EXPLORING

GPS

A GPS USERS GUIDE

Global Positioning System

2nd Edition

Easy to read

Department of Lands

THE GOLDEN RULES OF GPS

1. Use four or more satellites
2. Use only when the PDOP<5
3. Use the correct map datum
   and, if you can,
4. Use an average position

Exploring GPS - A GPS Users Guide

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For

The Global Positioning System Consortium

(GPSCO)

Although aimed at the general user, this book will go a long way towards satisfying the curious and technical reader

Introduction

This book is written to instruct and entertain.

It began life as a one-day instruction course for field workers and professional map users coming to grips with GPS, looking to see how it could be used in their daily work. Shortly after, the recreational aspects of GPS were recognised and included.

Here we side-step complicated equations and GPS-jargon and get down to the basics of how to get the most out of hand-held GPS receivers. You are encouraged to work through the 12 Exercises to get a working knowledge and feel for GPS in the real world.

Ways to improve accuracy, including Differential GPS (DGPS), are given particular attention.

One word two meanings

In this book, when we use the term "GPS" we mean the complete satellite system. That box of electronic wonders you hold in your hand we call either a "GPS receiver" or simply a "receiver".

GPSCO

GPSCO was formed in 1989 as a consortium of four organisations with an interest in GPS. The original membership changed in 1993 and now comprises:

- The School of Surveying and Spatial Information Systems University of New South Wales.
- Technical and Further Education New South Wales. (TAFE NSW).
- Land and Property Information, Department of Information Technology and Management.
- School of Civil Engineering, UNSW at the Australian Defence Force Academy, (ADFA).

In 1990, GPSCO won a grant from the New South Wales Education and Training Foundation which enabled development of a series of GPS training courses. Further funds from GPSCO and the cooperation of Land and Property Information allowed refinement of the course notes and production of this book.

Introduction

What's this book all about? What's in it for me?

Relax!

This book was written with you - the reader - as the central person.

The questions that are buzzing around in your head right now have almost certainly been asked before by people attending our courses over the last dozen or so years. So we have a fair idea of what you want to know. Even though you may be an absolute novice, we know you are not a fool, so we won't treat you like one.

We expect you to take a little while to get used to new concepts and new words, so we will explain their meaning when they first occur, after that, we won't bore you by repeating explanations. If you come up against a new word or phrase which is not explained, chances are, you missed it earlier. As an aid, we have also included at the back of the book, a list of commonly used abbreviations, and index.

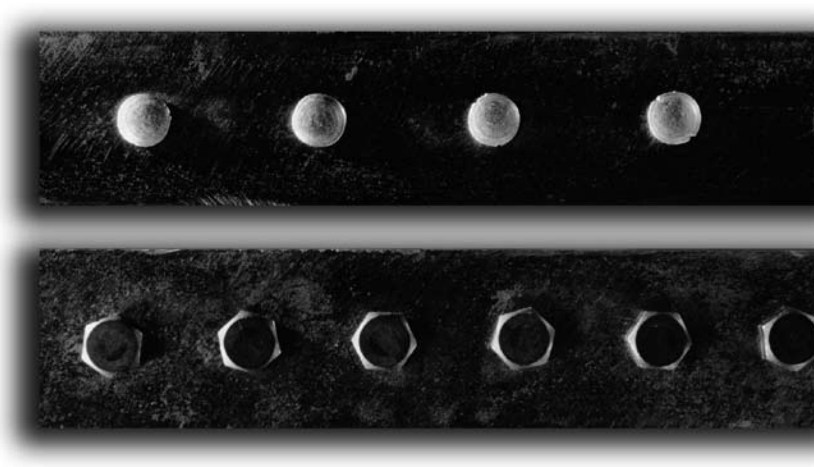
TRY TO RESIST the temptation to jump chapters - it really is important to understand why things happen the way they do - that way getting the most out of GPS will be so much easier. And that, after all, is why you are reading this book.

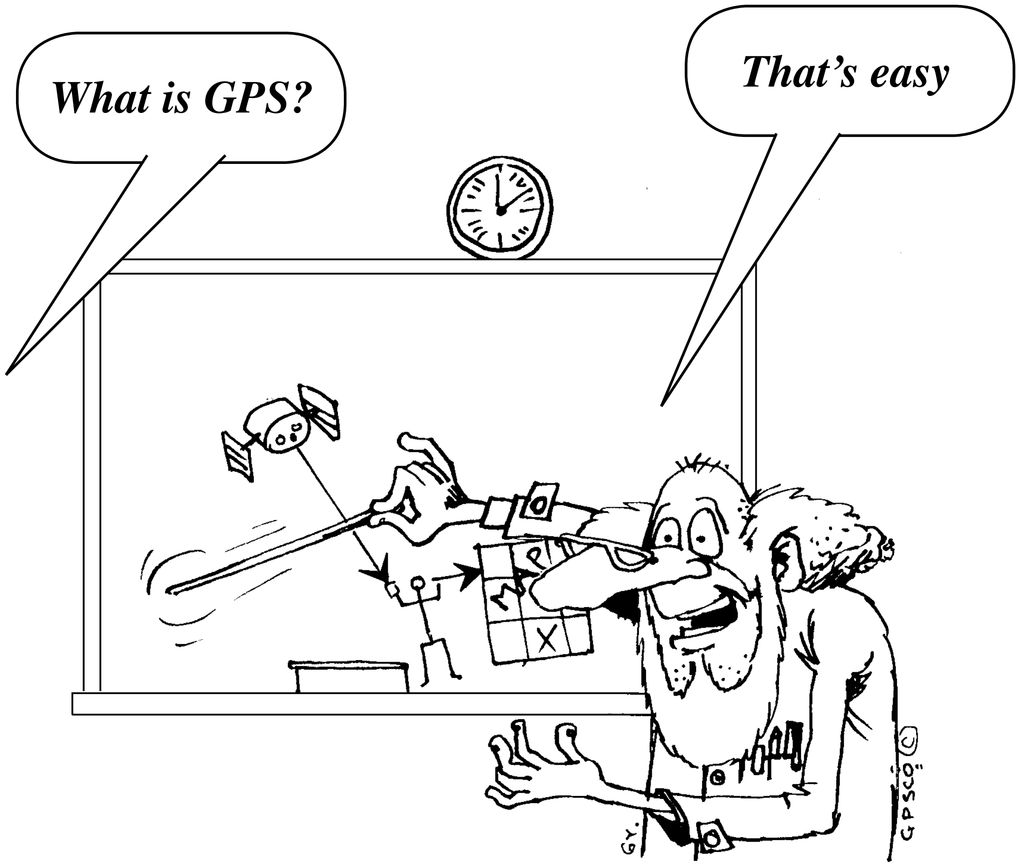
The technical bits

A book of this nature cannot avoid technical explanations, but it can limit their intrusion. We believe that too much techno-speak interrupts the flow of the text and could lead to incomplete understanding, or worse, confusion. So, we have printed the TECHNICAL BITS *in italics. You can skip them the first time round, and come back and read them later to nicely round off the subject.*

Contents

Chapter 1
The Nuts And Bolts




What is GPS?
That's easy

Where on Earth am I?

Map users and navigators over the ages have wrestled with this problem. They have devised many and varied solutions.

But not one of them came up with a method which gave accurate positions, day and night, in any weather conditions, anywhere on the globe. That is, not until GPS hit the scene.

So what is GPS?

GPS is not just the ideal navigation tool - it's much more!

It's an incredibly accurate timing system, and can also be used as a precise surveying tool. For our purposes though, we'll stick to navigation.

As you may already know GPS stands for "Global Positioning System".

What's in it for me?

GPS can find the things a navigator/map user wants to know most:

- your position on the Earth
- your height
- your speed and direction of travel
- the time

What do I need to get GPS to work for me?

You need only two things. A GPS receiver and your brain. Both come in a great variety of shapes, sizes and capabilities.

Like brains, GPS receivers are remarkably similar, no matter how different their packaging may be. So forget about the bells and whistles, those things aren't important yet. Right now, we are talking about the basic nuts and bolts.

Is GPS a new idea?

Not really! Satellites are only artificial moons, and mankind has navigated by the moon and stars for thousands of years. Today though, we find ourselves staring at a GPS receiver's screen rather than star gazing. So when you think about it, it's not exactly a new idea.

GPS is not even the first satellite navigation system. That honour goes to the TRANSIT Doppler System and it has been in use since the sixties.

Who developed GPS?

Actually, GPS has been under development since flared pants were the 'in' fashion. The United States Department of Defense (DoD) found the money and did all the hard work.

This ideal positioning system did not come cheaply. It cost DoD over 12 billion US dollars to develop GPS. And they don't let us forget who's in charge.

What did they get for all that money?

The best navigation system of all time - that's what!

We've already said that GPS gives you your position, speed and time.

What's not so well known - and extremely useful - is that GPS will also work:

- anywhere in the world
- 24 hours a day, every day
- in any weather condition
- without any cost to you. It's FREE!

What makes up the GPS system?

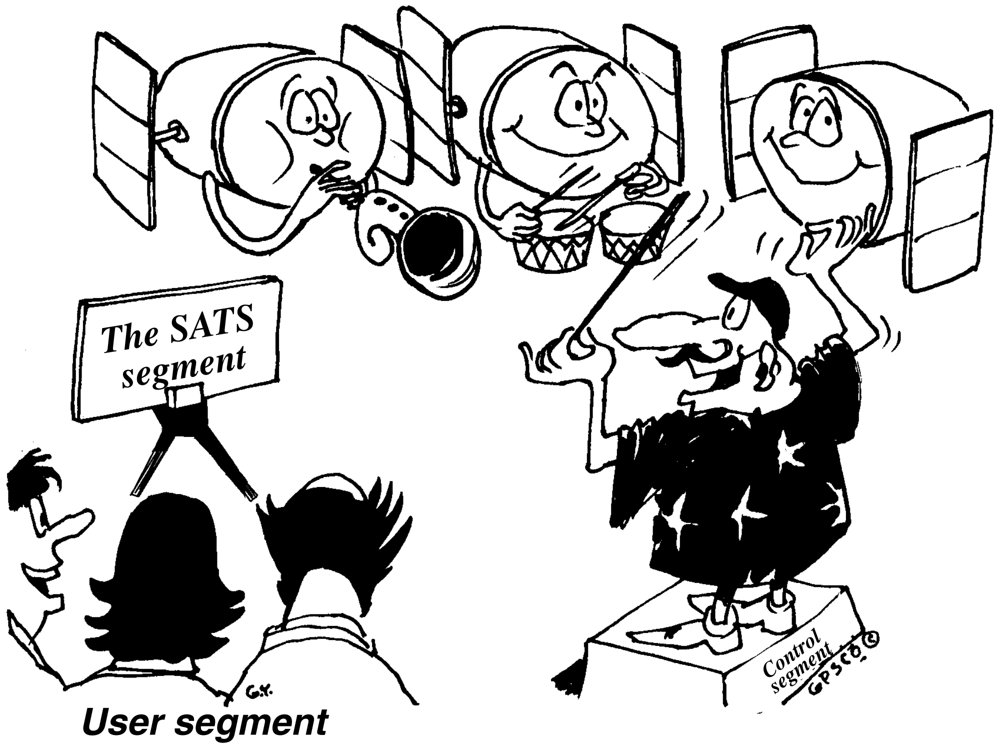
There are three segments.

1. First of all about 24 satellites. The actual number may vary as satellites are occasionally replaced or shut down. Not surprisingly, this is called the 'space segment'.

2. These satellites are tracked and controlled from strategically placed military bases on Earth which calculate each satellite's exact position and ensure that it is working properly. The bases form the 'control segment'.

3. The last part of the system may surprise you. It's the 'user segment'. That means you and anyone else who uses GPS.

The three segments work together like an orchestra. The conductor (control segment) tells the musicians (space segment) how and what to play, while the audience (user segment) can only listen and enjoy.



What is a GPS satellite?

Basically, it's an orbiting radio station - a transmitter.

Antennas for sending and receiving radio signals project from the casing of the 'platform', as the body of the satellite is called in space jargon. Attached are two large 'wings'. These wings are covered with solar cells which generate the power to run the satellite. All up, the satellite is about the size and weight of a large four-wheel-drive vehicle.

The heart of a GPS satellite is its atomic clocks. No, they don't run on atomic power; they are called atomic clocks because they use the regular vibration of atoms as a metronome. Atomic clocks are incredibly accurate. They lose only one second every three hundred thousand years or so, give or take a millennium. The satellites use them to generate the morse code-like signals that they transmit.

Although GPS satellites are built to withstand a lot of punishment, their real enemy is technology. Older models are continually being replaced by newer ones, with the latest design features.

Over the last two decades several generations of GPS satellites have been designed, built, launched, and eventually put out to pasture.

The Block I satellites were the 'experimental bunnies'. Eleven were launched between 1978 and 1985. Some proved their reliability by still functioning up to ten years later. They were replaced by the Block II 'Operational' satellites.

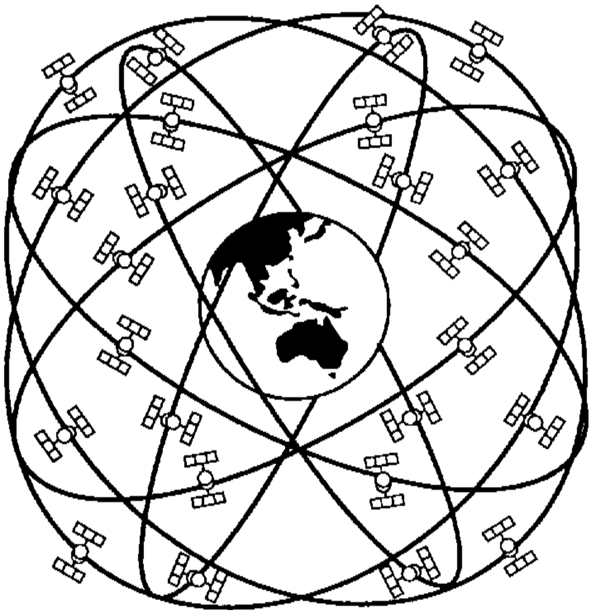
The next generation, the Block IIR's ('R' for Replenishment), began being launched in 1997. The last will be launched early in the 21st Century. These satellites have the special ability to operate without commands from the Control Segment for up to six months if necessary - called "AUTO-NAV" - it's an amazing and innovative feat.

The latest generation, the Block IIF's ('F' for Follow-on), will be our main workhorses for the next ten to twenty years. They have a longer design life, new signals, fancier atomic clocks, and can be easily upgraded with future satellite software improvements.

Planning has already started on the Block III satellites. The first one should be ready around 2010.

Where are they?

The 'SVs' (space vehicles) are launched into six high, nearly circular orbits, each containing four SV's. The orbits, like the satellites, are evenly spaced around the Earth enclosing it in an invisible birdcage.



Each satellite whizzes around about 20 200 kilometres above the Earth's surface. That's about the same distance as from the South Pole to the North Pole, the long way ... but straight up! This incredible altitude, and the birdcage pattern of orbits allows us to 'see' between four and ten satellites at any time, from anywhere on the globe.

GPS satellites travel at an amazing speed - about four kilometres per second - faster than a speeding bullet. Because they are not geo-stationary like communication satellites, they rise and set like any other star or planet. They orbit the Earth twice daily, rising four minutes earlier each day.

But what do we really see?

Nothing. Not even a light in the night sky. They're too far away. No problem; we only want to hear them.

On what frequencies can we hear GPS signals?

GPS satellites transmit on two frequencies, called L1 and L2.

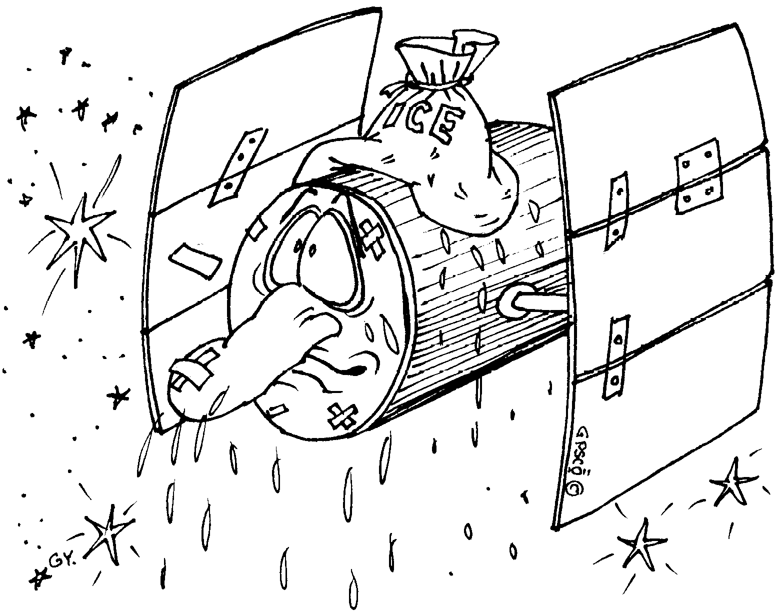
L1 and L2 are microwave (L-band) frequencies of 1575.4 MHz and 1227.6 MHz respectively. GPS uses these frequencies because instead of bouncing off or being absorbed by the atmosphere, as some radio waves are, they penetrate cloud, rain, smoke, smog, dust and air pollution.

What sort of signals do GPS satellites send?

Three different signals are sent. Two are in code: one for military users (the P-code) and the other for civilians (the C/A-code). Both are binary codes. If you took a peek at them, all you'd see is 0's and 1's in no particular order, much like a monkey's attempt at Morse Code.

The third signal, a navigation message, is available to all users. Basically the satellite is saying, "My position is X, Y, Z and I'm healthy" Healthy? It's been eating its greens? Not quite; it's just letting us know this SV is 'all systems go', so you can use it with confidence. So, The NAV message is like a star map. It tells you where the sats are in the sky.

Civilian GPS receivers can only use the C/A code and navigation message.

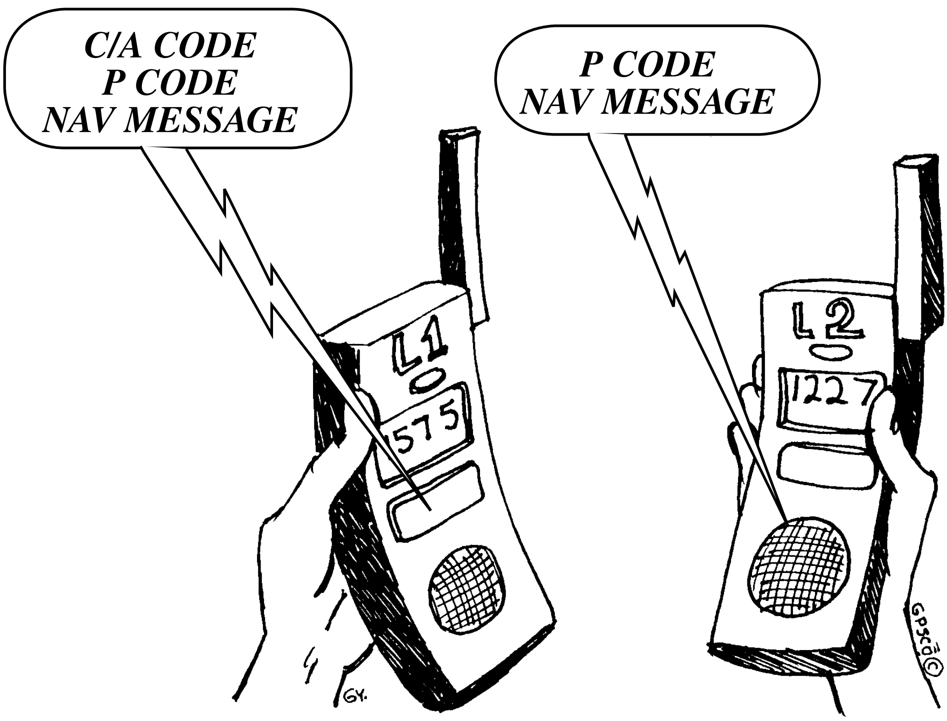


More about GPS signals

All these signals are broadcast simultaneously. If you were to listen in it would sound like a horrible mess, as if three songs were being played at once. This would worry mere mortals like us, but GPS receivers are designed to be able to recognise, and deal with each song separately.

The C/A-code is the 'Clear Access' or 'Coarse Acquisition' code. Available to all users, it is carried only on the L1 frequency. The C/A-code sequence is very short and lasts for only one millisecond. The sequence then repeats itself continuously. A different C/A code is broadcast by each satellite, so you can tell which satellite you are listening to.

The P-code is the 'Precise' or 'Private' code, and is available only to privileged users, namely the military. Carried on both the L1 and L2 frequencies, its code sequence is extremely long, lasting for 267 days before it repeats. In fact, the code is so long that it is broken down into one week chunks. Each satellite broadcasts a unique portion of the P-code, so you can tell which satellite you're listening to.

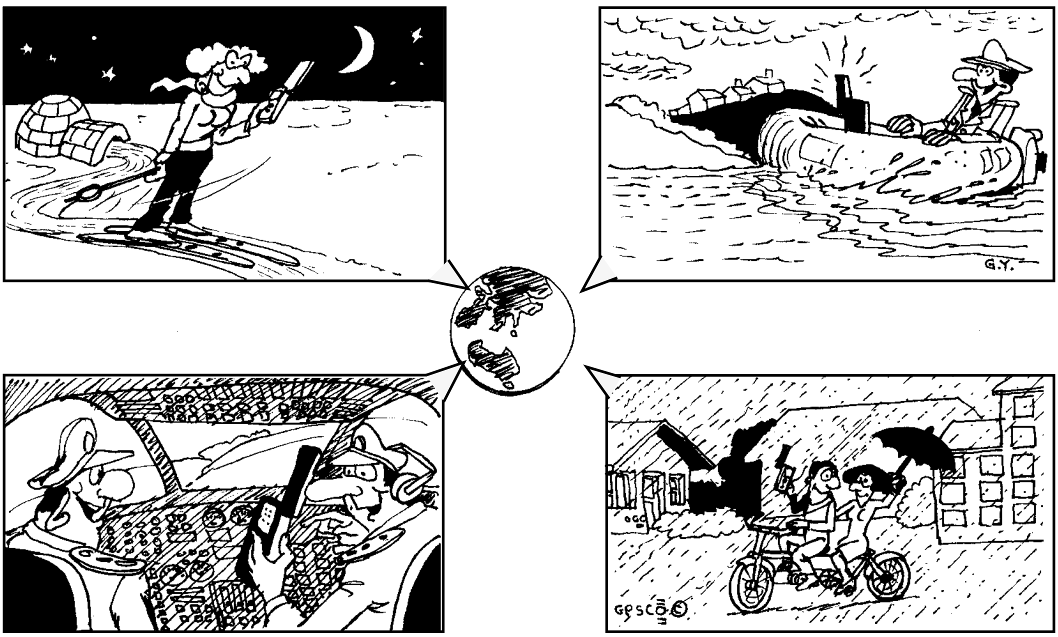


Anti-Spoofing (A/S)

'Spoofing' is a military term to describe broadcasting a false signal to confuse an enemy. Wary that the real P-code may be spoofed by baddies, the DoD, introduced an Anti-Spoofing measure, (the W-Code), which when added to the P-code resulted in the Y-Code. As such the resulting code is commonly called the P(Y) code. The Y-code can only be deciphered by specially equipped and authorised military users.

With all that security, are we still allowed to use GPS?

You bet we are. From the word 'GO!', civilian needs have been catered for. There are already more civilian users than military users. Also, the satellites have no idea who is listening to their signals. Neither does the DoD. So there is no way you can be billed for using GPS. It's free!



There must be a catch?

There is. In fact, there are a few.

You have no control over how the system is operated. The DoD and Department of Transport (DoT) have complete control.

At the risk of stating the obvious - we must say that GPS will only work when you can 'see' some satellites. GPS will not work in a building, underground or underwater.

Another catch is that you must be prepared to give over to blind faith when using GPS. GPS is a set and forget system. You just set up your GPS receiver, turn it on, and it tells you where you are.

"But you said the User Segment was an important part!", we hear you say. It is; this is where your brain comes in. Don't leave it at home. You'll need it to make sure the results you read on the GPS receiver's screen make sense. How do you do that? Well, first you'll need to know how the system works.

Chapter 1 Summary

- The US Department of Defense developed GPS as the ideal navigation tool

- GPS can give you your position, velocity and the time anywhere, anytime, in any weather

- GPS is made up of three main parts:
  - the space segment
  - the control segment
  - the user segment

- GPS satellites currently transmit on two different frequencies:
  - L1
  - L2

- GPS satellites currently send three different signals:
  - C/A-code
  - P(Y)-code
  - a navigation message

Chapter 2

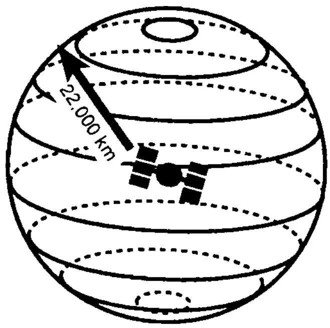
How Does it Work?


How does GPS work?
That's classified information
G.Y.
GPSCO ©

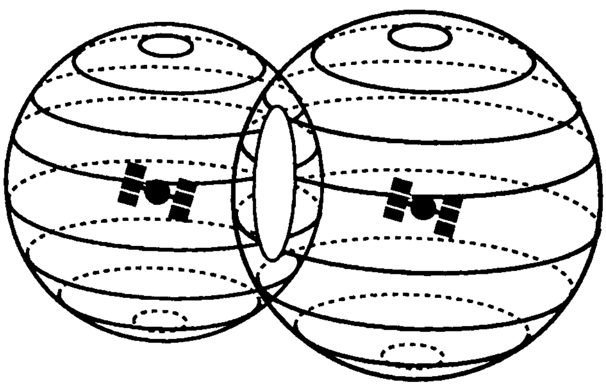
How does GPS calculate your position?

It's all based on distances and a little geometry!

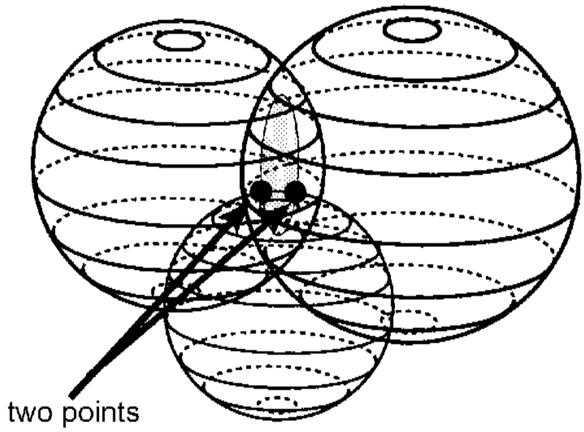
Let's assume you are lost. You take out your handy GPS receiver, push the 'ON' button, it finds a satellite and measures the distance to it. Let's say 22,000km for argument's sake. A single distance is not really a big help, because all you can conclude is that you are somewhere in space 22,000 kilometres away from the satellite. Even though you know where the satellite is (from the navigation message), you are still lost.



Now let's measure to another satellite, say 24,000km. This narrows down the possible places you can be. You are 22,000km from the first satellite and 24,000km from the second satellite. There are many such places. They trace out a circle in space and lie on the intersection of the two spheres. Your position is somewhere on this imaginary circle. You still don't know exactly where you are, but things are starting to look a bit better.



Your GPS receiver now makes another measurement, say 23,000km, to a third satellite.



This is more like it. It restricts the number of possible positions to just two, (the intersection of three spheres is two points.) Panic stations! Which one is right?

No problem. Your GPS receiver works it out for you.

To summarise, the three distances your GPS receiver measures enables it to calculate the three dimensions of your position: Latitude, Longitude, and Height. We refer to these as the three unknowns.

How do you measure the distance to a satellite?

We thought you'd never ask.

Remember this equation from High School?

Distance = velocity x time

It can be put to good use to solve a lot of practical problems, for example:

"How far will I go in 3 hours if I drive at 80km/hr?"

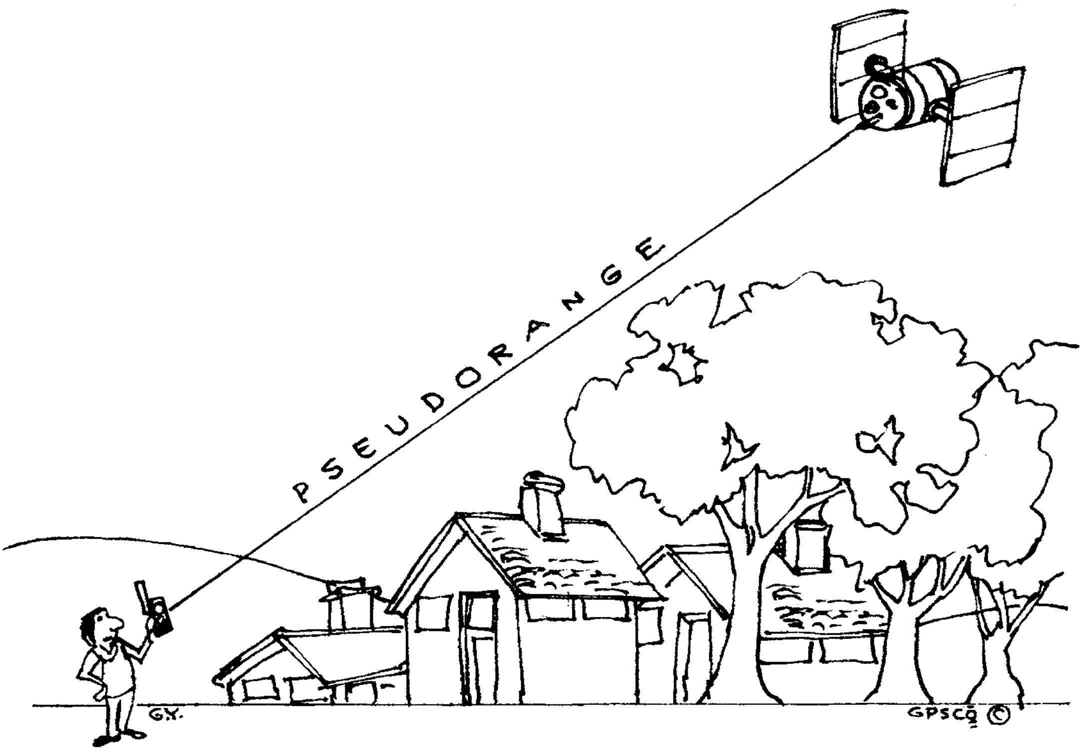
Using the above equation,

Distance = 80km/hr x 3 hours
Answer = 240km.

We do the same in GPS.

Measuring GPS distances

In GPS-speak we call the distance from you to the satellite a pseudorange.



Signals from GPS satellites are microwaves which travel at the speed of light - that's about 300,000 kilometres per second - quite a bit faster than a car. But the formula still holds.

So if you multiply the signal's travel time (from the satellite to your GPS receiver) by the speed of light, you have measured its pseudorange!

But how do you measure the travel time?

With a good stop watch?

Right! It needs to be a VERY good stopwatch, because a signal from a satellite takes only about seven one hundredths (0.07) of a second to reach us!

What if, instead of a stopwatch, you only had a clock?

Still OK! You note the time the satellite sent the signal and the time you receive it. The difference between the two is the time of travel.

Let's look at a real example;

You leave home to drive to work, noting that the time on the kitchen clock is exactly 8:00am. After battling the peak hour traffic you finally 'bundy' on at exactly 9:00am on the bundy clock. Your time of travel is exactly one hour.
Right? Well... almost!

You have used two different clocks to measure your travel time. Who's to say that the kitchen clock keeps the same time as the bundy clock? It's the same with GPS. Who's to say that the satellite clock keeps the same time as your GPS receiver's clock?

Surely they must have to be synchronised ...

How can you be sure that both clocks are synchronised?

You can't. GPS receivers and satellites cannot keep precisely the same time. This is because the satellites are provided with those extremely accurate, and expensive atomic clocks. GPS receivers, on the other hand, have only cheaper, less accurate, quartz crystal clocks - similar to the watch on your wrist. Like your watch, they may run fast or slow.

So your GPS receivers clock does not keep exactly the same time as satellite clocks. This lack of synchronisation leads to an error in the time of travel and therefore the length of the pseudoranges. Any change in the length of the pseudoranges results in a change to your computed position.

What to do?

For our purposes, all the satellites keep the same time. And our GPS receiver's clock is out of synchronisation by an equal amount for each satellite. All the distances measured by our GPS receiver will be affected by the same error. So why not just make it another 'unknown' (like the Latitude, Longitude and Height) and work it out at the same time, and in the same way?

Four unknowns

Now we have a total of four unknowns - the three position dimensions (latitude, longitude and height) and our GPS receivers clock error. So, instead of measuring pseudoranges to just three satellites, we measure to FOUR satellites. That'll do it! From the four known quantities, the measured pseudoranges, we can find the four unknowns - Latitude, Longitude, Height and Clock Error.

How many satellites do we need?

This is such an important point we call it our first Golden Rule;

GOLDEN RULE No.1
For a three dimensional (3D) position,
use four or more satellites.

So how accurate is GPS?

Statistical testing tells us that most of the time the civilian (C/A) code will give an answer to within 7 to 15 metres of your true horizontal position and about 12 to 35 metres of your true height.

Authorised P(Y)-code users can expect the same accuracy or better, and some signal protection advantages.

What do these 'errors in position' actually mean?

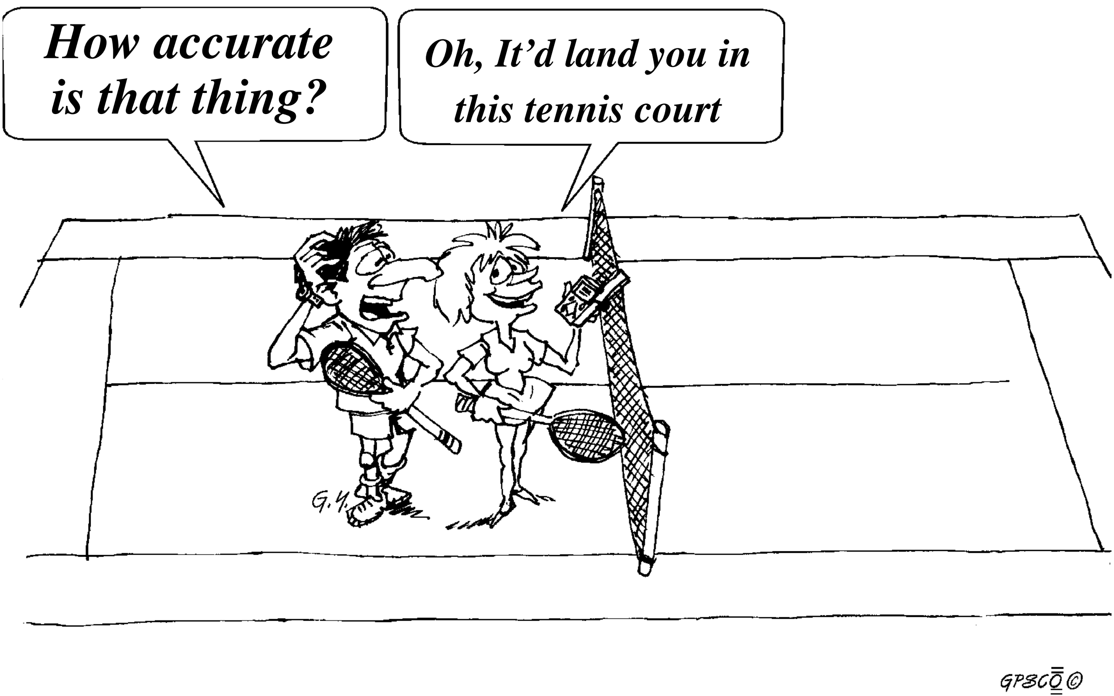
Let's begin with horizonal errors.

Horizontal errors

Say you took a position with a GPS receiver outside your front door two days ago, another yesterday, and a third today. You must expect that the difference in position given - for that same point! - will vary by anything from zero to up to 15m - or even, occasionally, up to 30m. Even positions taken seconds apart will have variations.

If you live in suburbia, an error of 30m, would put you in your neighbour's back yard, or the house across the road!

On your farm however, you might just as well say "So what? There's no house near me, that's good enough."



Another way of looking at it is to imagine you are standing in a tennis court. Your true position lies somewhere within an area of ground, about the same size as two tennis courts side by side.

Then again, a fisherman, or glider pilot, or traveller in the outback, only has to be navigated by his GPS receiver to within sight of his objective, to be thankful for the day he bought it.

Vertical errors

Vertical errors could be serious. The accuracy is about 30 metres most of the time. That's nearly 100 feet in the language aviators still use. Sailors at or near sea level are usually quite surprised when their GPS receiver indicates - by displaying a negative height - that they are under water.

Didn't the DoD scramble the GPS signals to decrease accuracy?

Yes, you're right, they did. But they stopped it in May 2000. Read on.

Selective Availability

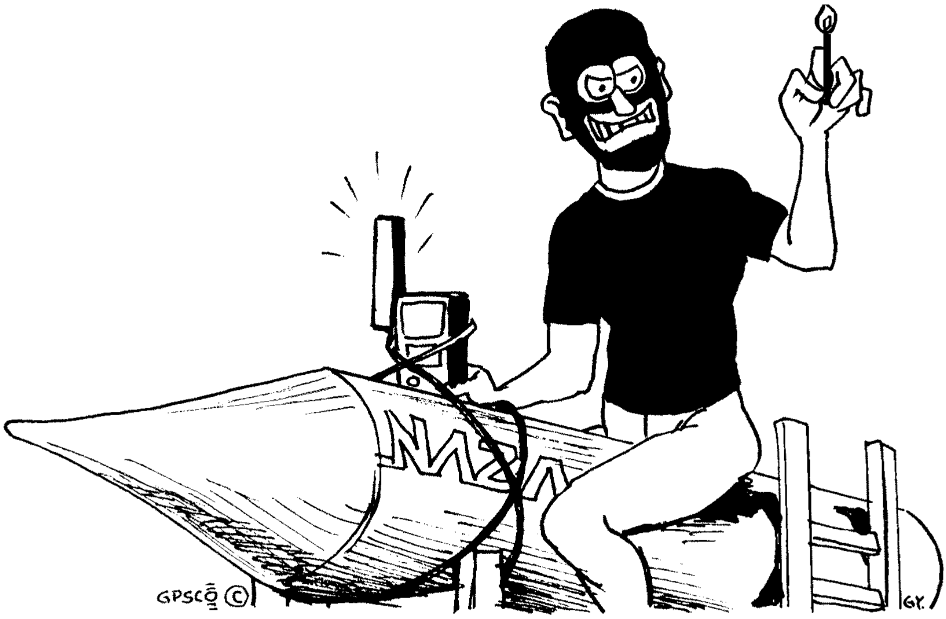
The policy of degrading the civilian (C/A) code was called "Selective Availability", or S/A for short. It was first invoked in early 1990. Basically, the DoD went to a whole lot of trouble to scramble the satellite signals so that civilians could not get accurate GPS results. This helped protect GPS being used against the establishment, as only authorised users could get accurate results.

S/A worked by introducing an artificial clock error into each satellite's signals and errors into each satellite's position in the Navigation Message. The combined effect of these errors was to downgrade the accuracy of GPS.

What was the accuracy when S/A was on?

For ten long years GPS users had to put up with horizontal positions that were accurate to only 100m. Heights were even worse; errors up to 150 metres were the norm. In those days, GPS only got you within sight of your objective, unless you went to a whole lot of extra effort and trouble.

So if you have the position of any favourite spots that you marked with your GPS receiver before May 2000, they may not be very accurate. It may be a good idea to do them again, since GPS is more accurate today.



Didn't something strange happen during the Gulf War?

S/A was designed so that the DoD could turn its effects up, down or even off. During times of national crisis the plan was to crank S/A up to even higher levels to really scramble any civilian GPS receivers the baddies might be using. However, in that first decade S/A was actually switched off on at least two occasions - temporarily. One was during the Persian Gulf War, the second during the Haiti Police Action.

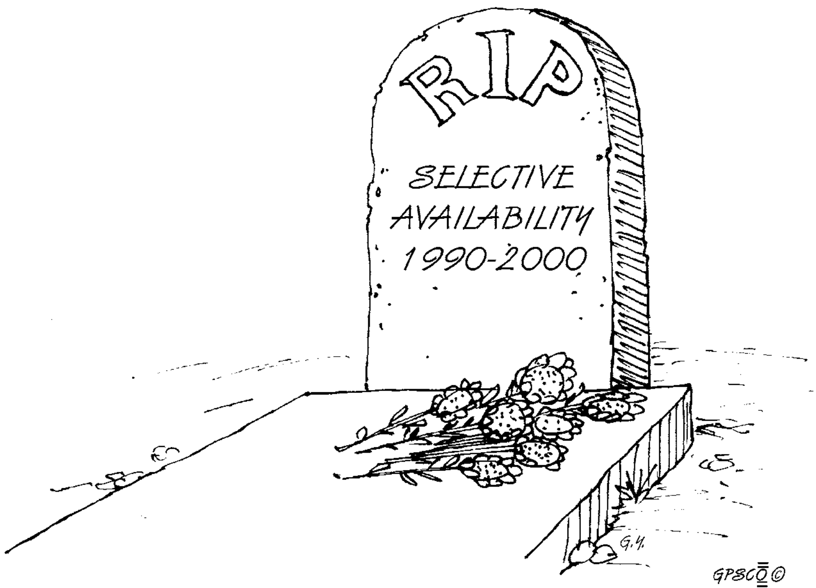
Why? Rumour has it that the DoD didn't have sufficient military GPS receivers for its troops and were forced to use models intended for civilians. So they had to turn S/A off, because they didn't want the GI-Joe's getting lost.

During these two crises civilians got a quick glimpse of the Global Positioning System's full potential. The accuracy was incredible but short lived. As soon as the shooting was over, S/A was switched back on.

Going the way of the Dinosaur

The growing pressure from world-wide GPS users ensured that the question on everyones lips was not "Will S/A be turned off?", but "When will it be turned off?"

In early 1996 the White House announced its intention to terminate the policy of S/A within a decade. Well! You can imagine everybody's surprise when in May 2000, fully six years earlier than planned, S/A was turned off once and for all. Overnight your GPS receiver was ten times more accurate.



Why terminate S/A? Well, GPS is a global utility, used by every man and his dog. S/A's termination offered major safety, scientific and commercial benefits to all. Besides, users had found a way to sidestep S/A, by using Differential GPS (DGPS). We will hear more about DGPS later. That, and the fact that DoD had been doing some homework on "NAVWAR" and had come up with "Regional Denial" - a new, slicker way to limit access.

Regional Denial

Our old bugbear S/A was based on global degradation. That is, everybody got the same dose of it. Big or small or average, all were affected just the same.

Now, in times of crisis, certain continents or regions of the world won't get signals. At the same time, the rest of us, who are behaving ourselves, will carry on as normal. That's Regional Denial in a nutshell.

What about Anti-Spoofing?

If you happen to have a Military P(Y)-code GPS receiver, then you should know that Anti-Spoofing (P-code encryption) will continue.

I need a more accurate position than that!

Suppose you do need to get the right house in the street, or to locate the source of pollution to better than 15m? Or, being more ambitious, find the exact position of Council's assets or a mine shaft to within a metre or two? Don't fret. You can. We describe how soon. But first, we need to choose a GPS receiver.

Chapter 2 Summary

- Your position has four unknown quantities:
  - Latitude
  - Longitude
  - Height
  - Clock error

- Your GPS receiver calculates your position by measuring pseudoranges (distances) to satellites

- To fix your 3D position you need to receive signals from at least four satellites

- GPS is accurate to between:
  ± 7 and 15m Horizontally
  ± 12 and 35m Vertically

- Selective Availability was terminated in May 2000

Chapter 3
Choosing a GPS Receiver

In terms of accuracy, most handheld GPS receivers are basically created equal.

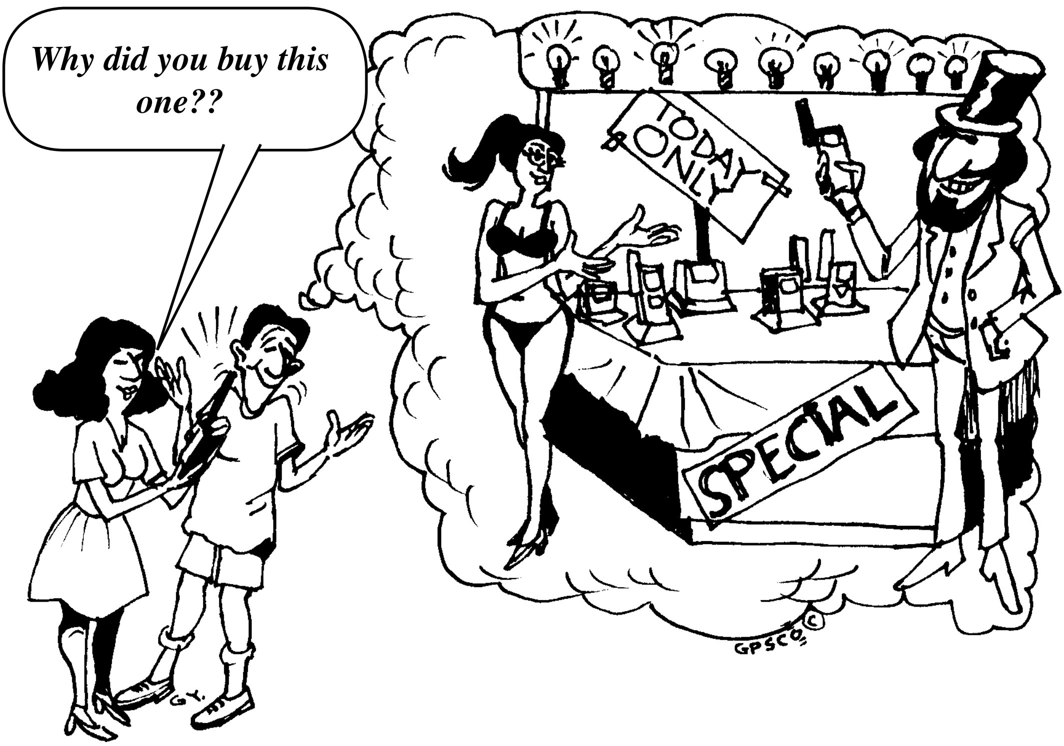
They have the same basic parts, and use the same signals.

It is what they do with what they get that makes the difference to the user.

Do you really need a GPS?

Is GPS just a rich man's toy, an expensive extravagance? Or is it an affordable life-saving device? Or perhaps a useful mapping aid? Your attitude probably depends on whether you are waiting in the dole queue, locating Aboriginal rock carvings or lost in a blizzard on Kosciuszko's snow slopes with only your GPS receiver to get you to safety.

Of course you may already have a GPS receiver, or you might be about to part with a few dollars and want to make sure it will do what you want. In the following pages we look past the sales talk. We describe tests that can be done in the showroom and questions that should be asked. All the time you can evaluate and compare different makes and models.



I want one!

Your GPS receiver is an investment, and you need to choose wisely. You are going to make and trust decisions based on the answers it gives you, so not only must they be the right answers, they must be in a form you can understand and use.

Let's not beat about the bush. Unless you are prepared to spend buckets of money, all the latest GPS receivers will give you the same basic accuracy.

What really should interest you is what you get for your money.

Features offered, and the flexibility to set controls to your particular needs are the most important things to be considered. Don't be conned by the pretty colours or bells and whistles - unless they really will be useful.

The salesperson doesn't know your needs - although he/she may try to tell you. Only you can decide.

If you want to use GPS in aviation or marine navigation, you may have to check with the authorities for compliance of a particular model to certain regulations.

How much does it cost?

For most of us cost is the major consideration. But be aware that a few dollars more, spent wisely, might just ensure that you buy a useful tool rather than a useless toy.

Let's check it out

"Could I have a closer look please?" Ask for a demonstration model - one with batteries, then work through the next few pages. We list questions that you should ask, things to check, as well as a few hints learned the hard way.

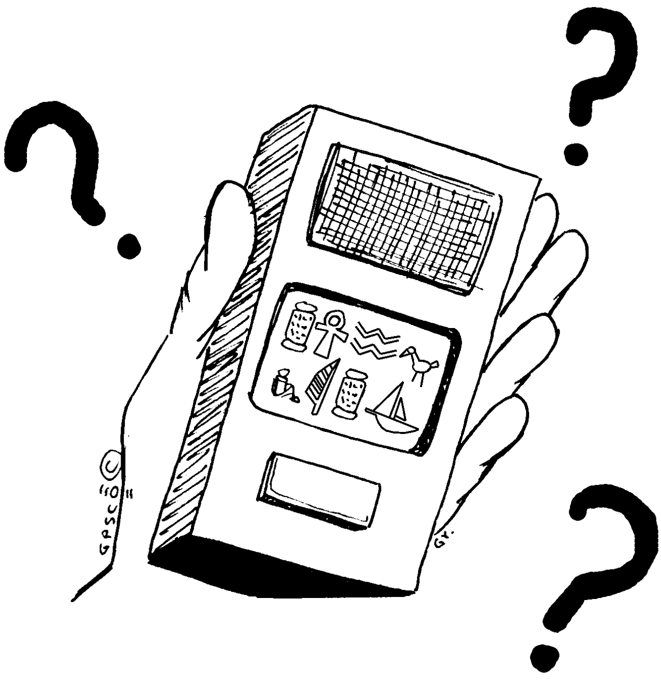
Display screen

Personal preference plays a large part here. Do you like - or will you need - a colour or black and white screen, what about a large or back-lit display? Can you read it well in direct sunlight? Does a graphical route display make life easier for you? Is there some means of protecting the screen - is it recessed? Does constant screen, or menu, switching irritate you? If so you may prefer a larger all-showing display. Now ask yourself, "How is it looking so far?"

Understanding what is being displayed

The hourglass you may see on the screen commonly means “Please wait” and is used to indicate the GPS receiver is ‘thinking’ or calculating, or loading data. There will be other cryptic icons used. They are different for each brand, and sometimes different for models of the same brand. There is nothing for it but to find out by diving into the Manual. Somewhere there should be a list of icons. Don’t assume what an icon means. Fancy displays of satellite tracks, orbits etc. are all very well - but are you getting the information you want, or simply being misled into thinking you are?

Looking ahead, you will want to know things such as: how many satellites you’re tracking; the PDOP; your present position; the Map Datum; whether it is a 2D or 3D position, and if it is differentially corrected. This is probably all gobbledegook at present, but the ideal GPS receiver will give you this basic data all on one - or at most two - screens. In short, you will want to know that the Golden Rules of GPS are being satisfied.



Map and chart display

A feature that automatically superimposes your position over in-built digital images of maps or charts can be very handy. These may show shipping channels, reefs, and lighthouses or perhaps the airport, its approaches and taxiways or even the local road network. The latest gimmick is to show the nearest fast food outlets, theatres, and petrol stations. Even their telephone number and street address are available. Don't smirk, they are out there.

But take a closer look. Some maps aren't detailed enough. For example, one GPS receiver had Sydney, a city with the world's biggest urban sprawl and over four million people, displayed with just one street. Oops! Some receivers have good maps of certain areas and thumbnail sketches for the rest. Others use maps stored on an electronic card, or cartridge, that can be slotted into the receiver. Still others can use maps downloaded from the Internet or a CD.

If you have a map display capability, remember that maps may not be available for everywhere you want. Also, they may be expensive to buy and can be hard to view if only available in black and white.

Buttons or control keys

GPS receivers often have push buttons, rather than a regular keypad, to give them commands. Commands are a combination of button pushes, so it is useful if you can feel a distinct 'click' when a button is pushed, so that you know each stroke has been registered. A simple key layout may look nice and easy to use - but pushing six or seven buttons for each command soon gets a little tedious.

Things to check out include: Does it beep to confirm a task is completed? Are the buttons so close together that it could be easy to push the wrong one? How do you enter numbers or letters? Are the buttons or keys backlit for night use?

Find out how to move from screen to screen and to different menus. Some have a four way direction switch that is quick and positive - like a flat joystick.

How weatherproof is each button, or the keypad itself? Dust and moisture are the greatest enemies of electronic switches like these push-buttons. As before, ask yourself "How is it looking so far?"

The antenna

The antenna receives the signal from each satellite. There are two main types; the Helix and the Microstrip.

Helix antennas are designed to operate in a vertical position, and usually pivot on the body of the receiver.

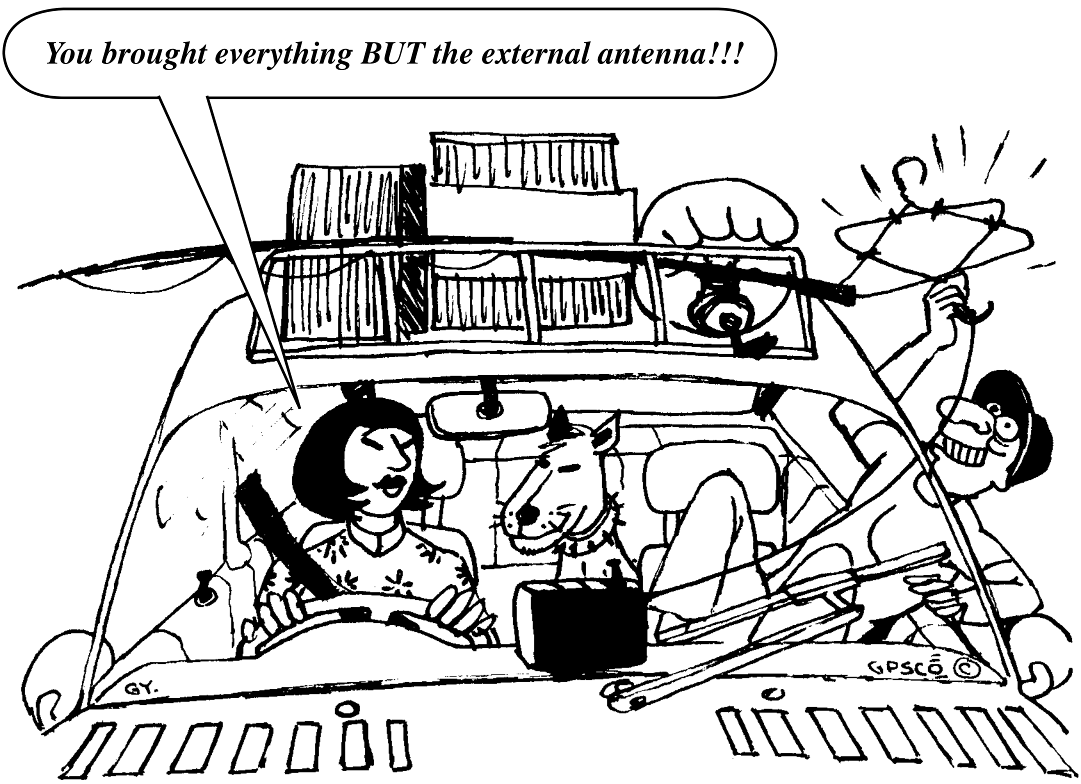
Micro strip antennas are more common, and since they are often built into the body of the GPS receiver, you may not even recognise it is there.

A flat microstrip antenna, sometimes called a 'patch', may be better in situations (eg on a vehicle roof) where the erect form of the helix could get caught in branches, rigging etc. But on a rocking boat in a choppy sea, the same feature of the erect helix may enable a better lock on satellites when the horizon is constantly changing.

External antenna

If the antenna for your GPS receiver is removable and can be mounted separately, on the bull-bar or roof of your four wheel drive, or atop the mast of your boat, you need some means of installing and connecting it. Check the shipping box contains the neccessities. It may even contain a magnetic base that clamps firmly to a steel bracket on your hang glider, mountain bike or Centurion tank.

If you are planning to use an external antenna, think about it. How is it going to be mounted? Is it going to be knocked off? Do you have enough antenna cable? What's the maximum length of cable that will work?



And importantly, if you're going to use it in your plane, what installation regulations have to be observed?

Power

Far and away the most popular power supply for GPS receivers is the standard penlight battery. In packs of up to eight they snap into place.

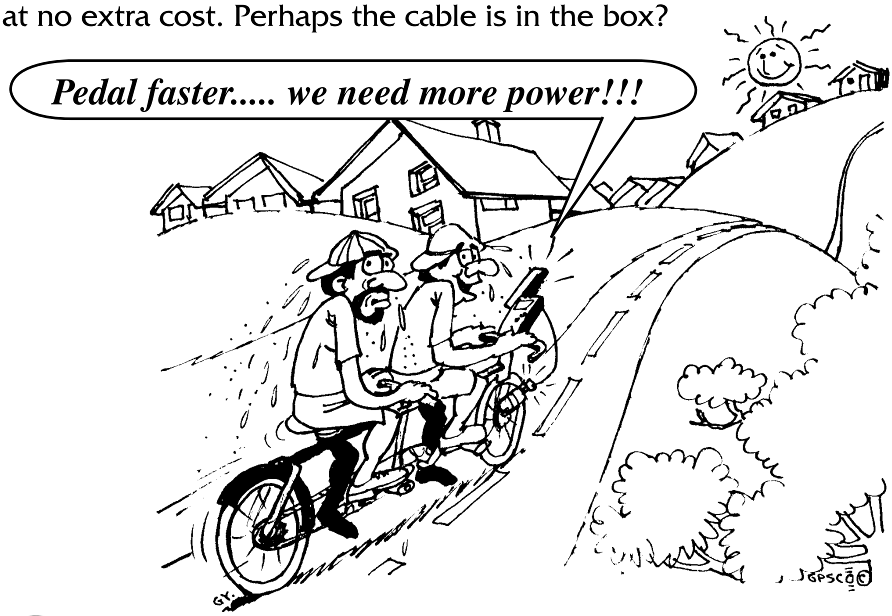
When your GPS receiver runs out of power - and it will! - it's going to be useless. So does the display show the battery level? Does your battery level indicator really indicate remaining battery charge? Read the manual, you may get a surprise!

A variation is rechargeable Nickel Cadmium (NiCad) batteries of various sizes and capacities. Since they don't last long, always have some on charge while you are using another set in the field.

Whilst rechargeable batteries may sound attractive; Do they have enough power for a full days work? Can you get enough charge into the batteries overnight? And when you go bush - or to sea or wherever - what are you going to plug the charger into?

External power source

An external power source is a distinct advantage if your GPS receiver is going to be permanently mounted in a car, plane or boat. Hopefully the manufacturer will provide the cable so you can connect the GPS receiver to the cigarette lighter at no extra cost. Perhaps the cable is in the box?



The hidden battery

Your GPS receiver has an internal battery to sustain life to its memory while the main power supply is switched off. What is its shelf life? What happens when it runs out? And how long will it last? Some last for years, others don't.

Power savers

Most GPS receivers have some form of power saver.

Some receivers can only be turned ON by pressing certain keys in a certain order or by holding a key down for a few seconds. This is an excellent feature, as anyone who has discovered too late that batteries are flat through an accidental start that you knew nothing about.

It may also have an option to measure less frequently, therefore using less power. Likewise, it should have an auto-shutoff. Check if this applies to the display light also, as a display that remains lit when not being viewed is a drain on battery power. We all love surprises, but no power when you were counting on it is one surprise we can do without.

External casing

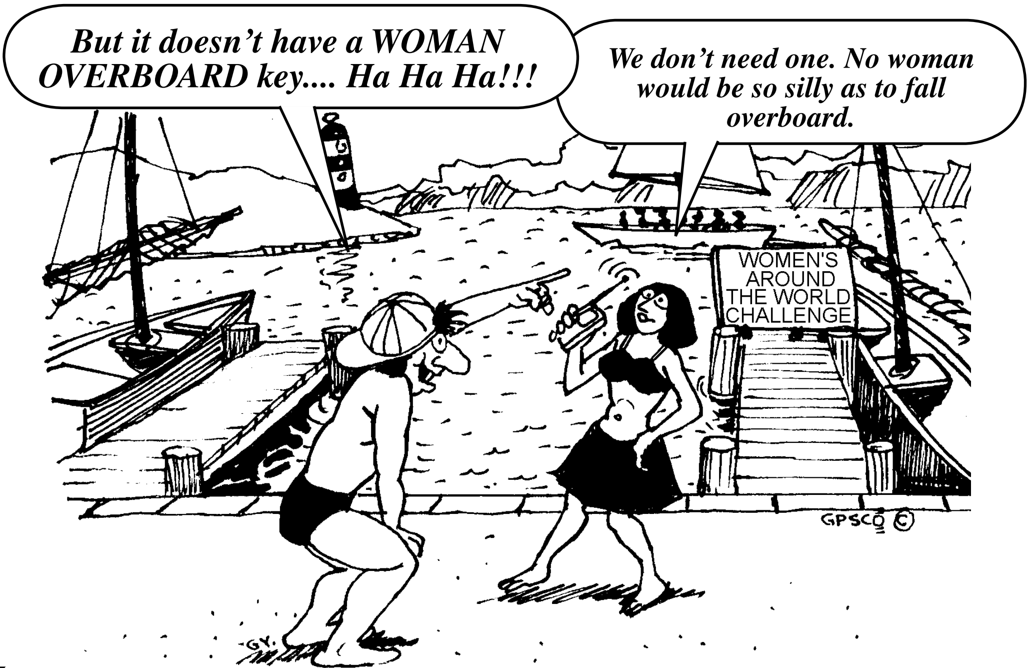
Will the GPS receiver stand up to the job you have in mind for it? It will be used outdoors, in all weathers and be expected to perform after having been packed, backpacked and unpacked time and time again. It's a big ask for a little miracle of electronics.

Does it float? Is it water proof, splash proof, dust-proof or shockproof? If it conforms to 'Military Specifications' then it should work even if run over by a tank! An external soft case may be an expensive extra. Is it included in the price? Maybe another type of protection (your old mobile phone cover?) will suffice. Colour can be important; is it easily seen - or easily camouflaged. A sexy black GPS receiver is more easily overlooked and left behind than its garish fluoro cousin.

Ergonomics

How do you have to hold the GPS receiver? An awkward operating position may result in repetitive strain injury - the rare GPS RSI syndrome!

Check its weight. A lighter model could be preferable if it has to be carried around all day, or held up to read or record for any length of time. When you're using it, does it have a safety cord or lanyard? Very useful to free a hand while working, or to save the GPS receiver from falling overboard.



Memory

You will want to store in the GPS receiver data such as the positions of landmarks, and how you prefer it to operate - (the setup parameters). Generally, anything stored can be recalled and viewed. It is helpful (to a fallible and fragile human memory) if landmarks (or waypoints) can be entered using letters instead of just numbers. A waypoint named "HOME" means much more than "WP15". Check if you can do this. If not, you may have to keep lists of numbered waypoints and descriptions, and update them regularly.

Memory limits

As you use your GPS receiver, you will gradually add more and more data to the memory. Does it have enough memory for your needs? What happens when the memory fills up? Does it automatically overwrite old waypoints? If it does what is the overwriting order or process? How do you overwrite or cancel existing or unwanted data? Don't wait until it is too late to find out.

Channels

A 'channel' is the collective name for all the electronics in the GPS receiver that lock onto the signals from a satellite. There is a lot of techno-babble about channels. But twelve dedicated or parallel channels is the norm.

Sequencing and Dedicated channels

'Dedicated' or 'Parallel' channels lock onto one signal from one satellite. 'Sequencing' or 'multiplexing' channels, however, locate a satellite, lock onto it, and store the data from it in its memory . The GPS receiver then finds another satellite, locks on and stores that data, and repeats the process until it has enough stored data to compute a position. And it can do it all on only one channel. There are variations on these themes with some GPS receivers having a combination of the two.

Dataports

Usually the dataport (that is, the socket to take some type of computer cable) is used for exporting position fixes into a fishfinder, autopilot, Nintendo - or any other gadget. If you want to connect your GPS receiver to a depth sounder, fish finder, computer and so on, then it must have a dataport and it must support NMEA (National Maritime Electronics Association) data.

Likewise, if you want to get more accurate positions using Real Time DGPS, your GPS receiver must be able to receive RTCM (Radio Technical Commission - Maritime) transmissions, via the dataport.

GPS Mapping Software

Does it have any mapping software you can load into your home PC? Why? So that at the end of that big 4WD adventure, cross country ski weekend or pig shooting trip you can download and store information on all your favourite spots.

This type of software generally allows you to measure the distance and direction between locations. Display a vertical cross section to show how far you climbed. Zoom in or out. Print a mud map. Click and upload new waypoints in a flash. Or output a file to email to friends. The slicker versions even allow you to import topo maps, nautical charts, aerial photographs, or satellite images as a fancy background image.

Check if the mapping software will work with any GPS receiver. Or is it specific to only one particular make or model, hopefully the one you use.

An ever-growing variety of GPS mapping software can be found on the Internet. Go for a surf. You may even find some free, low resolution, aerial photos, maps, or satellite images.

A new lease on life

Firmware is the software that lives inside the receiver. It makes it think and breathe and gives it a personality. As we all know, software can have bugs.

Some wise GPS receiver manufacturers have recognised that they won't get it exactly right, first time, every time. They also may want to offer you new features in the future. So their receivers firmware can be updated. It's a great idea. Just hook it up to your PC, run a program and your receiver gets a new lease on life. The better guys allow you to download the latest firmware versions, and matching user manuals, for free from their website. Just download and upgrade. Too easy.

Electronic nick-nacks

The latest trend is to have all sorts of "James Bond" type gadgets built in. Some have an electronic compass, others an altimeter, a few may even promise email. They sound great but do you really need them? Ask yourself, are they a useful tool, a nuisance, or just an extra drain on the batteries?

Remember that experienced map users always carry their old trusty magnetic compass. And it doesn't need batteries!

The manual

DON'T EVER ASSUME ANYTHING! - read the instructions. Often obscure, sometimes wrong, your manual will tell you how to do it - if you can translate the jargon.

Quick Reference Card

Most GPS receivers come complete with a handy quick reference card which is your manual in miniature, and can be carried in the soft case. As soon as you can after purchase, photocopy both sides of the card a few times. Store the original where you keep your will, as you will probably never get another.

This little card will show you which buttons to push, and in what order. Highlight frequently used procedures and consider adding a list of setup parameters and/or the coordinates of most-used waypoints. Laminate one or more of the copies for field use. Use these copies when working and never lend the original to anyone. They are worth their weight in Aztec gold, and need constant vigilance to avoid being 'borrowed'.

Types of GPS Receivers

Having looked at all the separate parts that make up a GPS receiver, let's put them all back together again and look at the types available. Hand held GPS receivers can be broadly classified into two types: Navigation and Mapping.

Navigation GPS Receivers

For the vast majority of users, a Navigation GPS receiver will do just fine. Bushwalkers, sailors, archaeologists, fishermen, 4WD motorists, cross-country skiers, prospectors - can all find satisfaction with a 'no frills' unit.

Mapping GPS Receivers

Mapping GPS receivers have additional features such as greater memory, control of output and input. It is important to realise that any single position - one POS button press - will still only deliver much the same accuracy as for Navigation GPS Receivers. Professional users, such as abalone divers, Customs Officers and Local Government engineers, will probably need its advanced capabilities to satisfy their serious requirements.

Survey GPS Receivers

You don't need one of these! While navigation and mapping receivers tend to look rather similar, you can't help noticing that Survey receivers are in a league of their own. For the cost of just one Survey receiver, you could equip a whole fleet with Navigation units. Larger, and designed for use with an antenna plumbed accurately over a survey mark, they require special observation and computation techniques. Surveyors have found ways to get their position to centimetre accuracy. This is a science in its own right, and well outside the range of this book.

Anything else?

Before you part with your hard-earned cash find out what guarantee is being offered. What is covered? What isn't covered? When does it expire? And when I have a problem, who will help?

At last ...

By this stage you will be chomping at the bit to get outside and try out your new toy. So let's go...

Chapter Summary

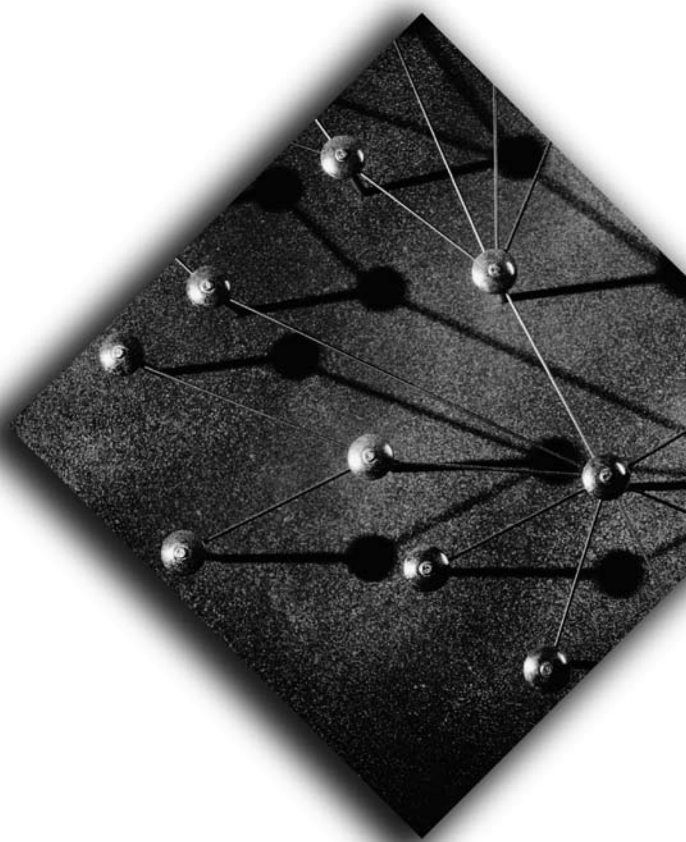
- All GPS receivers have the same basic parts

- Choose between:
  - Navigation receiver
  - Mapping receiver

- Don't let cost be your only guide

- Features and performance make the real difference between a toy and a tool

- Test drive it, to check it does what you want



Chapter 4
Getting Started


GPS
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In the real world

Getting our position from satellites whizzing around in space is all very exciting, but there is more to GPS than just wandering off, GPS receiver in hand, pressing the 'ON' button and expecting it to function exactly as you want.

Things which affect its performance, and usefulness, are not all obvious and may not be obvious from the manual.

Probably the best way to find out what is happening is to get your hands dirty - in the field. So let's go outside and do some Exercises.

Things you will need

- GPS receiver
- Manual, Field Guide, or quick reference card
- a map of your area - one with grid lines
- pencil and notebook
- a watch
- an open area; your backyard, a carpark, footy oval, beach or similar
- spare batteries
- and ... your brain!

EXERCISE 1:- How quick is my GPS receiver?

In today's world, we expect everything to happen NOW! - GPS is not always like that.

Step 1 Go to an open area.

Step 2 Turn your GPS receiver ON, noting the time on your watch.

Step 3 Press the POS button (or equivalent) to get a position.

"Why is it taking so long? What's going on?", we hear you ask.

Your GPS receiver is trying its best. Sometimes that may seem too slow for us. Do you always jump into your daily tasks straight out of bed? Or are you sometimes a little sluggish, and need a kick start? GPS receivers are like people - and need care and a little understanding at times.

Let's give it the benefit of the doubt, and look at what could be happening. Your GPS receiver is in one of three states of readiness.

Frozen start - It's straight out of the packing box for the first time. Or it's been doing a Rip van Winkle for the past few weeks. In either case, it does not have a recent navigation message and/or current position in its memory. Getting this information is called 'Initialisation'. Unfortunately it may take up to 15 minutes for your first position fix. So sit back and relax.

Cold start - Your GPS receiver is either trying to use an old navigation message or has been moved more than 300km since the last time you used it. You should only have to wait up to 5 minutes for your first position answer.

Warm start - Your GPS receiver has both a recent navigation message and is less than 300 km from its last position. It should be up and running in a minute or two.

Step 4 Finally! Action. Great. Note the time that the first position is displayed, and work out how long it took from power up. Was this a Frozen, Cold or Warm start? Was this delay expected? The upsetting part about startup delays, is that manufacturers usually only quote 'warm start' times in their literature. Let's give it another go.

Step 5 Turn your GPS receiver OFF and repeat steps 2 - 4. Surprise, surprise. Much quicker this time? Why? Because your previous position (and navigation message) gave it a head start.

You can hurry along a frozen start: just enter an approximate coordinate (within 300km) from an atlas, your map or sheer guesswork, if you can. The difference this makes is often substantial.

EXERCISE 2:- Is this where I am? - or where I was?

Oops! A real estate agent wanted to use his new GPS receiver to find the positions of five rural properties. At each property he pressed the ON button, then the POS button, wrote down the position displayed, turned the GPS receiver off, and drove to the next site.

Only when he got home again did he realise that he had listed the identical position five times. And that position was the same as the carpark at the office where he had tested his GPS receiver that morning. What had gone wrong?

He was only the latest in a long line of new users who assumed that the position displayed was where he was standing when he pushed the POS button. In each case he had not given his GPS receiver enough time to get a new position before he recorded it.

This story shows the need to satisfy yourself that you have a current position. How do you do it?

Step 1 Go to an open area.

Step 2 Turn your GPS receiver ON.

Step 3 Get a position. Stand still and watch the display for a minute or so.

Step 4 Is this position changing? If it is, good - it's what you want. The changing values prove that it is being updated every few seconds. This is your current position.

IF NOT, chances are that this is an OLD POSITION - and is NOT where you are now. Don't fall for the old GPS position trick like so many other novices.

Hint : Heights are less accurate than horizontal position. They vary more and it may be easier to check the height is changing.

No position is better than an old position

There are other ways to tell whether a reading is an old position. On some GPS receivers the display will flash, others warn of 'OLD POSITION'. Or maybe there is a some other special symbol (an hourglass?) to attract your attention. Don't ignore these warnings, and don't use the position shown either. These displays usually mean that your GPS receiver does not have enough satellites, so it is showing the last stored position, and is in the process of finding its present position. The remedy is easy - do nothing; just wait a little longer. Let your GPS receiver do its bit - finding satellites and working out where you really are.

Are there enough satellites?

Remember that you need to be able to 'see' at least four satellites for a 3D position. Let's see why - and what is happening when you get a 2D position.

EXERCISE 3:- 3D vs 2D positions

Step 1 Start with an up-to-date position on your GPS receivers screen.

Step 2 If you have a latitude, a longitude and a height, worry not - you have a three dimensional (3D) position. In fact '3D' is probably shown on the screen somewhere. You have at least four satellites, and this is what we are after. However...

If you have a latitude and longitude only and no height - a 2D position - your GPS receiver is telling you that it doesn't have enough satellites for a 3D position. What it isn't telling you is that even to produce the 2D position, it has had to fudge it.

2D Positioning

In valleys, canyons of skyscrapers, deep gullies or dense tree cover, where there are only three satellites in view, your GPS receiver may try to get a 2D position. To do this it will have to know, or assume, either the true time or your height. (Remember with 3 satellites we can only solve for 3 of the 4 unknowns. The other one has to be assumed). Not many of us carry atomic clocks in our back pocket, so it assumes a height. Where does your GPS receiver get it? Read on.

Automatic height aiding

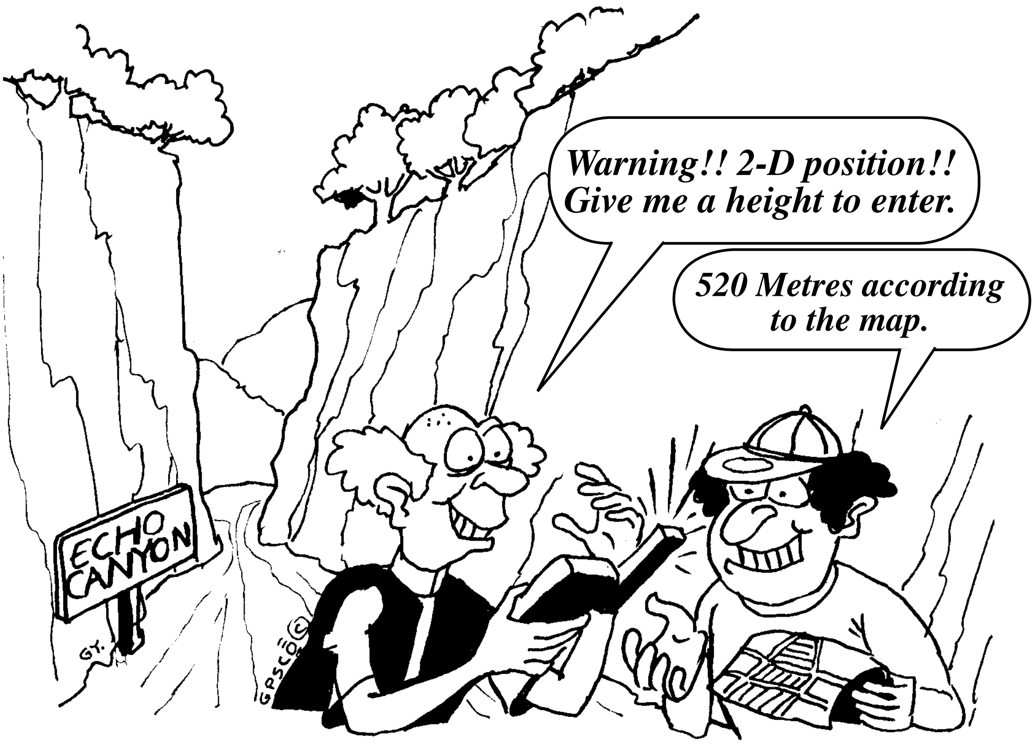
This is the way most GPS receivers will attempt to do 2D positioning unless you tell them otherwise. It will automatically use the height of the last position in its memory. That may be fine if you're on a large flat surface, like the ocean or a desert plain, but if you're in undulating or mountainous terrain, watch out.

Warning!!!

If the height assumed is wrong, then so is your position. A useful rule of thumb to remember is that every one metre error in the height can introduce an extra 1 to 2 metre error in your position. Wow! That sort of error could put you "off the map."

Manual height aiding - for better quality 2D fixes

If your GPS receiver is using a wrong or suspect height, then you must enter a better value. You should be able to work it out by interpolation on a contour map. Or estimate your height - easily done for mariners as it will be nearly zero. Enter this height into your GPS receiver - if you can.



Are 2D positions all that bad?

Yes. 2D fixes are generally regarded as being less reliable than a 3D fix because any height error can lead to a large position error.

To many yachties and wide-open-space users, 2D positions may be fine. But the rest of us should set our GPS receivers to "3D ONLY" mode. This means they won't do 2D positioning, neatly side-stepping the potential problem altogether.

Satellite Geometry - are they in the right place?

The satellites you use cannot be just anywhere.

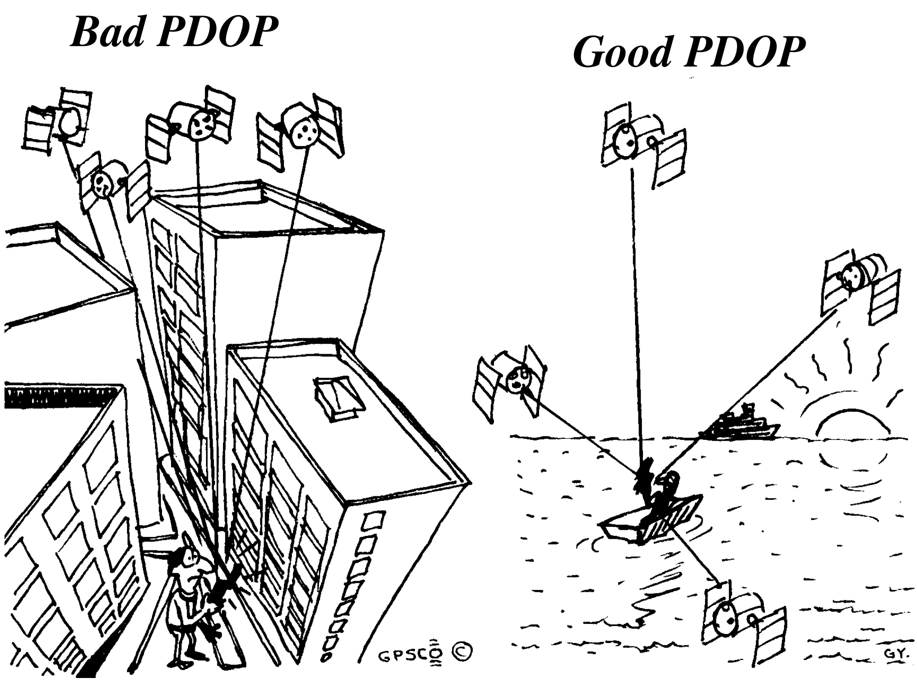
Ideally, the four satellites have to be spread evenly around the sky to obtain the most accurate result. If they are all in one sector of the sky, you will still get a position. But it may be well outside the limits of acceptable accuracy.

Introducing PDOP

The best position fix is given when one satellite is directly overhead, and the other three are equally spaced around the horizon.

This aspect of GPS is called the ‘geometry’ of the system. The most common measure of geometry is called PDOP (Position Dilution Of Precision) and pronounced ‘pee-dop’. PDOP is just a number.

All we need to know is that if the PDOP is low, less than 5, then the satellites are spread out around the sky. That means it’s a good time to observe. This fact is so important that we will make it our second Golden Rule of GPS.



GOLDEN RULE No. 2
Use only when the PDOP<5.

You must check the PDOP every time you take a position. If your GPS receiver does not display PDOP, there will be some indication of 'poor geometry' - perhaps an icon flashes. This is a warning. You decide whether you want to risk positional errors greater than expected.

With experience, you will soon discover that the more satellites you use the better the chance that the PDOP will be low. Likewise, if whole sections of the sky are blocked by nearby buildings, the roof of your vehicle, or even your body, you will get a high PDOP.

Luckily, with a full constellation of GPS satellites in orbit the average PDOP is less than 5. Even so, there may be a few times each day when the PDOP is higher. A period of high PDOP is called an 'outage' and only lasts a handful of minutes until another satellite comes into view.

Still confused?

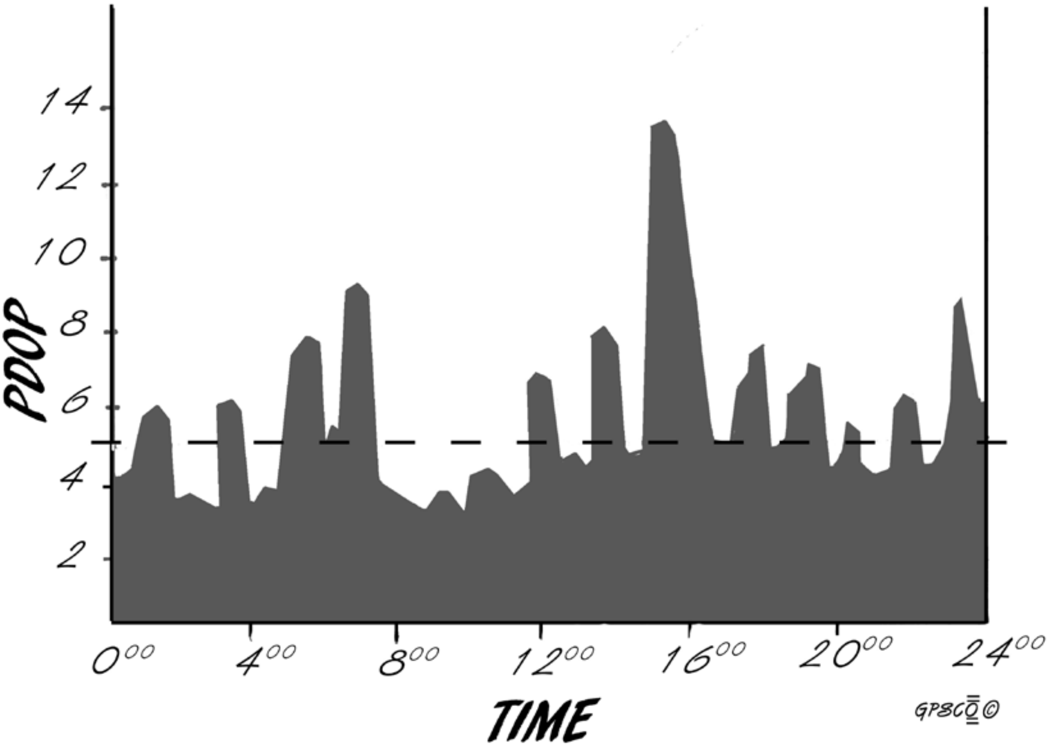
Ok, let's put it another way. PDOP is a multiplier. If the PDOP is 2 your GPS receiver may give results that are only half as accurate as for a PDOP of 1. If the PDOP is three, your displayed position may be may be three times less accurate.

Got the idea?

Now think what happens when the PDOP is 10, 20, or even 35. You could be better off stopping for lunch until the satellite geometry improves - and it will.

Proper PDOP Planning Prevents %^&* Poor Performance

PDOP depends on many things such as your latitude, longitude, the time of day, the number of healthy satellites and how many of them are available to you. The graph over the page is an example, and shows how it can vary over just one day. Site specific graphs are available from good GPS Mapping Software and some web sites.



One neat trick to remember is that the satellite orbits, and hence the PDOP, repeat day after day, but move forward by four minutes a day. So what? Well, if you find that 10:00 today is a bad time to do GPS, so also will 09:56 be tomorrow. And 09:52 the next day.

Four minutes a day is about half an hour a week (4 mins x 7 days = 28 mins) or two hours a month (4 mins x 30 days = 120 mins). Armed with this useful rule of thumb, you can guesstimate when PDOP will be bad and plan to avoid it by doing something else - like having a cup of coffee.

Coping with a high PDOP

What do you do if you get a high PDOP? You could:

1. Move away from any nearby obstructions.
2. Wait a few minutes and try again. The outage should have passed.
3. Try facing the Equator. There are more satellites in that direction.

What is HDOP?

A value for HDOP (Horizontal Dilution of Precision), instead of a PDOP, may be shown by your GPS receiver. It is used when in 2D mode. When the HDOP is less than 2.5 the satellite geometry is good.

Map Datum

Even if you have followed the Golden Rules so far, you may find that your position fixes, when plotted on a map, are still wrong by hundreds of metres. Obviously something is still amiss. Let's delve a little deeper.

EXERCISE 4:- Checking the Map Datum

Step 1 Pull out the map you'll be using. Go to a place that you can easily identify on the ground as well as on the map. Choose a road junction, bridge, wharf or other landmark.

Step 2 Turn ON your GPS receiver; and get a 3D position, with a PDOP less than 5.

Step 3 Write down your position; either latitude and longitude, or Easting and Northing.

Step 4 Plot these coordinates to scale on your map or chart. Don't try to fudge it. You will only be fooling yourself.

Step 5 Does your GPS position correspond with the true position on the map? Almost certainly they will not be exactly the same. Remember that a single point position from GPS should give you an accuracy of better than15 metres from your true position. Is your plotted map position within these limits. If not, why not?

WHAT? ... Wrong? ... Who's wrong?

Good question. Who, or what, is wrong?

Chances are you're wrong, not the map. Government-made topographic maps have to conform to rigorous standards. For example, on a 1:25 000 Standard

Topographic Map made to Australian standards, the plotted position of a landmark should not be in error by more than half a millimetre. That's about 12 metres on the ground and the same accuracy as your GPS.

If you can satisfy yourself that your GPS receiver is giving you wrong answers, the most likely explanation is that the wrong map datum has been set in it.

We won't bore or confuse you with what a map datum is or how it works. All you need to know is that GPS works in its own map datum called WGS84 (World Geodetic System 1984). So it calculates your position in WGS84. Chances are, your map is not using WGS84, so you have to tell your GPS receiver what map datum to use.

The name of the map datum used will be printed on the map, usually in the legend. For example; in Australia it may be; AGD66, AGD84, or GDA94. Select the correct map datum from the list in your GPS receiver. Take care: it could be listed as AUSTRALIA, or AUS84 or some other abbreviation. Whatever you do, don't accidentally select the AUSTRIAN datum, that will just make matters worse.

Ok. Now repeat Exercise 4 and see if the results are better.

Choosing the right Map Datum is so important, we call it the third Golden Rule of GPS.

GOLDEN RULE No. 3
Use the correct map datum.

Before you go anywhere with your GPS receiver always check the map datum. Don't assume that the previous user wanted everything the way you do. Kids, gremlins and Murphy love to push buttons. As you will read a few times in this book, DON'T EVER ASSUME ANYTHING. Check and doublecheck everything.

Note for Australian GPS users

All new (1996+) Australian topographic, hydrographic and aeronautical maps are being produced on the GDA94 (Geocentric Datum of Australia 1994) map datum. GDA94 is the same as WGS84. Your GPS receiver may not show GDA94 as an option - simply select WGS84 instead.

Map heights and GPS

Imagine it's late afternoon and you're out at sea. You have been fishing all day with no luck, then all of a sudden you're up to your elbows in fish. You can't keep fishing because you have reached the 'bag' limit. So what do you do?

Being a smart bloke you decide to get a position fix from your trusty GPS receiver so you can come back another day.

Your GPS receiver says your height is 100 metres below sea level. How can this be? Is this gadget on the blink? You are as near dammit to being actually on the sea's surface and you know that all heights are measured from Mean Sea Level Aren't they? No!

GPS heights are NOT Mean Sea Level heights

GPS heights are not measured above, or below, Mean Sea Level! GPS heights are measured relative to WGS84.

The heights on Australian maps are measured with respect to the average Mean Sea Level around the continent. This is called the 'Australian Height Datum', often shortened to AHD. Heights on maps may be given for a particular spot (usually the top of a hill), or depicted by contour lines which have a number representing their height above AHD.

The difference between AHD and WGS84 heights can be as large as 80 metres in Australia. For a navigator, the difference may be ignored. On the other hand, if you need more accurate heights, it cannot.

GPS heights can be corrected to MSL heights

One way to do this is to read off the correction from your topo map. The size of the correction and how to apply it should be written in the legend of the map. For example it may say "decrease all satellite heights by 17 metres". Your GPS receiver may have these approximate corrections stored in its memory. This allows the display of MSL heights at the push of a button.

So, as well as the map datum, you should also be aware of what height reference is used by your GPS receiver.

World Time Zones

Although not essential for the operation of a GPS receiver, it is handy to have the correct time displayed.

EXERCISE 5:- Checking the Time Zone

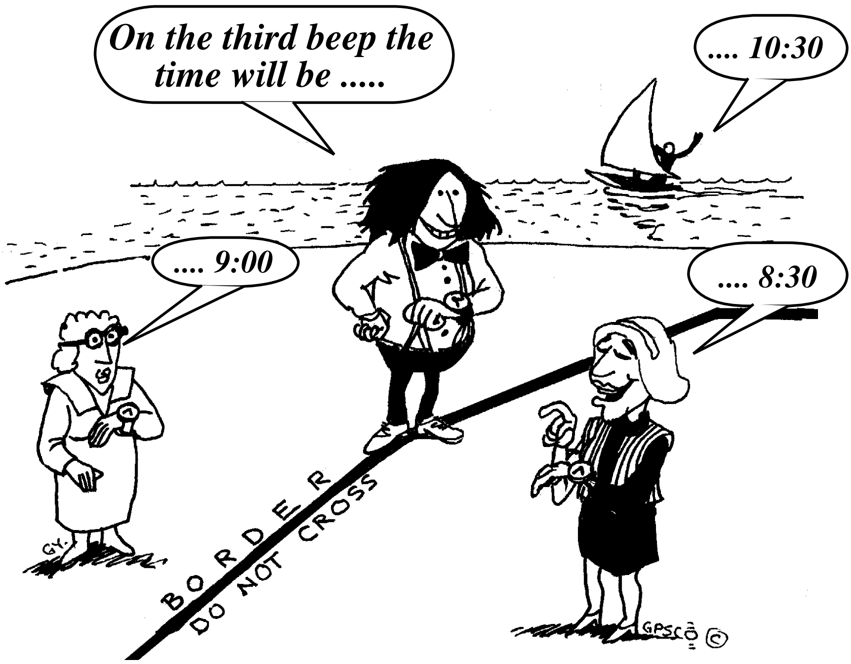
Step 1 Turn your GPS receiver ON. Display the time.

Step 2 Ignoring the seconds, is this close to what your watch shows? Iit s it hours out? And what happens when our clocks are reset to Summer Time ... will your GPS receiver still be right?

This all has to do with time zones. Time zones are defined as being so many hours before or after Universal Time Coordinated. Universal Time Coordinated (UTC) is sometimes called Greenwich Mean Time (GMT). In Australia we have:

- Eastern Standard Time, +10hr
- Central Standard Time, +9.5hr
- Western Standard Time, +8hr

In summer many countries, states, even towns, add an extra hour to make Summer Time.



Find out what time zone you are in or, more to the point - how many hours you are offset from UTC. Try looking in an atlas or international telephone book, or airline timetable. Then enter the correct offset (as a positive or negative number of hours), into your GPS receiver so that it displays the right local time for your locality and season.

GPS time

By now you won't be surprised to learn there is also GPS time. It's close to UTC time but out of whack by about a dozen or so seconds. Times stored in the memory of your GPS receiver, for example, when and where you caught that big fish last vacation, could be given in either GPS or UTC time. If a handful of seconds is critical to you, you had better spend a few minutes reading your manual to check which one is used.

Total power loss

By this stage, you have already started to customise the SETUP in your GPS receiver. What a pity if all that hard work were to be lost, and had to be repeated. And that's exactly what happens when the batteries go flat... you can lose everything. All the setup preferences, all your waypoints, your last position fix and the navigation message may be wiped out.

That means you're going to have to key it all in again. Now don't imagine that when that happens you can remember everything. You should write down your setup preferences. The back of the Manual is an excellent place. Or perhaps the Quick Reference Card. As we know, Murphy is alive and well and loves to play havoc with GPS. So, don't wait until you discover the batteries are flat.

Do it NOW!

EXERCISE 6:- Recording your setup preferences

Step 1 Turn your GPS receiver ON.

Step 2 Run through your setup menus. Step by step write down your selected set up for:

- Map Datum
- Display format
- Time Zone
- Positioning mode eg '3D Only'
- Important waypoints
- Etc, Etc

All dressed up and nowhere to go

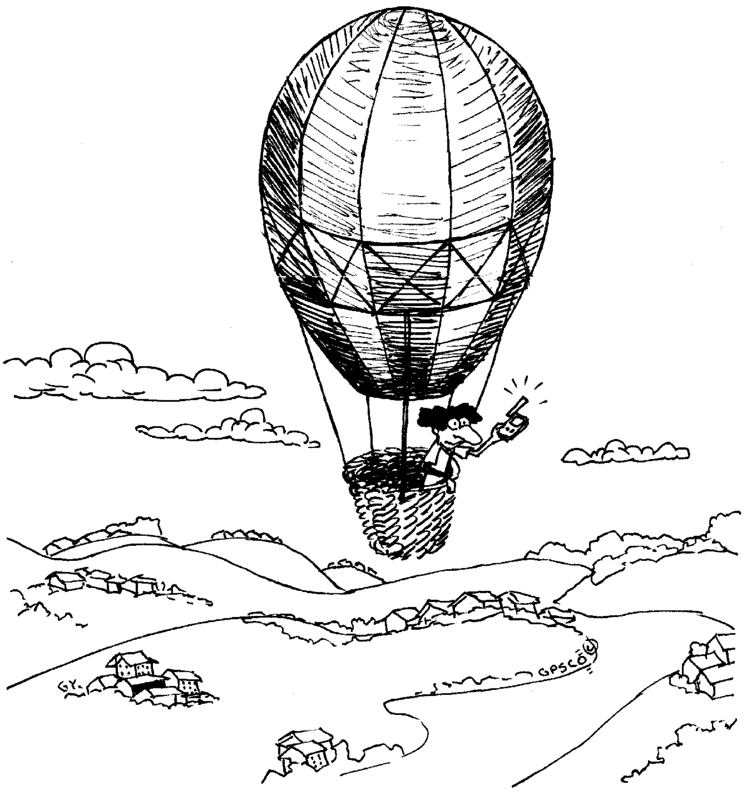
Now you are armed with the knowledge of how to get a good GPS position, you will undoubtedly want to use it to navigate somewhere. Perhaps to revisit your favourite fishing hole or to help you cross the Simpson desert.

You and your GPS receiver will be on the move, the very subject of our next chapter.

Chapter Summary

- Your GPS has three states of readiness:
  - Frozen start
  - Cold start
  - Warm start
- No position is better than an old position
- Be wary of old positions - ensure your displayed position is continually changing
- 3D positions are more reliable than 2D positions
- Observe when satellite geometry is good
- Use the correct map datum
- GPS heights are NOT above Mean Sea Level

Chapter 5
On the Move



Getting moving

Up to now you have been using your GPS receiver while standing still in a nice clear open area. And it worked just fine. When you venture out into the real world, it will have to cope with the hazards of trees and other obstructions to the satellite signals. Remember, the satellites transmit at less than 50 watts. And that's the same power as a weak light bulb.

Occasionally some satellites will be 'lost' as they disappear behind buildings, tree branches, or even your own body. Too much signal loss will affect the quality of your position. As you (and the satellites) move, they will become visible again and your GPS receiver will welcome them back by showing an improved position. At other times you will lose signal completely - in a tunnel, for example. But come out into the daylight and soon you are up and running once more.

While you're on the move you'll probably want your GPS receiver to guide you to some particular place - and back again. No problem, it can be done with a minimum of fuss and pain. Once again, we're right here with a few hints and tips to avoid the traps.

As before, you teach yourself through hands-on exercise, but first a word about units of distance. If you sort this out now it will make the exercises all the more rewarding.

Miles, Nautical Miles, or Kilometres?

We have to choose how we want speed and distance to be shown. The usual options are knots, miles per hour (mph) or kilometres per hour (km/h). Select the one that suits you best, then set it in your GPS receiver.

Which North?

Distance is one major component of travel, and the other is direction. By combining the two, we can go anywhere. Statements such as “Twenty two miles due North” are very definite. If we start where expected and travel for 22 miles in a northerly direction we will get to our destination. Provided we used the right NORTH! There is usually a choice of True North; Grid North or Magnetic North. If you’re using a compass - use magnetic. If you’re using a map to plot bearings - use Grid. Select the one which suits you, and set it in your GPS receiver. With that done we can get moving.

Navigating with GPS

Your GPS receiver is designed to work on the move. Every second or so it updates its position, and works out how fast you’re going, and in what direction. As we have come to expect - all is not perfectly clear sailing. For example, your GPS receiver may be slower off the mark or indicate you are moving even when you are standing still! Why? Read on.

Why does my receiver take longer to lock onto satellites when I’m moving?

Imagine you are motoring along in your car. You switch your GPS receiver on. As you whizz down the road objects that block signals may be coming thick and fast. One moment they are there and the next they’re not. You’re constantly losing lock on satellites, their signals and bits and pieces of the navigation message. You’re only getting a fraction of the whole story. This makes life a lot tougher for our electronic friend as it has to wait until those lost bits and pieces are repeated again later. Result: your GPS receiver is slower off the mark.

The Almanac and Ephemeris at work

The Navigation message contains all sorts of useful goodies about the satellites, including the almanac and an ephemeris.

The almanac is used to calculate every satellite's rough orbit. It allows your receiver to work out which "birds" are in view and where to start looking for them. The almanac takes 12.5 minutes to transmit but is valid for up to a couple of months.

On the other hand, the ephemeris is used to calculate an exact orbit. Each satellite broadcasts its own ephemeris every 30 seconds. It is valid for just that satellite and the next couple of hours only.

Back on the road and moving along. Your GPS receiver must collect a complete, up to date and error free ephemeris from each satellite it wants to use. As you zoom along, the receiver may momentarily lose signal and lose a bit of the ephemeris. It then has to wait for it to be repeated 30 seconds later. This all takes time and slows the receiver down.

How do you hurry it along?

Easy. In a clear place, slam on the brakes and stop. With fewer obstructions and less signal interruptions your receiver can quickly download the ephemeris.

EXERCISE 7:- Navigation displays

Step 1 Go to an open area.

Step 2 Turn ON your GPS receiver, and display your current position. Don't forget the Golden Rules of GPS - listed inside the front cover of this book.

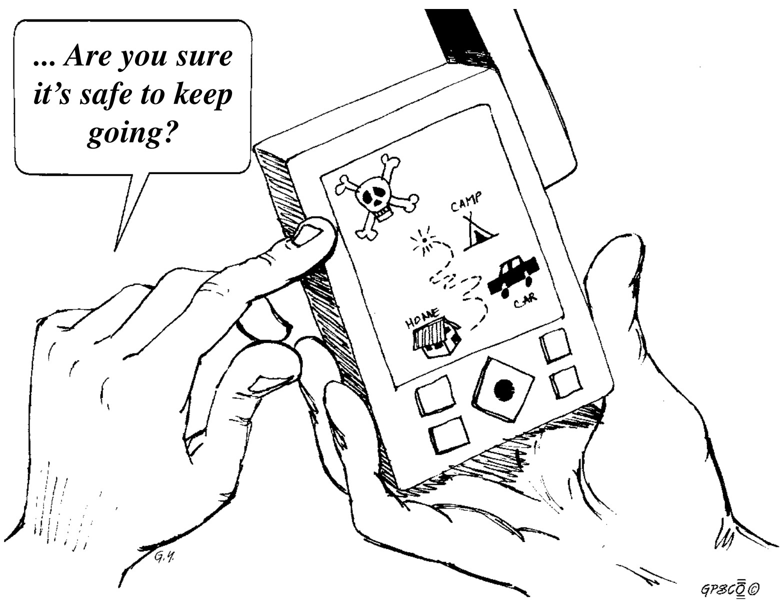
Step 3 Now switch to the screen that shows your speed and direction of travel. Satisfy yourself that you know which is the speed (HINT: often shown as SOG for Speed Over Ground) and which is the direction (often shown as BRG for Bearing). All OK? It may say you're moving. How can that be? You're standing still! There is a simple explanation: remember those continually changing positions we said you must have to prove that your GPS receiver was working? Because your

GPS receiver records a new position every few seconds, it figures you must be moving around. This is the speed it displays. At the same time, and for the same reason, you will notice the direction is constantly changing too. Actually the speed and bearing display only starts working properly when you are moving. Let's try it.

Step 4 Select a place where you can walk for at least 200 paces in a straight line without interruption or danger to yourself. A footpath or across the park is ideal. We will call your destination "AWAY". Where you start we will call "HOME". From HOME walk at a steady rate towards AWAY and watch the speed display. In a few seconds, it should settle. This is your walking speed. On the same screen should also be your direction of travel. Since you are walking in a straight line the bearing will not change significantly. Write down both your speed and bearing.

Step 5 Stop. Ignore the display for thirty seconds or so. Now turn around and face HOME. Does the display reflect your change of direction? No? This is because your GPS receiver only indicates true direction of travel when you are actually on the move. So, it doesn't work like a compass.

Step 6 To see our new direction start walking back to HOME. If you walked at the same rate, your speed will be similar, but the direction will be different to the outward walk. Write down the new direction and compare with the reverse direction in your notes. They should differ by about 180°.



How responsive is your GPS receiver?

As you have seen, your GPS receiver works well when you're cruising along. Like many of us, however, it is a little slow to respond to sudden changes to the status quo. What happens when you slam on the brakes or make a quick turn? Let's see.

EXERCISE 8:- Response times

Step 1 At HOME get a current position.

Step 2 Start walking at a steady pace towards AWAY. (If nothing else you're going to get a bit fitter by the end of these Exercises!). Read the current speed and direction display on your GPS receiver.

Step 3 After about 100 paces, stop suddenly. Look at the speed display. Does it now read zero or nearly zero? No? How long does it take to respond? What's going on? Why so long? All good questions.

Step 4 Resume walking. This time look at the direction display. After about 50 paces do an abrupt about face, and head back to HOME. What direction does the GPS receiver say you're heading? Still towards AWAY I'll bet. How long does it take till it gives you the correct direction?

Is my GPS receiver a bit slow on the uptake?

Plainly your GPS receiver does not show instantaneous changes. This needn't bother us, as long as we are aware of it. It's all part of the design of the GPS receiver to provide continuous navigation information, through firmware known as a 'filter'. Will it affect you? It depends on what you plan to do.

Let's say that you want to record the position of mailboxes along a road as you are driving by in your car. Your GPS receiver may not give accurate positions, unless you approach slowly - or even stop - next to each mailbox.

Filters

Similiar to dead reckoning a filter uses a history of positions over a certain period to predict a forward position, direction and speed. Your GPS receiver shows a predicted position, direction and speed based on the measurements made over the period, with emphasis on the most recent.

Bad points:- *As we may have found above, filters can cause a slow response to sudden changes in position, direction or speed. The displayed values are based on where you were and your speed and direction in the last few seconds.*

Good points:- *You'll still get answers in heavily obstructed locations where you are frequently losing lock, and regaining it. For example; a road flanked by tall buildings, or shady trees will provide continuous speed and heading even though there have been short periods when the signals have been lost.*

Moving right along...

In your travels you will encounter many different operating conditions. How your GPS receiver reacts really boils down to the degree of obstruction that can be tolerated and what we can do about it. As ex-Boy Scouts we are fully aware of the benefits of "Being Prepared". So let's prepare ourselves by seeing how different obstructions affect our GPS receiver.

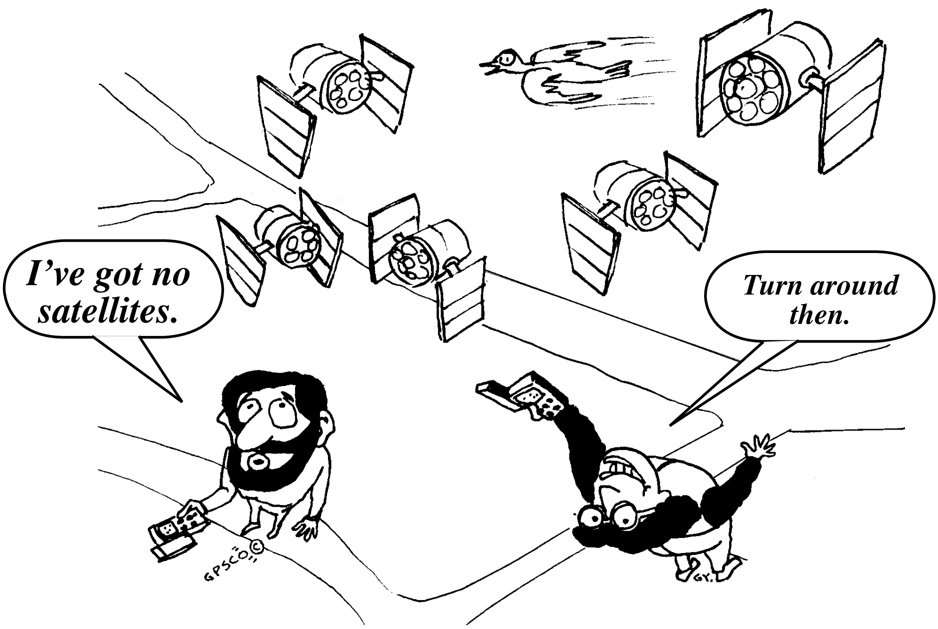
EXERCISE 9:- Coping with obstructions

First things first. The biggest and most common obstruction is you.

Step 1 Outside in a clear place, get a current position.

Step 2 Face north, and hold the GPS receiver comfortably in front of you.

Step 3 Find the screen that shows how many satellites are being tracked. Note this number.



Step 4 Face south, still holding the GPS receiver in front of you. Note how many satellites are being tracked.

Step 5 You will find that, either facing north or south will give you more satellites. This is proof that your body is blocking the signals from some satellites. Actually if you simply face the Equator, you'll get the best results. This useful fact can help us to overcome the effect of other obstructions too. For example, if you think a big tree or building is going to block signals, place yourself between it and the equator.

What about trees and things?

The radio transmissions from the satellites have travelled some twenty thousand kilometres before they reach the antenna of your GPS receiver. We should not be surprised to learn that the signals are weak and easily interrupted. A completely clear sky, free of buildings and trees, such as at sea, or in a desert, with nothing to interfere with the signals, is the best.

For those of us who are neither paddling an ocean-going canoe nor riding a camel, we are bound to find obstructions almost everywhere we go. Let's see what effect some common things have on the microwave signals from GPS satellites.

EXERCISE 10:- When is an obstruction not an obstruction?

Step 1 Go to a clear spot, face the Equator, and get a current position on your GPS receiver.

Step 2 Display the screen that shows how many satellites are being tracked. Take a mental note of this number.

Step 3 Cover the antenna with your hand, totally blocking all the signals. Observe the screen carefully. What is your GPS receiver telling you? Is there a warning that the signals have been lost? Check the signal strength display. Keep looking, it may take up to 30 seconds before your GPS receiver reacts to this indignity. Now you know what happens on total signal blockage, you can use this as a yardstick.

Step 4 Remove your hand and get a good position again. Now try covering the antenna with a plastic bag. Does it still work? How many satellites have you got now? What's the signal strength like? Can you wrap your GPS receiver in a plastic bag in rainy weather?

Step 5 Repeat these steps with as many items as you like. You might like to try your hat, a sail cloth, a pane of glass - why not try it in your car, under the windscreen, or in your tent?

Step 6 Wander off into the garden, climb a tree, or scramble amongst the bushes. Most GPS receivers should work in light tree cover. Chances are, you will find that getting a GPS position will be a little slower than normal, thanks to the leaves and branches reducing signal strength or maybe even totally blocking them.

How well your GPS receiver works under the trees will depend on many factors including what type of trees they are, how dense they are, even how wet their leaves are. The best way to find their effect is to test it.

Put your GPS receiver hard against a mighty oak, then move it around the trunk, trying different positions. Experiment with different densities and combinations of cover.

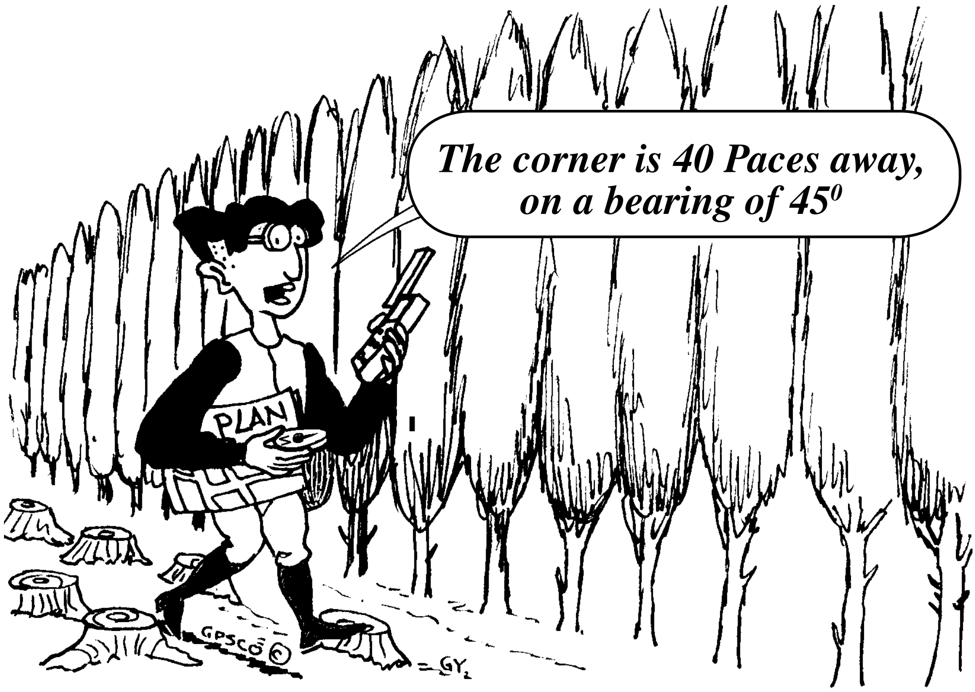
Step 7 Try it at night, in smoke or fog, under an umbrella or anywhere else that takes your fancy.

Tests like these are very educational and you quickly discover limits. You'll find that overhead power lines are no problem, but if you get too close to some radio, tv or mobile phone transmitters the signals to your GPS receiver may be swamped and it won't work.

The OFFSET feature - coordinates from a bearing and distance

What do you do if you want to find the position of a spot you can't occupy?

No worries. Firstly, find another place where you can get a GPS position and still see the spot you want to coordinate. Take and record your position. Now read a magnetic bearing, then pace or tape or estimate the distance to the obstructed point. Write them down. Armed with this bearing and distance, and the position of the unobstructed point, you can draw both positions on a map. Doing this is called using an 'offset' and it means that you can get a position for just about anywhere. Some smart GPS receivers have a built in offset feature that allows you to dial in the bearing and distance and it will automatically calculate the coordinates of the remote spot. However, this handy feature is under-used, and enables positioning of inaccessible points.



Getting to the Point

GPS will not only tell you where you are, but where to go!

All you have to do is scale the coordinates of your destination from a map, or you may have actually been there before and taken a position, store them in your GPS receiver and it will do the rest. In navigation jargon, these points are called 'waypoints'.

Navigation routes

Any series of linked waypoints forms a route. At least it does to your GPS receiver, whether the ground on the direct line between the waypoints is actually trafficable or not. It neither knows nor cares. If you trust your GPS receiver blindly, you could find yourself walking straight over a cliff.

So how do you navigate with a GPS receiver?

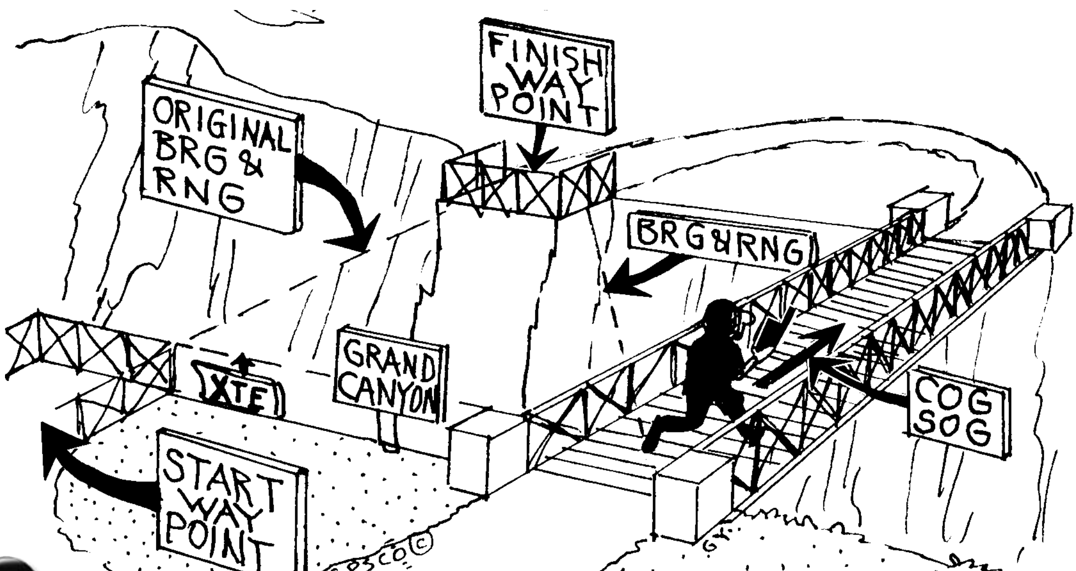
The secret is in using GPS as a tool - not an engine. Let it give you directions, but you keep a firm control of the steering wheel and 'GO' pedal.

All brands of GPS receivers use a different system of setting up navigation routes. A common procedure is to enter (or select) a series of waypoints in order and name them as a certain route. You'll have to wade through the Manual to find out how to enter, select, then follow a pre-set route. Your GPS receiver will keep taking positions as long as the power is kept up to it and it is receiving signals. From what we've discussed before, you will be able to recognise when lock has been lost. Either stop right there, or proceed to a more open location and wait for a new position.

Switch to navigation mode

You will be able to display the distance (sometimes called the RANGE or RNG) to the next waypoint in the route. Also you will be shown a direction, probably in the form of a bearing in degrees (BRG).

As you travel towards your waypoint, the distance/range will decrease, and the bearing will probably stay more or less the same, unless you are considerably off course. Another screen should show you how far off track you are, that is, the distance you are away from the straight line joining the waypoints that define this particular leg of the route. This is called the Cross Track Error, often shortened to 'XTE' .

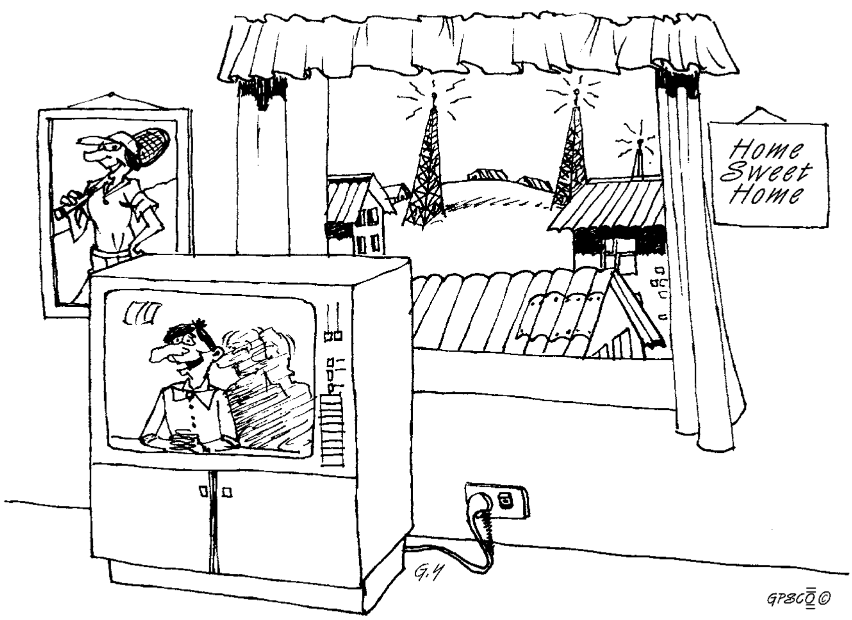


When navigating with your GPS receiver you don't have to leave it on all the time; that just wastes batteries. Hiking, skiing or driving, it's best to take note of the range and direct route bearing as you leave a waypoint, then move off, switch off and pocket the GPS receiver until nearer the next waypoint. Avoid following the screen blindly - you'll probably just trip over something. Remember that the bearing shown is the direction as the crow flies. We are not crows - nor do we fly. Sort out an appropriate safe walking or driving route, then check your range and bearing as you close in on the waypoint. GPS cannot replace common sense or years of accumulated navigation skills.

The Multipath Monster

As you move along, watch out or "Multipath" may get you. Constantly lurking and ready to pounce - it thrives in urban environments.

Similar to "ghosted" TV images, multipath occurs when you receive two sets of signals from the one satellite. One is beamed directly from the "bird". The other has taken a detour. It's been reflected or bounced off something along the way. Galvanised iron roofs, wire mesh fences, traffic and road signs and other metallic structures are common multipath offenders. Even lakes and wet trees can cause it. The stray signals can confuse our little electronic wonder and produce inaccurate results or signal reception problems.



Tackling Multipath

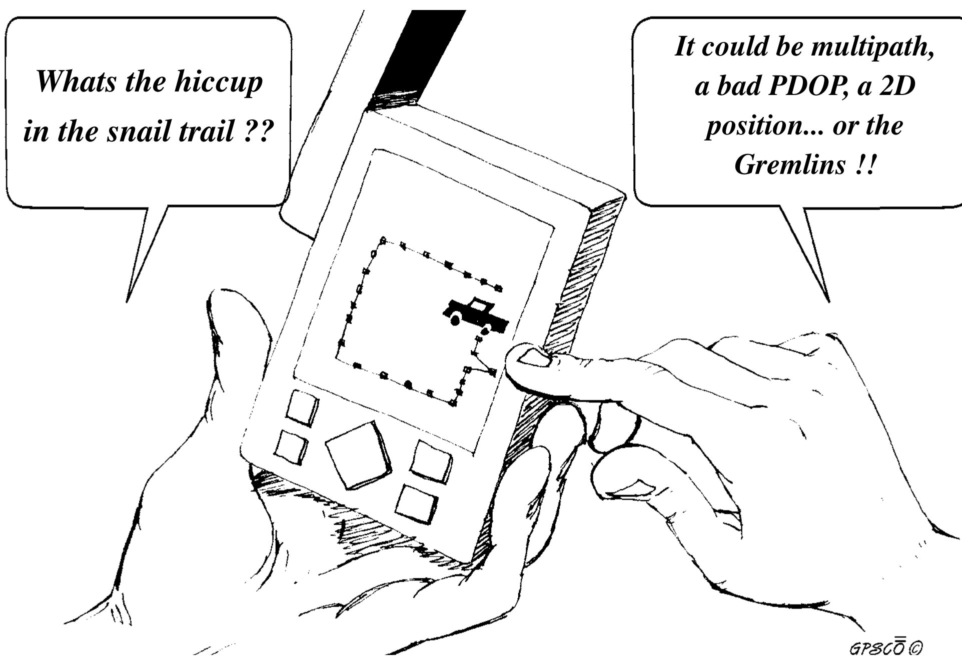
Tip one. Move away from the 'object' causing the reflected signal. About 50 m should be far enough. But the further the better.

Tips two and three. Wait for the satellite to move, or revisit the spot later. Either way the offending signal will be aimed somewhere else or have disappeared completely.

Yet another way, is to average a bunch of observations taken over a period of a minute or so. But the longer the better.

Sidestepping Multipath

When zooming along, multipath effects are short lived as you weave between reflected signals. Affecting only a few positions, they typically produce out-of-line points that simply don't fit the regular pattern. The odd spot off to the side of a straight road or regular curve, or erratic positions that bounce from one city block to the next indicate you have been ambushed by the multipath monster. They can strike without warning and are another good reason to take more positions than strictly necessary.



Are we there yet?

Most GPS receivers will give a warning or alarm when you are close. At this time, the GPS receiver may automatically start navigating to the next waypoint on the selected route. So if arrival at a waypoint is crucial, monitor closely when you are nearing it. If you can see the point, for example a bridge, summit, road junction, go to it and do whatever you have to do there. If the point is not definite, know that you can only get to within 15m with confidence.

How accurate is a waypoint?

It all depends.

Positions scaled from a map are limited by the scale and your map reading skills. Work out the ground distance (in metres) of 1/2 mm at map scale; this is an approximation of your waypoint accuracy.

In this way accuracies of scaled points from maps at 1: 4000 = 2m;
1:25 000=12.5m; 1:50 000 = 25m; 1:100 000=50m and 1:250 000 = 125m.

When measured using GPS it depends on the receiver's accuracy. But if taken from a list in a magazine or book ...who knows?

Whatever it is, the degree of accuracy of determination of position will directly affect how closely you can expect to navigate to that point.

EXERCISE 11:- Approaching a waypoint

Step 1 At HOME get a current position. Store it as a waypoint (call it HOME if you can).

Step 2 For this test to be meaningful, you'll have to leave HOME. Three or four hundred paces should do the trick - preferably in a straight line. Bye...

Step 3 When you are tired of walking, and want to return, get a position and set the Navigation mode in your GPS receiver to give you the bearing and distance to HOME.

Step 4 As you walk back, keep an eye on the display, as well as the traffic.

Note how the distance steadily reduces, and the bearing stays reasonably constant, perhaps increasing or decreasing slightly. As you get closer and closer to HOME, the bearing will vary more and more.

Step 5 Keep walking up to and past HOME. As you pass the waypoint - or within a certain range of it - your GPS receiver should sound a beep or alarm to alert you of your imminent arrival. When the alarm sounds, note the distance, steadily increasing as you pass the waypoint, and keep walking. Watch the bearing too, as it may appear quite erratic for a short while, then slowly settle as your distance from HOME increases.

Step 6 Stop, and head back for HOME. You may like to try to find how close your GPS receiver can get you. When you are down to the smallest distance (it is rarely at zero), are you exactly where you started out? All this goes to show the importance of choosing recognisable landmarks as waypoints.

An experienced navigator will choose only obvious features as waypoints. Road junctions, harbour entrances, landing grounds, vehicle parking areas, or other significant landmarks are excellent examples of well chosen waypoints. In the same way, a hike tour leader will enter the position where the bus will pick the group up, or where the group will camp for the night, having first located these points on a map and scaled the coordinates. That way you know when you have arrived, using the GPS receiver as a general guide, keeping you from taking a wrong turn, or straying too far off the route.

Even if you are navigating to a point you have never visited before, try to find some way that you can recognise your destination. When you think about it, there is very little sense in choosing anything as a waypoint unless it is significant as a landmark. Your map will help here as almost any mapped feature is a landmark - that's why it's on the map!

Now you've arrived, ... rest awhile

Having arrived, ask yourself "Does this make sense?" Look around, check your position by reference to other landmarks. Use the sun or a compass to orientate yourself. Don't assume all is well simply because you want it to be. There's always the possibility that you entered the wrong coordinates for the waypoint.

Or perhaps you've selected the wrong one. It's easy to do.

One way or another satisfy yourself you know where you are on the map, before setting off on the next leg. In the case where you are not sure if you have properly identified the waypoint, take a position at the point you decide is most likely, name it and store it and write it in your notebook. Retrieve the waypoint that you were heading for and compare values. If there is a difference of more than 20 or so metres, in position, find out why before going off and compounding the error.

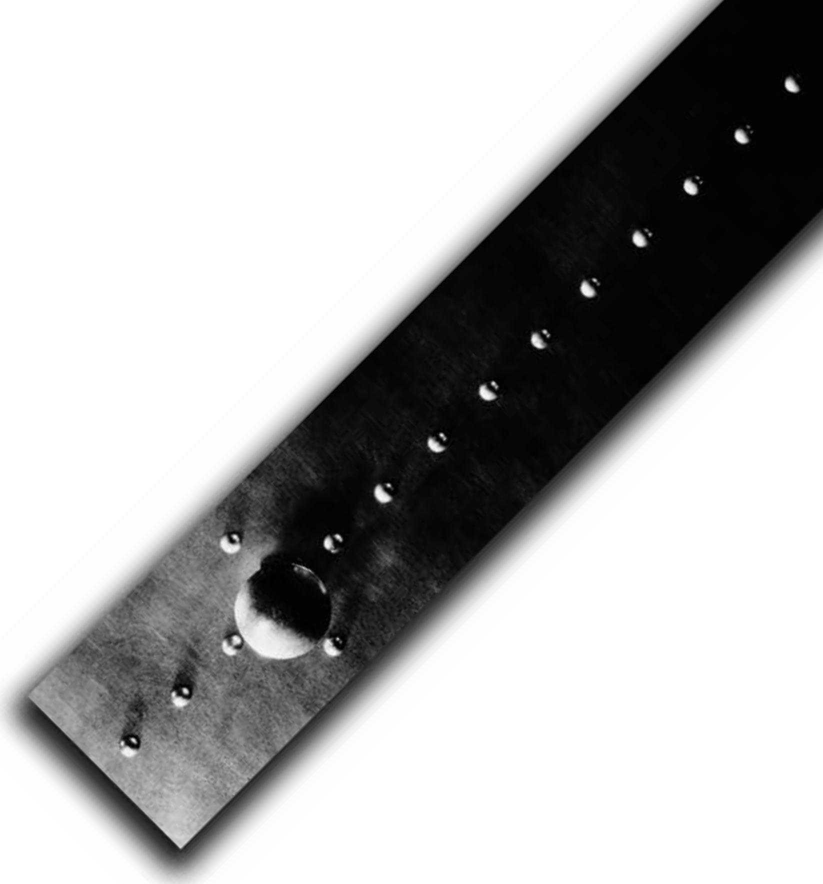
I wish GPS was more accurate

In the past few pages we have played around with basic GPS navigation, emphasising the part YOU play. You may have been a little surprised to find that our exercises reveal truths about GPS that don't rate a mention in advertising brochures. We err on the side of caution to show the necessity for attention to detail.

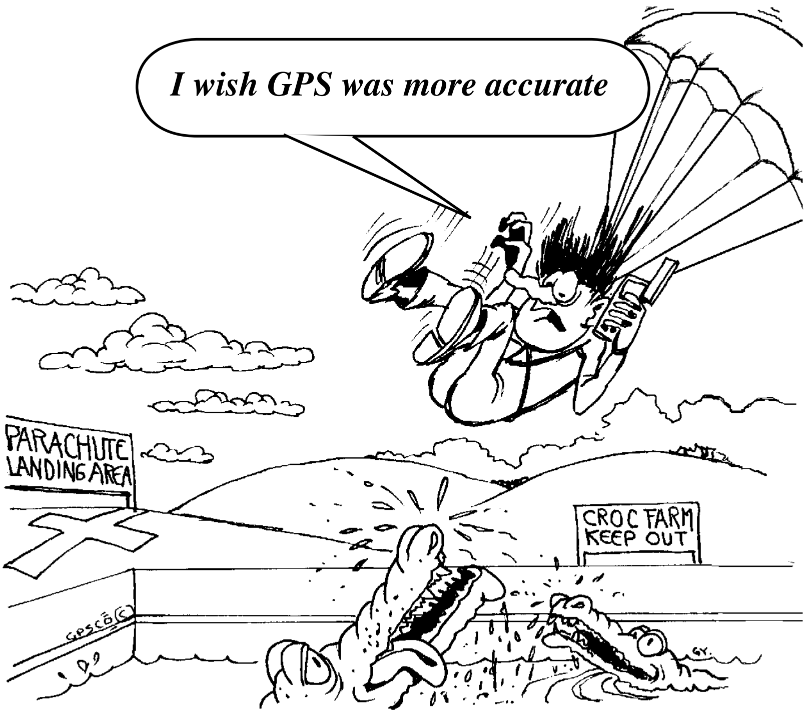
Now you are aware of the basics of GPS, and its limitations, you may be saying to yourself, "But I need better accuracy than that!" And you can get it too. Better and more spectacular results can be achieved by using the special techniques, practices and equipment described next.

Chapter Summary

- The bearing and distance display are only meaningful when you are moving
- Your GPS receiver is slow to respond to sudden changes in direction or speed
- To get the most number of satellites, face the Equator
- Choose landmarks as waypoints
- Do not rely on GPS alone for navigation
- Do not leave your brain at home
- DON'T EVER ASSUME ANYTHING



Chapter 6
Improving Your Accuracy


I wish GPS was more accurate
PARACHUTE LANDING AREA
CROC FARM KEEP OUT

The story so far...

Now we know that if we follow the "Golden Rules of GPS":

- Use 3D positions only
- Observe only when the PDOP is less than 5
- Use the correct map datum

then the horizontal position displayed on the screen of your GPS receiver should be accurate to within 15m.

For many users this accuracy is just fine. It's enough to get them within a stones throw of the boat ramp, the airfield or their car. However there will be times when some of us want, or need, more accurate positions. In this chapter we will look at a number of easy ways to do this.

Want more accurate heights?

OK, here's an idea. Find a topographic map that covers where you are. It will need to be one that shows contours and a mapping grid. Go to the spot where you want the height. Fire up your GPS receiver. Ignore the height displayed, but note and plot the horizontal position on the map. Interpolate the height of your position between the contours on the map. Assume an even gradient between contours (and accurate plotting!) and adjust to actual conditions. In this way, you should be able to estimate the ground elevation to the nearest half, or even quarter, of a contour interval.

Will accuracy improve... if the PDOP is lower?

Yes. The smaller the PDOP the more accurate the position fix. Some GPS receivers display the PDOP, others don't. If there are no cautionary signs or flashing icons or statements about 'Poor Geometry' - it's likely that you have a low PDOP.

Will accuracy improve... if I use more satellites?

Yes. The more satellites, the more accurate your position. This principle is commonly used by "all in view" or "12 channel" receivers to help squeeze out better results.

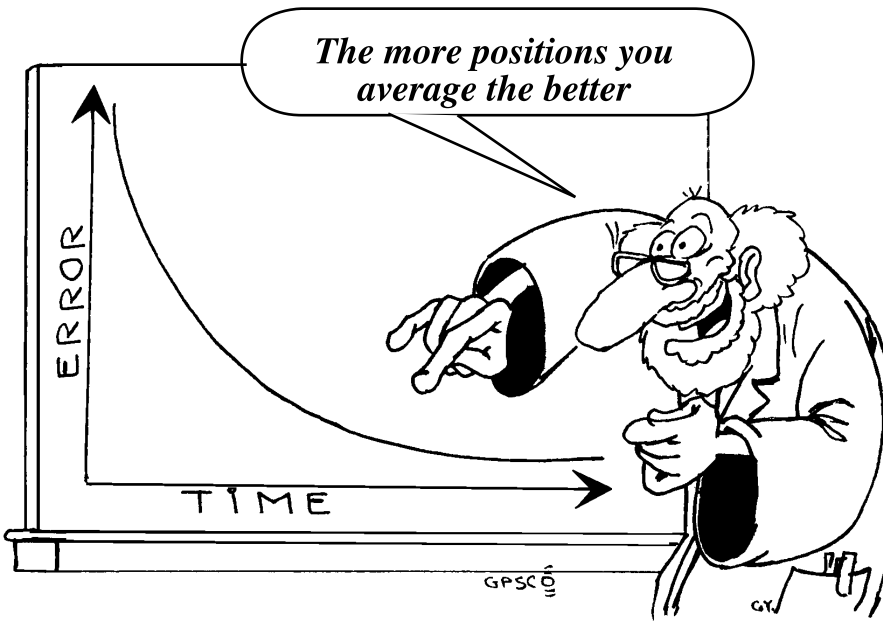
But your GPS receiver must actually use the extra satellites. Some older GPS receivers may have tracked 5, 6, 7 or even 8 satellites. However they only used the best 4 satellites, those with the lowest PDOP, to calculate a position. The others it simply ignored.

Will accuracy improve... if I average a number of position fixes?

Yes. The idea is to take a number of positions at the same spot, holding the GPS receiver stationary, then work out the average.

Some GPS receivers have an 'averaging' function, available at the touch of a few buttons, which will do the hard work. For those which don't, you can still do it manually. All you have to do is write down ten or more positions as they are displayed, and work out the average. Either way, you still have to pay for your better position by staying in the one spot for a minute or two, while it does its bit for you.

The more position answers you average the more accurate the result. The graph below shows how accuracy and reliability levels improve by averaging. A quick glance reveals that even a little averaging can rapidly improve your accuracy. However, the best you can expect is a couple of metres horizontal accuracy, and a dozen metres vertical accuracy before you die of boredom.



How do you get the best results in the least time?

Obviously you want the best results in the shortest time. The exact number of positions you should average will vary for different GPS receivers and the accuracy you want. To find out how many you need, you can't beat a test drive.

EXERCISE 12:- How's your average?

As we said earlier averaging comes at a cost. Here you will have to spend some time in preparation. This demo will give you an idea of how many fixes you should average to get the most acceptable balance between positional accuracy and observation time.

Step 1 Go to a point of known location, preferably a survey mark or trig point whose coordinates are known in the same coordinate system and on the same map datum as your GPS receiver. Your local surveyor, municipal engineer, or the web should be able to help you out. Store these coordinates as a waypoint - let's name it 'TRUE'.

Step 2 Turn your GPS receiver ON. Use the Golden Rules of GPS to get a good current position.

Step 3 Use the 'Average' function for a timed interval - say 20 seconds for a starter. Alternatively write down each new position as it is shown on the screen over the same interval.

Step 4 Calculate the average position and store it as a waypoint - say 'AV20'.

Step 5 In NAV mode calculate the distance between TRUE and AV20. Note this down. This distance represents the accuracy of your averaged fix.

Step 6 Turn your GPS receiver OFF.

Step 7 Repeat steps 2 - 6 for AV40, AV80, AV160 (doubling the time interval each time).

Step 8 From your noted distances, soon you will get a feel for how long you need to remain at a point to get an acceptable accuracy.

Be wary of seemingly 'good results'

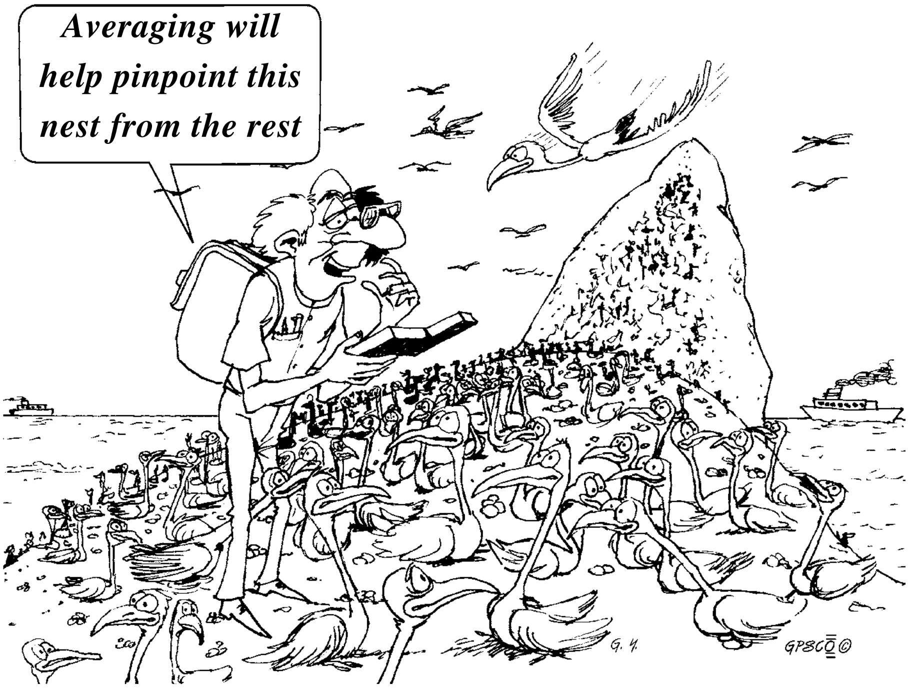
Because of the nature of GPS, positions taken only seconds apart may differ by a few metres only, giving, by their good grouping, a false impression of accuracy or repeatability. Therefore, it is preferable to repeat Exercise 12 at several different times, or even on different days.

Averaging... The Fourth, (and only optional), GPS Golden Rule

As you have seen averaging is great stuff. It avoids the chance of using a single rogue position that may be in error, while at the same time increasing accuracy and reliability. It is so important we have made it our fourth GPS Golden Rule. Since there are some GPS receivers without an averaging feature we have made the Golden Rule optional.

GOLDEN RULE No. 4

Use Averaging when you can



Differential GPS

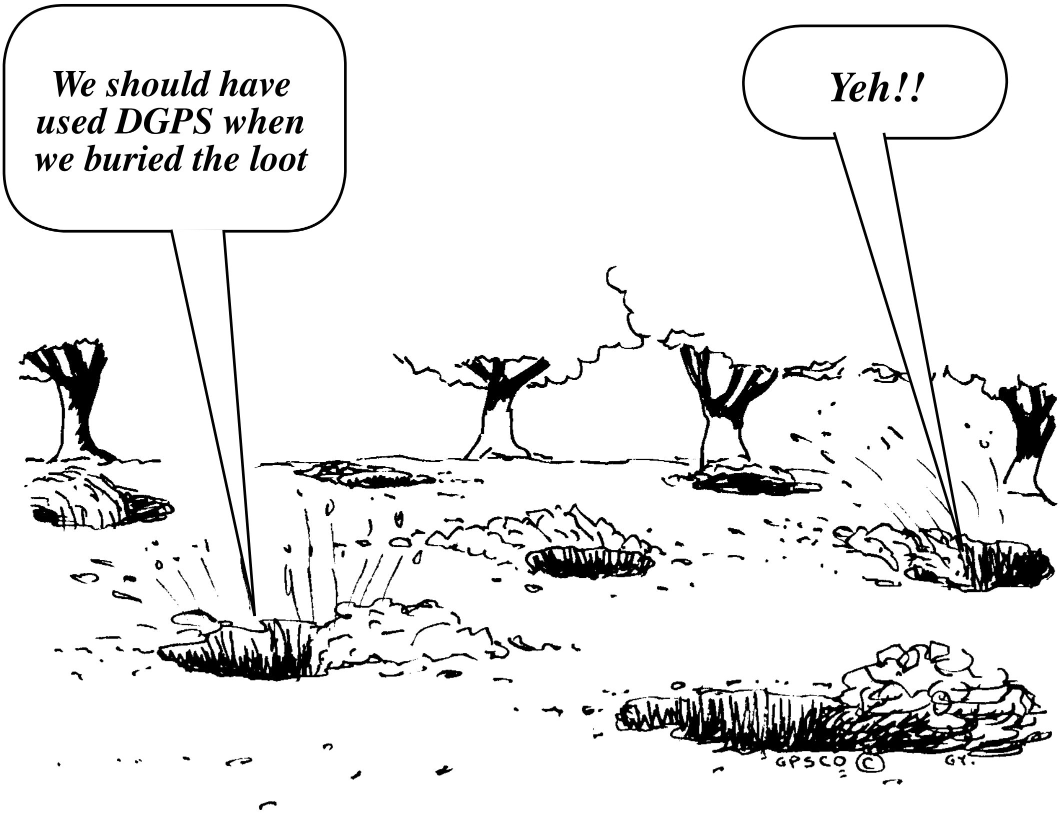
All the previous techniques will improve the accuracy of your position. We can improve from 15m to a couple of metres. This is probably more than good enough for your purposes, and it does not involve spending any more dollars. But for a growing number of users these techniques are still not accurate enough or are far too slow. They want pinpoint positions quickly and easily.

It may seem a big ask, for a little gadget, but by getting your GPS receiver to talk to another GPS receiver we enter a whole new world. The world of Differential GPS.

Chapter Summary

- The removal of Selective Availability has increased GPS accuracy
- A lower PDOP will give a better accuracy
- More satellites in your position solution will improve accuracy and reliability
- Averaging is a good and cheap way to improve accuracy and reliability
- Averaging is the fourth (and only optional) GPS Golden rule

Chapter 7
Real Time DGPS


We should have used DGPS when we buried the loot
Yeh!!
GPSCO ©
GY.

Real Time DGPS

Will the pace never let up! Real Time DGPS is another popular way to improve GPS accuracy. In these pages we reveal all - lots of warm fuzzies, and a few warts as well.

What is DGPS?

Differential GPS, or DGPS as it is often called, is a technique to squeeze accuracies of 2 to 5 metres - or even better - from many GPS receivers.

DGPS is something special. If it all sounds a little too good to be true, your cynicism is well founded, because we do need a little help from a Fairy Godmother. She's out there somewhere.

A free lunch? Not really

Remember the old saying "There is no such thing as a free lunch"?, well it's just as true with DGPS as with anything else.

But there are many, many users who are more than willing to pay the extra couple of hundred dollars needed to set up for DGPS.

In DGPS, more than any other aspect of GPS, you get what you pay for.

Essential DGPS equipment

Unlike averaging, where the extra cost was only in time, for DGPS you are going to have to beg, borrow or even buy, two main pieces of equipment: a special GPS receiver, and a special radio.

The GPS receiver

You'll need an "RTCM" capable GPS receiver - hopefully this is what you already own or are about to buy. Many suppliers simply call this "DGPS Ready". The "DGPS Ready" feature is standard in many of the latest and cheapest GPS receivers. Even if you have to buy the up-market, upgraded, luxury "XL" version, don't worry, the extra cost won't send you broke.

The radio

You'll also need a DGPS-capable radio designed to receive DGPS correction signals from something called a 'Base Station'. Don't worry, you don't have to buy a Base Station... just the radio. More about this shortly.

RTCM (Radio Technical Commission Maritime) is an internationally-accepted format for expressing Real Time DGPS corrections.

Is DGPS hard to do?

No, not really. If you can follow the Exercises in this book, and plug the right lead into the right socket, you can do DGPS.

"Off the shelf" systems from the big GPS players are easy to use. Basically all you have to do is connect power to the radio, link it and the GPS receiver by a computer data cable, and push a few buttons to check that both are talking to one another in the same language and at the same speed. That's all there is to it. Accurate DGPS-corrected positions are displayed on your GPS receiver's screen.

In fact, it's all a little too simple. Some people could be lulled into a false sense of security. Don't be one of them... you still have to obey the Golden Rules.

With SA gone, do I still need DGPS?

Yes ... or no. Your intended use of the position, and the scale to which the final product will be plotted is a good guide to what is required. For example; oyster leases side by side need accurate DGPS positions; locating helicopter landing pads probably do not.

If you absolutely must quickly and consistently get 2 to 5 metre or better accuracy - Yes, you still need DGPS.

On the other hand if, you can live with some positions that could be up to 15 metres in error, you can do without the cost of DGPS.

How does DGPS work?

Differential GPS is a technique that improves positioning accuracy by measuring the size of GPS errors at one point, known as the Base Station, and applying them as corrections to other GPS receivers, called the Rovers.

Let’s sort out this terminology right from the start. Your GPS receiver is called the Rover. It roves around - anywhere you want. That’s why it’s called the rover. The Base Station is another, very expensive, GPS receiver. It’s owned by someone else and its antenna is usually bolted to the top of a building, where it can see all the satellites in view. You don’t have to go near it - all you want is data from it.

With that sorted out, there are several different ways to do DGPS. Here we will describe only the technique known as Real Time DGPS, since it is by far the most popular and easiest to do. You may hear it referred to by a variety of names including the “Range Correction” or the “RTCM” method.

DGPS reduces the effects of a lot of errors that have limited the accuracy of your GPS receiver up until now.

The scenario

Imagine you are standing in a nice open area, a paddock perhaps, or a football oval, or maybe even the top of a mountain or on the deck of a boat. You have your GPS receiver - called the Rover. It is ON and tracking eight satellites. It measures a pseudorange to each satellite. Let’s take a moment or two to think about what’s happening in that little package of electronic wizardry in your hand.

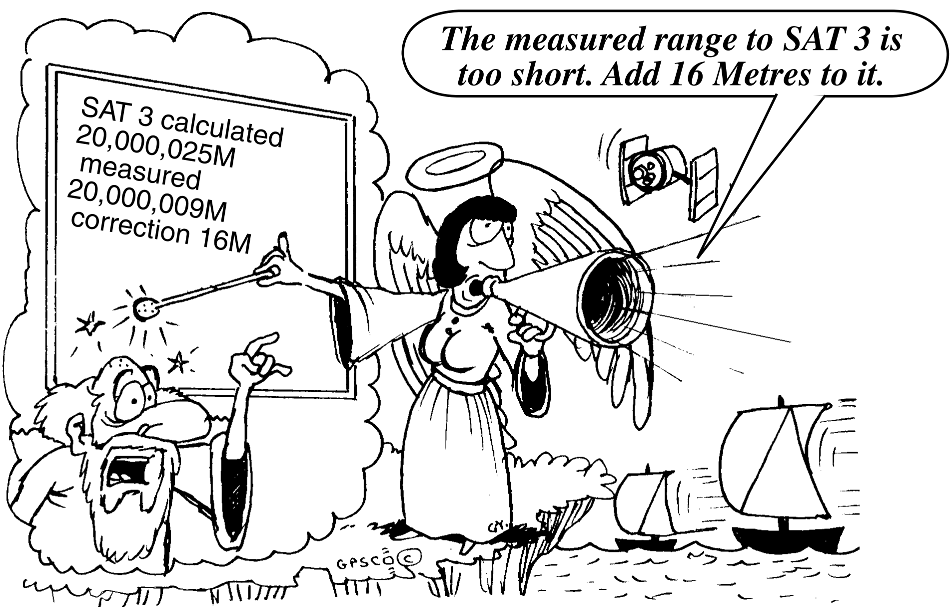
First; pick a pseudorange - any pseudorange. They all look the same - simply a distance to a satellite measured by your GPS receiver. At first glance you might say, "Looks OK to me. Twenty million and something metres. Very accurate. Clever little GPS receiver, well done."

But wait; it's not what it seems. That is not the correct distance at all! It's full of errors!

The size of these errors will be different for each satellite, but their combined effect makes each pseudorange either shorter or longer than the true length. What's more, its length is changing every second. We all know that garbage in leads to garbage out - that means our calculated position will be wrong!

What are we to do? To find the size of the error in each pseudorange, we need someone, (are you there Fairy Godmother?), somewhere, to work out the amount of error in each pseudorange at any specific instant of time.

This is the Base Station's moment of glory. Its position is accurately known, and as we mentioned earlier is equipped with a super GPS receiver operated by FG herself. Day in day out, she calculates the range to each satellite. This is done by a nice bit of reverse engineering. (She knows where she is and where the satellites are). At the same time she measures the pseudorange to each satellite. She's a very busy person.



By comparing each calculated pseudorange with each measured pseudorange she can work out the error in each range to each satellite. All pseudoranges to a particular satellite at a specific instant in time will be in error by exactly the same amount. Luckily, we don't have to do anything, the electronics - and FG - have everything well in hand.

While FG is doing her thing, we are in the field somewhere anxiously clutching our eight erroneous pseudoranges in our sweaty palms. Then, bingo! through the ether comes a message that looks something like the list below (when translated into human-speak).

Satellite	Error	Action required
3	+15.7 meters	Add 15.7m to pseudorange to SV 3
5	-32.1 meters	Subtract 32.1m from pseudorange to SV 5
9	-89.7 meters	Subtract 89.7m from pseudorange to SV 9
11	+4.5 meters	Add 4.5m to pseudorange to SV 11
15	+23.4 meters	Add 23.4m to pseudorange to SV 15
17	-12.6 meters	Subtract 12.6m from pseudorange to SV 17
21	-33.5 meters	Subtract 33.5m from pseudorange to SV 21
24	+11.3 meters	Add 11.3m to pseudorange to SV 24

This is what we are waiting for. Our little box of wonders beeps and gurgles in excitement as it corrects each pseudorange and calculates a new position using the now error-free pseudoranges. And in next to no time - typically just as quick as it delivers a single point position - our new, differentially corrected position appears on the display, along with corrected speed and bearing. Impressed?

Can there be more than one Rover?

Why not? DGPS is user-friendly in the extreme, and the Fairy Godmother at the Base Station can simultaneously look after any number of other GPS receivers, each roving around the countryside. Just like us, they are ON and listening to at least four of the same satellites as the Base Station. Because they are listening to the same satellites, at the same instant of time, they will all have the same errors affecting their pseudoranges.

Exit Fairy Godmother, enter RTCM

Dear old Fairy Godmother... what would we do without her? At this point, anyone who believes in fairies of any kind should quietly tune out and turn the page. The truth is... there is no FG. Instead we have RTCM radio transmissions from the Base Station to the radio connected to our GPS receiver.

Yes; that, and the constant monitoring of all visible satellites by the Base Station GPS receiver are the real brains behind sorting out the pseudorange corrections and sending them at lightspeed to us.

Do stale RTCM corrections affect DGPS accuracy?

Yes. There is a lot of number crunching going on here. The Base Station has to calculate the RTCM corrections, the Rover has to apply them. This all takes time. So does the actual transmission and reception of the signals. If it takes too long, the corrections start to become stale. They won't approximate the current error. The older the corrections are, the less they reflect the actual situation, and ultimately, the less accurate your displayed position.

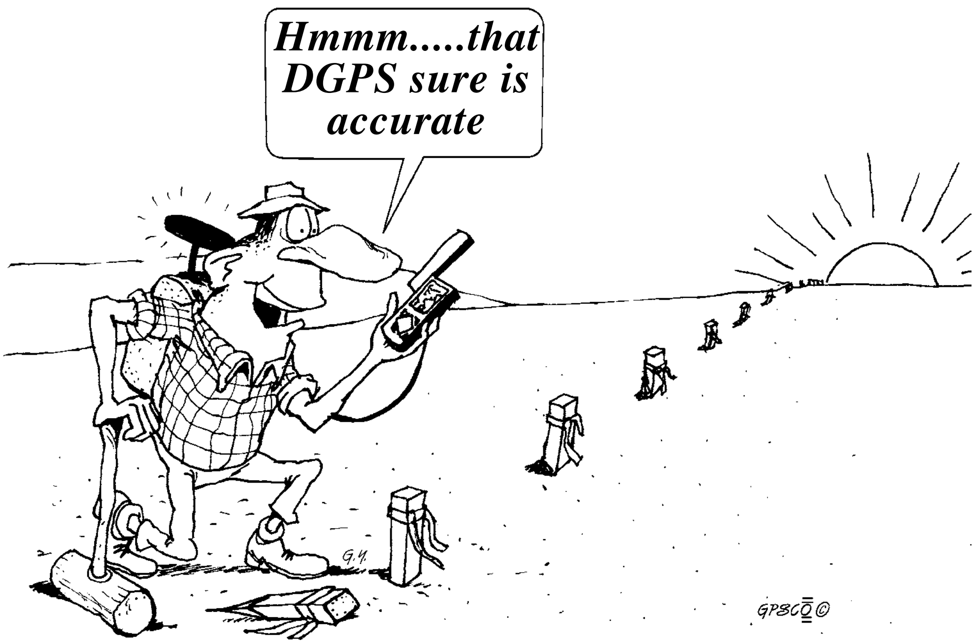
A correction to the correction

A correction is also calculated to take account of the rate of change of the pseudorange corrections. It could be, say -1.5 m every second for satellite number 3. This is needed because by the time the Rover has received the corrections they may be a few seconds old. And no longer exactly right. Let's say they are four seconds old. By subtracting 6 meters (4 seconds at -1.5 meter per sec) from the original correction for SV3 (15.7 m - 6 m = 9.7m) we remove the error caused through use of an 'old' correction.

Where do I get these RTCM corrections from?

A growing number of government organisations and multinational companies operate real time DGPS services. They may broadcast their RTCM corrections on FM, VHF/UHF, Cellular, or even Satellite radio links depending on the area they want to cover.

If you want to know who covers your neck of the woods, and can't find an advertised service, phone your local Government Survey and Mapping Organisation. Any GPS salesmen worth his commission will also know.



Most services have, in addition to a radio hire rate, a data usage cost that is based on the amount of correction signals you use. This could be charged by the minute, hour, day, month or even a flat yearly rate. The charge will vary depending on whether you're using FM, VHF/UHF or Satellite radio links. Shop around, some even offer free signals.

Is DGPS more accurate now that S/A has gone?

Not really. There was little improvement in accuracy, since DGPS already removed most of the effects of Selective Availability.

Do all DGPS receivers give the same accuracy?

Most. But not all. Your standard "run of the mill" DGPS-ready receiver will give a basic accuracy of 2 to 5 metres. But some older GPS receivers only have a DGPS accuracy of 10 metres. Your GPS receiver's differential accuracy will normally be quoted in either the manual or the specification sheet, or maybe even on the back of the box. Check it out before you hand over the cash!

If money is no problem, you can get top-of-the-range GPS receivers. With units like these one metre - or even submetre - positioning can be achieved using standard RTCM corrections. But if you have high blood pressure, make sure you are sitting down before you ask the salesperson "How much for one of these?"

Does the distance between the Base Station and Rovers affect accuracy?

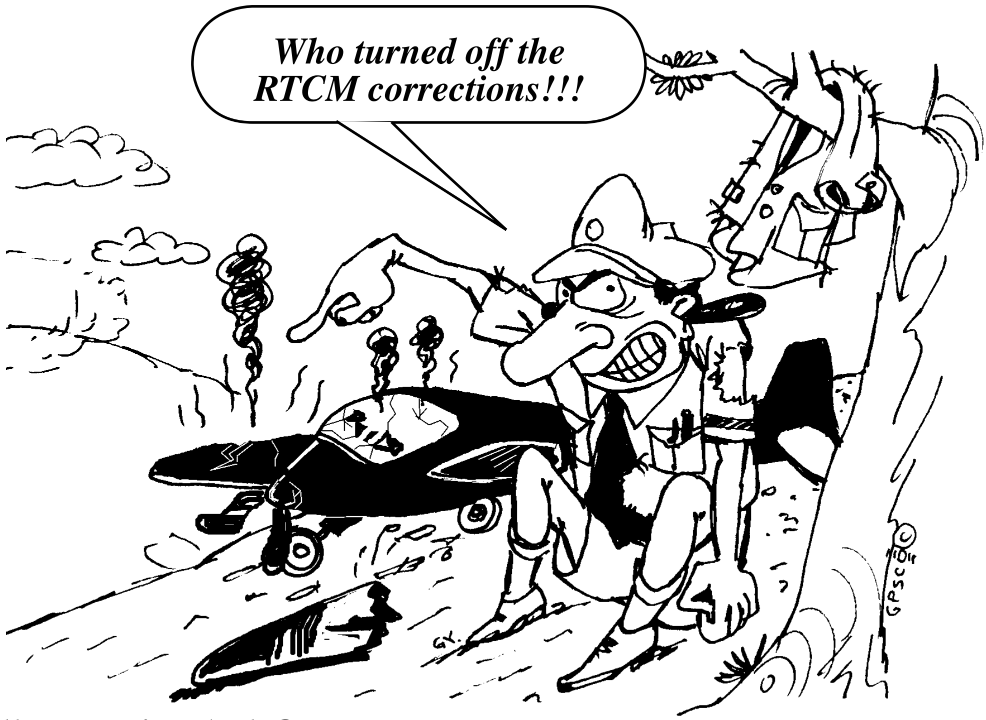
Yes. The general 2 to 5 metre accuracy we expect from DGPS occurs when you are within about 100 kilometres from your nearest Base Station. As the distance from the Base Station increases the accuracy will drop off by about an extra one metre for every extra 100 kilometres. For example, if you are 300 kilometres from the nearest Base Station you would expect a position within 4 to 7 metres (2 to 5 for the first 100km and an extra 2m for the extra 200km).

Stop!

Hang on a moment! You may have just missed an important point. That example just showed that DGPS was accurate to about 7 m over 300 km. Has the penny dropped? That's right; that 7m could just be the accuracy of your bare bones GPS receiver anyway. That's without all that extra gadgetry hanging off it. So DGPS may not have improved your position after all. Back to square one.

What you have to do is determine the accuracy of your bare bones receiver and the distance you will be from the base station. Then use the rule of thumb to work out if DGPS is going to improve things or not.

A few quick calculations could save you hundreds or even thousands of dollars worth of unnecessary DGPS equipment and RTCM signals. Rest assured, no-one will thank you if you get it wrong ...



Will averaging help?

Taking a number of DGPS positions for the same point and averaging them will increase your accuracy. As you will remember from the last chapter, your accuracy depends on how many observations are averaged. The more the better - up to a point. Averaging 20 to 30 DGPS position fixes can give accuracies of 2 to 5 metres up to 1,000 kilometres from a Base Station. That's right! And yes again, that is incredible! Averaging is great stuff ... that's why it is one of the Golden Rules of GPS. The only limitation is that you must remain stationary while you do it - but only for a minute or two.

Wide Area DGPS

Another DGPS method called Wide Area DGPS (WADS) has avoided the problem of the extra 1m per 100km, and the necessity to remain still while observing. WADS can achieve 2 to 5 metres for each and every position - while on the move. Even better results are possible if you have top class GPS equipment.

The 'wide area' can be as large as continental Australia and its waters. WADS works by using standard RTCM signals from a network of surrounding Base Stations, not just the nearest. From all these it will calculate the best RTCM correction for your location.

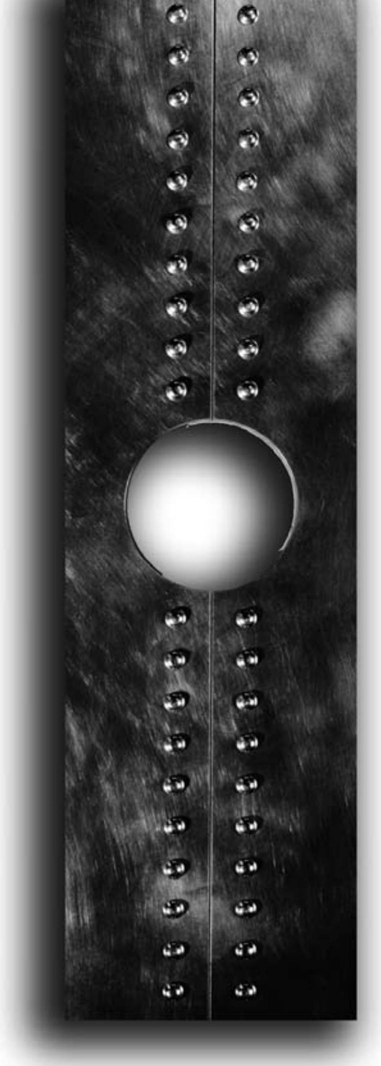
Can I get even more accurate positions?

If you need centimetre, or even millimetre, accuracy it can be, and is regularly achieved using GPS. The techniques employ DGPS principles, but there the similarities end. This type of GPS work is not for the novice or fainthearted. It uses specialised equipment and skills. You can learn what's involved by reading this book's big brother called "Getting Started with GPS Surveying".

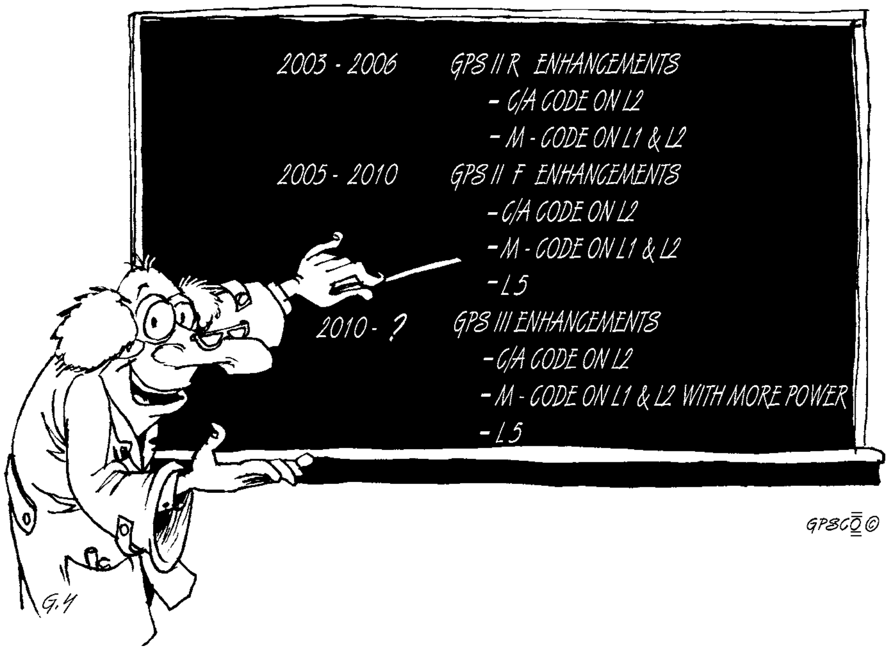
If you really need high accuracy you should contact the professionals. It's NOT just a matter of more expensive gear. Factors such as management of multi-disciplinary parties in a field situation, a thorough grasp of statistics and use of specialised software have to be considered. Surveying firms specialising in GPS are the people to see. When it comes to millimetre squeezing, they are the experts.

Chapter Summary

- **DGPS gives accuracies of 2 - 5m, or even better**
- **You'll need a DGPS-ready receiver, and a radio receiving corrections in RTCM format**
- **DGPS works by calculating and applying corrections to each pseudorange**
- **Accuracy deteriorates by an additional 1m for each 100km between the Rover and the Base Station**
- **Averaging improves DGPS accuracy**
- **Higher accuracies require specialised surveying DGPS techniques and instruments**

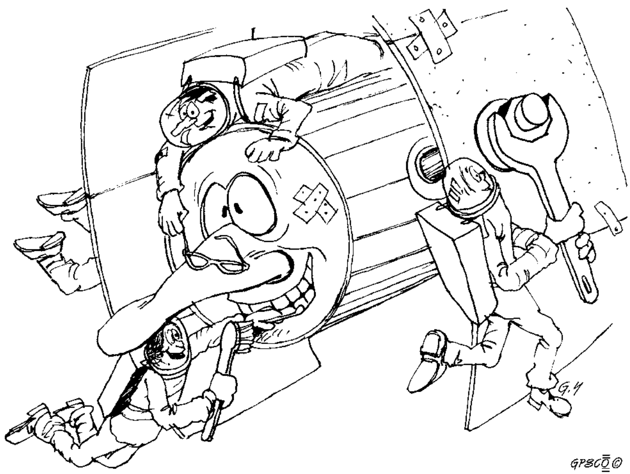


Chapter 8
Modernising GPS


2003 - 2006
GPS II R ENHANCEMENTS
- C/A CODE ON L2
- M - CODE ON L1 & L2
2005 - 2010
GPS II F ENHANCEMENTS
- C/A CODE ON L2
- M - CODE ON L1 & L2
- L5
2010 - ?
GPS III ENHANCEMENTS
- C/A CODE ON L2
- M - CODE ON L1 & L2 WITH MORE POWER
- L5
GPSCO ©
G.Y

Teaching an old dog new tricks

GPS has been knocking around for a quarter of a century. Over those 25 years just think how your own life has changed... school, marriage, children, homes, friends and absent loved ones. Not surprisingly GPS is starting to show its age. Let's be honest: aren't we all? So it's getting a face-lift. It's being updated, renovated and modernised.



In these last few pages we will try to identify, explain, and indicate the impact of GPS modernisation. As you read remember... plans change! Some things may have happened, some postponed, and others will never happen even if the moon turns blue. For what it's worth here is our attempt at crystal ball gazing.

The C/A code on L2

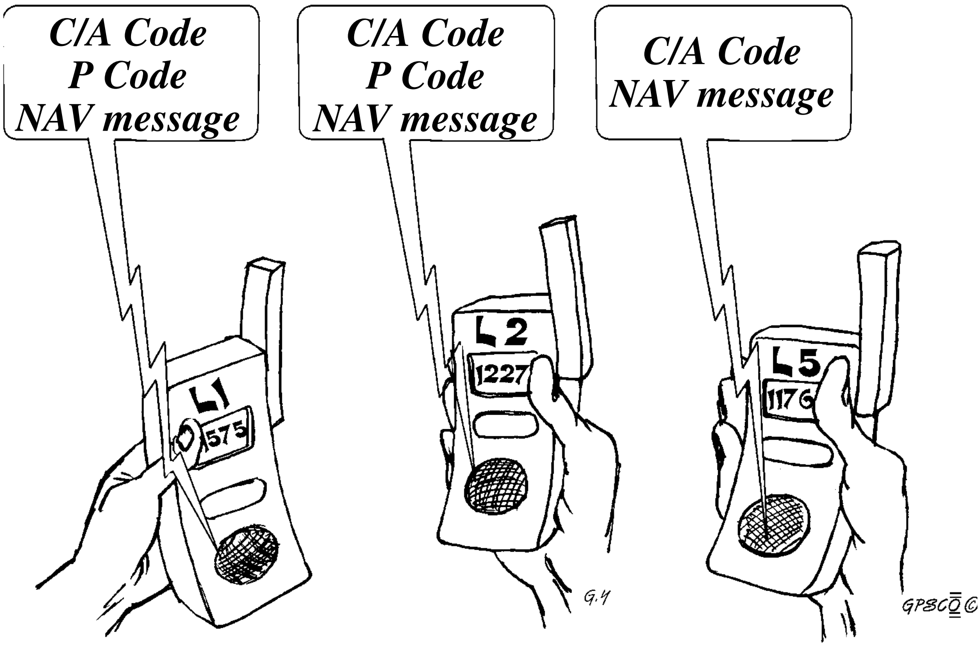
The civilian C/A code will be broadcast on the L2 frequency.

Available from the last dozen or so Block IIR "birds" onwards, civilians will be able to use signals on both the L1 and L2 frequencies. Improved signal availability, improved positioning accuracy, improved radio interference resistance, and signal redundancy are but some of the benefits promised.

The C/A code on a new third frequency (L5)

Block IIF satellites will transmit the civilian C/A code on a new third frequency (1176.45 Mhz). Since it is called L5 and not L3, one has to ask "was Military Intelligence involved"?

The future transmission of the C/A code on the L1, L2, and L5 frequencies promises a quantum leap in signal availability, positioning accuracy, radio interference resistance, and signal redundancy.



New Military codes... M-Codes

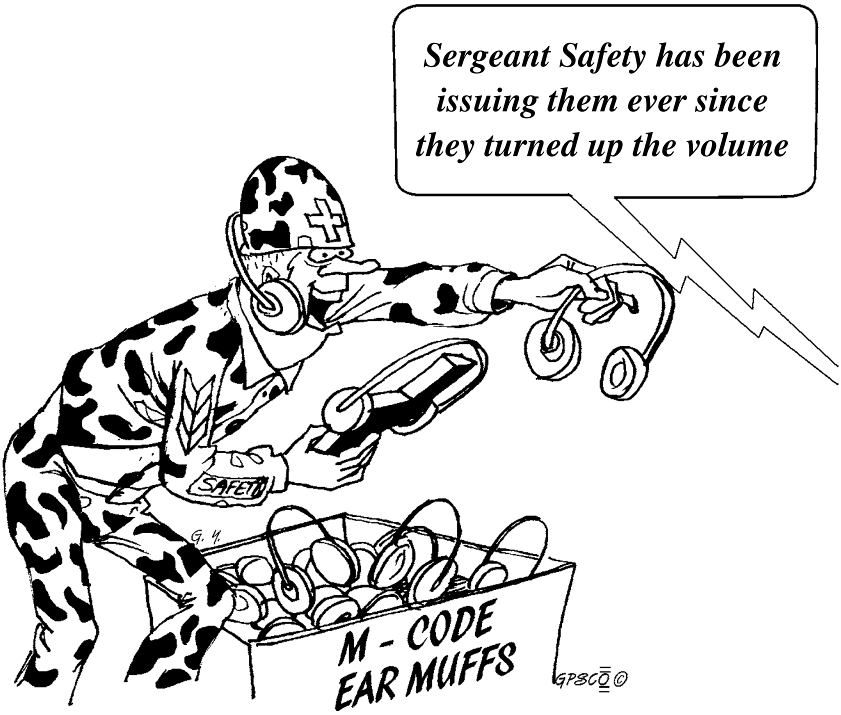
New and additional military codes known as the M-codes will be broadcast.

With improved cryptographic protection to baffle the baddies and transmitted on the familiar L1 and L2 frequencies, they will be available from the last dozen or so Block IIR "birds" onwards.

The M-code (Earth Coverage) will cover the whole Earth. The M-Code (Spot Beam) will, as you may have guessed, be beamed down and focused on those regions of the Earth as, when and where the "GI's" need it.

Increased Signal Strength for Military users

Block III satellites will pump the M-code (Spot Beam) out at 20 dB more power. Turning up the volume will give the US Military better protection from signal jamming when things start to get a bit "noisy" on the battlefield.



Am I going to need a new GPS Receiver?

In all probability - YES.

Odds are that "Old Faithful" won't make the grade. It's not designed to receive either the L2 frequency, nor the new L5 frequency and you'll miss out on all the extra goodies. Plan to beg, borrow, buy, or ask Santa for a new GPS receiver with these features in a year or two.

Control Segment refit

A refit and expansion of the Control Segment is underway. Dinosaur era gear is being sent to the scrap heap. New digital "thingamajigs", "doodads", and "doohickeys" are being wheeled in. Resulting in improved satellite tracking, we will enjoy better Navigation Messages and increased GPS accuracies. Boffins are talking of accuracies better than 10 metres with "Old Faithful" and five meters or less from future receivers. It will be like a free receiver upgrade.

Galileo

Gazing ever deeper into the crystal ball, we see... smoke, images, and ... Galileo !?!

Not that old Italian bloke with the telescope. No, we see a new European Satellite Navigation System in the design phase. It could work in tandem with GPS. That would mean more satellites, more signals, and yet another quantum leap for users.

GLONASS

The former Russians have their own system called GLONASS. It looks and works much like GPS. Operating since the early eighties, it has come on hard times. While its future is unknown, some are still hoping for recreational receivers that use both GLONASS and GPS signals and that fit into a backpack.

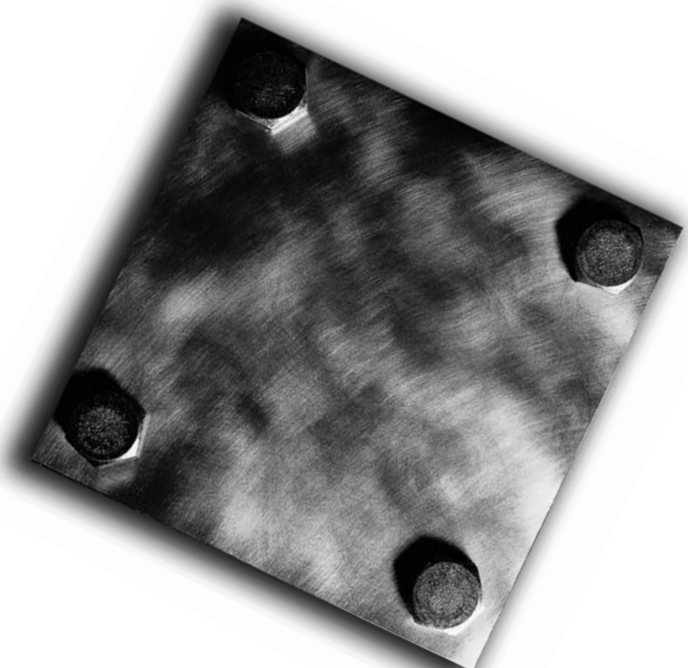
What's next?

Let's drag ourselves back to reality. Stick to the Golden Rules of GPS. Apply what you have learnt. Keeping these in mind will ensure that you can sail the seven seas, roam the skies or deserts and know precisely where you are at all times. How you use this priceless gift is up to you - and your imagination.

Chapter 8 Summary

- GPS is being modernised
- C/A code will be transmitted on the L2 frequency
- C/A code signals will be broadcast on a new L5 frequency
- New Military M-Codes will be broadcast on both L1 and L2 frequencies
- M-Code (spot beam) will have increased signal power
- GPS signals may be broadcast from other satellites

Abbreviations



Abbreviations used in this book:

AGD66	Australian Geodetic Datum 1966
AGD84	Australian Geodetic Datum 1984
AHD	Australian Height Datum
A/S	Anti Spoofing
BRG	Bearing
C/A Code	Clear Access/Course Acquisition (civilian) code
CD	Compact Disk
COG	Course Over Ground
DGPS	Differential Global Positioning System
DoD	Department of Defense
DoT	Department of Transport
GDA94	Geocentric Datum of Australia 1994
GMT	Greenwich Mean Time
GPS	Global Positioning System
GLONASS	Global Navigation Satellite System
GPSCO	Global Positioning System Consortium
HDOP	Horizontal Dilution Of Precision
Km	Kilometre
NAV	Navigation
NMEA	National Maritime Electronics Association
m	Metre
M Code	Military Code
MHz	Mega Hertz
MSL	Mean Sea Level
P Code	Precise/Private (military) code
PDOP	Position Dilution Of Precision
RNG	Range
RTCM	Radio Technical Commission Maritime
S/A	Selective Availability
SOG	Speed Over Ground
SV	Space Vehicle
TV	Television
US	United States
UTC	Universal Time Coordinated
WADS	Wide Area DGPS
WGS84	World Geodetic System 1984
XTE	Cross Track Error
2D	Two Dimensional
3D	Three Dimensional
4WD	Four Wheel Drive

Index

Over 10,000 Copies Sold

Read this book
and get the most out of your GPS

Explore the golden rules of GPS

Discover practical hints, tips and tricks

Find out what the manual forgot to tell you

Step by step guide to a dozen
hands-on exercises

Cartoons illustrate common
problems and solutions

Easy to read and understand