Water Awareness and Charge Certificate Manual

Module 60: Global Positioning Systems

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Module Contents

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Outcomes

After completing this module, the certificate holder will:

- Be able to explain the principles of satellite navigation systems
- Be able to perform basic operations on GPS receivers
- Be able to interpret co-ordinate systems and datums

1 Introduction

The global positioning system (GPS) is a generic term for a system of satellites that provide autonomous geo-spatial positioning with global coverage. It allows small electronic receivers to determine their location (longitude, latitude, and altitude) to within a few metres using time signals transmitted along a line-of-sight by radio from satellites.

The first system with global coverage was the US NAVSTAR system. Originally designed specifically for military applications throughout the world, the utility of position finding from orbiting satellites was quickly recognized by other non-military agencies in the United States, and the Department Of Defence was quick to realize that a global positioning system would be in the best interest of everyone. Twenty four satellites, plus three spares, orbit the earth twice a day at an altitude of 10,800 miles. This bird-cage constellation of orbiting satellites always assures anyone in the world that they could see at least six satellites above the horizon at any time.

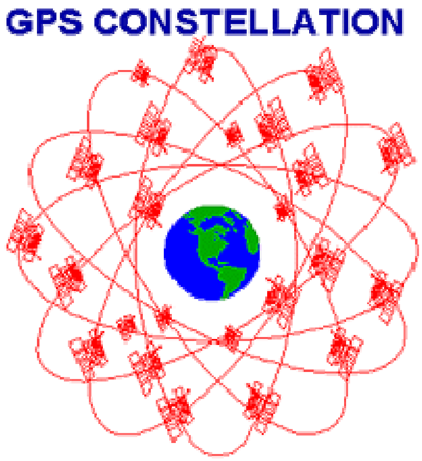

Figure 1: GPS Constellation

As of 2012, the Russian GLONASS system is fully operational with global coverage, while the Chinese Beidou and European Galileo systems are in deployment phase.

2 Operation

Each satellite transmits radio signals carrying satellite time ticks, which are kept accurate by on-board atomic time measurements. The GPS receiver calculates the distance to each one of the satellites by the amount of time delay and the velocity of radio waves in both free Space as well as through the atmosphere and ionosphere at certain elevations off the horizon. The misnomer is to call these calculations "triangulation." Since we are not taking bearings on the satellites, but rather measuring time delay, this is technically called "trilateration."

Once your GPS goes through these calculations on three or more satellites in view, it self-calculates three or more spheres of time delay that will come close to a specific spot of intersection. This takes about half-second of time after about a three minute warm-up.

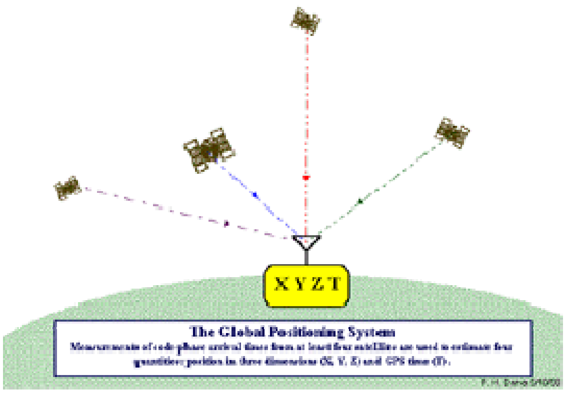

Figure 2: GPS Trilateration

Once the GPS has calculated a position fix, you'll usually have anywhere from five to twelve satellites in view. The receiver will then continuously select the best satellites in view to update your position. Although a GPS receiver needs four satellites to provide a three-dimensional (3D) fix, it can maintain a two-dimensional (2D) fix with only three satellites. A three-dimensional fix means the unit knows its latitude, longitude, and altitude, while a two-dimensional fix means the unit knows only its latitude and longitude.

Many modern GPS units and GPS enabled mobile phones make use of Assisted GPS (A-GPS) to aid start up and allow quicker position fixes. In AGPS, the Network Operator deploys an AGPS server. These AGPS servers download the orbital information from the satellite and store it in the database. The A-GPS capable device receives acquisition assistance, reference time and other optional assistance data from the A-GPS server. With the help of the above data, the A-GPS device receives signals from the visible satellites and sends the measurements to the A-GPS server. The A-GPS server calculates the position and sends it back to the A-GPS device.

3 Accuracy

For the average GPS user, accuracy is a mute point as generally the GPS is much more accurate then our ability to navigate. Accuracy, therefore, depends on the application as there are situations when accuracy might be important such as precise harbour navigation in a fog situation. The average handheld unit available today is accurate to within 10 metres, but larger units with external antennas can be even more accurate.

In addition to man-made accuracy errors there are other natural satellite signal delays that are not always predictable, such as slow down of incoming signal as it passes through extra dense regions of our ionosphere. And there are also errors in geometry when your GPS receiver may lock onto three or more satellites, all in one general area of the sky, creating time delay spheres that don't intersect at acceptable angles.

NAVSTAR is accurate to 5 metres. Galileo is promising an accuracy of 1 metre.

4 Co-Ordinates

In South Africa, we are accustomed to using the Geographic coordinate format Hddd mm ss.s *datum*. This is the standard for aviation and maritime applications.

Within the Geographical format, there are 2 other accepted coordinate formats:
Hddd mm.mmm *datum (default setting on most GPS devices)*
Hddd.dddddd *datum*

These are all correct, but it absolutely vital to notate the format correctly.
For example, S33555 E18258 could be interpreted as
S33 55.5 E18 25.8 (Cape Town Caslte)
S33.555 E18.258 (Point at sea, 10nm north west of Robben Island)

There are many other coordinate formats

- South African Grid (used for surveying and town planning)
- Military Grid Reference System (MGRS)
- Universal Transverse Mercator
- Mapcode

All of these are in use and can be considered correct. Use a format that you understand and indicate which format you are using by applying the correct symbology.

5 Datums

All coordinate systems need a fixed point of reference. This reference point is called a datum and over 100 different datums have been plotted over the years. The datum most commonly used in South Africa is WGS84. WGS84 uses the theoretical centre of mass of the earth as the reference point, as calculated in 1984. The Hartebeeshoek Radio Telescope (Hart94) is plotted as the surface reference point in South Africa

Many countries have not yet changed to WGS84 and use their own datums, which is why the datum must always be quoted.

South Africa used to use the Cape Datum (Clarke 1880) based on the Buffelsfointein trig beacon near Port Elizabeth and some older maps may still reference this.

The effect of datums is that every point on earth as multiple different coordinates.

6 Types of GPS Receiver

6.1 Handheld

The original handheld GPS devices show waypoints, routes, distance and time information, track, and heading. These GPS's do not have a base map (road map) and, therefore, do not show terrain features and items normally found on a typical road map. These original devices are not available in the market anymore, but you may encounter them.

Modern handheld GPS receivers all include some type of base map GPS models and generally will provide all the needed information to navigate in a wide variety of circumstances. They are simple to use, effective, versatile and have been in use for many years. Most are also IPX-7 waterproof. Some devices also provide a breadcrumb trail, which allows you to retrace your route. This is a very useful feature.

The price range for these units has dropped considerably in the last few years. A good unit can now be purchased for under R1500. Garmin is the market leader in this area

Figure 3: Basic and Mapping Handheld GPS

6.2 In-car Navigation

The road map is visible at all times and the GPS will calculate a route for you to follow. You can observe your movement across the map from waypoint to waypoint on a pre-determined route and the GPS will provide voice route guidance. Good devices are Garmin Nuvi and TomTom. These devices are very affordable, but are not well suited to outdoor activities.

Figure 4: In-Car GPS

6.3 Marine

Marine devices are designed specifically for use on water vessels and can include advanced functions such as chart plotting, depth sounding and fish finding. For obvious reasons, these devices are waterproof (usually IPX7) and have large screens for ease of use. However, they are much more expensive than handheld devices.

Figure 5: Marine GPS

7 GPS Operation

Understanding the common terminology of GPS usage helps one understand the method of operation, which is common to all units. Waypoints, Routes, Trackback, and Navigate to are vocabulary common to GPS operation. Understanding the concept of Waypoints, Routes, Trackback, and Go-to will result in a good understanding of how a GPS works. They all operate on the same basic idea - some GPS units have many more features and options but these are the most used

7.1 Waypoints

Waypoints are specific locations on the earth's surface that the user designates by entering a latitude/longitude and giving that location a name or number (or symbol). One may enter hundreds of waypoints into a GPS memory. There are a number of methods to obtain latitudes and longitudes (Lat/Lon) to enter as waypoints.

1. Take the lat/long off a chart. (Least accurate unless one has a large scale chart)
2. Use Google Earth. The program will show lat/long for any place you position the map pointer.
3. With the chart based GPS one can make a waypoint by browsing the chart.

7.2 Routes

Routes are specific directions from one place to another using pre-entered waypoints to define the route. Most GPS units provide an option for setting up routes using the pre-entered waypoints and then naming each route with a unique name. A route could have a few waypoints or hundreds. The advantage of making a route is that it gives one overall distance, leg distances, leg times, arrival times, and total time for the route, etc.

7.3 Trackback

Trackback is the process of retracing your steps. Most GPS will show a visual representation of your path, and you can use this to retrace your steps

GPS devices designed for outdoor activities may be able to use the breadcrumb trail created by the device to provide you with full navigation instructions for returning to your starting point

7.4 Navigate to

The "navigate to" feature allows one to enter many waypoints but not designate a route if a route is not certain. One would simply press "Navigate to" and then highlight a waypoint of choice. Your GPS would then set itself up to direct you to that waypoint. Map based devices will attempt to guide to the destination using known roads / tracks unless you configure it accordingly.

7.5 COG and SOG

Chart based GPS displays will give you COG (Course Over Ground) and SOG (Speed Over Ground) readings. These are very useful for calculating leeway and drift.

7.6 Other Info

Other items of information are provided by most GPS receivers.

- Average Speed
- Speed (speed over ground – for marine navigation)
- Course to next waypoint
- Distance to Waypoint and Destination
- Time of Arrival At Waypoint and Destination
- Date and Time
- Your Location in Lat/Lon
- Time of Sun Rise and Sun Set at your Present Location
- Altitude at your present location
- Total Distance Travelled and Distance Remaining
- Trip Odometers

8 Summary

Map reading and navigation are skills that should come first and then the GPS used as a secondary means of navigation or confirmation. The GPS will make navigation easier and more precise over terrain that is not well mapped. It can help one determine trail heads, side roads and generally make navigation more enjoyable when landmarks are not well defined. It certainly provides a degree of security if one becomes disorientated and in an emergency situation it could make the difference in finding medical help quickly. If you are required to transfer GPS obtained Lat/Long co-ordinated to a paper chart, check that the chart conforms to the WGS84 standard, otherwise indicated positional errors may occur.