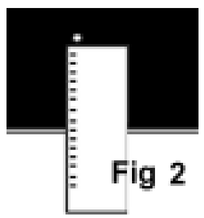


Fig 2

Task: How to get LOPs from sunrise and sunset
Discussion: It is not too often that we get to see the sun set or rise over the true sea horizon because there is usually a low band of clouds that obscure the sun before the actual moment of crossing. If we can, though, see the upper limb cross the true sea horizon, the time of this observation is a good LOP that does not require a sextant.
Solution: Note the GMT of the sunset or sunrise and then do a normal sight reduction using Hs upper limb = 0° 0'. The Hc you obtain will typically be negative, but StarPilot will solve for the proper intercept and azimuth for this type of "horizon sight." Typical accuracy of these sights is some ± 6 miles due to uncertainties in refraction at the surface.

Task: How to find course and distance to destination
Discussion: If you know the Lat/Lon of your present position and that of your desired destination, then type then into the StarPilot as DR position (setting 1-3) and Destination position (setting 1-4). This is the basic information we need and it should be recorded in the StarPilot as soon as possible. If only approximate values are known, enter those.
Solution: Execute the Route sailings utility called Rhumb line and it will read the DR and Destination position you stored and compute distance and course to the destination.

Task: How to find magnetic variation
Discussion: Assuming the compass works OK — or at least no reason to doubt it — but the local magnetic variation is not known, then we can easily find it from a known position and known time. All basic computations in StarPilot (i.e. sight reductions and route sailings) are in true, so to use a compass we need the variation. Alternatively, and perhaps eventually, we can disregard variation and magnetic headings all together and simply use the compass as a relative pointing device and set courses from true directions read from celestial bodies in the sky. In any event, so long as we know position and time, it is a simple matter to find variation and this will be the simplest approach to begin with.
Solution: Point the boat toward any known celestial body and note the compass heading, time, and DR position. Enter DR position in StarPilot, and do Precompute (under Celestial bodies) to get Zn, the azimuth or true bearing to the body. Difference between Zn and compass heading is the local magnetic variation. This can be a low sun or moon, or any star or planet. If there is a convenient body low in the sky but it is unknown to you, then do Sight Planner for a plot of the sky. That will identify the body.

Task: Check or calibrate the compass (i.e. find compass deviation)
Discussion: May need to do this after lightning strike or other physical damage to compass or mounting, or when installing or first using a new compass underway, or in normal conditions underway you doubt its readings and learn that it has not been checked in a long time. Note that you can do this with or without knowledge of local variation.
Solution: Easiest approach is to use the sun's shadow on the compass card and Celestial utility 6, Compass calibration. Required input are time, date, DR position. Or point the boat toward some identified celestial body roughly in the direction you wish to travel and then use Celestial bodies 4, Precompute to obtain the true bearing of the body (Zn) which you can compare to the compass reading. (If needed, to identify bright stars and planets in the sky, do Sight Planner.)

Task: Find the time from a known position
Discussion: The onset of a navigational emergency might leave us with a correct position and a running watch, but uncertainty as to the correct time. This problem can be solved easily pro-

viding we do it quickly enough that we do not lose position accuracy. The resulting time we determine will be as accurate as our longitude — a 15' error in longitude will cause a 1 minute error in time, or 4 seconds time uncertainty for each 1' of longitude uncertainty.
Solution: Easiest is to note the watch time of sunrise or sunset (upper limb on the visible horizon) and then compute this time from Celestial bodies 1, Sunrise/LAN/sunset. The difference is the GMT offset of your watch… the result will be a combination of watch error and zone description.

Task: Find proper date, knowing approximate position and time
Discussion: It has happened that mariners in distress have lost track of the correct date although other information remained more or less in tact. Needless to say, this is something we need to be sure of, and it is easy to determine with the StarPilot. The key here is the location of moon relative to stars or planets.
Solution: The moon moves eastward about 12° per day relative to the stars and planets, that is about 24 moon diameters per day, which is easy to detect by eye alone, without the use of a sextant. At any time the moon is visible near another body, run Sight Planner to get a map of the sky on the presumed date. Compare the relative location of the moon and nearby bodies. Then do the same for one day before and one day after your guess. It will be obvious which is the right day as it will be the only one that is even close with the relative positions.

Task: Find approximate latitude without time or accurate longitude
Discussion: Knowing the date alone will fix the declination of the sun to within about 20' at worst and usually better depending on the season and your knowledge of longitude or time.
Solution: Input your best guess of DR Lat and Lon, and then do Sunrise/LAN/sunset function to get the time of LAN (it will be as accurate as your longitude, but plenty good enough if you are within some 500 miles of right). Then do a LAN sight for Hs max, and run Celestial utility 1, Lat/Lon by mer pass. Input Hs max and the computed time of LAN and that should give your Latitude to within some 20 miles at worst. The longitude out will be just what you put in so that is of no value. Maximum error will be near the Equinoxes with no