Chapter 5
Global Positioning System

In this chapter you will learn about:
- *How the Global Positioning System works*
- *Using a GPS receiver*

The Global Positioning System (GPS) is a satellite based navigation system that can be used to locate positions anywhere on earth. Designed and operated by the U.S. Department of Defense, it consists of satellites, control and monitor stations, and receivers. GPS receivers take information transmitted from the satellites and uses triangulation to calculate a user's exact location. GPS is used on incidents in a variety of ways, such as:

- To determine position locations; for example, you need to radio a helicopter pilot the coordinates of your position location so the pilot can pick you up.
- To navigate from one location to another; for example, you need to travel from a lookout to the fire perimeter.
- To create digitized maps; for example, you are assigned to plot the fire perimeter and hot spots.
- To determine distance between two points or how far you are from another location.

The purpose of this chapter is to give a general overview of the Global Positioning System, not to teach proficiency in the use of a GPS receiver. To become proficient with a specific GPS receiver, study the owner's manual and practice using the receiver. The chapter starts with a general introduction on how the global positioning system works. Then it discusses some basics on using a GPS receiver.

How the Global Positioning System Works

The basis of the GPS is a constellation of satellites that are continuously orbiting the earth. These satellites, which are equipped with atomic clocks, transmit radio signals that contain their exact location, time, and other information. The radio signals from the satellites, which are monitored and corrected by control stations, are picked up by the GPS receiver. A GPS receiver needs only three satellites to plot a rough, 2D position, which will not be very accurate. Ideally, four or more satellites are needed to plot a 3D position, which is much more accurate.

Three Segments of GPS

The three segments of GPS are the space, control, and user (Figure 5-1).

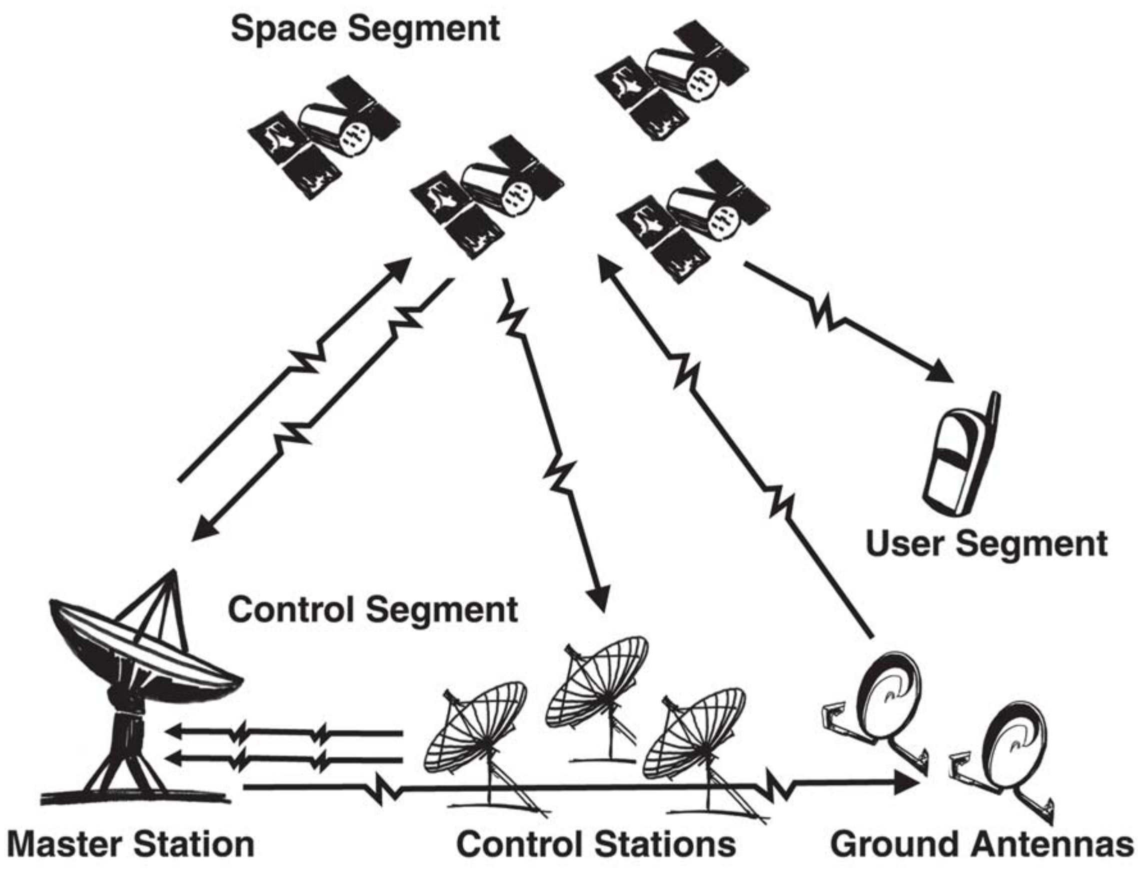

Figure 5-1. Three segments of GPS.

- Space Segment — Satellites orbiting the earth

  The space segment consists of 29 satellites circling the earth every 12 hours at 12,000 miles in altitude. This high altitude allows the signals to cover a greater area. The satellites are arranged in their orbits so a GPS receiver on earth can receive a signal from at least four satellites at any given time. Each satellite contains several atomic clocks. The satellites transmit low radio signals with a unique code on different frequencies, allowing the GPS receiver to identify the signals. The main purpose of these coded signals is to allow the GPS receiver to calculate travel time of the radio signal from the satellite to the receiver. The travel time multiplied by the speed of light equals the distance from the satellite to the GPS receiver.

- Control Segment — The control and monitoring stations

  The control segment tracks the satellites and then provides them with corrected orbital and time information. The control segment consists of five unmanned monitor stations and one Master Control Station. The five unmanned stations monitor GPS satellite signals and then send that information to the Master Control Station where anomalies are corrected and sent back to the GPS satellites through ground antennas.

- User Segment — The GPS receivers owned by civilians and military

  The user segment consists of the users and their GPS receivers. The number of simultaneous users is limitless.

How GPS Determines a Position

The GPS receiver uses the following information to determine a position.

- Precise location of satellites

  When a GPS receiver is first turned on, it downloads orbit information from all the satellites called an almanac. This process, the first time, can take as long as 12 minutes; but once this information is downloaded, it is stored in the receiver's memory for future use.

- Distance from each satellite

  The GPS receiver calculates the distance from each satellite to the receiver by using the distance formula: distance = velocity x time. The receiver already knows the velocity, which is the speed of a radio wave or 186,000 miles per second (the speed of light). To determine the time part of the formula, the receiver times how long it takes for a signal from the satellite to arrive at the receiver. The GPS receiver multiplies the velocity of the transmitted signal by the time it takes the signal to reach the receiver to determine distance.

- Triangulation to determine position

  The receiver determines position by using triangulation. When it receives signals from at least three satellites the receiver should be able to calculate its approximate position (a 2D position). The receiver needs at least four or more satellites to calculate a more accurate 3D position. The position can be reported in latitude/longitude, UTM, or other coordinate system.

Sources of Errors

The GPS is not a perfect system. There are several different types of errors that can occur when using a GPS receiver, for example:

- User mistakes

  User mistakes account for most GPS errors; and a GPS receiver has no way to identify and correct these mistakes. Common examples of user mistakes include:

  – Inputting incorrect information into a GPS receiver, such as the datum, and when creating a waypoint.

  – Unknowingly relying on a 2D position instead of a 3D position for determining position coordinates. This mistake can result in distance errors in excess of a mile. The signal from the satellite may be blocked by buildings, terrain, electronic interference, and sometimes dense foliage. A GPS receiver needs a fairly clear view of the sky to operate.

  – The human body can cause signal interference. Holding a GPS receiver close to the body can block some satellite signals and hinder accurate positioning. If a GPS receiver must be hand held without benefit of an external antenna, facing to the south can help to alleviate signal blockage caused by the body because the majority of GPS satellites are oriented more in the earth's southern hemisphere.

- Multipath interference

  Multipath interference is caused by the satellite signal reflecting off of vehicles, buildings, power lines, water and other interfering objects (Figure 5-2). Multipath is difficult to detect and sometimes impossible for the user to avoid or for the receiver to correct. When using a GPS receiver in a vehicle place the external antenna on the roof of the vehicle to eliminate most signal interference caused by the vehicle. If the GPS receiver is placed on the dashboard there will always be some multipath interference.

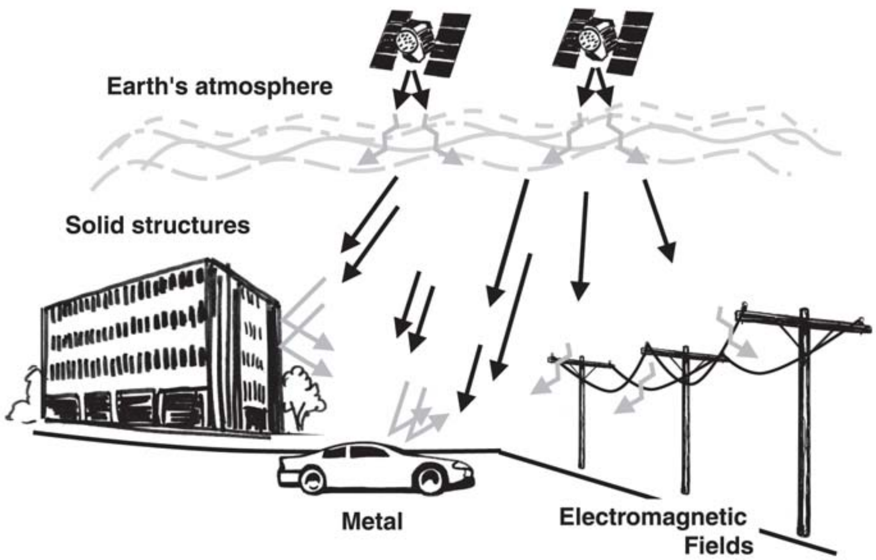

Figure 5-2. Sources of signal interference.

- Satellite and receiver clock errors

  These can be slight discrepancies in the satellite's atomic clocks which may cause slight position errors in the GPS receiver. Errors are monitored and corrected by the Master Control Station.

- Orbit errors

  Satellite orbit pertains to the altitude, position, and speed of the satellite. Satellite orbits vary due to gravitational pull and solar pressure fluctuations. Orbit errors are also monitored and corrected by the Master Control Station.

- Satellite geometry

  The location of GPS satellites in relation to a GPS receiver on the ground can impact the receiver's ability to triangulate a 3D position. The quality of a receiver's triangulated position improves the further apart GPS satellites are located from each other in the sky above the receiver. The quality decreases if the satellites are grouped close together in the sky above the receiver.

- Atmospheric interference

  The atmosphere can slow or speed up the satellite signal. Fortunately, error caused by atmospheric conditions (ionized air, humidity, temperature, pressure) has been reduced with the implementation of the Wide Area Augmentation System (WAAS), which is discussed later in this chapter.

- Selective Availability

  Selective Availability is the intentional degradation (limits accuracy of satellite signals) of the GPS system by the U.S. Department of Defense for security reasons. At this time there is no Selective Availability in force; however, it can be reactivated without notice to GPS users.

- Correction systems

  Correction systems have been designed to reduce some of the sources of error with GPS.

- Real-time Differential GPS

  Real-time Differential GPS (DGPS) employs a second, stationary GPS receiver at a precisely measured spot, usually established through traditional survey methods (Figure 5-3). This receiver corrects or reduces errors found in the GPS signals, including atmospheric distortion, orbital anomalies, Selective Availability (when it existed), and other errors. A DGPS station is able to do this because its computer already knows its precise location, and can easily determine the amount of error provided by the GPS signals. DGPS cannot correct for GPS receiver noise in the user's receiver, multipath interference, and user mistakes. In order for DGPS to work properly, both the user's receiver and the DGPS station receiver must be accessing the same satellite signals at the same time.

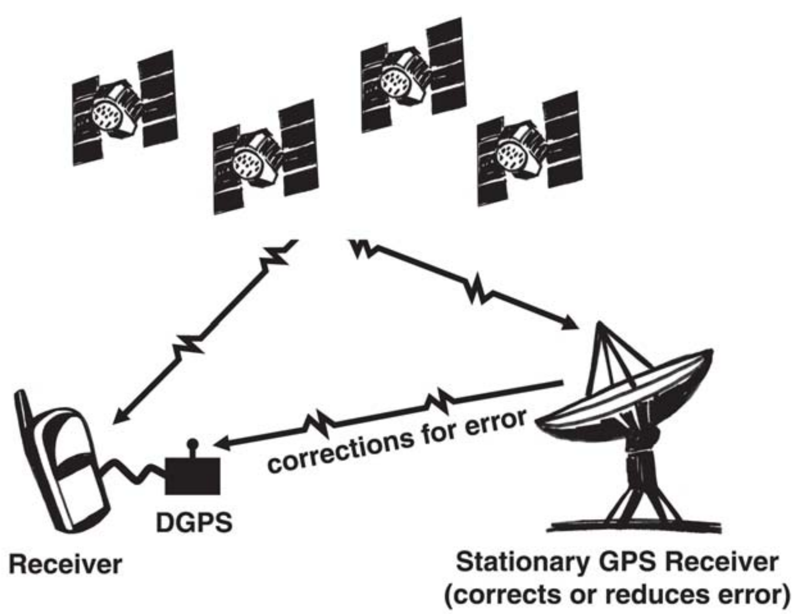

Figure 5-3. Real-Time Differential GPS.

- Wide Area Augmentation System

  The Wide Area Augmentation System (WAAS) is an experimental system designed to enhance and improve aircraft flight approaches using GPS and WAAS satellites. The WAAS can be considered an advanced real-time differential GPS. It uses its own geo-stationary satellites positioned over the equator to transmit corrected GPS signals to receivers capable of receiving these signals.

  Problems with WAAS include poor signal reception under dense tree canopy and in canyons, as well as decreased capability in northerly latitudes. Many GPS receivers are now capable of receiving the WAAS signal. However, WAAS should not be considered a consistently reliable source for improving the accuracy of GPS until the technology improves.

Using a GPS Receiver

There are several different models and types of GPS receivers. Refer to the owner's manual for your GPS receiver and practice using it to become proficient.

When working on an incident with a GPS receiver it is important to:

- Always have a compass and a map.
- Have a GPS download cable.
- Have extra batteries.
- Know memory capacity of the GPS receiver to prevent loss of data, decrease in accuracy of data, or other problems.
- Use an external antennae whenever possible, especially under tree canopy, in canyons, or while flying or driving.
- Set up GPS receiver according to incident or agency standard regulation; coordinate system.
- Take notes that describe what you are saving in the receiver.

Inputs

Each time you use a GPS receiver, you will need to input information such as:

- Position format units (example: UTM 11T 0557442m E 4836621m N).

  This input determines the way positions are displayed on the receiver screen. For example, sometimes you may want to use latitude/longitude coordinates and other times it may be better to use UTM coordinates.

- Map datum (example: WGS 84, NAD 27 and NAD 83).

  This input ensures that your GPS receiver and map are both using the same datum, which is extremely important for accuracy.

- Distance units (feet, miles, meters).
- Elevation units (feet or meters).
- North reference (true, magnetic, or grid).
- Time format (12 or 24 hour) and time zone.

Waypoints

A waypoint is a position based on geographic coordinate values, such as latitude/longitude and UTM, stored in the GPS receiver's memory. They are sometimes referred to as landmarks. Once the waypoint is saved it remains static in the GPS receiver's memory until edited or deleted.

How Waypoints are Determined

A waypoint can either be a saved position fix or can be created by manually entering coordinates into the receiver.

- To turn a position location into a waypoint is simply a matter of saving the receiver's current position as a waypoint. The receiver will give the position coordinates an alpha-numeric name or the user can designate a name. Once a position fix is saved, it becomes a waypoint with static coordinates saved in the receiver's memory.

- Users can enter waypoints into the GPS receiver. For example, coordinates on a map or coordinates radioed in from a remote location can be entered into a GPS receiver.

Naming Waypoints

The GPS receiver will automatically name waypoints with an alpha-numeric name; however, it is best if you designate a unique name for each waypoint so you will know exactly what the waypoint is referring to. Use short descriptive designations because long names can be hard to read when they are downloaded. You can make up your own names as long as you know what they are. Some possible designations include:

- D1, D2, D3 for different dozer lines
- HL1, HL2, HL3 for different handlines
- DP1, DP2, DP3 for different drop points
- H1, H2, H3 for different helispots
- A1, A2, A3 for different access points

Record a description of each waypoint in your notes, otherwise it will be difficult to remember.

Routes

Routes are just a sequence of waypoints (Figure 5-4). When navigating a route, the GPS receiver will automatically change the destination waypoint to the next waypoint on the list as it reaches each waypoint.

Once one waypoint is passed, the GPS receiver will navigate to the next waypoint. When a route is first activated, the GPS receiver will assume that the first leg is A to B. B is the waypoint being navigated to and A is the anchor point that defines the first leg of the route.

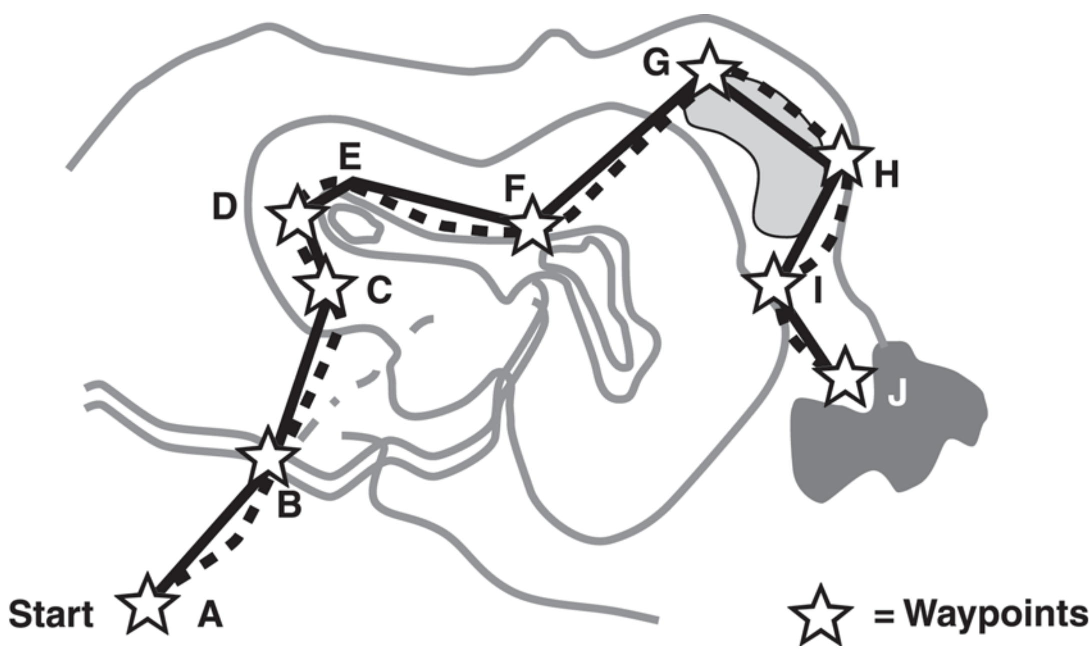

Figure 5-4. Example of a "route" that is displayed on a GPS receiver screen.

Terminology

There is a lot of terminology associated with using a GPS receiver. Some of the common terms are defined below and illustrated in Figure 5-5.

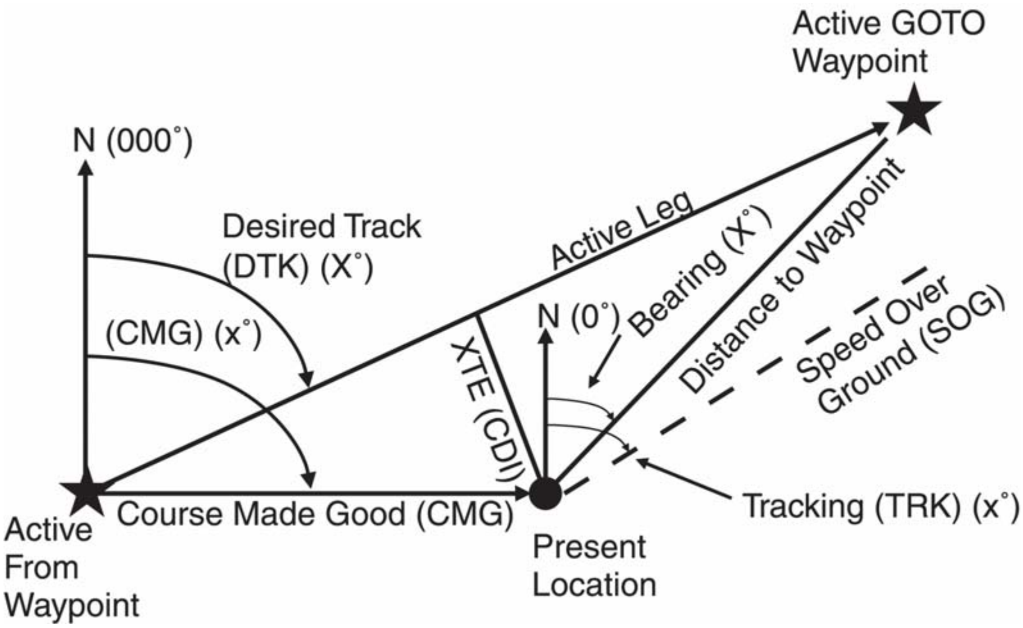

Figure 5-5. GPS navigation terminology.

- Active from Waypoint

  This is the starting waypoint or the receiver's last waypoint in an active route.

- Active GOTO Waypoint

  This is the designated destination in the receiver, whether in an active route or as a single waypoint.

- Active Leg

  Active leg is always a straight line between the last waypoint and the GOTO waypoint. A GPS receiver always plots the most efficient, straight-line course of travel between two points – the active leg. If the receiver is following a route, the active leg will be the desired track between the last waypoint in the route, and the next waypoint in the route. If the receiver has deviated from the route, the receiver selects the closest leg to its position and makes it the active leg in the route (the next waypoint in the route list becomes the GOTO destination waypoint).

- Bearing (BRG)/Desired Track (DTK)

  In GPS the term bearing is used instead of azimuth. As used in GPS, bearing is the compass direction (expressed in degrees) from the present position to desired destination waypoint or the compass direction between any two waypoints.

- Course Deviation Indicator (CDI)

  This graphically shows the amount and direction of Crosstrack Error.

- Course Made Good (CMG) or Course Over Ground (COG)

  This is the present direction of travel expressed in degrees from north. It is not necessarily the most direct path.

- Crosstrack Error (XTE)

  This is the distance off the desired track (active leg) on either side of the active leg. It's the linear difference between the Desired Track (DTK) and your actual Course Made Good (CMG).

- Desired Track (DTK)

  This is a function of GOTO. It is shown in degrees from north. DTK is measured along the active leg (a straight line between two waypoints in a route) or from your current position to a designated GOTO waypoint, when not navigating a route.

- Estimated Position Error (EPE)

  A measurement of horizontal position error in feet or meters based upon a variety of factors including dilution of precision (DOP) and satellite signal quality.

- Estimated Time En Route (ETE)

  The time left to destination based upon present speed and course.

- Estimated Time of Arrival (ETA)

  The time of day of arrival at a destination

- Fix

  A single position with latitude, longitude (or grid position), altitude, time, and date.

- GOTO Function

  The GOTO function gives GPS receivers the capability of leading a person to any specified place. Simply enter the coordinate of desired destination into the GPS receiver as a waypoint and then, by using the GOTO function, tell the receiver to guide to destination. The receiver guides to destination using a steering screen. There are several different versions of a steering screen, but they all point in the direction needed to travel to from present position to the waypoint selected.

- GOTO Waypoint

  If traveling from one waypoint to another (using GOTO), then XTE will show the distance of deviation of your actual route from the active leg (a straight line) between those waypoints.

- Speed Over Ground (SOG)

  This is the velocity you are traveling.

- Tracking (TRK)/ Heading (HDG)

  This is the direction you are actually traveling or heading, expressed in degrees from north.

- Track Log

  A track log is the GPS unit's record of travel or where you have been. As you move along, your every movement is being stored. Receivers with a TracBack feature will allow you to reverse your route taking you back the same way you originally traveled. As you move along, most GPS receivers show your track on a map screen.

- Velocity Made Good (VMG)

  Velocity made good is the speed at which the destination is approached. If you are directly on course, VMG is the same value as SOG, but if you stray from course, VMG decreases and is less than SOG.

Checking Your Understanding

Answers to "Checking Your Understanding" can be found in Appendix B.

1. Practice storing and naming waypoints and tracks using a GPS receiver.

2. Determine how many waypoints your GPS receiver can store in the memory.

3. List three ways you can prevent making user mistakes when using a GPS receiver.

4. List three things that are important to do when you are taking a GPS receiver with you on an incident.

5. How should you name waypoints?