WHS

World Health Survey

# GPS Field guide

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# CHAPTER 1: INTRODUCTION TO GPS

## 1.1 What is GPS?

The Global Positioning System (GPS) is a system allowing to precisely identify locations on the earth's surface.

The GPS system has 3 parts (Figure 1):

- The *Space segment*: a network of 24 satellites placed into orbit (Figure 2). The first GPS satellite was launched in 1978 and a full constellation of 24 satellites was achieved in 1994. Each satellite is built to last about 10 years. Replacements are constantly being built and launched into orbit.
- The *Control segment* which consists of ground stations, located around the world that make sure the satellites are working properly.
- The *User segment*: the GPS receivers used by the community (eg. ETrex device).

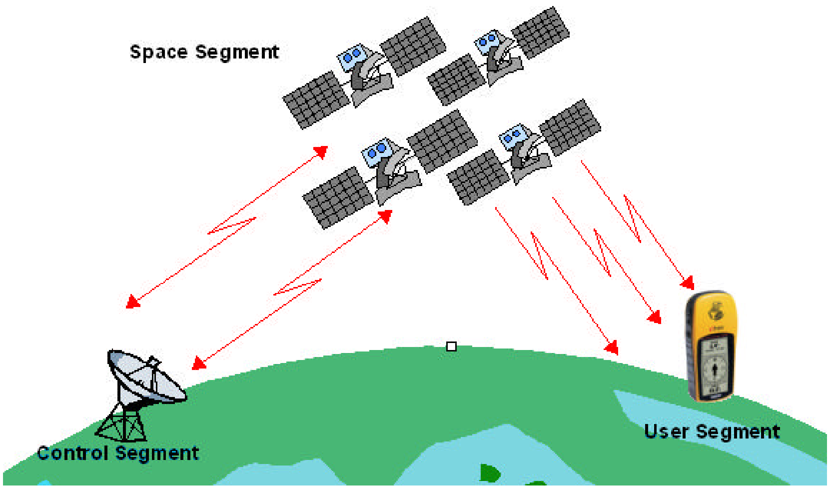



**Figure 1** : The 3 GPS segments

This satellite-based system offers highly precise location data for any point on the planet, in any weather conditions, 24 hours a day. It is mainly used for navigation, positioning and other research applications.

## 1.2 How does GPS work?

GPS satellites circle the Earth twice a day in a very precise orbit at an altitude of around 19 000 Kilometres (Figure 2). This constellation allows any user to access between **five and eight satellites from any point on the Earth**.

**Figure 2**: The GPS Satellite network

Each satellite transmits radio signal information which is tracked and used by the GPS receiver to calculate the user's exact location.

***The satellite signal:***

This constantly transmitted radio signal **passes through clouds, glass and plastic but not through most solid objects such as buildings and mountains.**

A GPS signal contains three kinds of coded information essential for determining a position:

- An **I.D**. that identifies each of the 24 satellites of the network
- The **almanac data** that contains the orbital information for all satellites in the system.
- The **ephemeris data**, which contains important information about the status of the satellite (healthy or unhealthy), and the current date and time.

To determinate precise latitude and longitude/position, the receiver measures the travelling time of the signal between the satellites and itself and transform it into a distance.

The receiver:

1. Calculates the distance to the first satellite he is able to catch. Let's suppose that the receiver calculates a distance of 17'000 km between this first satellite and the receiver. This will mean that the receiver is located somewhere on a sphere that is centred on this first satellite and that has a radius of 17'000 km (Figure 3).

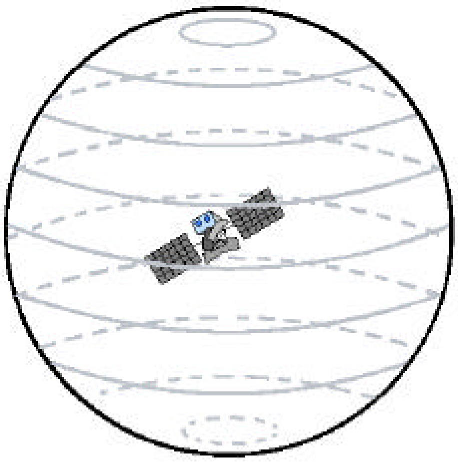



**Figure 3 -** Sphere indicating the potential location of the GPS receiver with one satellite signal

2. Calculates the distance to a second satellite for which it is able to catch a signal (19'000 km for example). This tells the receiver that it is not only located on the first sphere (Figure 3) but also on a second sphere centred on the second satellite and that has a radius of 19'000 km. Or in other words, that the receiver is somewhere on the circle where these two spheres intersect (Figure 4 point a).

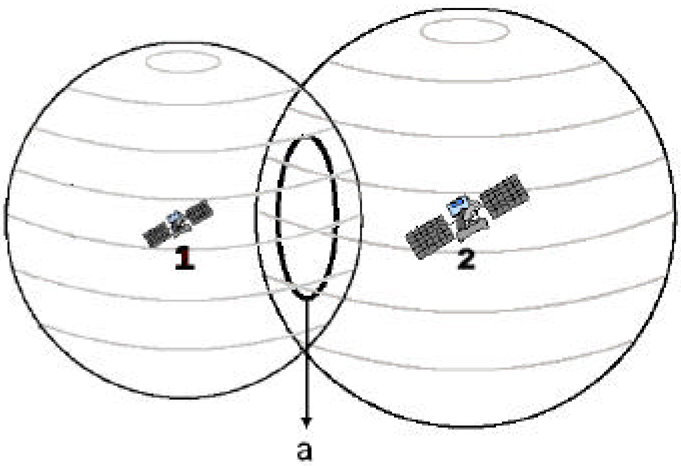



**Figure 4 -** Circle indicating the potential location of the GPS with two satellite signals (a)

3. Repeats the operation mentioned under point 2 with a third satellite. In our example the receiver finds out that it is 20,000 km from the third satellite which narrows its position down even further, to the two points (Figure 5 point b) where the 20,000 km sphere cuts through the circle reported on Figure 4 (corresponding to the intersection of the first two spheres).

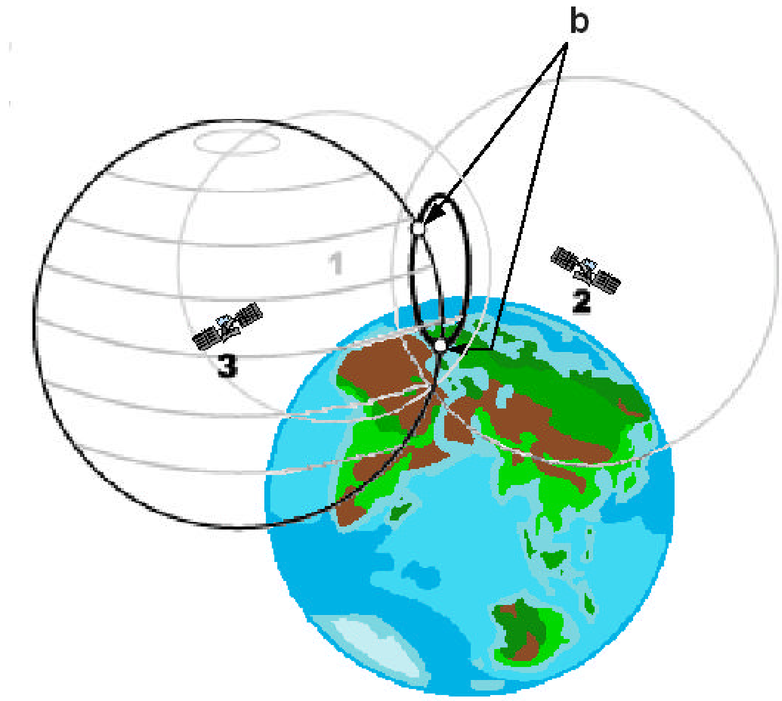



**Figure 5** - Potential locations of the GPS receiver with 3 satellites signals (**b**)

Most of the time one of these two points is absurd and is rejected by the receiver that is then able to give the exact location. In some cases, a fourth satellite is necessary to know which of the two points is the correct one. In any case, a configuration with 4 satellites is better in order to increase the accuracy and/or reduce the sources of error.

## 1.3 Sources of GPS signal errors

Even if today's GPS receivers are extremely accurate, certain atmospheric factors and other sources of error can affect the accuracy of GPS receivers.

If most of the sources of error are unavoidable, it is important for the user to be aware of the ones that he can influence and be prepared to take steps to reduce their impact.

The greatest source of error is connected to the position of the satellite in the sky when taking the measurement. The spread of the satellites in the sky is called the Positional Dilution of Precision (PDOP). A good PDOP is obtained when the satellites are located at wide angles relative to each other (Figure 6 a). In the contrary, a poor PDOP result from satellites being located in a line or in a tight grouping (Figure 6 b).

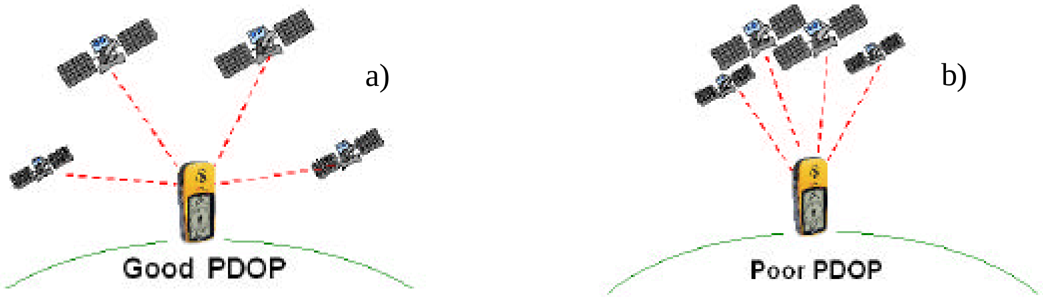



**Figure 6**: a) Good PDOP b) Poor PDOP

The second source of error comes from the infrastructure (buildings, bridges) and particular landform (mountains) that are located around the receiver. These objects can block the reception of the signal (Figure 7), causing position errors or possibly no position reading at all.

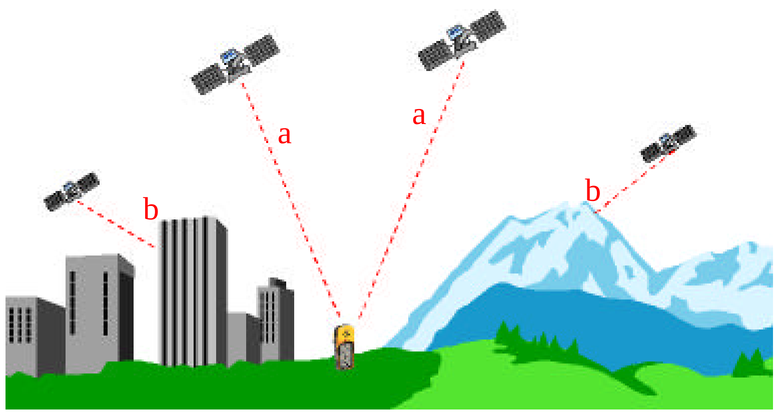



**Figure 7** - Example of good visibility (a)
and bad visibility (b) of satellites due to obstacles

GPS units typically **will not work indoors, underwater or underground.**

There may also be sources of signal multipath (i.e on Figure 8) occurring when the GPS signal is reflected off these objects before reaching the receiver. This increases the travel time of the signal and creates errors of distance estimation between the satellite and the receiver.

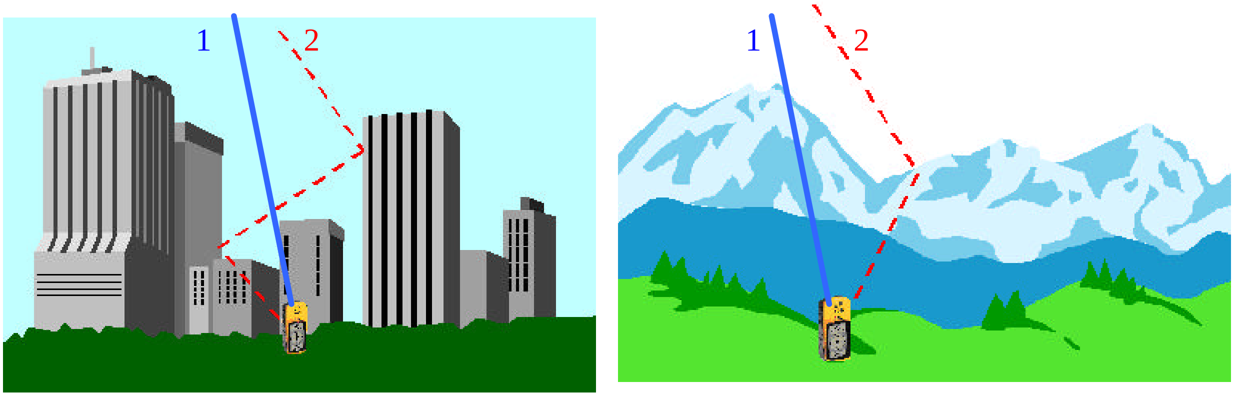



**Figure 8** - Example of multipath GPS signal connected to buildings or mountains

This underlines the importance for the users to be located in the most open area as possible before taking the measurement.

There are other sources of error over which the user does not have control, including:

- Atmosphere delays — The satellite signal slows as it passes through the atmosphere. The GPS system uses a model that calculates an average amount of delay to correct for this type of error.
- Receiver clock errors — A receiver's built-in clock is not as accurate as the atomic clocks onboard the GPS satellites. Therefore, it may have very slight timing errors.
- Orbital errors — Also known as ephemeris errors, these are inaccuracies of the satellite's reported location.

# CHAPTER 2: WHY USING GPS IN THE CONTEXT OF THE WHO WHS ?

The first reason for using GPS in the WHS context is the added value it gives to the survey by allowing the geographical dimension to be taken into account without requiring important investment (many GPS receivers are inexpensive, GPS data is free, and survey staff can be trained quickly to their use).

By knowing the geographic location of each cluster it will be, for example, easier to go back to the same place for supplementary data collection.

With the geographic location it is also possible to use the information collected by the receiver within the Geographic Information Systems (GIS). A GIS can be defined as being a computer system for capturing, storing, checking, integrating, manipulating, analysing and displaying data related to a position on a surface (AGI dictionary).

By integrating the location of the WHS clusters into a GIS it will firstly be possible :

- to examine the relationship that may exists between the data collected and the infrastructure located within or around the clusters. This concerns, for example, health facilities, roads, market, water pumps and so on. If the location of these is known, the GIS tool will be used to calculate the distance to the nearest infrastructure and include this information into the survey analysis.

- to extract figures at the cluster level from other spatially distributed information such as Digital Elevation Models (altitude), environmental parameters (climates, landuse,…) and use them in multivariable analysis.

- to aggregate the clusters according to new units of analysis, such as climatic zones or ethnic regions.

- to extrapolate some of the figures collected by the survey using other geographically distributed parameters which include modelling capabilities.

With all this information being implemented in the GIS tool it will then be possible to have a first picture of the distribution of the poor. Knowing where they are located could then be used to know if this distribution is related to the distribution of other parameter (health, education,…).

The use of GIS will also help in the creation of thematic maps that will be used in presentations and/or reports.

Finally, GIS could be used in the future in order to help designing the sampling frames and the GPS used to find the location of the selected clusters.

# CHAPTER 3: THE GARMIN ETREX UNIT

The Garmin eTrex GPS receiver has been chosen for the WHO WHS because it is easy to use and inexpensive.

Its utilisation in the context of different surveys operated in the field has proven its suitability for this kind of work. This device is completely waterproof, runs for approximately 22 hours on two AA alkaline batteries and can operate under dense tree canopy.

The present section describes the receiver as well as the operating system allowing the user to measure the geographic co-ordinates. Information about how to use the receiver is provided in the Document Test and use of the GPS in the field and in the GPS data collection protocol.

## 3.1 Overview of the unit

One of the advantage of this receiver is the reduced number of elements and buttons on the unit (Figure 9 and 10)

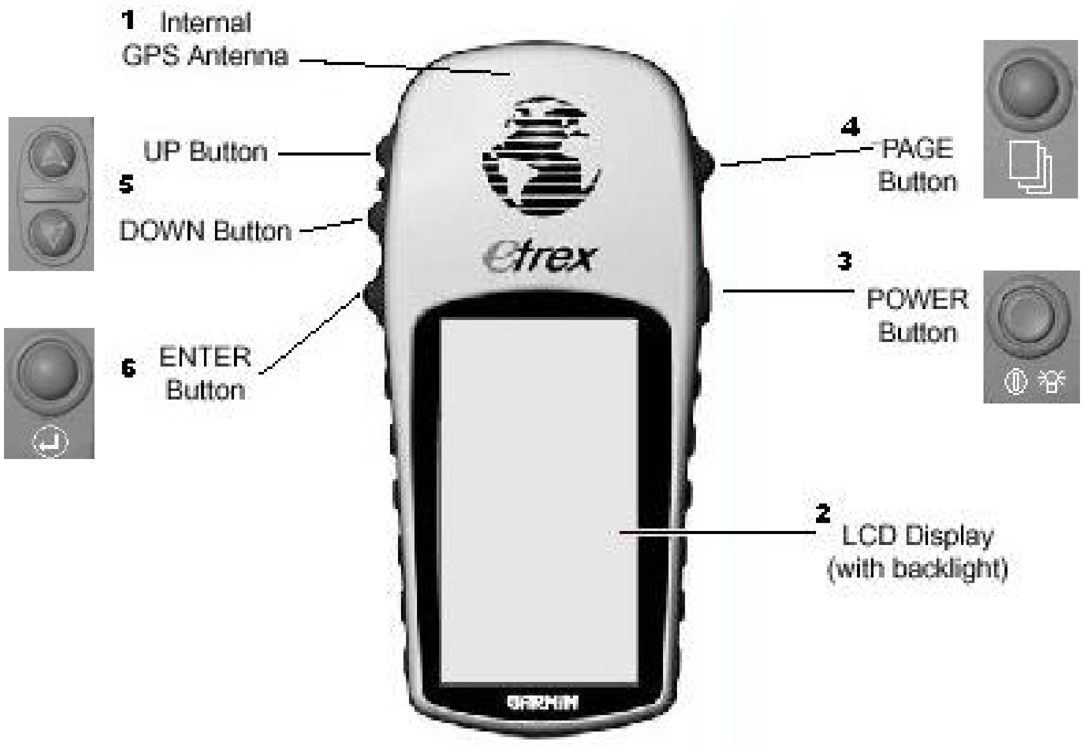



**Figure 9** - Front view of the Garmin eTrex device


**Figure 10** - Back view of the Garmin eTrex device

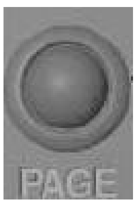
Table 1 describes the elements reported on the Figures 9 and 10

Inside the waterproof case are located a set of electronic components that allow the receiver to perform different operations and to display the final result on the LCD screen through a specific operating system.

The case also contains an internal built-in clock and memory that has the capacity to store the data received through the satellite signal like the almanac data.

Depending on the GPS provider the POWER, PAGE and ENTER buttons are not identified with the same symbols as the ones reported on the Figure 9 but as follow:





| | |
|---|---|
| 1. Internal GPS Antenna | This antenna allows the receiver to track satellites signals.<br>Thus, when using the GPS, the unit should be parallel to the ground and facing upwards.<br>Apart from the cover of the holster nothing should be put on this part of the unit as this may stop satellite signal. |
| 2. LCD Display Screen | Screen where all the information is displayed.<br>**The LCD Display is one fragile part of the eTRex it may be injured and it must be well protected.** |
| 3. The "Power" button | Is used to turn the unit on and off as well as switch on the display backlight. |
| 4. The "Page" button | It allows switch between pages and stop something that you have started but that you don not want to continue. |
| 5. The "Up" and "Down" buttons | These buttons are used to select options on pages and menus and to adjust the display contrast. |
| 6. The "Enter" button | This button is used to confirm data entry or menu selection and to display options from the main pages. |
| 7. The waterproof case | This plastic case protects the electronic part of the device from water. **If the receiver falls into water make sure that the battery compartment is dry before using it again**. |
| 8. The battery Compartment | Represents the location of the 2 AA alkaline batteries used to make the GPS receiver work. |
| 9. External Power and Data Connector | Allows the connection to an external source of power and to a computer for data download **(will not be used in the context of the WHS).** It should stay closed all the time in order to protect the connections. |

**Table 1 -** Description of the different eTrex components shown on Figure 9 and 10

## 3.2 Utilisation of the eTrex unit

This section presents the major elements that will be used in the context of the WHO WHS.

It introduces you to the basic features of the eTrex as well as some basic definitions of terms in a more detailed way than presented on the Document Test and use of the GPS in the field.

### 3.2.1 Installation of the batteries

To install the batteries, remove the battery cover (Figure 10) by turning the D-ring at the back of the receiver 1/4 turn counter-clockwise. Insert the batteries into position observing proper polarity. Attach the battery cover by turning the D-ring 1/4 turn clockwise.

Important Battery Installation Information:

**Warning : Improper installation may cause damage and/or battery leakage.**

Be sure to observe the proper polarity when inserting the batteries:
It is very important to install the TWO batteries with the proper polarity, positive (+) and negative (-) orientation as indicated in the unit's battery compartment and in the Document Test and use of the GPS in the field.

**Remove the batteries from your eTrex if you don't expect to use it for several months.**

### 3.2.2 The eTrex operating system

In order for the user to read information and setup the unit, the eTrex receiver contains an operating system. To access this system, hold the unit so the built-in antenna (the flat area above the display) is parallel to the ground, the screen facing upwards. Press and hold the **POWER** Button firmly to turn on the unit.

The 'WELCOME' page (Figure 11) is then displayed on the screen while the unit conducts a self test.

Once testing is complete this page will be replaced by the 'NORMAL SKYVIEW SATELLITE' which represents the first element of the operating system.

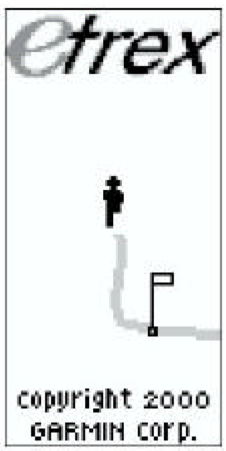



**Figure 11** -
The Welcome page

### 3.2.3 The Garmin eTrex Pages

The eTrex operating system is composed of different pages organised in a hierarchical way starting from 4 main pages (Figure 12). The 'NORMAL SKYVIEW SATELLITE' page is one of them.

To Switch from one of these main page to the other you have to use the 'PAGE' button. In the context of the WHS we will only need to use two of them:

- The 'NORMAL SKYVIEW SATELLITE' page
- The 'MENU' page.

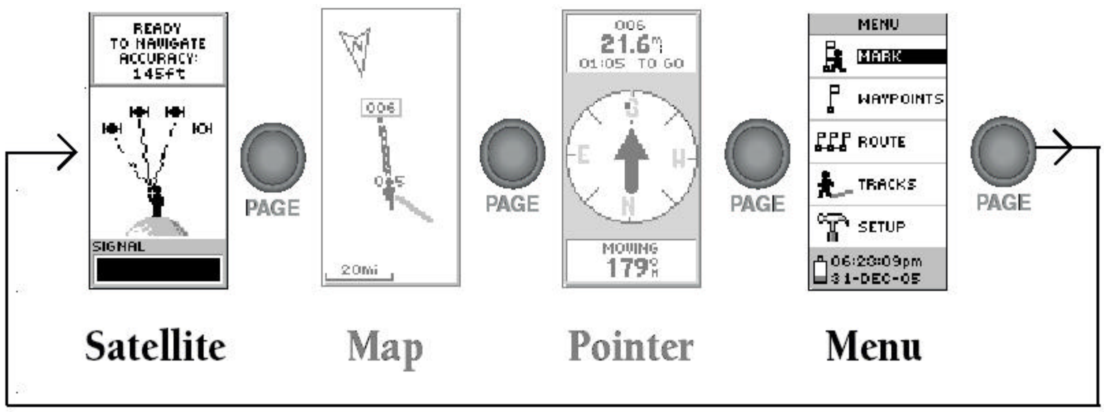



**Figure 12** - The 4 Main pages of the Garmin eTrex GPS receiver

Following is the description of these two pages.

#### 3.2.3.1 The 'NORMAL SKYVIEW SATELLITE' page

As mentioned earlier this main page is the first one appearing after the 'WELCOME' page.

The 'NORMAL SKYVIEW SATELLITE' page displays different information on the acquisition of satellites signals (Figure 13)

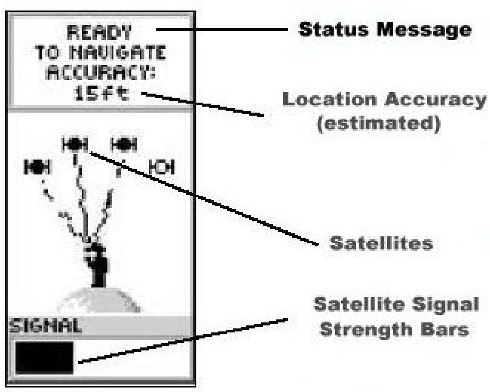



**Figure 13** - The "NORMAL SKYVIEW SATELLITE' page elements

This information concerns:

- The Status of the device. Two type of messages can appear:
  a) "WAIT…LOCATING SATELLITES" indicating that the receiver is tracking satellite signals.
  b) "READY TO NAVIGATE" indicating that the receiver has found satellite signals strong enough to know its location and that you can start to use it.

- The location accuracy message that is displayed when the device is ready to be used ("ACCURACY"). The value given is an indication of the precision that the device is able to offer regarding its position, based on the satellite's localisations.

- The number of satellite signals that the receiver is tracking indicated by the drawing in the middle of the screen. Each line between the character and a satellite indicates a connection. On the Figure 13 for example the device is actually receiving the signal from 3 satellites.

- The satellite Signal strength bar which indicates the intensity of the satellite signal received. When the bar is full (black) the signal is generally strong enough to allow the use of the device.

From this main page it is possible to have access to two sub-pages as indicated on Figure 14.

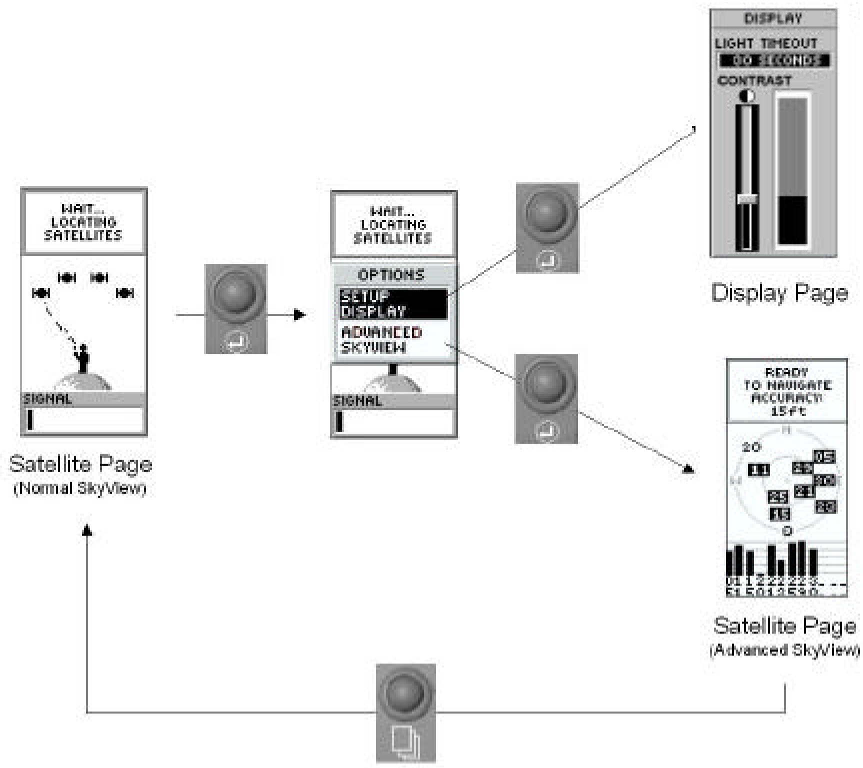



**Figure 14** - Scheme to access the 'DISPLAY' and 'ADVANCED SKY VIEW' pages from the 'NORMAL SKYVIEW SATELLITE' page

You can access to these two pages by pressing the **ENTER** button from the 'NORMAL SKYVIEW SATELLITE' page in order to open the 'OPTIONS' window. From there you can use the **UP** and **DOWN** buttons to highlight the page you want to access and press the **ENTER** button.

Once you have finished working on one of these pages you can come back to the 'NORMAL SKYVIEW SATELLITE' page, pressing the **PAGE** button again (Figure 14).

## The 'DISPLAY' page

This page allows you to setup the back-light time out and the display contrast. The first element may be useful for night reading and it is important to setup the contrast correctly in order to insure a good reading of the information on the LCD screen.

When you arrive on this page the 'LIGHT TIMEOUT' field is highlighted and you can make the scrolling menu by pressing the **ENTER** button (Figure 15 a). Once you have selected the desired time press the **ENTER** button to save the option. **It is recommended to choose 30 seconds as this option uses a lot of battery power.**

You can then pass to the contrast option pressing the **DOWN** button. Once the contrast bar is highlighted (Figure 15 b) press the **ENTER** button. You can then use the **UP** or **DOWN** button to modify the contrast until you get an appropriate reading on the screen. Then press the **ENTER** button to save the setting.

a) b)

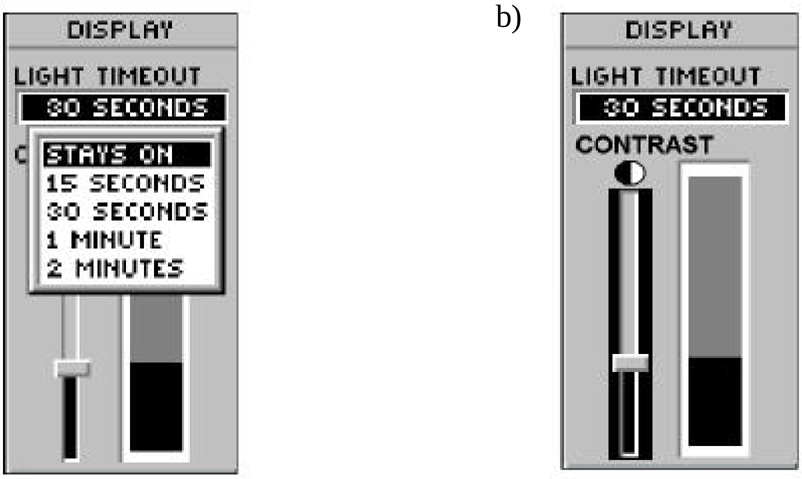



**Figure 15 -** 'DISPLAY' page with the 'LIGHT TIMEOUT' menu (a) and the contrast bar highlighted (b)

**The 'ADVANCED SKYVIEW SATELLITE' page**

This page contains the same elements as the 'NORMAL SKYVIEW SATELLITE' page but presented in a different graphical way (Figure 16).

This display gives more information about the location of the satellites in the sky (represented as a numbered square) around your location (the point at the centre of the screen).

In the Figure 16, the GPS device is surrounded by 9 satellites, 7 of them have a signal strong enough to be received (square in black) one (in grey) having a signal not strong enough and the last one not being read by the device (the n°20).

This display is very helpful to check the Positional Dilution of Precision (PDOP) (see section 1.3). In case you have difficulty finding satellites, because it also can help you to identify obstacles that might block the signal (such as buildings, mountains…). For that you may use the North indication on the screen to orient the unit.

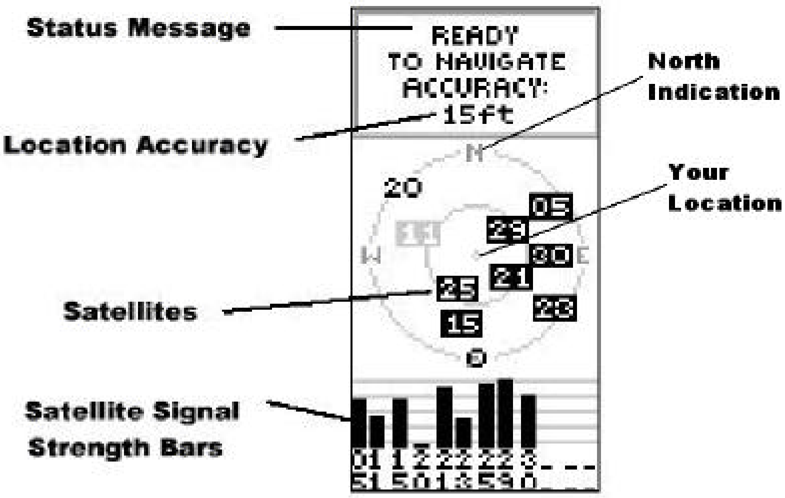



**Figure 16** - 'ADVANCED SKYVIEW' page

### 3.2.3.2 The 'MENU' page

The 'MENU' page (Figure 17) presents a list of options as well as the indication of the Time/Date and Battery strength. This last element can help the user to identify when to replace the batteries.

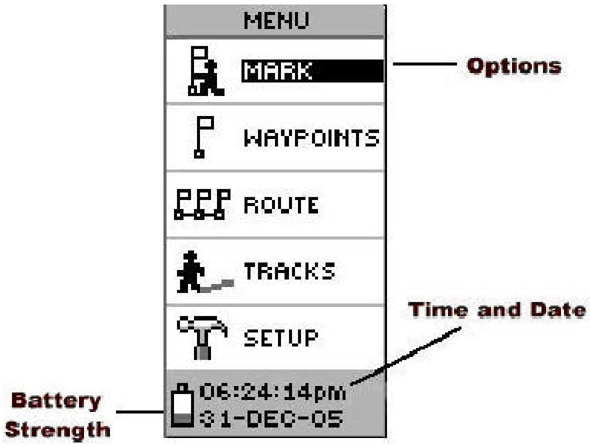



**Figure 17** - The 'MENU' page

There are two options of interest for the WHS on the 'MENU' page: the 'MARK' and 'SETUP' ones. The Figure 18 allows you to visualise how to access to the structure of these two options.

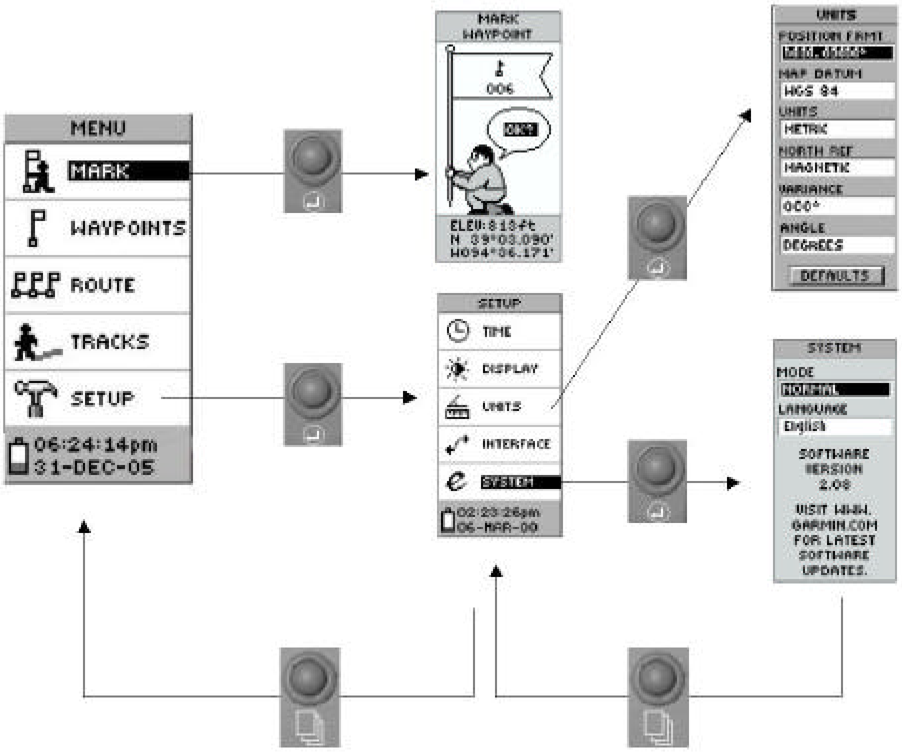



**Figure 18** - Scheme to access the 'MARK' and 'SETUP' option pages

To access to the selected option you have to highlight it in the menu using the 'UP' or 'DOWN' button (on Figure 16 the 'MARK' option is highlighted ) and press the ENTER button.

Once you have finished working on one of these pages you can come back to the 'MENU' page by pressing the 'PAGE' button.

## The 'MARK WAYPOINT' option page

Once the GPS receiver has been set-up and that the user has found an open area for the reading, this page will allow the user to visualise his location (Figure 19). The other information or options reported on this page will not be used in the context of the WHS.

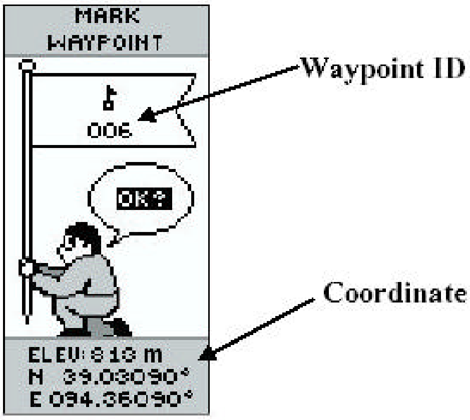



**Figure 19** - the 'MARK WAYPOINT' option page

This page can also be directly accessed from any other pages by pressing and holding the **ENTER** button

## The 'SETUP' option page

The 'SETUP' option page (Figure 20) allows the user to customize the eTrex. This page contains a list setup pages. In the context of the WHS survey we only need to deal with two of them: the 'UNITS' and 'SYSTEM' ones (the 'DISPLAY' page corresponds to the same page as the one described under section 3.2.3.1).

To access the desired setup you have to highlight its name in the list using the 'UP' or 'DOWN' buttons and press the 'ENTER' button.

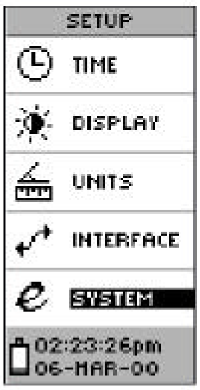



**Figure 20** - The 'SETUP' option page

## The 'UNITS' setup page

This page (Figure 21) allows the user to setup the units of the different parameters. It is important to make sure that this page contains the setting specific to the WHS as indicated in the Figure 21 a) and in Document Test and use of the GPS in the field.

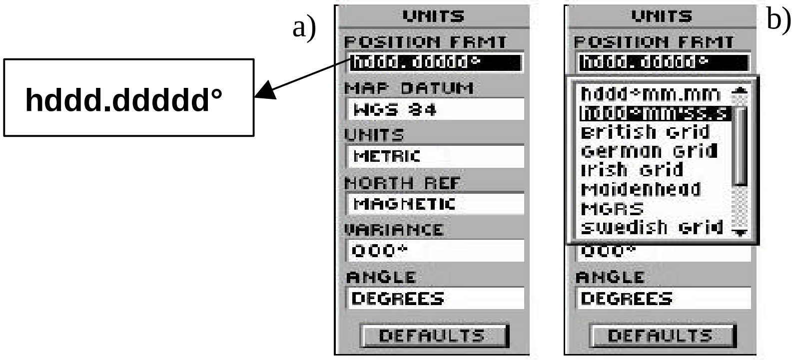



**Figure 21** - The 'UNITS' page (a) with the scroll down list (b)

To change the value or format in a specific field you have to first highlight it using the **UP** or **DOWN** button (e.g. the position format field on the Figure 21). Press the **ENTER** button to make the corresponding scroll down list appear from which you will select the desired format or value (Figure 21). Press the **ENTER** button again in order to save the change. The variance field cannot be change, this value is given by the GPS unit and connected with the Earth's magnetic field variation.

## The 'SYSTEM' setup page

This page (Figure 22) allows the user to fix the operation mode (Normal, Battery Save, Demonstration). It is recommended to put the device in the 'BATTERY SAVE' mode in order to extend their life. It is also possible to set the receiver language. We recommend using the receiver in English in order to follow the instruction reported on the different documents provided. It may however be useful in certain case to change the language in order to improve understanding  of some options.

Changes can be done as in the other pages by highlightning the concerned field, pressing the 'ENTER' button to make the scroll down list appear, selecting the desired language and pressing the 'ENTER' button again to save the change.


**Figure 22** -  The 'SYTEM' page

# CHAPTER 4: TROUBLESHOOTING

## 4. 1 eTrex does not turn on:

1. Check to see if the batteries are installed correctly and if the battery terminals are clean.

If the eTrex does not turn on after point 1: place a fresh set of AA batteries in the unit (refer to Document **Test and use of the GPS in the field** point 2.2) ' **Installing the Batteries'** and use Alkalyne batteries as they have a longer life).

2. If eTrex still does not turn on, the problem requires the help of a technician (please contact your supervisor).

## 4.2. The message "READY TO NAVIGATE"(Prêt à naviguer) does not appear on the screen:

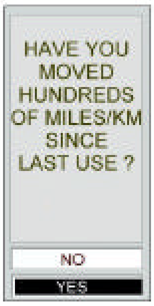
1. There may be large obstacles around you that stops the satellite signals; move to a new location: a large, open area with a clear view of the sky.
2. Another window with a message may appear (see section 4.3 for the list of these messages and their explanations).

## 4.3. The message "TROUBLE TRACKING SATELLITES. ARE YOU INDOOR NOW?" appears on the screen.


1. You are indoor:

- Press the **DOWN** Button,
- Highlight 'YES', and press **ENTER**
- Go outdoor for the receiver to catch satellites signal (as the GPS unit cannot receive the satellite signals when you are indoors.)

2. You are not indoors and you are close to the open place where you turned the GPS on (less than 800 km):




- Press the **UP/DOWN** buttons,
- Highlight 'NO'
- Press **ENTER**.
- eTrex then asks:**'HAVE YOU MOVED HUNDREDS OF MILES/KM SINCE LAST USE?"**
- Press **UP/ DOWN** buttons
- Highlight 'NO'.
- Press **ENTER**.

- eTrex then asks: **'IS TODAY dd-mmm-yy?'.** Two possibilities:


a) The date indicated matches the current date :
   - Press **UP/ DOWN** buttons
   - Highlight 'YES' and press the **ENTER** button, the eTRex will continue tracking satellites and switch to the Satellite page.

b) The date is incorrect:
   - Press **UP/ DOWN** buttons
   - Highlight 'NO' and press the **ENTER** button, the eTRex will do an 'AUTOLOCATE' and switch to the Satellite page. (An 'AUTOLOCATE' forces the eTrex to search for any available satellite to determine its location.)

3. <u>You are not indoors but you are far from the place where you turned the eTrex on</u> (more than 800 km):

-Press the **UP/DOWN** buttons
- Highlight 'NO'.
- Press **ENTER**.
- eTrex then asks:'HAVE YOU MOVED HUNDREDS OF MILES/KM SINCE LAST USE'?
- Press **UP/DOWN** buttons
- Highlight 'YES'.
- Press **ENTER**.
- eTrex will do an 'AUTOLOCATE' and switch to the Satellite Page.

## 4.4 I am not getting an accuracy higher (better) than 20 meters:

1. Wait 5 minutes on the same location
2. If the situation does not change after 5 minutes:

   Move to a new location with a clear view of the sky. The best location would be (in order of preference):
   - The front door of the building/house (for building: try to see if it is not possible to go on the roof)
   - The side of the building/house
   - A parking lot or a park close to the building/house

## 4.5 eTrex does not display the desired units when making the accuracy or co-ordinates reading :

Check to make sure the eTrex is configured to use the Position Format, Datum and Units desired. (Refer to the point 2.9) of the Document **Test and use of the GPS in the field: 'Units Setting'**)

## 4.6 eTrex does not display the local time in the 'SETUP' page

The eTrex operates on universal time (or GMT, Greenwich Mean Time ).
It is not necessary to have your local time displayed. Do not worry about a wrong displayed time.

## 4.7. The geographic coordinates I get are outside the range indicated in the 'Country information' document :

Make sure the eTrex is configured as indicated in point **2.9)** of Document **Test and use of the GPS in the field** and redo the reading correctly.

1. If the eTrex is well configured, check that you have a clear view of the sky.
2. If this still does not work, move to a better place and take a new reading.
3. If the coordinates are still outside the range: change the batteries.
4. If all of that does not lead to a better result, contact your supervisor.

# GLOSSARY

**Accuracy :** How close to the real value a measurement is.

**Backlight:** Selectable on/off illumination that lights the display for enhanced screen at night and in low light.

**Contrast:** The difference between the lightest and darkest areas on a display screen.

**Coordinates** : The unique description of a geographic position using numeric characters.

**Dilution of Precision (DOP):** The dilution of precision (DOP) is an indication of the quality of the results that can be expected from a GPS point position. It is a measure based solely on the geometry of the satellites in the sky.

**Ephemeris:** The predictions of current satellite position that are transmitted to the user in the data message.

**Initialization:** Refers to the procedure of telling a GPS receiver where it is, when it is turned on for the first time. Information required for initialization includes approximate present position in latitude/longitude coordinates, the current local time and date (information obtained through the satellite signal when using the eTrex unit).

**Map Datums:** Since the Earth is not flat a model needs to be used in order for the GPS receiver to give the coordinates. These models are calls Datums.

**Multipath:** Mutipath is the phenomena by which the GPS signal is reflected by some object or surface before being detected by the receptor antenna creating multipath for a same signal that results in a calculation error when estimating the distance between the satellite and the receiver

**Position:** A geographic location on the earth, commonly measured in latitude and longitude.

**Satellite constellation:** The arrangement in space of a set of satellites.

**Segment:** One of several parts or pieces that fit with others to constitute a whole object.

**GPS Control segment:** A Master Control Station and a number of monitoring stations around the world that ensure the accuracy of satellite positions and their clocks.

**GPS Space segment:** The network of 24 GPS satellites.

**GPS User segment:** The receivers of GPS signals such as your eTrex Unit.

**Variance:** In this context correspond to the errors in magnetic compass readings caused by variance in the earth's magnetic field at different locations on the planet.

**Waypoint:** Current location on the face of the Earth, in terms of the specific latitude/longitude coordinates.

# BIBLIOGRAPHY / LINKS

**This document has been created using information coming from the following publications or Web Sites:**

Garmin International, Inc. (2000): *Garmin eTrex personal navigator, owner's manual*.

MEASURE Evaluation *(2001): Incorporing Geographic Information Into MEASURE Surveys: A field Guide to GPS Data Collection.*

Garmin Website: http://www.garmin.com

Garmin GPS Guide for beginners : http://www.garmin.com/manuals/gps4beg.pdf

Eagle GPS Tutorial: http://www.eaglegps.com/tutorial/gps/default.htm

Lowrance Electronics GPS Tutorial : http://www.lowrance.com/Tutorials/GPS/gps_tutorial_01.asp

Mercator GPS Systems, The GPS Tutor: http://www.mercat.com/QUEST/gpstutor.htm

The Aerospace Corporation: http://www.aero.org/publications/GPSPRIMER/

Trimble GPS Tutorial and Glossary: http://www.trimble.com/gps/work.html

University of Colorado: http://www.colorado.edu/geography/gcraft/notes/gps/gps_f.html

Smithsonian National Air and Space Museum, Washington, GPS: A New Constellation http://www.nasm.si.edu/galleries/gps/