Global Positioning System

Location, Location, Location

What is GNSS?

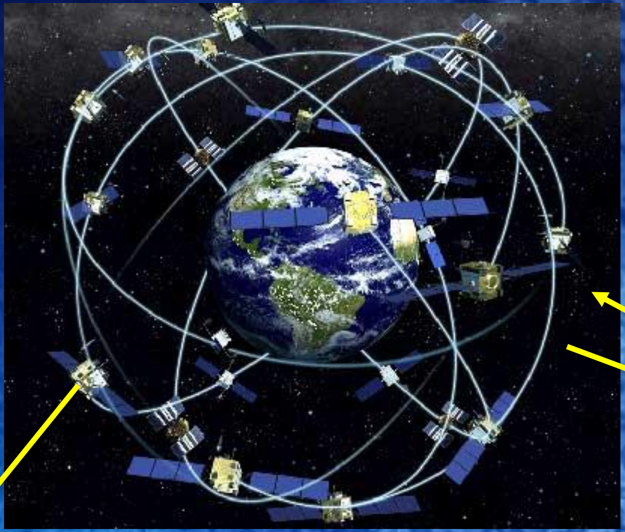
- GNSS stands for Global Navigation Satellite System.
- It is a general term for all satellite navigation systems.
- GNSS includes:
  - GPS is the United States positioning satellite system
  - GLONASS is Russia’s positioning satellite system.
  - Galileo is the European Union’s positioning system
  - BeiDou is China’s positioning system
  - Other regional systems

What is GPS?

- GPS is an acronym for Global Positioning System
- NAVSTAR (Navigation Satellite Timing and Ranging) is the name given to the U.S. GPS Constellation
- Location based system own, operated and controlled by the Department of Defense (DOD)
- Developed in the 1970's as a military locating utility, and over the years has become a important tool for non-military use.
- Constellation of at least 24 satellites orbiting the earth at altitudes of around 12,600 miles.

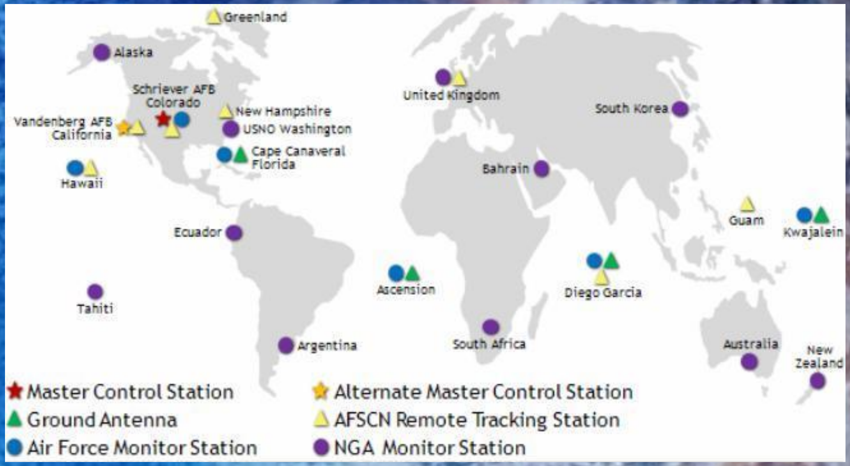
The 3 Segments of GPS

Space Segment



Control Segment

User Segment



Control Segment

- The Control Segment is the big brother of the GPS satellite constellation.
- Control Stations continuously track and monitor the GPS satellites. They update the positions of each satellite when necessary.
- The DoD operates this segment from Falcon Air Force Base in Colorado Springs, Colorado.
- The control segment has monitoring and upload stations distributed throughout the world.
- Each satellite passes over a monitoring station twice a day.

Space Segment

- There are at least 24 satellites in operation at all times. Currently there are 31 satellites available for use.
- The number of satellites constantly changes as satellites are decommissioned and commissioned. Taken out of use and put into use.
- Each satellite makes one revolution around the Earth approximately every 12 hours.
- The Air Force launched the sixth GPS IIF satellite on May 16, 2014, and set it operational on June 10, 2014.

User Segment

- The user segment is you and me and a whole list of other people.

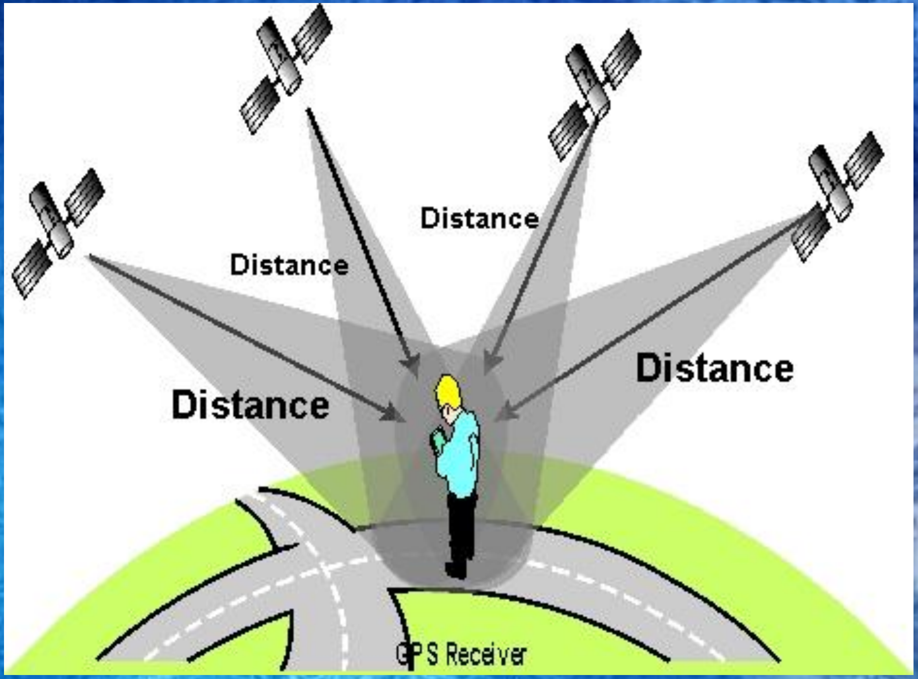
Precision Construction & Agriculture

Solar GPS Cattle Herder

- Surveying, Mapping & GIS
- Agriculture
- Utilities and Construction
- Aviation
- Vehicle Tracking
- Emergency
- Recreation
- Military
- Governments
- Marine
- And the list goes on and on. GPS is world-wide

How does GPS work?

- GPS is based on satellite ranging. This measurement is determined by timing how long it takes a radio signal to reach the GPS receiver from the satellite, and using that time to calculate distance.



Measuring Distance

- To measure the distance you need to know two things. The speed of a radio signal, which is equal to the speed of light (186,282 miles per second). You also need to know the time it takes for the radio signal to reach you.

For Example: If it takes 0.06 seconds to receive a signal transmitted by a satellite, you can use this formula to find your distance to the satellite.

Velocity x Time = Distance

186,000 mps **x 0.06** seconds **= 11,160 miles**

How is the time calculated?

- Each GPS satellite transmits data that indicates its location and the current time. All GPS satellites synchronize operations so that these repeating signals are transmitted at the same instant.
- The GPS receiver compares digital codes generated at precisely the same time by a GPS satellite and the GPS receiver.
- This codes are called "pseudorandom" codes and are generated by the satellites and the receivers.
- Time is calculated as the difference between when the satellite generated the code and when the receiver receives the code.

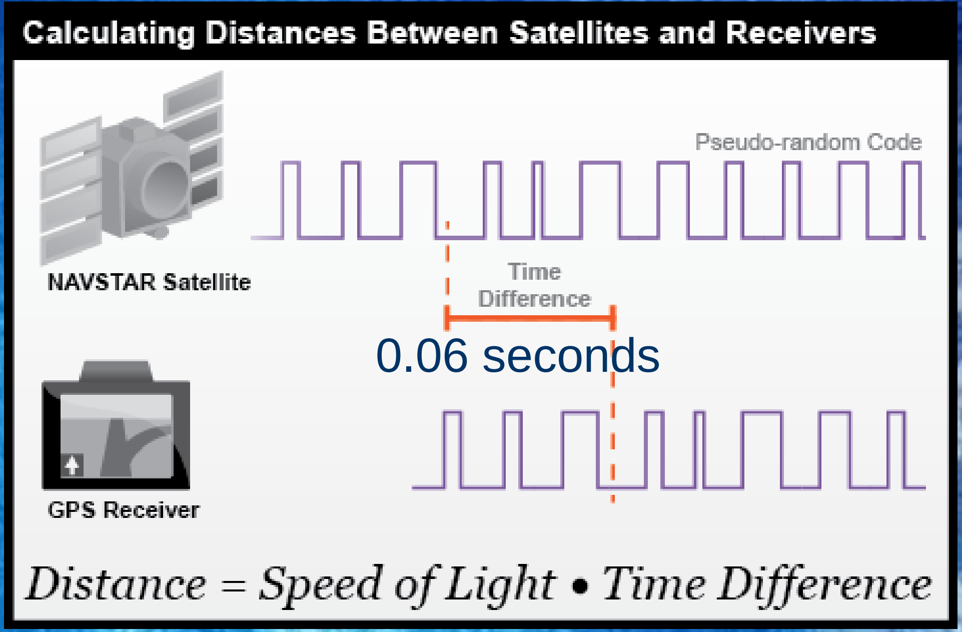
Pseudo Random Code

- The Pseudo Random Code is the code used for communication between the satellites and receivers. It's a very complicated digital code, or in other words, a complicated sequence of "on" and "off" pulses.
- The signal is so complicated that it almost looks like random electrical noise. Hence the name "Pseudo-Random."
- The complex pattern helps make sure that the receive doesn't accidentally sync up to some other signal. The patterns are so complex that it's highly unlikely that a stray signal will have exactly the same shape.

Distance = Velocity X Time

- When calculating the distance you are taking the time it takes the signal to reach you and multiplying that by the speed of light. The satellite code and the receiver code are generated at exactly the same time.

186,000 mps **x 0.06** seconds **= 11,160 miles**



Calculating Position
It's called Trilateration.

- **Trilateration** the measuring of the distance from at least three satellites to establish a position on Earth.

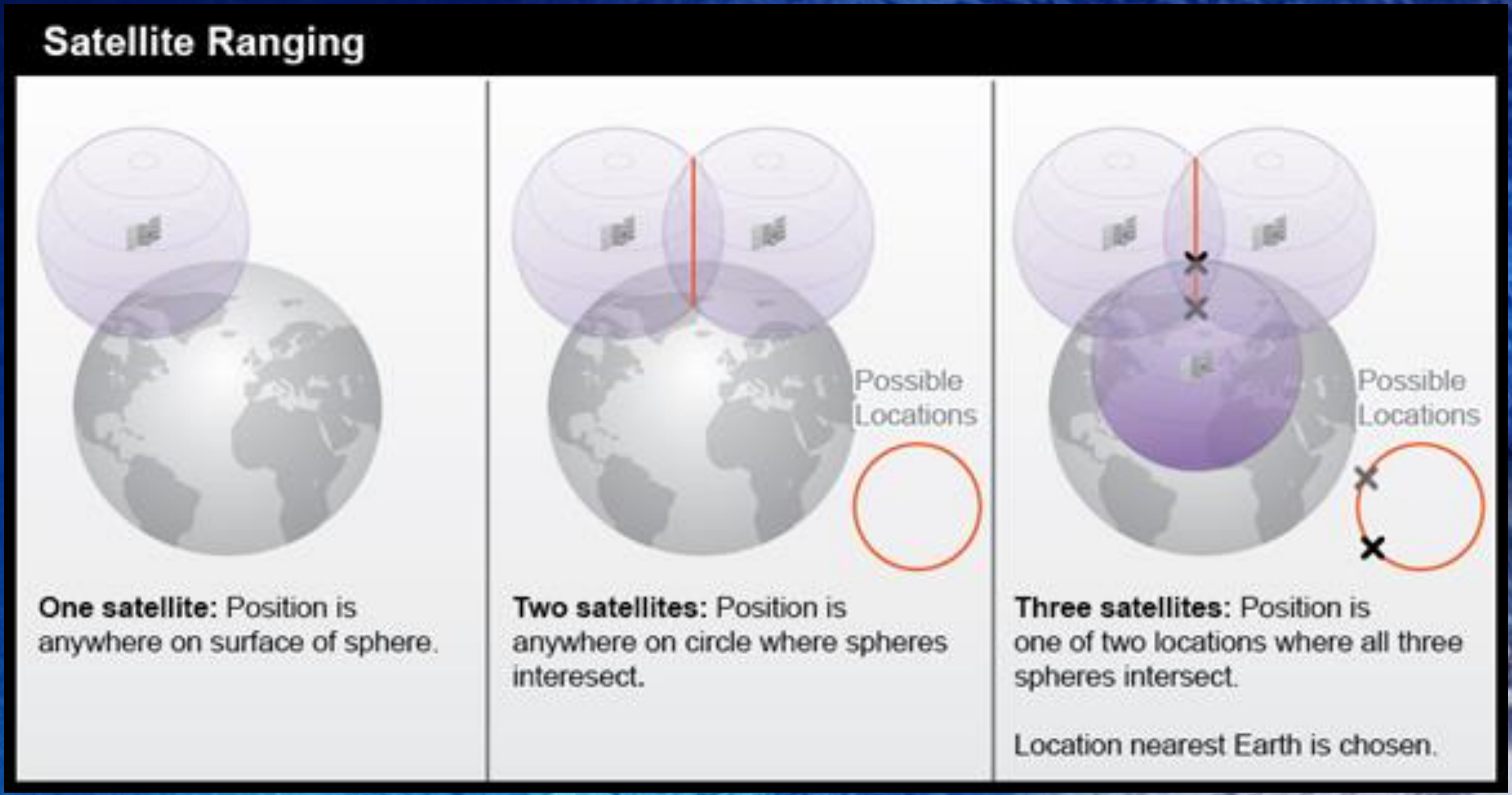
- The accuracy of a measurement based on three satellites may be diminished due to non-synchronization of clocks in the GPS satellites and the receiver. So a fourth measurement from another satellite is used to eliminate timing offsets.

- The GPS receiver recognizes timing offset when it receives a series of measurements that it cannot intersect at one point.

- It automatically starts subtracting the same amount of time from all of the measurements until one point is determined.

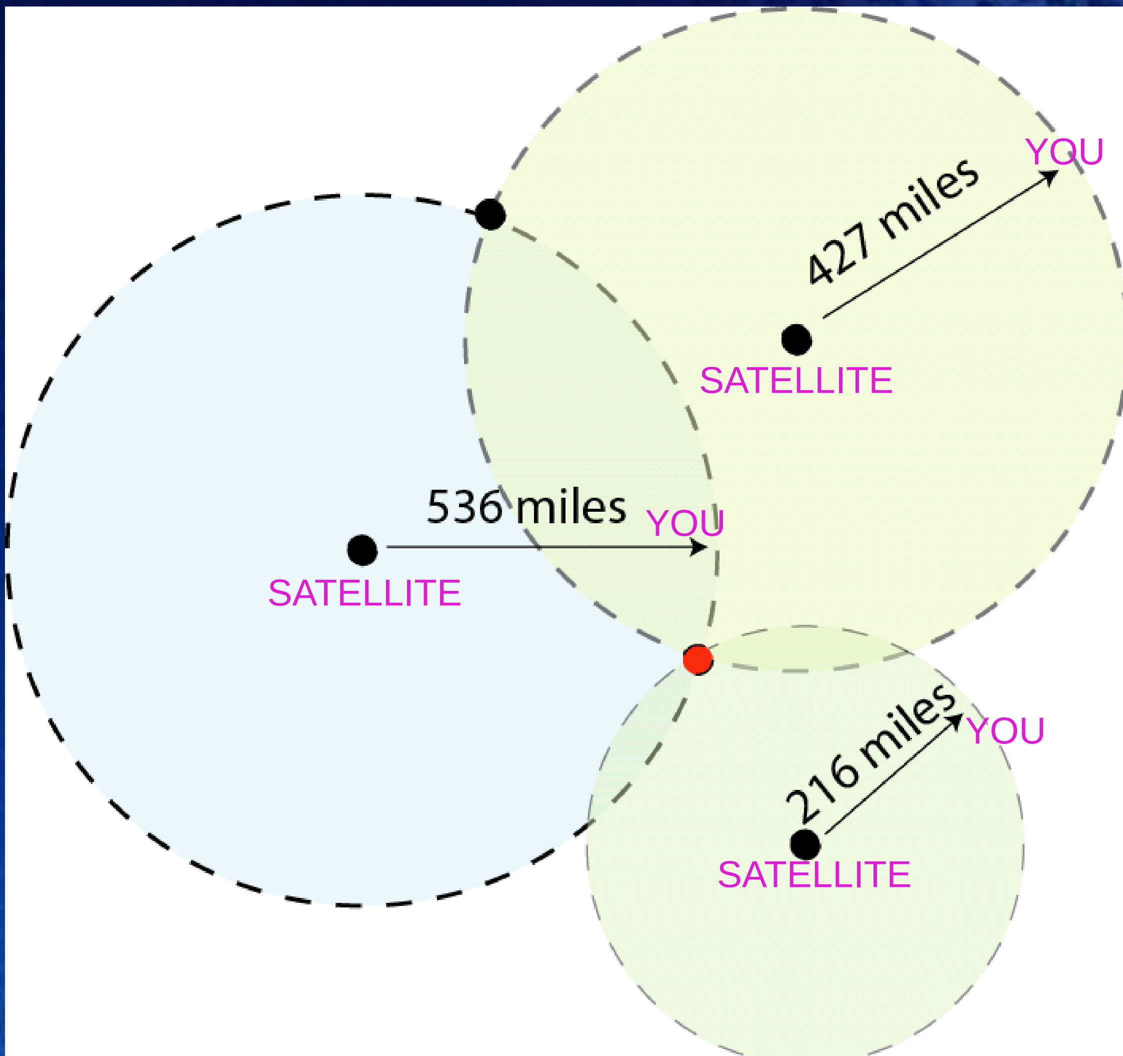
- To calculate an accurate position 4 satellites must be used.

Example of Finding Your Position



A fourth satellite is required to determine exact location and elevation

One More Example in 2D



You are 427 miles away from one satellite. You could be anywhere on a big circle.

Now, you get a reading from a second satellite, and you are 536 miles away from it. You could be anywhere the two circles intersect.

Okay, now you have a reading from a 3rd satellite, and you are 216 miles from it.

All 3 circles intersect at one point which must be your position.

Must to have that 4th SV for elevation and timing offsets though.

Other Elements of GPS
The Almanac

- An almanac is a general bus schedule of where the satellites will be for a particular time of the day.
- Each GPS satellite continually broadcasts the almanac.
- Your GPS receiver will automatically collect this information and store it for future reference.
- Almanacs are used while planning a work project, and for quick acquisition of satellite positions by the receiver.

Why is an almanac important?

- You can use an almanac file to see when the best time for you to go out an collect data with your GPS receiver.
- The almanac will tell you how many satellites you will be able to see at any time of the day or night.
- If you are not using an almanac to plan collection time, you could travel 100 miles to a location and find out you don’t have enough satellites to collect. What a waste of time!
- The almanac will also tell you when the geometry of the satellites is good at any time of day or night. It’s important to have good satellite geometry when collecting data.

Ephemeris Information

- The DOD constantly monitors the orbit of the satellites looking for deviations from predicted paths. Remember the Control Segment?

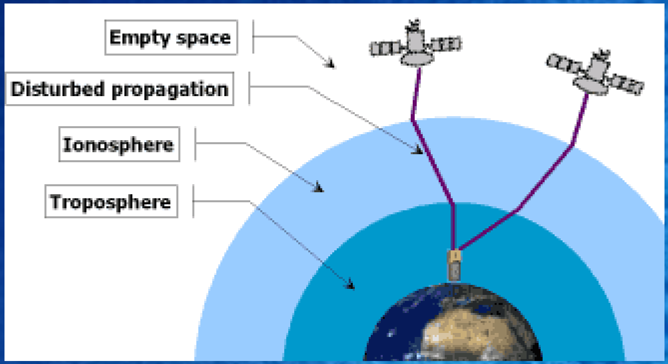
- Deviations are caused by natural atmospheric conditions such as gravity. Even though the satellites positions are constantly monitored, they can't be watched every second. So slight position or “ephemeris" errors can sneak in between monitoring times.

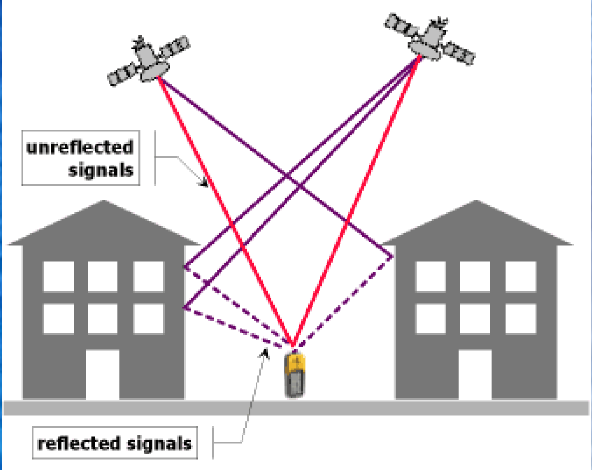
- Deviations are known as ephemeris errors.

- When ephemeris errors are determined to exist for a satellite, the errors are sent back up to that satellite, which in turn broadcasts the errors as part of the standard message, supplying this information to the GPS receivers.

Sources of Error in GPS

- Atmospheric Delay
- Multipath
- Obstruction





Atmospheric Delay

- GPS signals bounce around when traveling through the ionosphere and troposphere.
- The signal is delayed which will change the calculated position by changing the amount of time it takes the signal to reach the GPS receiver.

Multipath Error

Multipath error occurs when a GPS signal bounces (reflected) off an object before reaching the receiver.

A few examples include dense canopy, buildings, a parking lot full of cars.

Obstructions

- An obstruction is anything that is blocking the signal from reaching the GPS receiver.
- A few examples are tree canopy, tall buildings, and canyons.

Differential Correction Short Version

- The underlying principle of differential GPS (DGPS) requires that a GPS receiver, known as the base station, be set up on a precisely known x, y location. The base station receiver calculates its position based on satellite signals and compares this location to the known it's known location. The difference is applied to the GPS data recorded by the roving GPS receiver.

- Differential Correction is used to remove errors from the data you collected. Errors from the ionosphere, troposphere, signal noise, ephemeris data and clock drift.

GPS and GIS Working Together

- GPS can provide any point on earth with a unique address. It's latitude and longitude location.
- A GIS is basically a descriptive database of the earth.
- GPS tells you that you are at point X,Y,Z while GIS tells you that X,Y,Z is an oak tree.
- GIS tells us the "what". What's there.
- GPS/GIS is reshaping the way we locate, organize, analyze and map our resources.

GPS and GIS Work Together

- GPS tells us where the location of an object is; GIS tells us what the object is and any additional information we want to know about the object.

- The objects at locations are referred to as "Features", and are used to build a GIS. It is the power of GPS to precisely locate these features which adds so much to the utility of the GIS system. Without feature data, a coordinate location is of little value.

Types of Features

- There are three types of features which can be mapped:
- Points, Lines and Areas.

- A Point Feature is a single GPS coordinate position which is identified with a specific Object.   X TREE

- A Line Feature is a collection of GPS positions which are identified with the same Object and linked together to form a line.

ROAD

- An Area Feature is very similar to a Line Feature, except that the ends of the line are tied to each other to form a closed area.

POND

Feature Descriptions

- The ability to describe a Feature in relation to a multi-layered database is essential for successful assimilation with any GIS system.

- For example, it is possible to map the location of each house on a city block and simply label each coordinate position as a house. However, the addition of information such as exterior material, square footage, current market value, occupants, etc. will provide the ability to sort and classify the houses into categories.

Feature Attributes

- These categories of descriptions for a feature are know as attributes. Attributes can be thought of as questions which are asked about the Feature.

- For Example: Feature = Tree
  Feature Attributes could include:
  Type of tree
  Height of tree
  Diameter of tree
  Condition of tree
  Tree canopy diameter

Feature Attribute Values

- Each question asked by the attributes must have an answer. The answers to the questions posted by the attributes are called values.

For Example: Feature = Tree

Feature Attributes could include:

Type of tree	Value = Oak
Height of tree	Value = 20’
Diameter of tree	Value = 2’
Condition of tree	Value = Excellent
Tree canopy diameter	Value = 12’

- By collecting the same type of data for each tree which is mapped, a database is created. Tying this database to position information is the core philosophy underlying any GIS system.

Final Step is to Export the Data to GIS

- After the GPS data has been collected, downloaded, and corrected, the data can be exported into a GIS system such as ArcGIS.
- During this process, a GIS "layer" is created for each feature in the GPS job. For example, house, road, and parcel data would create a house layer, a road layer and a parcel layer in the GIS system. The house layer would be a point layer. The road layer would be a line layer and the parcel layer would be a area layer.
- Once the GPS job has been exported, the full power of the GIS system can be used to classify and evaluate the data.

Citations

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References:

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CMT is the leading manufacturer of rugged, water-proof hand-held computers for field professionals in forestry, utility, fisheries, wildlife and environmental assessment.
http://www.cmtinc.com/gpsbook/

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