When GPS appeared on the scene, it was an expensive piece of equipment most often found on large yachts and commercial vessels. At over $1,000 it was too expensive for most casual boaters. What a difference a year makes! Or a decade or two! GPS is available for less than a good hand-held radio, and small enough to fit in a jacket pocket, or in an emergency beacon, for that matter. We even have it in our smart phones.

The typical GPS unit tells you where you are, how fast you're going, what time it is and what time you'll get to your waypoint, how far away and in what direction is that waypoint, and where were you five minutes ago. It lets you store your most frequent destinations and follow a favorite route from one place to another. Fancy units even tell you how high the tide is and how much current you'll feel. Really fancy units talk to your radar and your autopilot, bringing up just the right chart to find the harbor entrance, or the sea buoy, or exactly which light it is in front of you. Pretty amazing stuff.

But there are a couple of things you need to know: Batteries (and all nautical things electrical) <u>will</u> fail at some particularly inconvenient time; without charts, the GPS numbers are meaningless. And there are — and will be — times when the most popular portable GPS units simply can't read the satellite signals. "Poor satellite coverage" is not useful information if you're lost.

So the point of this exercise is to take some of the fancy whiz-bang features on a small GPS unit and connect them with some fundamental piloting skills, so that you, as a prudent boater, can get the maximum benefit from this incredible piece of equipment.

A. I'VE GOT ONE — WHAT IS IT?

1. Parts and Pieces

The basic display on a GPS tells you your position by latitude and longitude, the direction you are moving, and the speed over the ground based on the most recent satellite data. It probably tells the time, and it may give you an altitude figure. You get to this basic display usually by turning the unit on and giving it some small amount of time to "find" itself. Depending on the unit, you may have buttons dedicated to major functions, or some sequence of combined buttons which will let you get to those functions. Keep the manual handy until you've used the unit enough to remember where all those functions are.

The GPS depends on reading signals from satellites through its antenna. On hand-held units, the antenna is internal and needs to be put some place where it can see the sky. So, they may not work in a shirt pocket, or under a Bimini top, or on the nav station below. If you don't get good readings, move the unit until you do. And if you're running under a heavy cloud cover, you may be out of luck!

Maybe the most useful display is the one which tells you which way to steer and shows you how far off course you currently are. This is called "crosstrack error." More later. The unit can only tell you which way to steer if you've entered a destination "waypoint" which is, in fact, where you want to go. This is the "go to" function. Waypoints, in turn, are entered based on latitude and longitude, hence a need for a chart, or for having been there at least once and "marked" the waypoint based on what the satellite signals told it about its coordinates.

You may have a display which tells you how many satellites are talking to you, and what their approximate angle is above the horizon. Generally, the unit will select from the most useful signals to determine your position. You may have some sort of graphic display to tell you which satellites are giving you the best signal. Nice to know, but not necessarily critical.

Putting a series of waypoints together gives you a "route." Routing can alert you to the points when you need to change course, tell you how far you need to go overall, and give you some idea of how long it will take to reach the final waypoint at your average or instantaneous speed. Routing, like waypoints, requires a chart.

Somewhere in the collection of functions, a hand-held GPS will have a battery power indicator. Unless you have a separate connector to an on-board power supply, keep an eye on your batteries. Have plenty of spares around, and expect that over a long voyage, you will run out of power at some point. Some units automatically switch to a "battery save" mode, particularly when it comes to display lights. This may not be convenient, if you're running at night. Invest in spares.

2. Using The Numbers

Most boaters are interested in two pieces of information: "where am I now," and "how do I get to there?" Assuming you are working with a simple on-board unit, or a hand-held unit, and that you do not have the kind of integrated chart plotter that looks so neat and costs so much, you need a good chart. With the proper tools, the chart will help you answer both questions.

a. Waypoints

Every place on the planet can be described by using latitude and longitude, which is why GPS is called the "Global Positioning System." Waypoints generally need a name that is meaningful to you, and the latitude and longitude from the chart.

Some units simply list the waypoints by name, allowing you to scroll through the list until you find the right waypoint. Others assign sequential numbers, or allow you to assign numbers, as well as the names. Some units may only list waypoint numbers, in which case you need some sort of quick reference to find the number for the waypoint you want.

Entering waypoints is not mysterious, once you have the coordinates. If you go by some simple naming rules, you should have no problem finding them easily:

1) If you use names, particularly abbreviated names, use names that are as close to the real name as possible. For example, "AVALON" might be the outer buoy at Avalon harbor. "SD3" might be San Diego entrance buoy 3. "LBEAST" might

be the east end of the Federal breakwater in Long Beach harbor. "O-SIDE" might be the outer buoy at the Oceanside entrance. "14-MILE" might be your favorite spot on the fishing grounds.

2) If you use numbers, and a reference system, make some permanent notation on the chart. You can buy number decals and colored circles that stand out from the rest of the chart. Then, find some way to alphabetize the reference list, so you don't have to memorize all those numbers. Make your alphabetized list as close as possible to the names used on the chart. Then you won't have to guess whether "Shelter Island" means the Shelter Island Yacht Basin, the Commercial Basin, or the mole around the launch ramp. Or none of the above.

b. So, where exactly am I?

You might consider the coordinates on your position display as your current waypoint along a route to somewhere. Except you didn't select it from a list, and it may or may not have a name. To make it useful, you need to be able to attach it to some place on the planet, particularly if you need to know which direction to turn to get to some place else. Hence, charts.

Nautical charts are much like land maps, except there are no streets to follow. If you can use a map book, or a common highway map, you can find yourself on a nautical chart. The basic setup is a grid: the horizontal lines measure latitude, the vertical lines measure longitude, and north is up. Find a chart that has the general area, and read the numbers on the GPS screen:

1) First, read along the side to find the degrees and minutes that correspond to the latitude figure on the GPS. Now draw or imagine a line across the chart at that number.

2) Now, read along the bottom or top of the chart to match the longitude number, and draw a line from there up or down the chart to intersect with your latitude line.

3) Where the two lines intersect is where you are. It's like finding the right square on a land map grid, except you don't have to read the small print to find the street name.

There is a little more to reading charts, but we'll get there later.

C. And, the "go to" part?

When you know where you're starting and where you're going, you can figure out which way to point the boat to get there. (Remember, there are no streets on the water, and no street signs, either.) Your compass will tell you if you're heading in the right direction, or which way to turn.

If your destination is already recorded in the waypoint list, simply select it and push the "go to" button (or whatever sequence of buttons your manual describes) and the GPS will tell you what direction to steer, and how far you have to go.

If it isn't in the list, go back to the chart, find the coordinates, and enter a new waypoint into your list.

And while you're looking at the chart, draw a line from where you are to where you want to go, and see if you can actually follow that line without getting into trouble! Your GPS only knows which way to go. It can't tell you about the island in the way, or the shoal water, or the bend in the shoreline. Only your chart can do that!

3. **Crosstrack Error???**

One of the displays on your GPS can show you graphically how close you are to the direct course to your waypoint. Frequently this screen looks like a view down a highway, with a center line and some sort of marker that represents your boat. When your boat is on course, or close to it, the display shows your boat close to the center line. The further you move away from the direct course, the further your vessel marker will be from the centerline.

At some point, you may find that your boat is way off track, and the crosstrack screen tells you something like "Steer 276" or it flashes some sort of visual alarm. What you need to remember is that the GPS only knows the original course line from departure to destination, and it only cares about keeping you on that line. So that instruction to "Steer 276" means "steer 276 to get back to the centerline of the crosstrack display."

If your original course was 180, and there are no hazards, you don't need to go back to the track line. You can simply re-enter your destination using the "go to" function, and get the new heading from your current position.

But, if your original course was intended to keep you down the middle between a couple of islands, or safely down a channel between some other hazards, then you DO want to "steer 276" and get back as close as possible to the center line of the display track.

B. **CHARTS — THE LOW-TECH PART OF THE PROGRAM**

There are plenty of good, detailed, well-written, well-illustrated navigation text books on the shelves, so this discussion will be limited to a basic introduction to charts and what you can do with them. By all means, invest in at least one good instructional book and take the time to learn the basic skills so that, when the GPS does fail, you have more to fall back on than wishful thinking.

Just to give you an overview, however, let's look at what charts can tell you, and how to connect them to the numbers on the GPS display screen. We'll also touch briefly on some basic tools that will make charts even more useful.

If you have one handy, a Chart Kit book will help you to put all this into some useful context. Barring that, having two or three charts of different scales will do the same thing, but take up a lot more physical space.

1. **Charts Parts**

A. Grid Coordinates

We introduced latitude and longitude in the first section, along with the concept that a chart is much like a map, using grids to zero in on each location. Actually, latitude and longitude are like incredibly fine grid lines. Charts show lines only for the major intervals. You use plotting tools to draw in just the small part you actually need of the lines for the smaller intervals.

Unlike maps, however, the numbers on the edges of the chart are read from bottom to top for latitude, and from right to left for longitude, on Southern California charts. Further, the numbers do not start over when you shift from one chart to another. San Diego is always about 32 degrees North by 117 degrees West, whether the chart shows only Point Loma, or everything from Ensenada to San Francisco.

The fine tuning is done by dividing degrees into minutes and seconds, or into minutes and tenths of minutes. This part is simple:

One degree (latitude or longitude) contains 60 minutes
One minute (latitude or longitude) contains 60 seconds
Six seconds is the same as one tenth of a minute.

The key in working with charts is to remember that the divisions are like the divisions on a clock: minutes and seconds, which are fractions of degrees instead of hours. This will come in handy later when you start measuring distances.

Reading the grid becomes a matter of finding the number of the nearest whole degree, and then moving up or down the appropriate distance to measure how many minutes and parts of minutes there are between the degree line and your position.

If there is only one degree number on the scale, look at the minute numbers on either side to figure out whether you are in the middle of a degree, or at the dividing point between two degrees. If there are several degree numbers on the scale, remember that the numbers will always read bottom up and right to left.

B. Roses — Compass, That Is

Somewhere on the chart, possibly several places, there will be a circle numbered clockwise from 0 to 359 degrees. Inside this circle usually will be another like circle, only shifted slightly to one side or the other. In Southern California, the shift is toward the right, or eastward.

Both of these circles will have some sort of notation that says that 0 degrees is North. The outer circle refers to what is called "true north." The inner circle refers to "magnetic north." It's the inner circle that is most relevant to the small-boat operator. Your compass is a magnetic device. What it tells you is "which way to the magnetic north pole?"

Why two circles? The earth has two poles. One is the "axis of rotation" and never changes. It is the north pole to which all of our charts and maps are referenced -- true north. The other is the center of the magnetic influences that result from the earth's molten core. This pole is offset from the rotational pole, and it's actual position changes gradually because of internal changes within the core. That's really all you need to know about the poles, other than the fact that your compass only talks to the magnetic pole, and your charts refer to the true pole.

Most of the time, the small-boat operator can work entirely with the magnetic pole. If, however, the chart only shows the one pole, then you need to know how to factor in the difference, which is noted in the center of the rose. It's simple if you remember two easy rules:

> If the number in the middle of the rose is followed by "E" as in east, you subtract it from the number you read from the circle to get the magnetic value.
>
> If the number in the middle of the rose is followed by "W" as in west, you add it to the number on the circle.

So after you measure the angle of your course line, look at the correction factor (which is called "variation") and either add or subtract it to get to the number you need on your compass.

C. All Those Tiny Numbers

As you look around the chart, you see lots of very small numbers, along with lines that have italic numbers printed at intervals. In some places, the numbers are enclosed in irregular loops. Close to shore the numbers are in an area which is colored light blue. Further away, the numbers are printed on white areas.

All of these numbers have to do with depth. The blue areas are generally shallow areas, and the white areas are deep water. The lines marked with italic numbers are depth contours — every point along a given line is at the depth indicated by the number. The numbers enclosed in loops are points which rise up from the sea bottom, much like hill tops on land.

Whatever chart you use, look for a notation somewhere that indicates "soundings in..." When the chart shows coastal waters, usually these soundings (depth measurements) will be given in fathoms, and one fathom is equal to six feet. On harbor charts, and charts which show small areas in great detail, such as around the Channel Islands, soundings will usually be given in feet. On international charts, soundings may be indicated in meters (one meter is just over three feet), and eventually U.S. charts will all be converted to metric depths.

D. All Those Weird Symbols

Finally, there are a wide variety of dots, circles, abbreviations, odd shapes, and purple plumes scattered around the chart, all of which mean something important. And there are footnotes near the title block, and miscellaneous information in blocks and colors.

If you have a chart book, these marks may be explained in a series of reference tables at the back of the book. If not, then you should invest in a publication referred to as "Chart No. 1" which is available where the charts are sold, and which contains all of the chart symbols used on any chart and now also the sumbols used on electronic chart displays.

The key to these references is to identify the general type of symbol (lights, buoys, rocks, dangers, etc.) and then find the specific symbol or abbreviation which explains it.

Some quick examples:

Plumes indicate lights
Small circles indicate things which move
Dots around other symbols indicate hazards

Think of the aids to navigation in your own harbor, and find their symbols on a chart to get an idea of how the system works.

2. **Distances**

Measuring distances on a chart is very simple, as long as you remember two things:

One minute of latitude equals one nautical mile.
Always measure distance using the latitude scale on the side of the chart closest to the area where you are operating.

Between degrees there are always 60 minutes, so there are always sixty miles of distance. A quick way to estimate a coastwise trip is to look at the latitudes of the start and end points. If you go from 32 degrees to 34 degrees, you will have traveled 120 miles (two degrees, each containing 60 minutes – 60 miles, totaling 120 minutes which is the same as 120 miles).

On large-area charts, the fractions of minutes (and miles) will be measured in tenths, based on the segments between minutes. On small-area charts, the fractions of minutes may be indicated in seconds. Just remember that there are 60 seconds in a minute, and six seconds is the same as one tenth of a minute, hence one tenth of a mile.

3. Directions

To figure out which direction to go between two points, draw a line from one to the other (making sure you won't run through any hazards along the way). Then align one edge of a parallel rule or straight-edge with that line.

If you use parallel rules, then "walk" one edge to the center of the compass rose, and read the direction from the magnetic circle (or do the correction if there is no magnetic circle) which corresponds with the way you want to go.

If you have a triangle with a protractor, you can read the true direction by aligning the triangle with the straight-edge and with the nearest north-south reference line (meridian of longitude). Then apply the correction factor so you can give the information to your helmsman.

When you look at the compass rose, it's easy to read the wrong end and get a number 180 degrees away from what you really intend. The common-sense approach is to remember the following:

> If you want to go generally northeast, the number has to be between 0 and 90 degrees.
>
> If you want to go generally southeast, the number has to be between 90 and 180 degrees.
>
> If you want to go generally southwest, the number has to be between 180 and 270 degrees.
>
> If you want to go generally northwest, the number has to be between 270 and 360 degrees.

So, if your navigator tells you the course is generally southeast, and the compass heading should be about 325 degrees, take a second look — find the number on the opposite side of the rose, and let that number be your heading, in this case 145 degrees.

C. DEAD RECKONING IN BRIEF

In order to keep track of whether you are getting where you want to go, you need to have some way to compare intent to actual progress.The first part is called "dead reckoning" which is a distorted abbreviation of "deduced reckoning." As in, you deduce your position based on what direction you ran, and how long you were running in that direction.

The basic line is the DR track line. This line is nothing more than a line which shows the course you plan to run, and where you expect to be at given points in time. When you have this line drawn, you can compare your actual progress by plotting the GPS positions at each of those time points. By looking at the difference between expected and actual position, you can figure out if you're being pushed off course, running at a different speed, or running right on track.

Drawing the track line is easy. So is plotting the GPS position as you travel along. The step that takes a little more work is figuring out the DR positions at those given time points, usually marked every 30 minutes on the hour and the half hour.

The final piece of information to do this is the speed-time-distance calculation, which is expressed as a formula: 60 D = S T. Translated, this means 60 times the distance in miles is equal to the speed in knots times the time in minutes. Example: Avalon is about 85 miles from Shelter Island in San Diego. Your boat will cruise at 18 knots. To figure out how long it will take to get there, do the algebra:

$$60 \times 85 = 18 \times T$$

$$\frac{60 \times 85}{18} = T$$

283 minutes = T Or 4 hours 43 minutes = Time to run

Along that hypothetical track line, how far will you travel in 30 minutes?

$$60 \times D = 18 \times 30$$

$$D = \frac{18 \times 30}{60}$$

D = 9 miles

So, along your track line, you would measure nine miles between each DR position, and mark your DR track line with a small semicircle and the expected time to be at that position. (Your first DR position will be some irregular time period, unless you depart exactly on either the hour or the half hour.)

Once you have your DR positions and your track line, you can turn to your GPS to see whether you are, in fact, following your planned track in the planned time. What difference does it make? Work the problem at the end of this article, and see.

Good voyaging!

A PRACTICAL EXAMPLE — PUTTING IT ALL TOGETHER

The point of all these measurements and calculations is to be able to determine your position accurately based on what you know about what you're planning to do, or have been doing, en route to your destination. We call it "*dead reckoning*" but what we mean is we are *deducing our position based on our last known position, our speed, and our direction*. There are two parts to the process: drawing our *DR track line*, and then *revising or confirming our route based on being able to determine exactly where we are by bearings and fixed reference points.*

This hypothetical voyage will give you practice in using the *DR track* for planning and then executing your voyage. It will also give you some ideas about why a *DR track line* is an important part of coastal piloting. By convention, all times are based on a 24-hour clock. You should get in the habit of figuring both true and magnetic directions, so both are given in the answers. But don't look until you've done the whole exercise, or hit a reef trying to figure something out. Bon voyage!

Here's the plan:

You want to take your boat to Baja Naval in Ensenada for some maintenance work. As you head south out of Shelter Island in San Diego Bay, you get your charts and tools and lay out the course you plan to run. You also note that the winds and swells are, as usual, out of the northwest.

At 0820 you pass close aboard the San Diego safe water buoy and set a course of 187M and a running speed of 12 knots. You plan to run outside the Coronado Islands, and then turn toward a special-purpose buoy just outside Bahia de Todos Santos, and then turn east toward the Ensenada harbor light.

Your Coronados turning point is the intersection of your initial course line and the 200-meter depth contour.

1. What time should you be at this first way point?

2.. What will be the latitude and longitude?

3. To confirm your position, you plan to take bearings on the lights on Coronado del Sur. What should be the bearings to the northern light? To the southern light?

4. What is the overall distance from this DR position to the buoy outside of Bahia de Todos Santos? What is the direction to run? How far is the buoy from the outer jetty light at Ensenada Harbor? What is the course from the buoy directly toward the light? If you maintain your planned running speed, what time will you reach the buoy, and about what time do you expect to be at the harbor entrance?

5. With your GPS, you plan to keep track of your progress by noting your position every

hour on the hour. What should be your latitude and longitude at the following times?

a. 1000
b. 1100
c. 1200
d. 1300
e. 1400

6. On your final approach to the Ensenada jetty light, you will again cross the 200-meter contour. About what time should this happen? How far from the jetty will you be?

You planned your departure so that the yard will be able to haul your boat immediately upon your arrival. However, the hoist will be in use until 1400, and there are no slips currently available which will hold your boat. You made your course change at the Coronados within minutes of your DR estimate, but your hourly GPS readings differ from your DR plots.

7. Based on the following GPS readings, what time will you arrive at the special-purpose buoy if you maintain your present speed?

a.	1000	32 18.8' N	117 14.4' W
b.	1100	32 07.6' N	117 04.7' W
c.	1200	31 56.2' N	116 55.0' W

8. You decide to come close aboard the buoy, and then to reduce speed on your final leg. What speed should you run in order to cross the 200-meter contour at your originally planned time?

9. At this reduced speed, about what time will you finally be entering the harbor (using the distance to the jetty as your last leg)?

You should be using pages 33, 40, and 42 of the BBA Region 12 Chart Kit for this exercise.

Problem	Answers	Comments
1	0924	The way point is 12.8 miles from the safe water buoy
2	32 25.8 N 117 19.6 W	
3	To the northern light — 103 or 090M To the southern light — 116 or 103M	All bearings are plotted in True, although taken with magnetic compasses.
4	Overall distance — 43.3 miles Initial heading — 145 or 132M Alongside the buoy — 1300 Buoy to jetty — 11.2 miles, course 087 or 074M ETA at harbor entrance — about 1356	The actual time of arrival will depend on traffic around the entrance. Using a jetty or a light gives us a general idea with enough accuracy for planning our voyage.
5	DR positions: 1000 32 19.8 N 117 14.8 W 1100 32 10.0 N 117 06.8 W 1200 32 00.2 N 116 58.7 W 1300 31 50.2 N 116 50.7 W	Convention is to calculate DR positions on the hour (and half hour), and to calculate the first plot after a fix to bring the overall plot into an hourly format. Thus the first DR position is only 36 minutes down the track line.
6	Cross the 200-meter contour at 1347 Distance to the jetty — 1.75 miles	You could use the depth contour and a radar range ring to establish a fix at this position, if visibility were poor.
7	Revised ETA at the buoy — 1230	With the prevailing winds and swell, and possibly a tidal current as well, you are getting a 2-knot boost in your speed made good (SMG).
8	Revised speed from buoy to jetty — 7.4 knots	The contour is only 9.5 miles from the buoy, and you have 77 minutes to fill.
9	Final ETA — 1401	Again, traffic will dictate your actual arrival. However, this planned ETA at the jetty will assure you the hoist will be free when you arrive.

