Unit 19, Land Navigation VI: Basic GNSS/GPS
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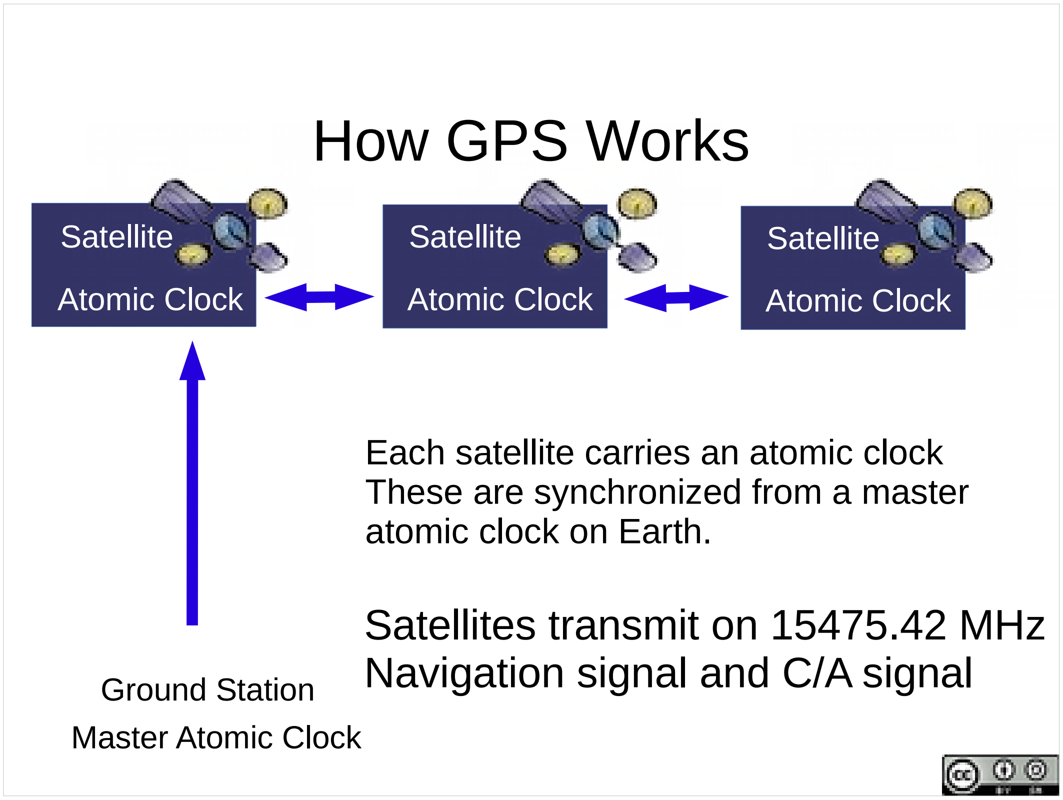
GNSS/GPS

- Global Navigation Satellite System
  - GPS (US)
  - GLONAS (Russia)
  - Galileo (EU)
  - BeiDou (China, regional, global by 2020)

GNSS: Global Navigation Satellite System, of which the US Global Positioning System (GPS) is one.

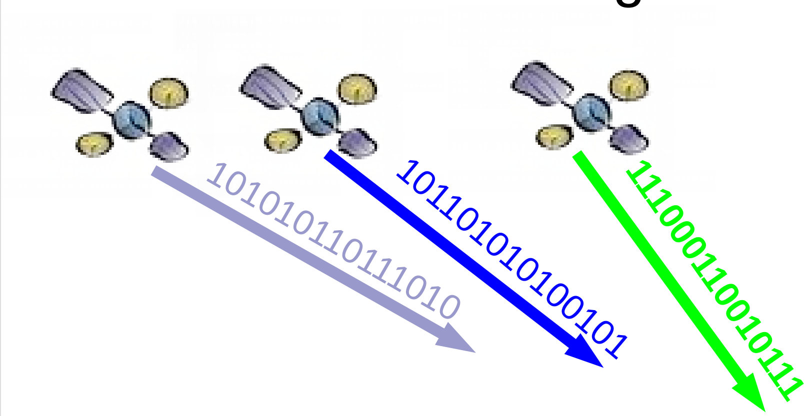
There are multiple such systems. Newer receivers listen to more than one of them (and give a more precise and accurate position).



The GPS system is a marvel. It depends on very precisely synchronized atomic clocks carried on each GPS satellite. The satellites transmit a variety of spread spectrum signals in the low microwave bands. The key civilian signals are the Navigation signal and the Coarse/Acquisition signal.

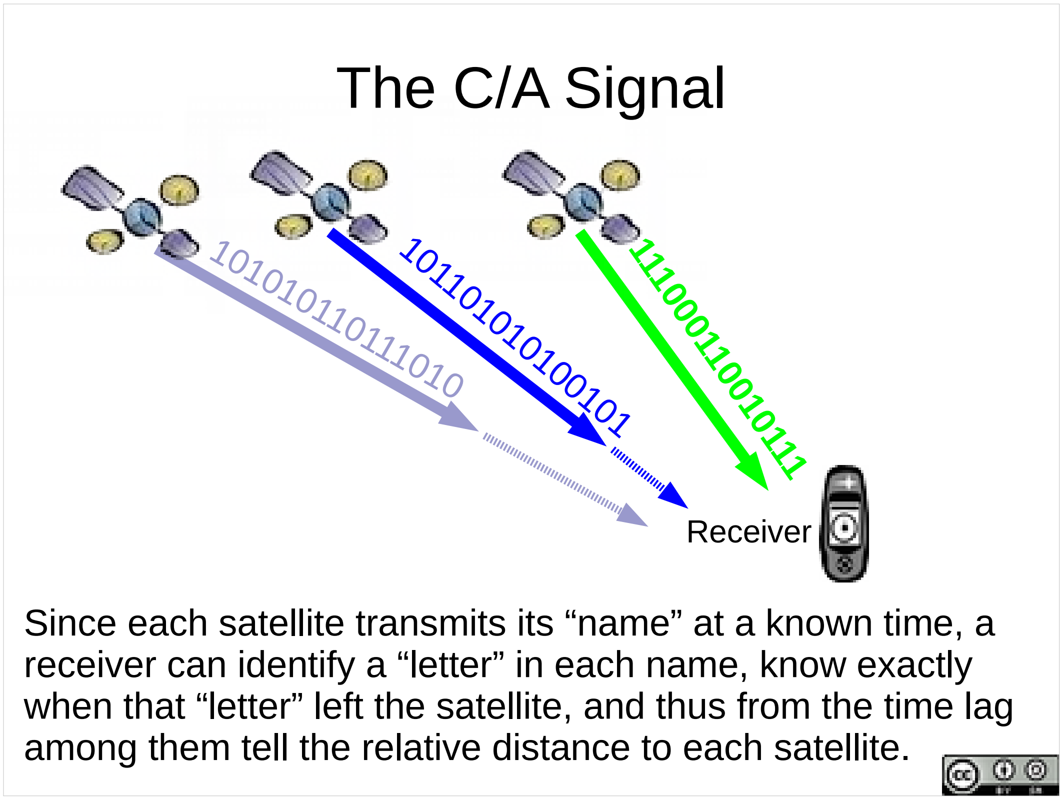
[The Navigation signal is transmitted at a low bitrate and takes 12.5 minutes for complete transmission. It is modulated with the Coarse/Acquisition signal running at high bitrate (repeated once per millisecond), in a CDMA spread spectrum signal, where all satellites transmit on the same frequency, and the code sharing allows receivers to separate the signals from different satellites.]

The C/A Signal



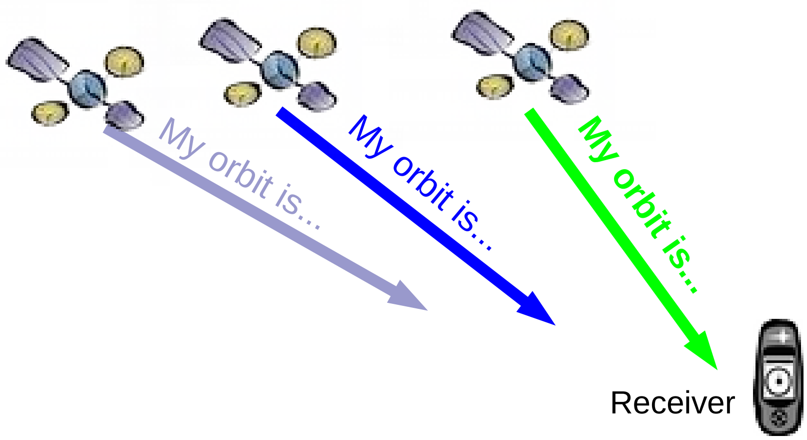
Each satellite transmits its own unique “name” a 1023 bit Pseudo Random Noise word.
All satellites start to send this signal at known times.

Each GPS satellite transmits a unique name in the form of a 1023 bit string (generated as a pseudo-random noise word, where each satellite’s pseudo random noise word is distinct (in a particular mathematical way known as Gold Code)). Each satellite transmits its Pseudo Random Noise name at a known time (once every millisecond). This information forms the Coarse/Acquisition signal.



Because the names are transmitted at known times, a GPS receiver can listen for the time lag between signals transmitted by different satellites and calculate the relative distance to each satellite.

The Navigation Message

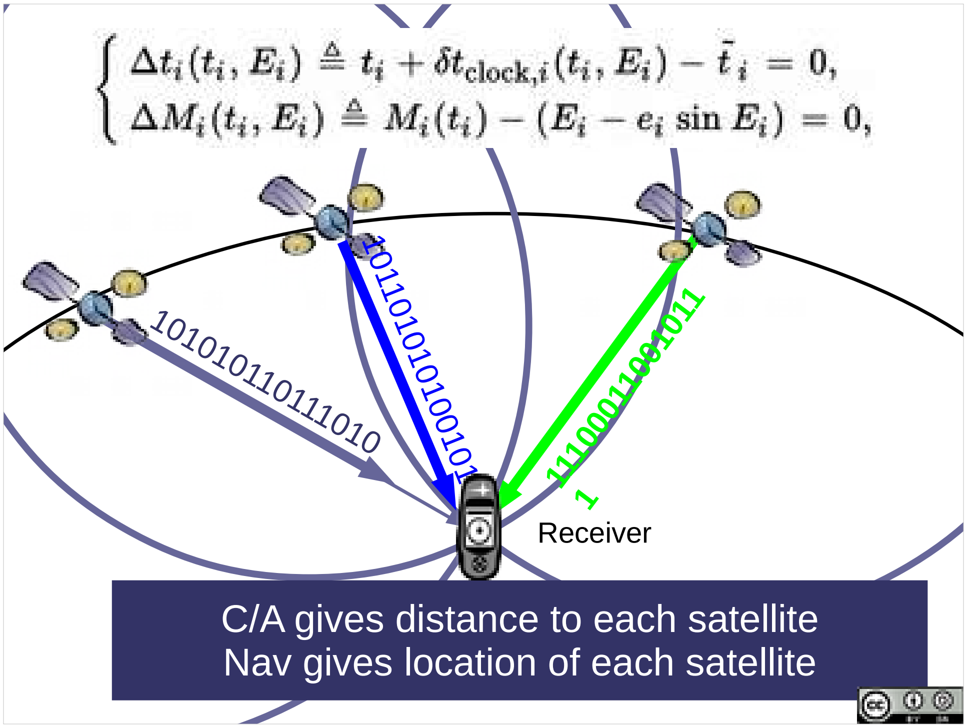


The Navigation message includes the orbital parameters and the time the C/A signal was sent.
(I’m here, I started sending my name at...)

Each satellite also transmits a navigation message containing the information needed to calculate its orbit (and where in its orbit it is) and information needed to determine the exact time that the PRN name was sent.

The receiver can identify the particular part of the pseudo random noise signal (in the C/A) signal it is hearing, match it to a particular satellite, and know at exactly what time that part of the signal left the satellite. Knowing the speed of light, the receiver can calculate the distance to each satellite.

This is much like seeing a flash of lightning, counting seconds to the clap of thunder, knowing that sound travels at about 1000 feet per second, and being able to say how distant the lightning was.

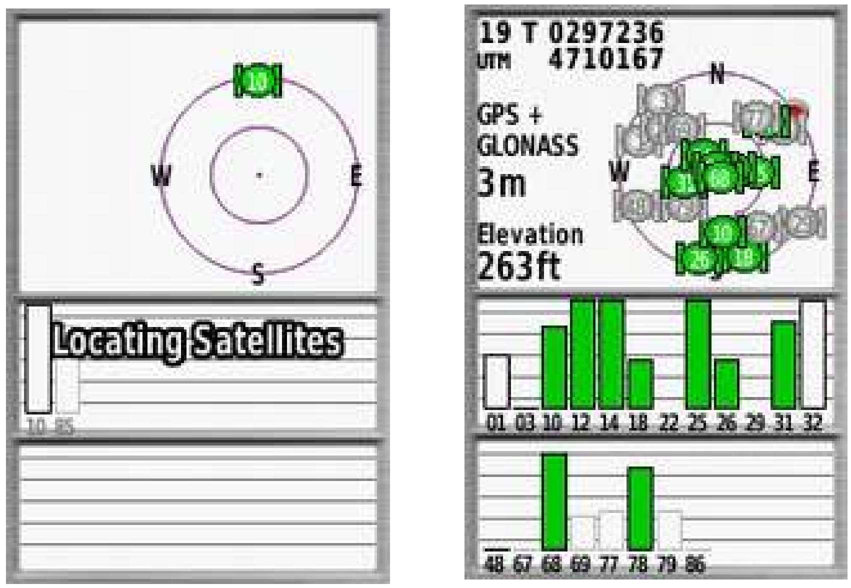


Then it is just math...

Triangulating to 4 or more satellites gives a reasonable solution in both position on Earth’s surface and elevation.

Position is more precise than Elevation.

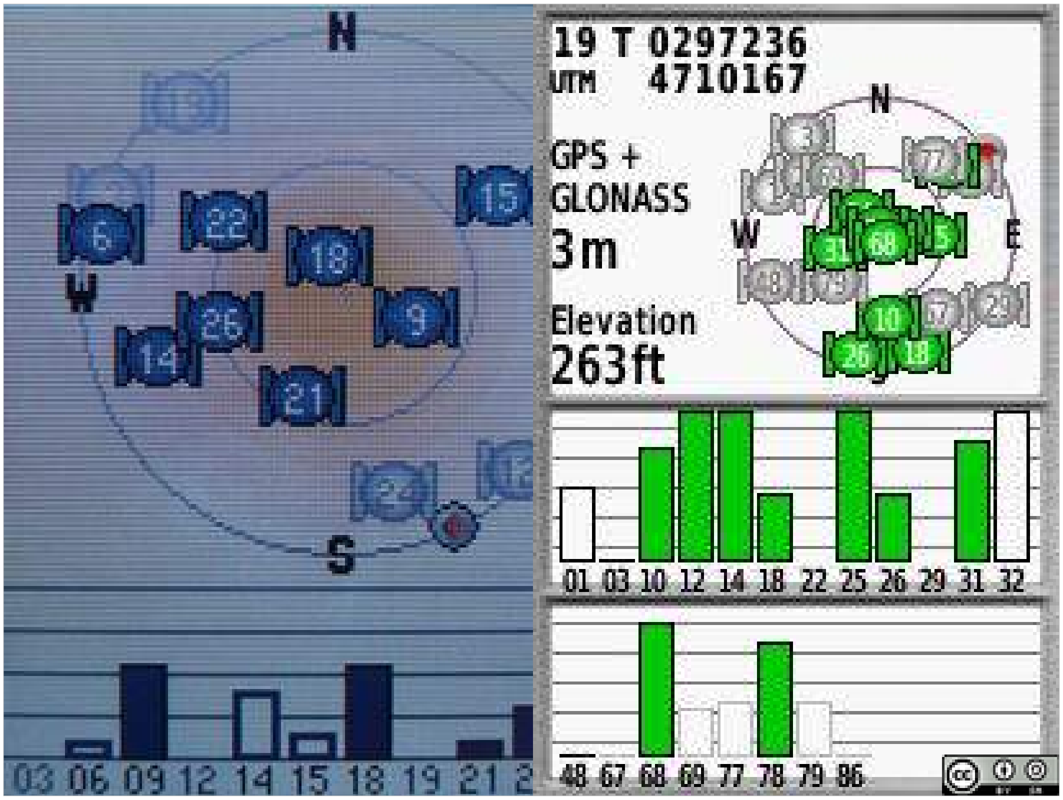
Does My GPS know where it is?



Turn on your GNSS/GPS receiver, it listens to satellites to figure out where it is. This takes time and a good enough view of the satellites in the sky.

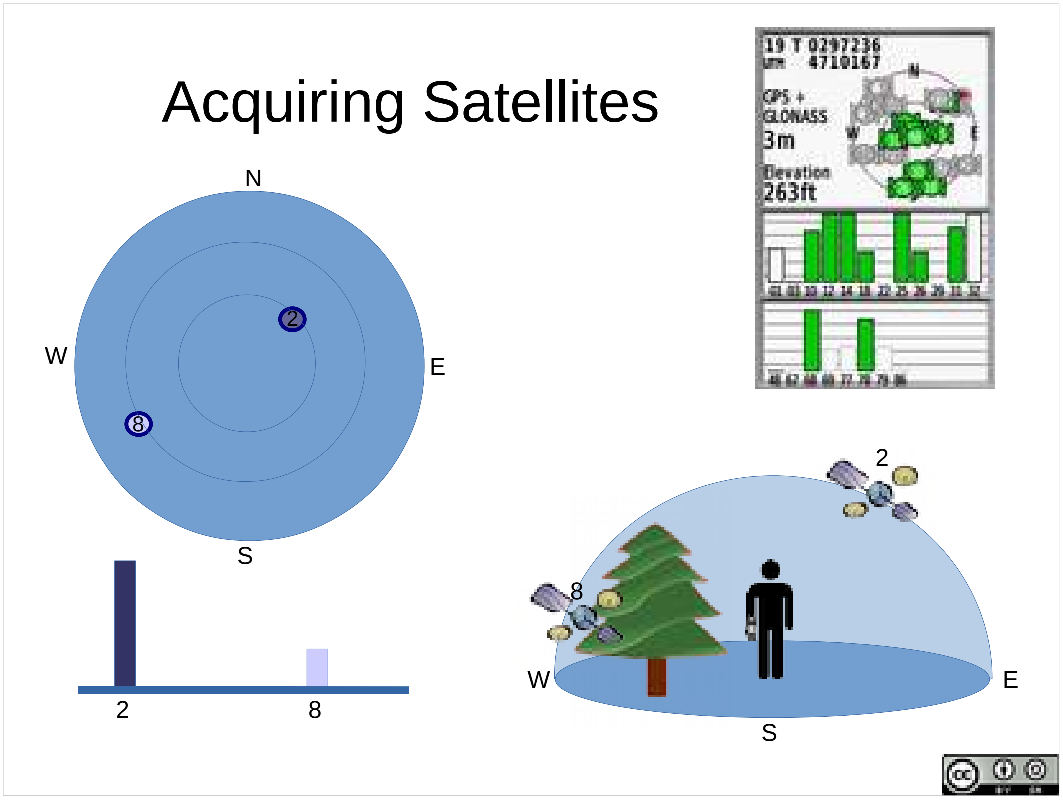
(1) The GPS will give you a position.
(2) The GPS will give you an estimated position error (in the horizontal, error in elevation will be greater).

This GNSS (reading both the GPS and GLONASS satellite constellations) claims a position accurate to about 3 meters.



Here’s a couple of GNSS receiver’s view of what satellites they are currently receiving.

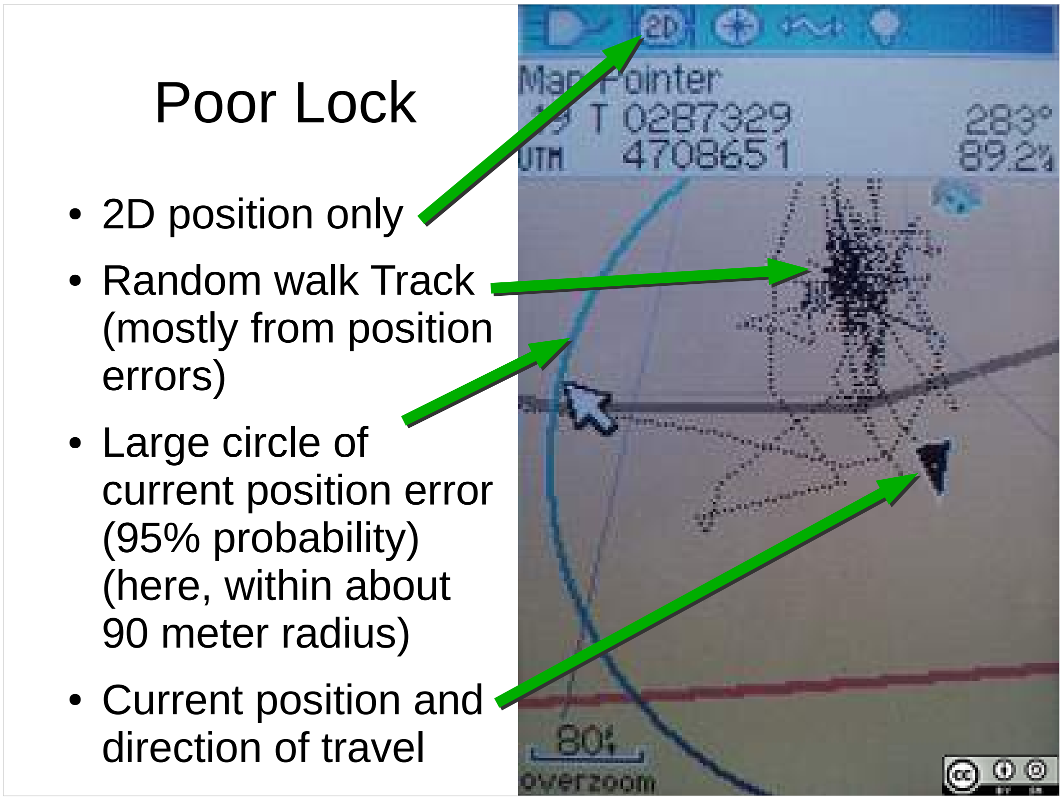
Typical view is a circle representing the sky, with satellite positions in it, and bars indicating signal strength and lock (have I got enough information from this satellite to use its signal to calculate a my position).



The concentric circles in the display represent the dome of the sky overhead (with North, South, East and West marked). A satellite in the center is right overhead. A satellite near the edge is near the horizon.

Here, satellite 8 is low to the horizon in the Southwest, while satellite 2 is higher in the Northeast.

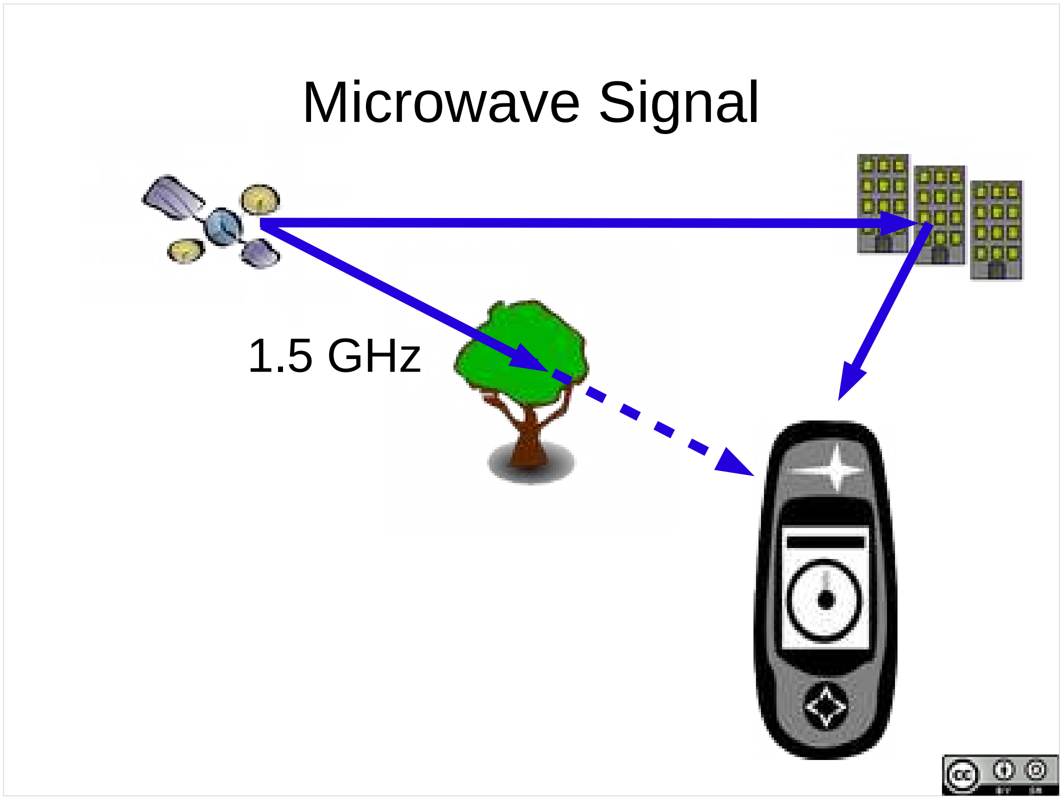
Satellite 8 has a weaker signal and hasn't got a lock yet. How could you improve this? (move to get a clear view of the satellite in the sky (not blocked by trees)).



You can also get hints of poor position accuracy in other displays of the GNSS receiver.

Here are some indications of a poor lock in the map display of on an (older) Garmin GPS 60 series receiver.

The map display may include a circle of position error (95% probability that you are somewhere inside that circle), or show a random walk from the GNSS changing its mind about its location.



The GPS signals are on microwave frequencies.

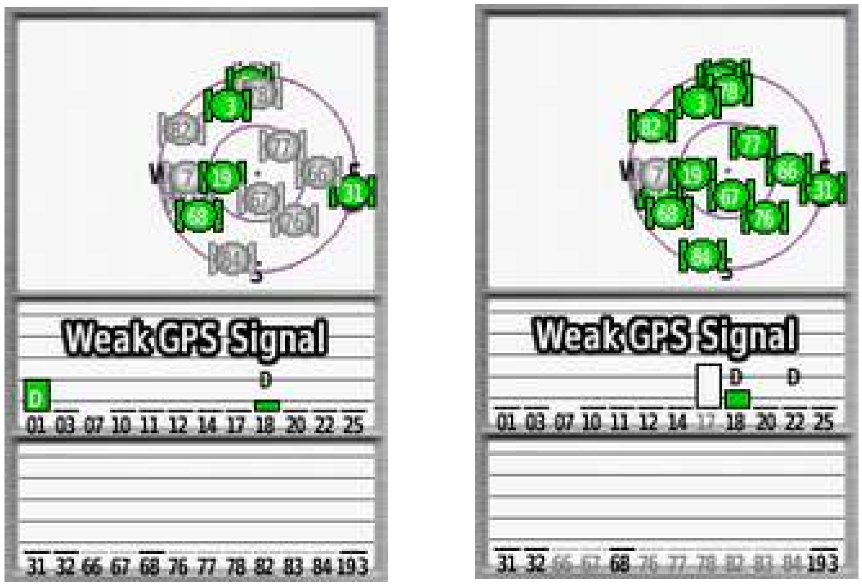
Tree leaves are good at attenuating microwave signals, thus GPS receivers get weaker signals from satellites under tree canopies.

Microwave signals can bounce off of buildings, canyon walls, etc, and travel on multiple paths to the GPS receiver (thus confusing it about distance and travel time).

(Rain drops attenuate higher frequency microwave signals in the 3-30GHz range, so rain (or snow) doesn’t appreciably affect GPS reception).

Calculations of distance to each satellite are dependent on knowing the speed at which the microwave signals are traveling, assumes that that they travel straight paths, and assumes that the signals are not distorted. Large solar storms which stream charged particles into the high atmosphere can distort and disrupt microwave signals.

A GNSS receiver's ability to obtain a lock and its position accuracy are affected by space weather. A large solar storm (which results in lower latitude auroras) can produce degraded GNSS position accuracy.



Here's a GNSS receiver in New Zealand experiencing an episode of poor reception

Some Limitations of GNSS Receivers

- Need Batteries
- Altitude is lower accuracy than position
- Need Line of sight to 3+ satellites
  - Accuracy can be reduced under tree canopy
  - Accuracy can be reduced by multi-path in urban areas or canyons
  - Accuracy can be reduced by solar weather
- Many opportunities for human error

GNSS receivers have limitations.

They need batteries to work. What can you do to help mitigate the risks around batteries dying? (Carry spare batteries, change out the spares, check the battery charge before leaving staging, carry a compass...)

The receiver needs good signals from at least 4 satellites to calculate a precise location and elevation. Trees, buildings, things getting in the way of satellite reception can reduce accuracy.

Solar storms can affect the travel time of GPS signals, and thus GPS accuracy.

Complex tools, practice with them regularly.

Let's now look at how to use a GNSS receiver.

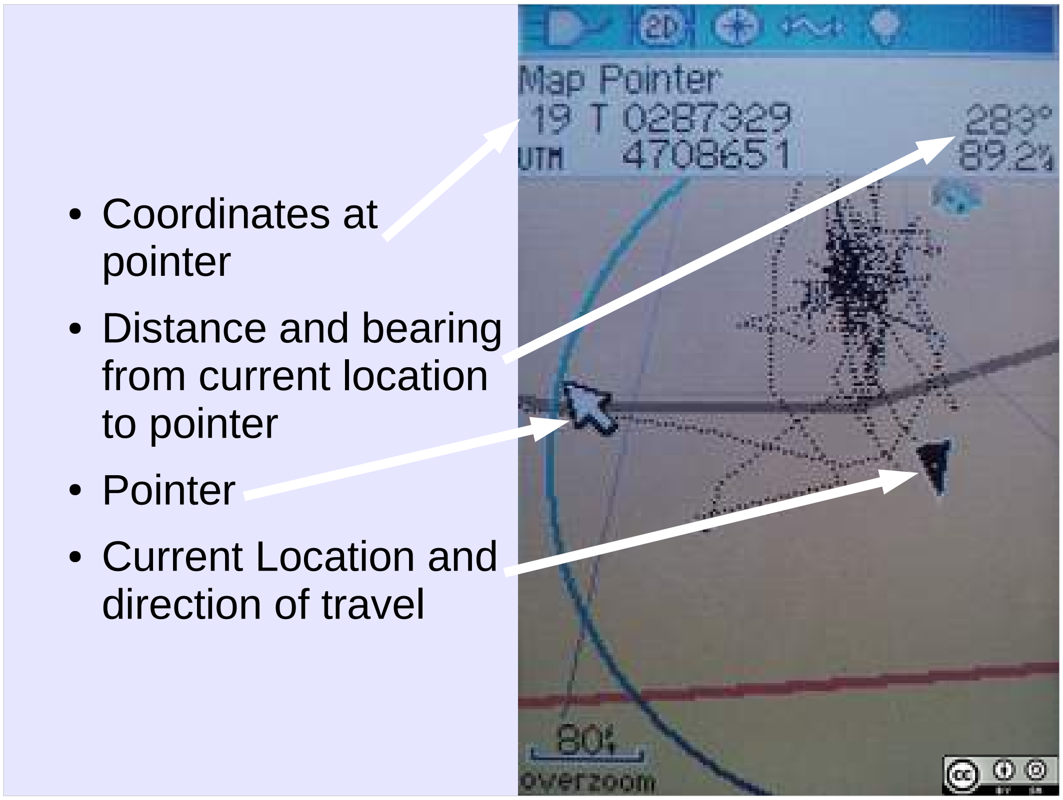
Here are two examples of a GNSS receiver displaying location on a map.

One claims its current location is just off the end of Harwood Ave.

And it is giving us a location (in UTM coordinates).

Another claims its is off Depot Road, and it is giving us a location (in Latitude/Longitude)

Both cases – triangle is current location (and heading).



Here's a display in a few years older GPS receiver
Get used to your GNSS's display (and how you can configure it).

What are we seeing here?

Pointer (left center)

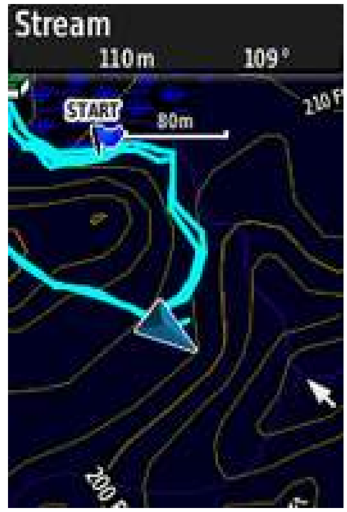
Current position (black triangle, right center)

Circle: Estimated position error.

Black squiggly line – drifting position error by the GPS.

Displays Vary (Learn Yours)

Current Location (Blue Triangle)

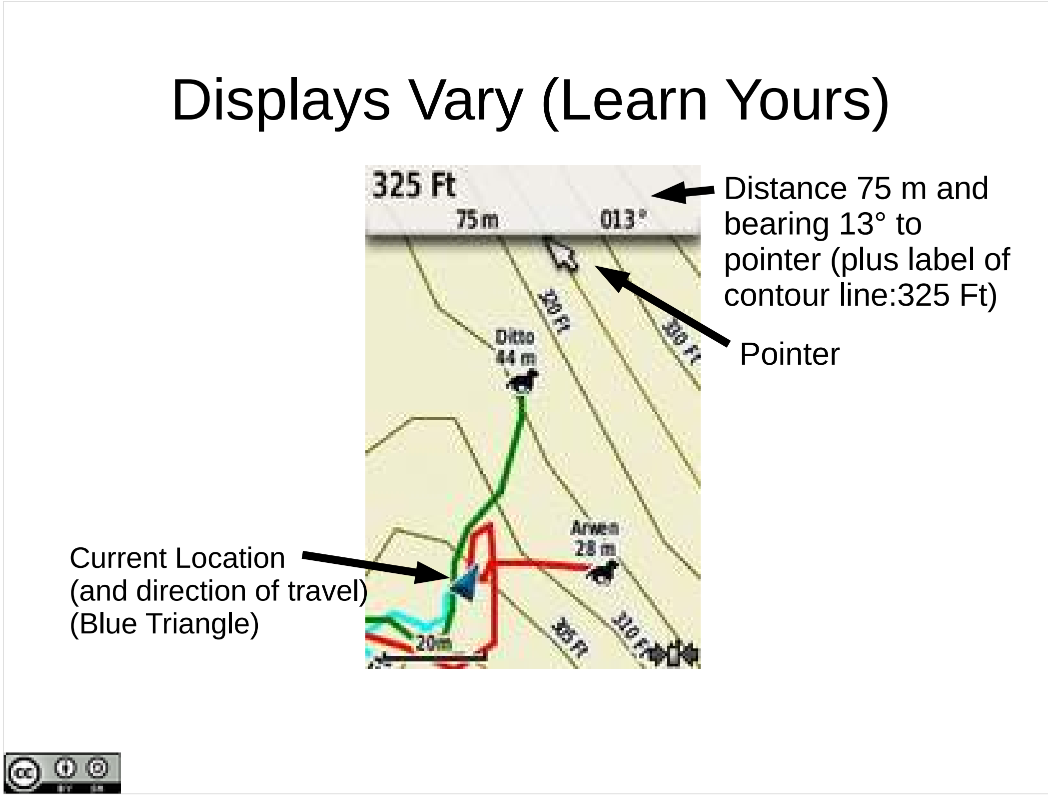


Distance and bearing to pointer (and label at pointer (Stream))

Here's a Garmin Astro (tracking two dogs), displaying the coordinate of the current location (configured to display the coordinate of the current location).

And a Garmin GPSMap64 scrolling the pointer on map, showing the distance and bearing to the pointer.

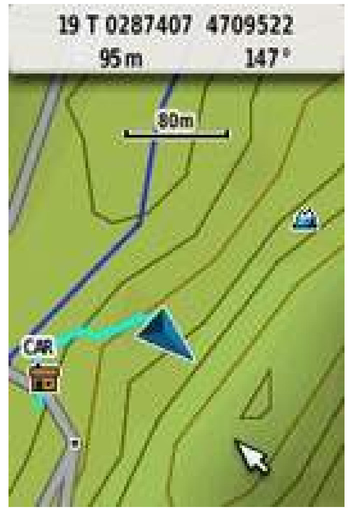
GNSS displays with a movable pointer can give you the distance and bearing to a feature you can see on the map(s) loaded into the GNSS (may need to purchase separately, fancy models include subscriptions and air photos, lots of variability in available maps, minimum can approximate 1:100k topo).



If the pointer, as confusingly in this case, is on a labeled contour line the top of the display looks like a distance, it isn't, it is the label of the feature the pointer is on. (the pointer is on the line 325 Ft. This point is 75 meters away on a bearing of 13 degrees))

Simple Navigation

- Bearing and distance to a point
- Track
- Waypoints
- Go To a Waypoint



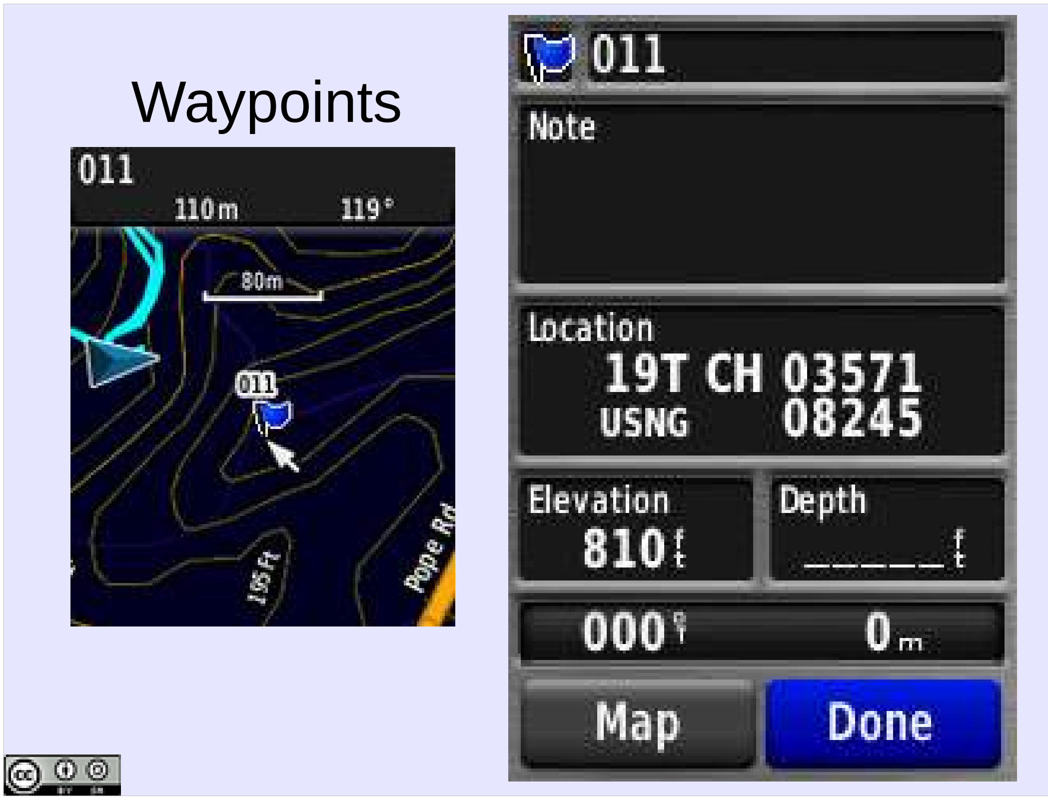
WE can do all kinds of fun things to help us with navigation using a GNSS, let’s start with just a few.

In a GNSS with a movable map pointer, we can obtain the bearing and distance to a point.

Pointer is on top of a ridge (how far at what bearing – 95 meters at 147 degrees) from our current position (triangle).

We can also see our track – where we’ve been recently (for user configurable values of recently).

Track meanders back to a waypoint we marked on getting out of the car.



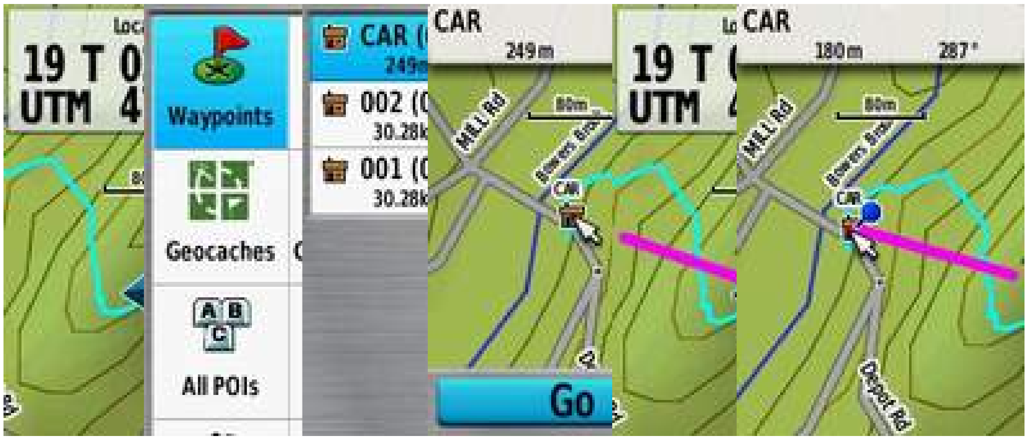
You can store a location. This is a waypoint (011).

You can give it a name (Truck, Clue, Staging, etc.) (in this case, when viewing the waypoint details, move the highlight to the waypoint name (011), then enter to edit).

Often created with a button “Mark” on the GNSS.

You may be able to tell your GNSS to listen to the satellites for longer and get a better position for the waypoint you’ve just created from your current position (Waypoint Averaging). Can be helpful to do this at a clue.

Go To Waypoint



[Find]

You can ask your GPS to give you a bearing to an existing waypoint (e.g. waypoint manager, pick a waypoint, select Go).

You can navigate back to the dropoff point...

287 degrees (True)

180 meters.

If You Remembered To Store It

Assuming you remembered to mark the dropoff point.

Practice Good Habits:

- Before you start: Check your batteries.
- When you get out at the drop off point
  - Make sure your GPS has an accurate position.
  - Mark a waypoint with your GPS.
  - Save and clear the current track (dog's too).
  - Make sure that your GPS is recording the track.
- When you start your assignment
  - Mark a waypoint
- When you complete your assignment
  - Save the track for the assignment.

Get into some good habits whenever you train:

Check your batteries (and spares).

Mark the point you get dropped off at (so you can get back there).

Save and clear the current track before you start your assignment, and save it when you complete your assignment (this makes it easy to download a track that just represents your assignment, not lots of other points that someone will need to exclude to put your assignment on the map.

Waypoints at the start and completion of your assignment document location and time.
(And of course, waypoint significant things you find)

And Calibrate the Compass (often)

When you are moving, your GPS may be able to calculate your heading based on your last position and your motion (this works better if you are moving faster than on foot).

When you are standing still or moving slowly, a GPS with a built in electronic compass can detect local magnetic north and determine your heading (and which way it is pointing).

Re-calibrate whenever you start an assignment.

Capabilities and battery draw vary.

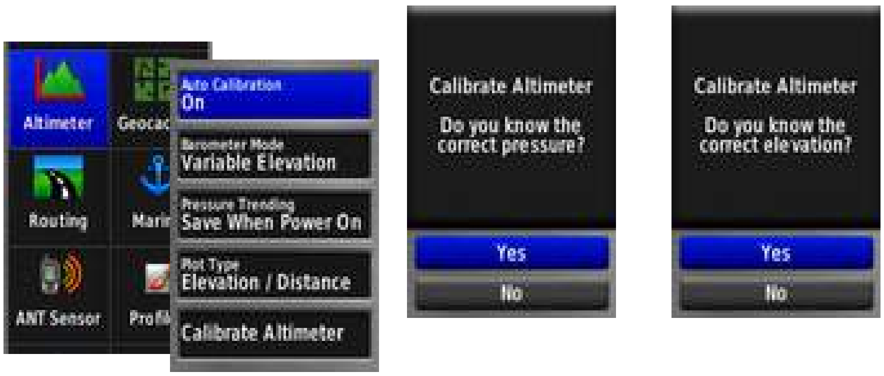
Practical: Startup Sequence

Practical Evolution

(1) Actions on turning a GNSS receiver on.

Altimeter Calibration

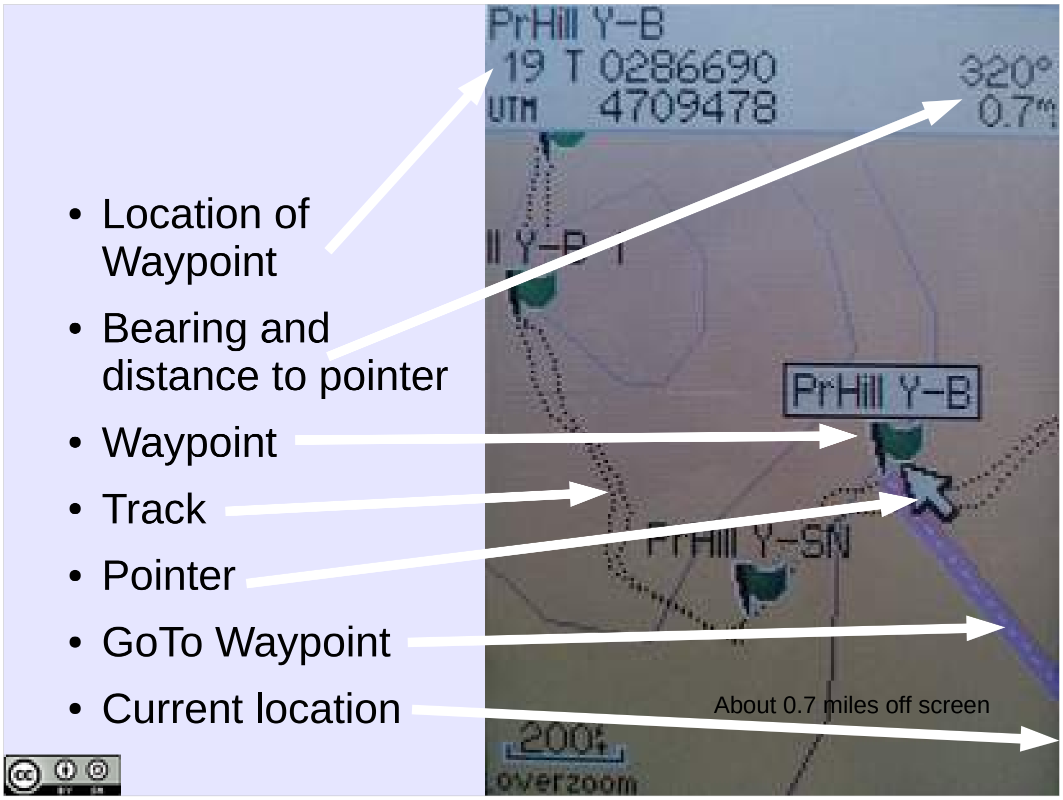
- Known Elevation
- Known Barometric Pressure



Some GNSS receivers also have an altimeter that can provide a better elevation than GNSS alone (mostly important for mountainous terrain, can also be display barometric pressure trends for weather forecasting).

Altimeter needs to be calibrated.

Typically need to know current elevation and barometric pressure for calibration.



Here’s a GPS with the pointer hovering over a waypoint, displaying the name of the waypoint, the coordinate for the waypoint, and a distance and bearing from the current location (not on the map) to the waypoint.

We’ve told the GPS to go to the waypoint, so there’s a heading line from the current location (off the map) to the waypoint.

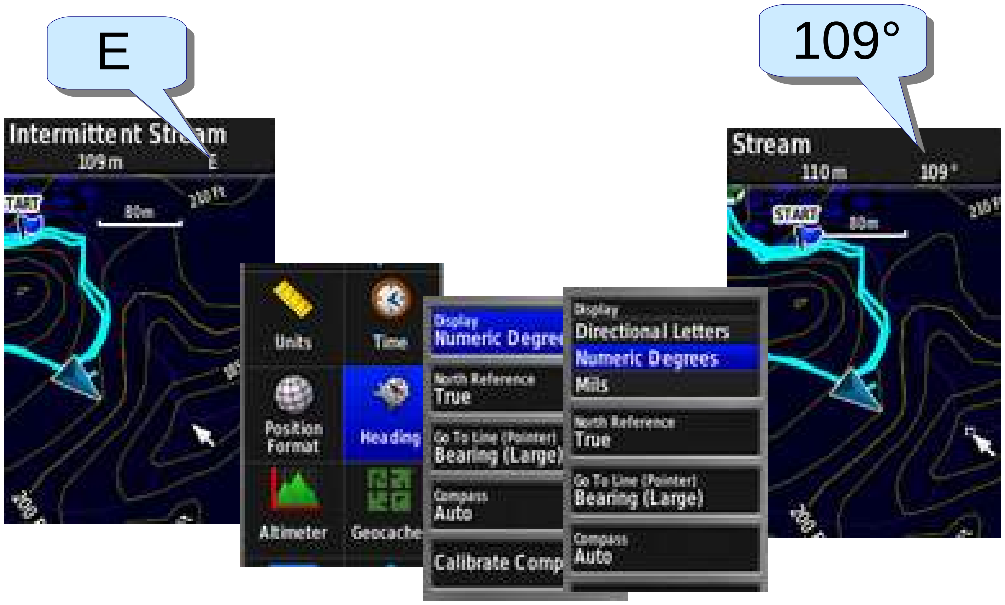
Customize Your Screen For Your Task

Your GNSS receiver may have a compass view and a current route view that display configurable information fields.

Configure the fields you want to see for the task at hand.

Here is a compass view, showing a current direction of travel to the SSE, without a Go To Waypoint (or route) selected, thus a current heading, but not the bearing to the next waypoint.

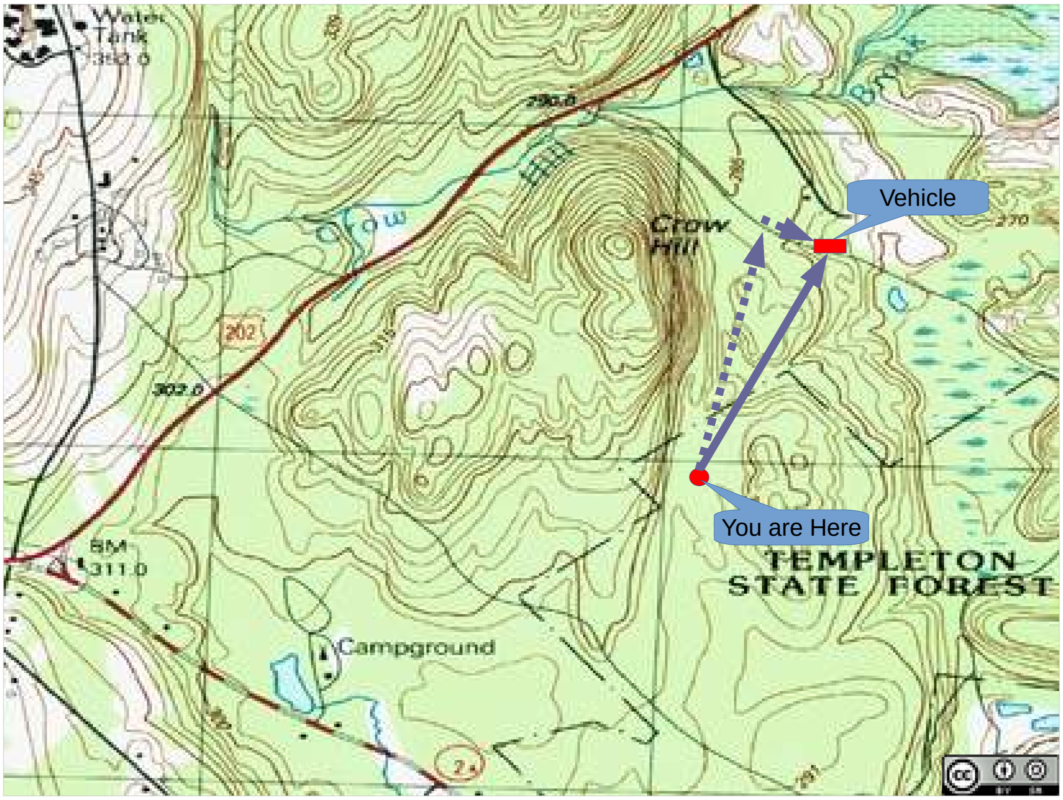
May need to change Heading Settings to see Bearing in Degrees



If you move the map pointer and see the distance from your current location to the pointer, but with letters for cardinal direction (e.g. N, or SE) instead of bearing in degrees, change the setting for the display of the Heading to give you the bearing in degrees (you can also set bearing relative to True or Magnetic north).

Fields on Map View

You may be able to configure your GNSS to display fields on the map view. Configure for your task (and your eyesight).



When navigating back to a waypoint on a (road, trail) linear feature, navigate off to one side or the other, rather than directly towards the waypoint.

Why?

When you hit the linear feature, you know which way to turn.

(Bearing back to vehicle on solid line, travel a few degrees west of that bearing, then you know to turn right when you hit the road.)

Also, note the distance, and pace count it – linear features can be easy to cross without noticing.

Ways to Create a Waypoint

- At your current location (Mark)
- At your current location, then edited to a given location (Mark/Edit).
- At your current location, then moved with the map pointer (Mark/Menu/Drag)
- Projected from your current location (Sight & Go).
- Projected from another waypoint. (Waypoint Manager/Waypoint/Menu/Project Waypoint)

There are multiple ways to create waypoints from the GNSS receiver. (Parentheses list typical Garmin means for carrying out each, receivers vary).

At current location – often a button on the receiver to do just this (e.g. “Mark”).

Once you have created a waypoint, you can edit it (either directly on creation, or by finding it in the waypoint manager). Given a location over the air, write it down, then create a waypoint and edit the waypoint to match the given coordinates (then sanity check, you may have copied it down incorrectly or entered it incorrectly, or it might be across a grid square or zone boundary...).

A waypoint may be able to be selected, then dragged to a new location.

Waypoints may be projected.

Project a Waypoint from current location

At a location, you can project a waypoint some distance on a bearing.

You need to:

Be at a known point.

Have a known distance you want to travel.

Have a known bearing you want to travel on.

Project a Waypoint from another Waypoint

You can also project a waypoint from any other waypoint.

Select the start waypoint. Menu -> Project waypoint.

Enter bearing, units, distance, then project the waypoint.

You don’t need to be at the start location.

You can use this (carefully) to set up waypoints for the grid for an area (make sure you sanity check).

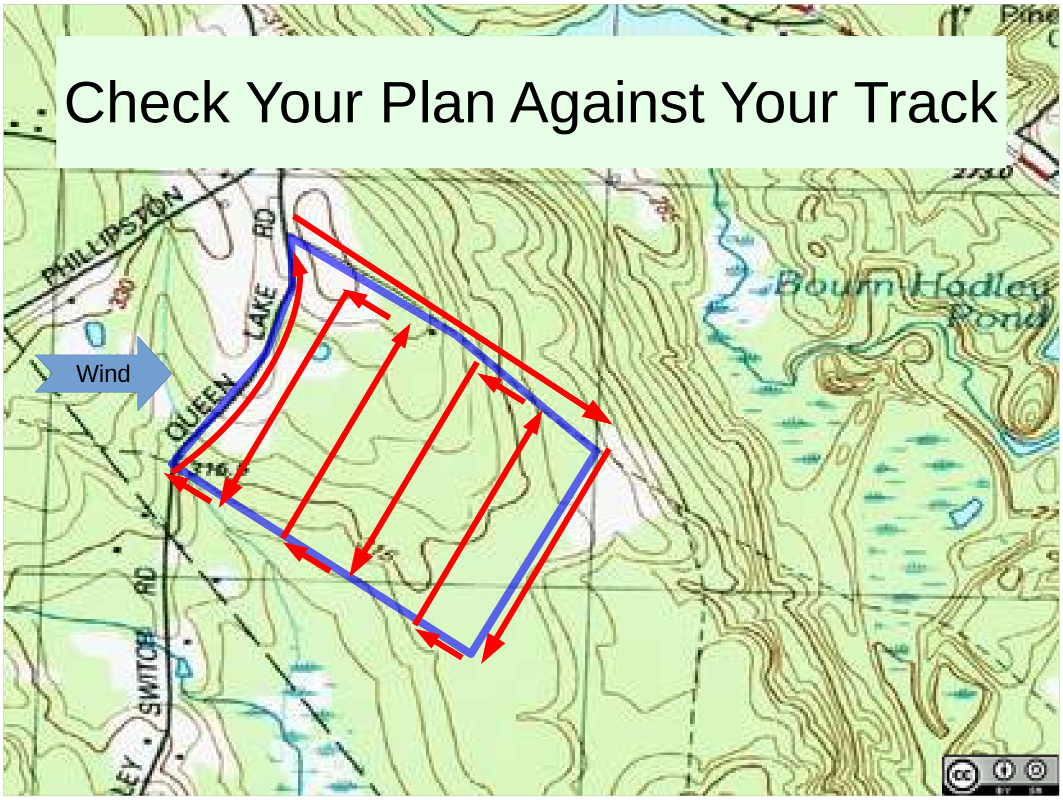
Practical: Waypoints

Practical Evolutions:

(2) Determine bearing and distance from current location to point on display..

(3) Mark Waypoint, Edit and Project Waypoints.

(4) Record waypoint, navigate back to waypoint with a compass.



You have some plan about how tactically you want to search some segment.

While working it, look at the map view in your GNSS.

You can see how the execution of your plan is playing out. How neat are your grid lines? Are they spaced as you planned? Have you left gaps?

Building Your Own Map

- Waypoints
- Routes
- Tracks

- Finding your way back to a pickup point
- Documenting where you have searched
- Documenting a flagline segment boundary
- Documenting a clue

A GNSS can show your location (and can show you a map), but you can also, conceptually, build your own map with a GNSS.

You have three tools for this:

Waypoints: Stored Locations.

Routes: Linked sets of waypoints that make up a travel route.

Tracks: The record of where you’ve been with the GNSS (e.g. along a trail).

All of these capabilities can be exploited in SAR.

Finding Your Way Back to a Pickup Point

- Create a waypoint at the place you are dropped off for a search segment.
- Create a waypoint at the point you enter a search segment.

We already touched on one of these – if you remember to mark a waypoint at the dropoff point, and you mark a waypoint when starting to search a segment, you've got information in your GNSS to help you get back to the dropoff point.

Documenting Where You Have Searched

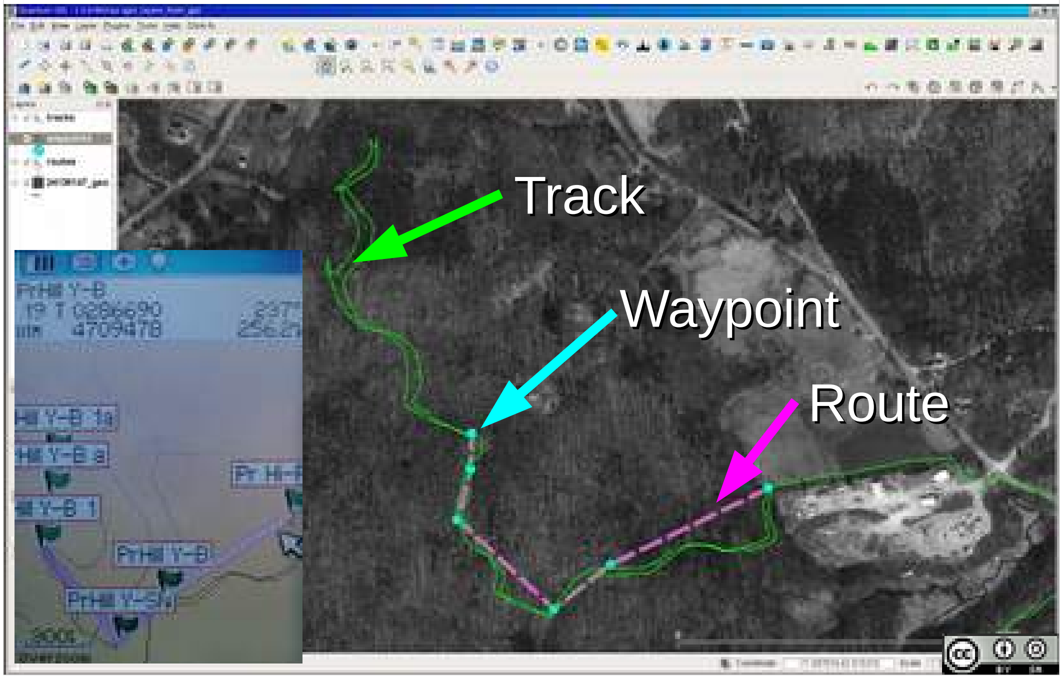
- If your GPS can store tracks:
  - Record your track with your GPS.
  - Start recording the track when you start a search segment
  - Stop and save the track when you finish a segment.
- If your GPS can't store tracks:
  - Carry a GPS logger.
  - Record Waypoints at extreme points in your search segment (e.g. when your grid hits a segment boundary).

Your GPS can help document where you searched.

Were you in your assigned segment? Were there any parts of your assigned segment that you didn’t search?

Tracks are usually not easy to edit with either your GNSS receiver or mapping applications used in the command post – make life easier for everyone, start recording a new track when you start an assignment, and save that track when you complete the assignment.

Tracks, Waypoints and Routes



Tracks are the GPS's record of where it has been.

Waypoints are point locations that you store in the GPS.

Routes are connected sets of waypoints that can be followed one to the next.

Here's a track, waypoints, and a route on a GNSS receiver and imported into a GIS application with an air photo.

Tracks

Tracks record the sequence of positions recorded by the GPS.

If you have poor GPS reception: Track won't reflect actual route taken.

Following exactly the same track back and forth on the ground will show the wandering error in the GPS's position.

Your GNSS is probably configurable to record and show your current track.