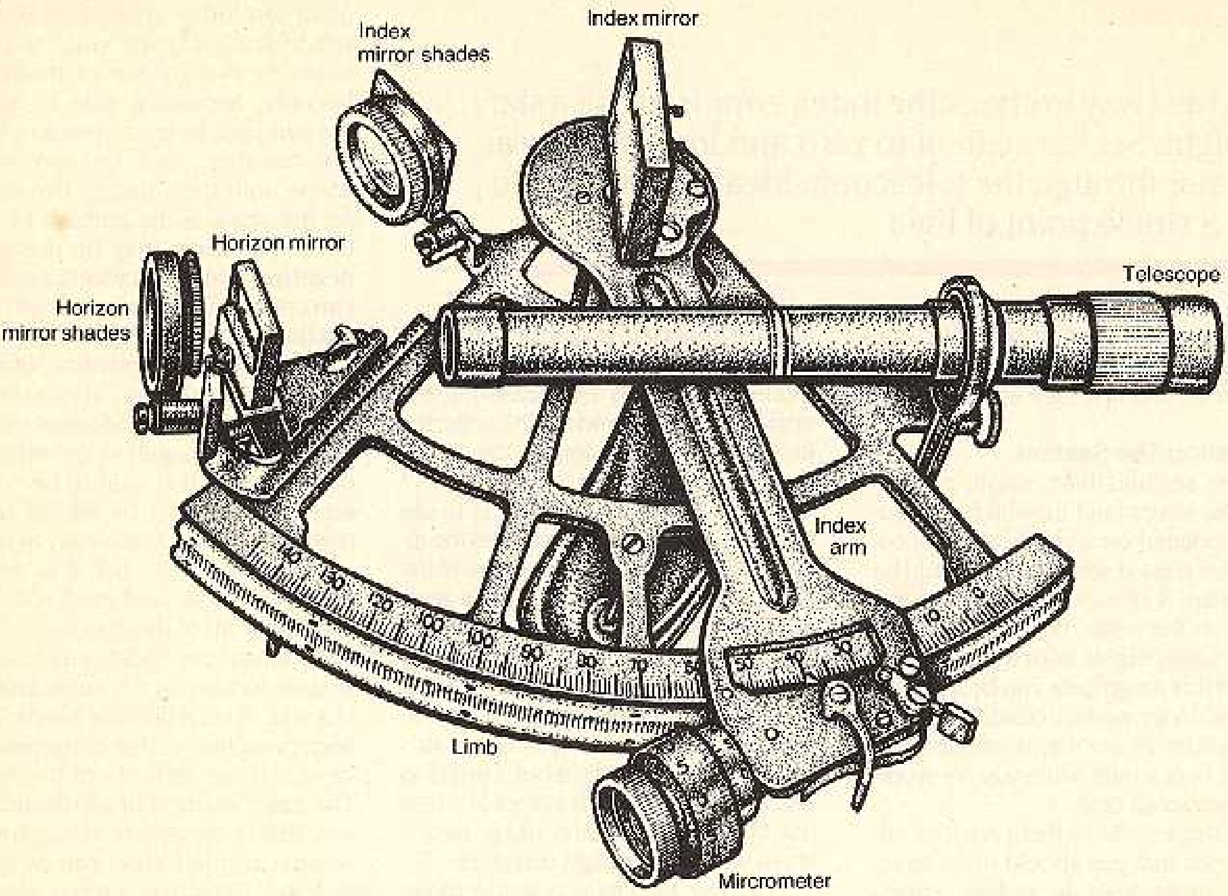

Mastering The Sextant

by John Campbell

A seasoned navigator explains the fundamentals of adjusting and using this venerable tool

IN TODAY'S AGE of sophisticated electronics, many of us have become too reliant on magic black boxes for our offshore navigation. Satellite navigation equipment regularly plots our position and the temptation is to forget to keep a running plot on the chart. After all, at any given moment we can expect a new position as soon as the next satellite comes over, can't we?

We have been sailing with SatNav now for two years. The machine has broken down once and the satellites themselves have gone awry twice, sending out the wrong time and hence the wrong position. Despite the possibility of an electrical problem on board the boat, there is always the chance that the electronic systems themselves may fail to give you a viable position at the crucial moment.

However many electronic aids to navigation a vessel has, it is still prudent to carry a sextant and to know how to use it. The plotting of sights has become very easy with the advent of modern, highly calibrated calculators

Fig. 1 (Above): A typical micrometer-drum sextant and its primary components.

and computers and with the aid of the available tables; but what still requires practice is the actual use of a sextant in taking a sight. It doesn't matter which tables you use, or how fancy your computer or calculator is — without an accurate sight from the sextant, these are virtually useless items.

Let's take a look first of all at how to adjust the sextant to enable us to take accurate sights. Then we can see how

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the sextant is used in practice and perhaps learn some of the little tricks that make taking a sight easier.

Adjusting The Sextant

Most sextants have small, non-adjustable errors built in, which are usually tabulated on a certificate of accuracy. On a good sextant they should be less than ¼ of a minute of arc at any point on the scale. For our purposes, when taking sights from a sailboat, errors of this magnitude can be ignored. Except under perfect conditions, it is impossible to get sights consistently within ¼ of a mile when you are working from small craft.

On most sextants there are four adjustments that you should make to remove or at least to reduce errors. These involve adjustments of the two mirrors — the *index mirror* on the end of the movable index arm and the *horizon mirror*, which is in line with the telescope (Figure 1).

When you look through the telescope of a sextant you see one image directly and another that is reflected by the two mirrors. When taking a sight, the direct image is usually the horizon and the reflected image the heavenly body. The sextant determines the altitude of the body by measuring the angle of the mirror when the reflected image appears to touch the direct image of the horizon.

The first error to check for is to see that the sextant reads zero when the direct and the reflected images are of the same object. If the reading is not zero, all sights will be out by this amount. This is called the *index error*. Many books on navigation will tell you how to measure the index error and how to allow for it. I find that, because this error is so easy to adjust out, I prefer to adjust it to zero, which makes one less line of calculation that could go wrong when working the sight on paper.

The best way to check the index error is to use a star at night. Set the sextant to zero and look directly at a star through the telescope. Ideally you should see a single point of light. If you turn the micrometer screw of the sextant a little, you will see the star separate into two images. Turn the screw back until they merge and it should again read zero.

If, when looking through the telescope with the sextant set to zero, you see two stars one above the other, an index error is present. We will discuss shortly what it means when the two images are misaligned laterally, appearing side by side. If the two images are above and below one another, turn the micrometer screw until they merge. The reading on the scale is the amount of index error. The error may be positive or negative, and this is where confusion can creep in if index error is left for inclusion in the calculation.

If the reading is positive, which is said to be "on the arc," it must be subtracted from any subsequent sights. If the reading is negative, or below zero on the scale, it is said to be "off the arc," and it must be added to any readings. This is quite easy to understand in principle, but it is another matter when you are cold, wet, tired, seasick or all of the above.

To adjust the index error, set the sextant to zero on the scale and look at a star. Then adjust the screw on the horizon mirror — that determines the *up-and-down* attitude of the mirror. The exact method of adjustment will vary from one sextant to another. On some a knurled knob can be turned by hand. On others a screw cap must be removed to expose the adjusting screw. Yet others require a special key, which should be supplied with the sextant. Whatever type of adjustment is used, turn the screw very slowly and gently, until the two images are either superimposed, or at least level and side by side. The index error is now zero.

It is possible to use the sun for checking the index error, but this is a bit more complicated. First of all, remember to put *both* sets of shades down before looking at the sun, otherwise you may seriously damage your eyes.

Looking directly at the sun, with the sextant set to zero, turn the micrometer until one image of the sun is sitting on top of and just touching the other. Read the sextant and note the reading. Then turn the screw until the images are reversed, with the other image sitting on top, and again note the reading.

Each angle that the sextant is measuring is twice the *semi-diameter* of the sun, which is a fancy way of expressing the distance from the center to the edge of one image and from the edge to the center of the other image. It

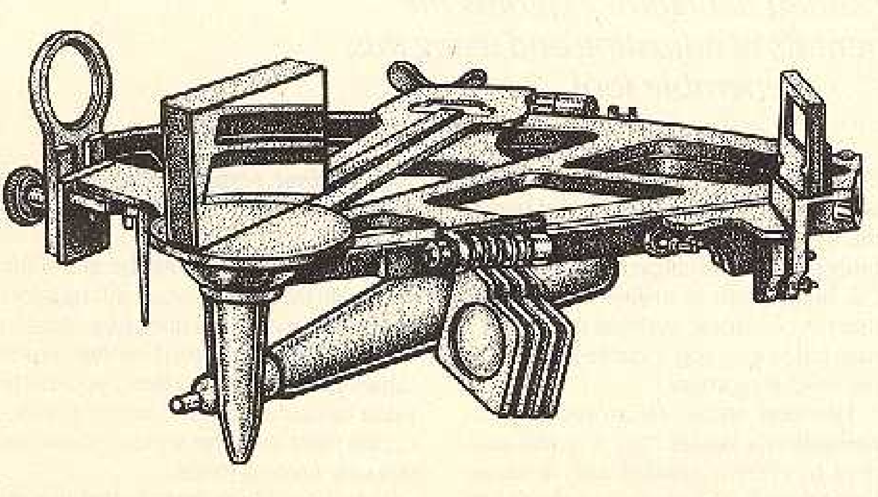

Fig. 2 To check index mirror perpendicularity, view the actual edge of the limb and the image reflected in the mirror itself; the two images should line up as one.

should be close to 32 minutes. For the measurement that is on the arc or positive, you can read the value directly off the micrometer; but for the reading off the arc, do not read the scale directly, but count how many minutes of arc the scale has moved backward from zero. In other words, if the micrometer scale reads 25 minutes, but the reading is off the arc, or less than zero, the micrometer screw has moved through 35 minutes of arc to get to that position (60 minutes minus 25 minutes), so the appropriate reading is not 25 minutes, but 35.

Having logged these two readings, subtract the smaller from the larger and divide by two to give the value of the index error, and note whether it is on or off the arc. It is positive or negative, on the arc or off the arc, as determined by the sign of the *larger* reading. Perhaps you can see why many navigators prefer to use a star!

A third way often touted for finding the index error is to use the horizon. This is possible, but you must take great care to adjust the sextant accurately. The first problem is that the horizon is quite close to us, certainly a lot closer than the sun or any star. So it is possible that the sextant will be reading a small angle because of the height of the index mirror above the horizon mirror. To reduce this to negligible proportions use a height-of-eye as high as possible, which will push the horizon farther away.

The second snag is that even with a clear and calm horizon, it is not easy to get the direct and reflected images perfectly superimposed. If you do use this method, start with the reflected image above the direct image, bring it down until they are superimposed and read the sextant. Then reverse the procedure; with the reflected image below bring it up and again read the sextant. It is unlikely that you will get exactly the same reading both times.

Any of these methods provides a quick check to see that the sextant is still in adjustment when taking a sight, but using a star is probably the most dependable strategy when you come to make the actual adjustment. A good habit to get into, though, is to check the horizon with the sextant set on zero just before taking a sight, to be sure that it has not been knocked out of adjustment since the last use. Any large index error will show up easily as a double image of the horizon.

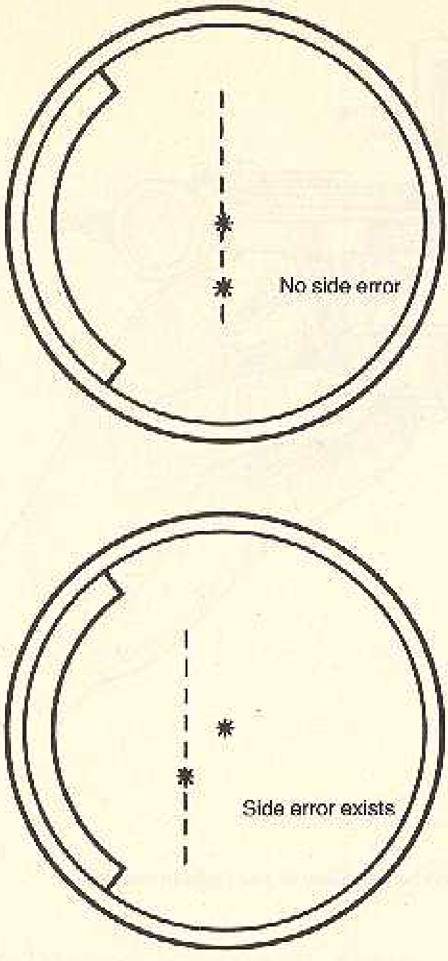

Fig. 3 To determine side error in the horizon mirror, view a star with the sextant set to zero. If the two images are not superimposed or verticaly aligned, side error exists.

The second error to check involves making sure that the index mirror is perpendicular to the body of the sextant. If it is not, this is one reason why the two images of the star in our discussion of index error may have been misaligned laterally, appearing side by side.

To check for perpendicularity of the index mirror, move the arm of the sextant until it is possible to see part of the scale directly and to see part of it reflected in the index mirror (Figure 2). On most sextants this will be possible when the arm is set to about 50 degrees. If the reflection of the scale and the scale itself line up, then all is well. If not, adjust the screw on the side of the index mirror until they do line up.

A third adjustment to check for is perpendicularity of the horizon mirror. The easiest way to do this is to use a star. When looking at a star with the sextant set to zero, the two images should be superimposed. If they are still side by side, then the horizon mirror might need adjustment. Turn the adjusting screw that determines the *side-to-side* attitude of the mirror until the two images are exactly one above the other or superimposed (Figure 3).

Adjusting this screw may well affect the index error, so check it one more time and make a further adjustment if required. If the mirror was far out of adjustment, it may take a series of small adjustments on these two screws finally to get it right.

When checking for index error before taking a sight, it is also worth looking at the sun, with both sets of shades down, with the sextant set at zero. If the two images are more or less superimposed, the mirrors are still perpendicular. If there are two images side by side, then one of the mirrors is out of adjustment and should be checked again.

About the only other thing that may be out of adjustment is the *telescope* itself. This is easy to check but very difficult to rectify. To check on its alignment look into the index mirror. You should be able to see right through the telescope; indeed, this is the path that rays of light take through the sextant when it is being used (Figure 4). The index arm can be in any position, but it is easiest to see the reflected images when the arm is set to the lower part of the scale. If you cannot see right through the telescope, it must have been knocked out of align-

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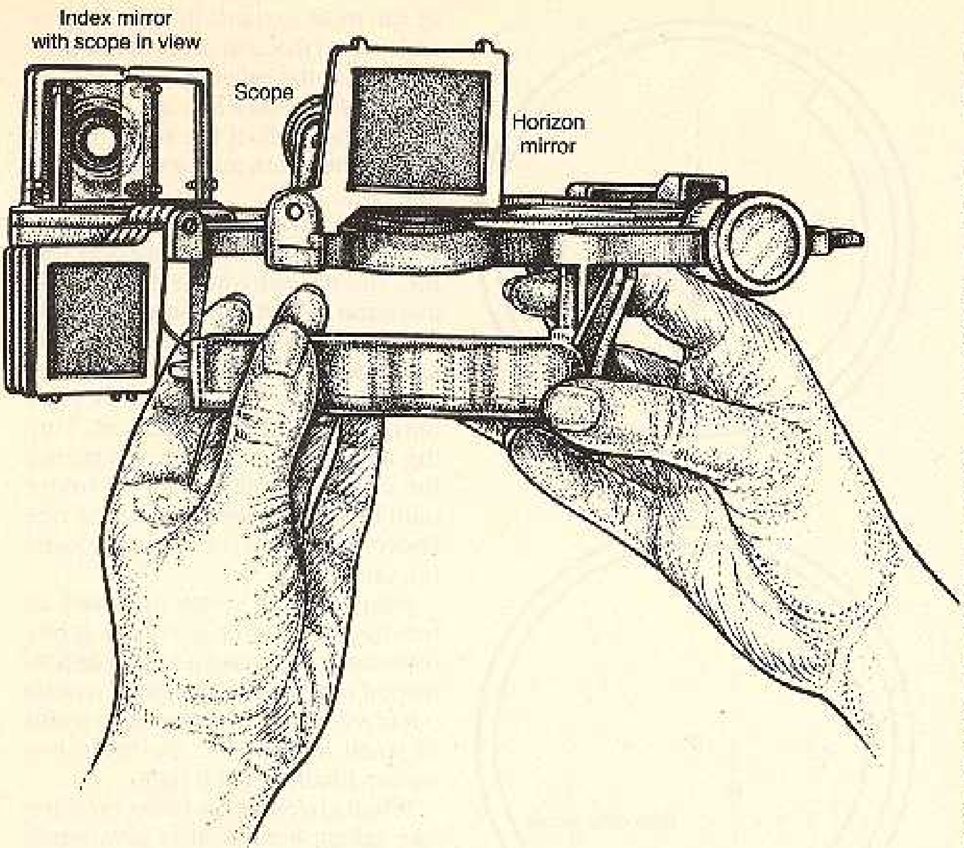


Fig. 4 Looking into the index mirror, it should be possible to see right through the telescope if the scope is correctly aligned.

ment and may prove very difficult to adjust on board.

With the sextant adjusted, we will now look at using it to take sights.

Using The Sextant

Like most physical skills, practice in taking sights makes perfect. It is fine to start off by taking sights when standing firmly ashore, but it is afloat and under rougher conditions that we must make ourselves practice.

One of the most important ingredients in taking a good sight involves one's own body position. You have to be well braced so that both hands are free and you should feel secure enough so that you are not constantly reaching out to steady yourself. On many boats the companionway is a good location, but a Bimini may well preclude taking a noon sight from there. So look around the boat and select a good spot, or several spots if necessary, and perhaps improve them by fitting an extra foot brace or harness anchorage point. It is important that the upper part of your body be free to move around, to compensate for the movement of the boat.

Having selected the best spot, practice "bringing the sun down." Move the index arm and you will see the sun split into two images. Keep moving the arm and follow the lower image (this is the reflected image) down until the sextant is horizontal. Flip up the horizon shades and you should find that the sun's image is close to the horizon. Adjust the micrometer until it is just touching the horizon.

If you lose the image of the sun on the way down, don't despair, just start again. This movement is much easier on a sextant with big mirrors, especially when you come to try it with a star. If the sextant has small mirrors, it is very easy to lose sight of the image, so if you are about to buy a sextant, chose one with the biggest mirrors that you can find.

One trick that you can try here if you are having problems, especially with stars, is to use the sextant upside down. Start off with it set to zero and look at the heavenly body, remembering the shades if you are looking at the sun. Hold the sextant upside down, in your left hand and, while keeping the telescope pointed at the body, move the index arm. As you move the arm, you should see the reflected image of the horizon come up to meet the direct image of the body. You can then turn the sextant over and make the final adjustments in the normal way. This method has the advantage of the telescope staying still, pointed directly at the heavenly body, which becomes much easier to keep in sight.

When the body is brought down close to the horizon, the final measurement must be made with the sextant absolutely vertical. As this is hard to determine accurately, the best way is to swing the sextant deliberately from side to side in a rocking motion. The body will appear to swing from side to side in an arc and the altitude is measured when it just touches the horizon at the bottom of the swing (Figure 5).

It is easiest to have a second person take the time when you say "mark," but if this is not possible, then have a stopwatch attached to the handle of the sextant and start it at the crucial moment. The time from the chronometer can be taken at leisure and the reading of the stopwatch subtracted to give the time at which the sight was taken. The time of the sight is obviously of critical importance.

There are only a few days when a sun sight is not possible. Even in heavy overcast, the sun can be seen through the telescope of a sextant and even if it looks a little blurred, it will often give a surprisingly accurate sight. Often just before sunset, or soon after dawn, the sun will peep through under the clouds. Although lots of textbooks say

One trick, if you are having problems, is to use the sextant upside down. Set to zero, look at the heavenly body, holding it upside down in your left hand. As you move the arm, see the reflected image of the horizon come up to meet the direct image

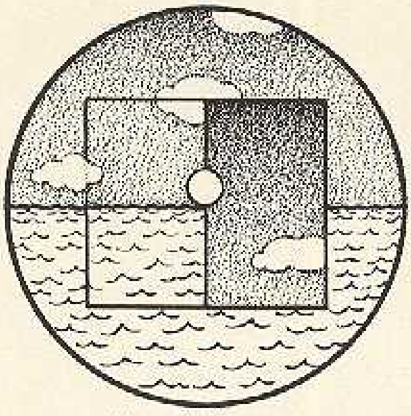
that you must not take sights when the sun is very low, if all the corrections are applied, we have found that such sights are often quite accurate.

Local noon, when the sun passes due north or south of your position, is the traditional time for a sight because such a sight gives you your latitude. When the sun is very high, noon sights can be quite hard and it is easy to keep adjusting the sextant and following the sun only to find that noon has passed and you have missed the highest altitude. The secret here is to bring the sun down to the horizon a few minutes before noon, then as it appears to rise a little above the horizon adjust the micrometer to increase the altitude by one minute. Then looking through the sextant again, the sun will at first appear to be a little below the horizon, but will soon rise up to and above it. Again add one minute to the altitude and look again. This will keep being repeated until the sun no longer rises. This is the noon altitude. If you deliberately add one minute each time, there is no danger of following the sun down without realizing it. Using this method you cannot be more than one minute wrong in altitude.

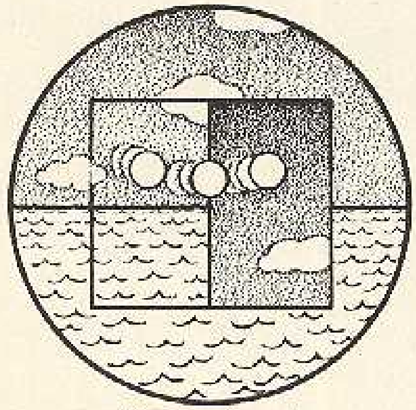
The moon is the most difficult of all the bodies we use to take sights because it moves so fast. It is often visible at the same time as the sun and a sight of each, one after the other, can give you a fix rather than a line of position — better than what you get from a single sight of either. However, before you rely on a moon sight, practice a lot because it is so difficult.

Planets and stars can only be used at dusk and dawn, when both they and the horizon are visible. Dawn is easier than dusk because, theoretically, you have had all night to identify the stars in their relative constellations. When taking star sights at dawn, remember that the sun rises in the east and the easternmost stars will be the first to vanish, so take them first. The next to go are others that are low down and the last to go are those more or less overhead. At dusk the order is reversed; the stars low in the west are the last to become visible.

At dusk, it is useful to calculate ahead of time which stars will be used and what their altitudes and azimuths will be. Preset the sextant and use the compass to look in the right direction. Often stars will become visible in the telescope before they can be seen with the naked eye. In the tropics it gets dark so quickly that one has to work fast and the sooner the first sight can be taken the better.



Moment of tangency



"Swinging the arc"

Fig. 5 By 'swinging the arc' after bringing the sun close to the horizon, it is possible to determine when the sextant is vertical.

Be very wary of taking star or moon sights during the night. It is very difficult to get a true horizon by moonlight. If you must, then use as low a height of eye as is practical to bring the horizon as close as possible. This somewhat reduces the chance of error. Another dodge worth trying is to use the sextant without the telescope in place and to keep both eyes open. This gives you a better chance of seeing the horizon. These are suggestions of last resort and these are the sorts of sights that, while difficult and chancy, can be very interesting to practice.

In rough weather the sight must be timed to coincide with the boat being on top of a wave, the theory being that the horizon is also being made by wave tops. This is a technique that also comes only with practice. At first it is worth plotting a series of sights on a graph and averaging the results to work out a single sight. However, with practice, most people will get a feeling for good sights. Aim for this degree of proficiency.

Many modern sextants, including even some of the better plastic sextants, no longer are equipped with the traditional split-horizon mirror. On the split type, one-half of the mirror is silvered and the other half is plain glass, so that when you look at the horizon, you actually see two images side by side, just overlapping a little in the center. With this type of mirror, you are more likely to lose sight of a star when you are bringing it down to the horizon. The newer type of mirror is such that you can see *through* it, though it also *reflects* over its entire surface. When looking at the horizon through this type of mirror, you can see the two images over the entire width of the mirror. This makes it much better for bringing down a star, as the star's reflected image can be anywhere in the mirror without getting lost. With the older split type, if the image wanders over to the unsilvered part of the mirror, it vanishes from sight.

If shopping for a new sextant, one of these new mirrors is worth the extra cost and, again, pick the sextant with the biggest possible mirrors.

The better plastic sextants, those that have a micrometer drum on the index arm just like a "real" sextant, are capable of quite accurate sights. They do, however, show a tendency to go out of adjustment very easily, so they must be checked with care before every sight. The plastic sextants with a sliding vernier scale are perhaps less suited to serious navigation, but even one of them might save the day if all the black boxes give up the ghost, or somebody has just dropped the super-duper new metal sextant over the side.

Englishman John Campbell is a professional yacht captain whose various charges have taken him and his wife Lana all over the world. He has written a number of magazine articles as well as a book on sailing rigs published in the United Kingdom. When not at sea he lives in a small cottage on the coast of Ireland, 10 miles from Fastnet Rock.