

# GPS Project

(purpose, process, product)

## Purpose or Problem Statement

For example, in a sentence or two ...

Inventory campus features to create a visitor map, including service roads, trails, benches, signs, building locations, prominent areas like arboretum, amphitheater, nature trail, bridges, ATM location... I will use heads-up digitizing to draw the outlines of buildings using aerial photographs.

## Initial Set-up

Create basic data dictionary with points, lines and polygons. Include attributes necessary, as well as values. Example, roads have a width attribute with values like -- single lane, narrow 2-lane, wide 2-lane, extra wide, boulevard). Other attributes set-up in the data dictionary include surface material, condition, treads, etc. for the roads feature.

## Major Steps

You will have the major steps here either as text or bullets. The objective will be to teach someone else what you have just learned so that they can produce the exact same map or product as you. Think of this person as a student, just like yourself, who will need to start from scratch. Components of the steps should include:



- Field collection methods and challenges. At first, the project will always be evolving.
- Map projection / datum and other set-up information
- How you set up the GPS unit and then transfer info. including Pathfinder steps
- How to clean-up & differentially correct raw *rover* files. Include how to export files, and in what format. You might explain how you will import into your presentation application as well (*ArcGIS*, *Google Earth*, *CAD*, spreadsheet, etc.)
- Include extra activities or processes, such as *H-Star* correction, set waypoints, special processing. The main thing to include are troubles & challenges, what to expect, and how you overcame these obstacles. Finally, make an attractive map or graphic product that helps the end-user comprehend, solve, or other find joy in GPS and mapping.

# GPS Tutorial Worksheet 1 (Beginning Steps)

(Points = 10)

1. GPS works in five logical steps:
  - 1) \_\_\_\_\_.
  - 2) \_\_\_\_\_.
  - 3) \_\_\_\_\_.
  - 4) \_\_\_\_\_.
  - 5) \_\_\_\_\_.
2. The GPS measures distance using very accurate \_\_\_\_\_ to determine distance.
3. Ideally the satellites are well space apart and \_\_\_\_\_ in the sky.
4. The average height of GPS satellites above the Earth averages around \_\_\_\_\_ (kilometers) or \_\_\_\_\_ miles.
5. What do we call the code the satellites generate? \_\_\_\_\_
6. Also known as Pseudo random noise or number (PRN), each NAVSTAR satellite has its own \_\_\_\_\_.
7. We have to multiply the – time delay, often referred to as travel times -- by \_\_\_\_\_ to compute the distance from the satellite
8. We've got atomic clocks in the satellites (100K each), but how do we get that accuracy in 100 dollar GPS units?
9. On the ground, GPS receivers have a(n) \_\_\_\_\_ programmed into their computers to tell them where in the sky each satellite is, moment by moment.
10. The Dept. of Defense checks the precise location of each satellite, their altitude, location and speed. We call these \_\_\_\_\_ errors caused by the gravitational pulls of the moon and sun and by pressure of solar radiation on the satellites.

**Bonus:** If the timing is off by just one thousandth of a second, at the speed of light, then we can translate into almost \_\_\_\_\_ miles of error!

Primary Resource: Trimble GPS Tutorial (<http://www.trimble.com/gps/>)

Other Resources: Trimble Orientation Guide

## GPS Tutorial Worksheet 2 (Correcting Errors)

(Points = 20)

1. Charged particles exist in the \_\_\_\_\_, which can alter the speed of light and thus the GPS signal, creating one of the most significant error sources.
2. The troposphere, the lower portion of the atmosphere where all weather occurs, including a lot of water vapor, temperature and pressure variation, causes a great deal of error. T/F
3. We can solve much of these challenges through \_\_\_\_\_, which attempts to predict the kinds of error on a typical day.
4. In addition to calculating effects of the atmosphere on the signal, the GPS must also factor in the \_\_\_\_\_ each signal as it enters the atmosphere in order to determine the length of the trip through the perturbing medium.
5. Some sophisticated GPS units can compare these atmosphere-induced errors by comparing the relative speeds of two different signals, which is known as " \_\_\_\_\_ " measurement.
6. Light moves slower (by refraction) at a certain \_\_\_\_\_ frequency (L1). Light moves faster (no refraction) at a certain \_\_\_\_\_ frequency (L2).
7. By comparing the delay between these two (2) carrier frequencies of the GPS signal, we can deduce what medium (i.e. atmosphere), and we can correct for it. T/F
8. The signal may bounce off various local obstructions before it reaches our GPS receiver. This is called \_\_\_\_\_.
9. Signal \_\_\_\_\_ techniques minimize this problem on good receivers.
10. The \_\_\_\_\_ arriving signals are also the direct ones, which are the signals that GPS units rely upon to achieve an accurate distance (and ultimately correct position).
11. The intentional errors are called \_\_\_\_\_.
12. DGPS stand for \_\_\_\_\_.
13. Using Differential GPS, moving applications can yield accuracy of around \_\_\_\_\_.
14. Stationary application using Differential GPS can yield accuracy of around less than 2 meters.

15. The stationary receiver is key because it ties in all the other satellites by knowing a solid \_\_\_\_\_.

*Please complete table below (5 points)*

**Summary of GPS Error Sources**

(Typical Error in Meters)

<b>Error Source</b>	<b>Standard GPS</b>	<b>Differential GPS</b>
Satellite Clocks		
Orbit Errors		
Ionosphere		
Troposphere		
Receiver Noise		
Multipath		

**Bonus:** The travel time for a satellite right over our head (90 degrees in the sky from our position) is about \_\_\_\_\_ seconds.

- Primary Resource: Trimble GPS Tutorial (<http://www.trimble.com/gps/>)
- Other Resources: Trimble Orientation Guide

Hertz = number of cycles per second (wave crest) -- **Speedy Fun Facts** --

Microsecond (1  $\mu\text{s}$ ) = 1 millionth of a second (.0000001) or 1/1,000,000

Millisecond (1 ms) = 1 thousand of a second (.001) or 1/1000

Note: faster as you work your way down the page

- 1 **microsecond** (1  $\mu\text{s}$ ) – cycle time for frequency 1 MHz,
  - radio wavelength 300 m
- 10 microseconds - cycle time for frequency 100 kHz, r
  - radio wavelength 3 km
- 20.8 microseconds - sampling interval for digital audio with 48000 samples/s
- 22.7 microseconds - sampling interval for CD audio (44100 samples/s)
- 38 microseconds - discrepancy in GPS satellite time (compensated by clock speed) due to relativity
- 50 microseconds - **cycle time for highest human-audible tone (20 kHz)**
  
- 1 **millisecond** (1 ms) – cycle time for frequency 1 kHz
- 1 millisecond – duration of light for typical photo flash strobe
- 1 millisecond – time taken for sound wave to travel 34 cm
- 1 millisecond – repetition interval of GPS C/A PN code
- 1.000692286 milliseconds – time taken for light to travel 300 km in a vacuum
  
- 2 milliseconds – half life of hassium-265
- 2.27 milliseconds – cycle time for the A above middle C in music (440 Hz)
- 3 milliseconds – **a housefly's wing flap**
- 3.4 milliseconds – half life of meitnerium-266
- 5 milliseconds – a honey bee's wing flap
  
- 8 milliseconds – 1/125 of a second (125), a standard camera shutter speed
- 9 milliseconds – typical average seek time for a 7200rpm hard disk

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\* 100 milliseconds = the reaction speed of a human

\* 102 milliseconds = half-life of bohrium-262

\* 125 milliseconds = a thirty-second note at MM = 60

\* **134 milliseconds = time taken by light to travel around the earth's equator**

\* 150 milliseconds = recommended maximum time delay for telephone service

\* 250 milliseconds = recommended maximum time delay for a computer terminal or web page

\* 250 milliseconds = an approximate average of the round trip time for communications via geosynchronous satellites

\* 250 milliseconds = a sixteenth note at MM = 60

\* 200 to 670 milliseconds = the tempo of modern dance music (128 - 150 BPM)

\* **300 to 400 milliseconds = the blink of a human eye**

\* 400 milliseconds = time in which the fastest baseball pitches reach the strike zone

\* 500 milliseconds = an eighth note at MM = 60

\* 838 milliseconds = half-life of lithium-8

### GPS Tutorial Worksheet 3 (advanced concepts)

(Points = 20)

1. Differential GPS can yield more accurate measurements with moving applications (as opposed to stationary applications). T/F
2. Differential GPS puts you in the center of the runway in an airplane.
3. The reference station does not calculate distance from the satellites (because it already knows its exact position). Instead, it uses its known position to then calculate \_\_\_\_\_.
4. Once it calculates the travel time, it compares with what it should be with roving receivers. This difference is known as the \_\_\_\_\_.
5. In addition to transmitting timing errors for each satellite, the error code transmission also includes \_\_\_\_\_ to fill in the gaps or interpolate positions between updates.
6. The stationary receiver (a.k.a. reference station or receiver) calculates distance errors for a particular satellite. But, because it does not know which satellite the roving receivers are using, it quickly calculates and encodes the error corrections for \_\_\_\_\_ visible satellites.
7. The roving GPS receiver gets the complete list of errors and applies the corrections for the particular satellites they are using. T/F
8. Today, most sophisticated GPS receivers can receive corrections real-time and in the field through a \_\_\_\_\_. (Note: there are other ways to do this)
9. While some GPS applications require real-time, on-the-fly corrections, many applications can do DGPS back in the office. This is known as \_\_\_\_\_.
10. The only criteria to apply corrections in the office, are the recorded position and the exact \_\_\_\_\_.
11. The Internet is a great way to receive these correction files today. T/F
12. GPS receivers receive "pseudo-random code" and then slide it along to match its own exact pseudo-random code (to calculate travel time)... This is known as "Code-Phase," which still has a lot of slop in this syncing process. Thus, the GPS can use the \_\_\_\_\_ carrier to significantly improve accuracy of GPS.
13. Review: What is the difference between a millisecond and a microsecond?

14. Because the Pseudo-random code has a cycle width of almost a microsecond, which multiply by the speed of light is almost \_\_\_\_\_ meters of error when comparing codes to calculate distance!
15. A car radio tuned to 94.7 MHz equals 94.7 \_\_\_\_\_ wave cycles per second, which is "carrier frequencies." The pseudo random code has a bit rate of about 1 MHz.
16. The carrier frequency is much higher than code-phase frequencies and thus its pulses (or waves) are much closer together (1 GHz or 1000 times faster). Consequently they are more accurate. There are some problems, however, the main one being \_\_\_\_\_.
17. WAAS stands for \_\_\_\_\_.
18. The FAA or Federal Aviation Administration got wind of the value of accurate DGPS. They set up their own monitoring system that can detect errors with their own system of geosynchronous satellites parked somewhere over the United States. It could do at least three things at once:
- 1) send corrections directly to the GPS receiver if there was an error
  - 2)
  - 3)
19. Local Area Augmentation (LAAS) is used for \_\_\_\_\_.
20. Tell me about a case study you in enjoyed. Please limit you discussion to only 1 paragraph.

- Primary Resource: Trimble GPS Tutorial (<http://www.trimble.com/gps/>)
- Other Resources: Trimble Orientation Guide

**GPS Worksheet A (GPS Fundamentals)**

(Points = 30)

1. What is the name of the Trimble software found on the GPS receiver / handheld data collector? \_\_\_\_\_
2. What is the name of an alternative field collection software package? \_\_\_\_\_
3. What is the name of the Trimble software found on the desktop or laptop computer to process the information in the office. \_\_\_\_\_
4. Name a few of its common functions of the desktop software:
  - 1) \_\_\_\_\_
  - 2) \_\_\_\_\_
  - 3) \_\_\_\_\_
  - 4) \_\_\_\_\_
  - 5) \_\_\_\_\_
5. Under the GPS segments, they are divided into 3 segments of:
6. What is the function of control?
7. What does NAVSTAR stand for?
8. When at full operational capacity, how many satellites are there?
9. Does the number stay the same?
10. According to the GPS Master Plan, the spacing of the satellites are arranged so that a minimum of \_\_\_\_\_ satellites are in view from every point on the globe.  
(Hint: Look in Trimble GPS Tutorial)
11. Each satellite makes one revolution around the Earth how often?
12. How high in orbit are the satellites floating?
13. Who are the GPS users, typically?
14. Tell me about any case studies in a video or class presentation.
15. Tell me about another case studies in a video or class presentation.

16. With GPS, you need line of sight to \_\_\_\_\_.
17. What is the speed of the radio signal?
18. The GPS receiver compares the digital codes generated at precisely the same time by a GPS satellite and GPS Receiver , which are generated every millisecond.
19. What is the difference between a millisecond and microsecond?
20. Because an atomic clock is only on the satellite (at about 100K each), how does the handheld receiver compensate for that lack of accuracy? In other words, how does the satellite calculate an accurate position?
21. How many channels or satellite transmissions can a typical Trimble GPS Receiver track all at the same time?
22. What is the purpose of the Almanac?
23. \_\_\_\_\_ is the term used to adjust for the minor changes from the intended precise orbit of a satellite.
24. Forces such as \_\_\_\_\_ can cause these satellites to stray ever so slightly from their intended orbit. (Hint: see Trimble tutorial)
25. What are common sources of error?
  - 1) \_\_\_\_\_
  - 2) \_\_\_\_\_
  - 3) \_\_\_\_\_
  - 4) \_\_\_\_\_
26. Which one is best associated with "largest during the heat of the day"?
27. Which one is best associated with "urban canyons and dense foliage"?
28. Which one is best associated with "government interference"?
29. Which one is best associated with "loses lock on one satellite"?
30. Does the GPS work in all weather conditions?

## GPS Worksheet B (Equipment Setup)

(Points = 15)

1. The *TerraSync* system has three (3) components
  - 1) Orig. MS *ActiveSync*... now varies with connection software
  - 2) \_\_\_\_\_
  - 3) \_\_\_\_\_
  
2. To transfer software files, such as Rover files, between the data collector and an office computer, you need:
  - 1) \_\_\_\_\_
  - 2) \_\_\_\_\_
  - 3) \_\_\_\_\_
  
3. Of the five (5) sections within *TerraSync* software: Map, Data, Navigation, Status, Setup – which section should be begin with in order to avoid problems later.  
\_\_\_\_\_.
  
4. Perhaps one of the most pressing issues is what environment you will be working. In an open area, for example, you can adjust the GPS slider bar to the \_\_\_\_\_ side of setting box.
  
5. PDOP, which stands for Position - Dilution of Precision is an indicator of \_\_\_\_\_ . How many coordinates needed \_3\_
  
6. HDOP, which stands for Position - Dilution of Precision is an indicator of just horizontal accuracy \_\_\_\_\_. How many coordinates needed \_2\_
  
7. Some "Logging Settings" that are available for high-end GPS units are:  
\_\_\_\_\_
  
8. According to the lecture and instruction (not in manual), you should leave your GPS unit to the default Filename Prefix. T/F

1. An important "Logging Setting" is whether account for you log every second or every 5 seconds (where perhaps it's not necessary to gather so many positions). That setting is called \_\_\_\_\_.
2. A common real-time setting in the Setup screen is \_\_\_\_\_, which includes WAAS used in the United States).
3. In *TerraSync* software, all GPS is collected in \_\_\_\_\_ & \_\_\_\_\_, which is a common standard datum & grid system.
4. Datums are important to set with your GIS maps datum and grid system; thus you can convert your datum (and grid system) upon "Exporting" to a GIS map. The main reason these positions or coordinates will not match if they are NOT in the same datum is because \_\_\_\_\_.
5. You have two choices for the height values, which are \_\_\_\_\_ and \_\_\_\_\_. The default mode is \_\_\_\_\_.
6. When navigating with a compass or perhaps a GPS unit, you would use magnetic north. However, most maps reference \_\_\_\_\_, and thus this should be your default setting.
7. Another necessary step before leaving the office is to make sure your \_\_\_\_\_ are **charged**.

Primary Resource: Trimble *Orientation Guide* (<http://www.trimble.com/gps/>)

Other Resources: Trimble *Getting Started Guide* (that comes with the GPS units)

1. Signals can be blocked by \_\_\_\_\_.
  2. Signals can go through \_\_\_\_\_.
  3. If a SBAS satellite is being tracked you see this icon. \_\_\_\_\_
  4. The number located above the logging icon indicates \_\_\_\_\_.  
(Note: for H-Star receivers only)
  5. The real-time icon looks like \_\_\_\_\_
  6. What section do you use to start collecting data?
  7. According to experts in the field, should you use the default file system?
  8. Geographic features can be broken into 3 classes (shapes).
    - 1) \_\_\_\_\_
    - 2) \_\_\_\_\_
    - 3) \_\_\_\_\_
  9. \_\_\_\_\_ features will average positions to compute one final position.
  10. Under "Data," to start collecting data you need to select the \_\_\_\_\_ sub-section then complete a few more simple steps, such as \_\_\_\_\_.
  11. The first and \_\_\_\_\_ positions are joined to create a polygon feature.
  12. Why would you want to pause logging at any time?
  13. You can view your progress of collecting GPS features under the \_\_\_\_\_ section.
  14. With H-Star postprocessing, you can achieve 1 foot (the best) accuracy with \_\_\_\_\_ features. (Note: It's not as good for other feature classes)
  15. With H-Star, you need a carrier lock to achieve PPA values. (careful here)
- Bonus:** With H-Star, you find base files as a group or single station?

## The fourth satellite

A further complication: because the distances are so great, if the time measurement of the journey time of a satellite signal were to be out by just 1/1000th of a second, it would result in an error in the calculation of your location of nearly 200 miles/ 300km.

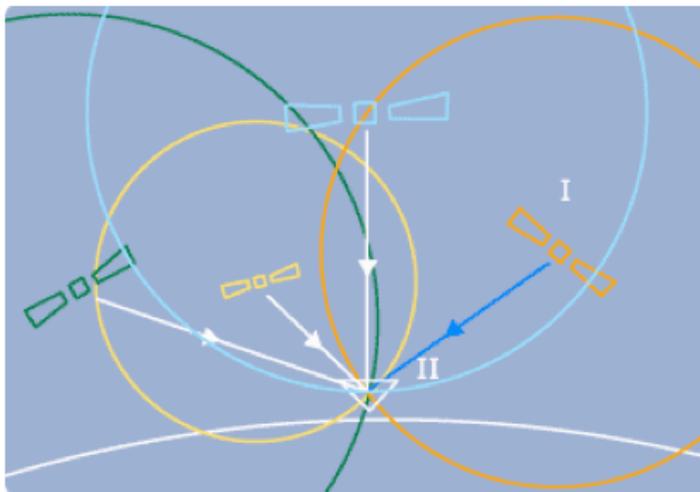
So our receiver and satellite both need clocks you can synchronize down to the nanosecond. A level of accuracy normally only achieved by atomic clocks. Unfortunately atomic clocks cost around \$50,000-\$100,000 each, which would make your navigation device just a tad more expensive than a new Porsche.

Fortunately, GPS has an answer to this problem, too.

### Making GPS affordable - the 4th Satellite

Each satellite carries an atomic clock. Your receiver uses an ordinary, far less accurate, quartz clock, but calculates the quartz clock's error using a fourth satellite measurement. How?

If your navigation device had a perfect clock, all the satellite ranges would intersect at a single point (your position). But with imperfect clocks a fourth measurement from a fourth satellite, done as a cross-check, doesn't intersect with the first three.



I = fourth satellite: checking & correcting satellite measurements

II = Intersection point of the satellite signals: your location

Your navigation device's computer knows it gets a discrepancy in measurements and that the correct time would cause all the signals to intersect at a single point. So it looks for the single correction factor that could be subtracted from all its timing measurements to cause them all to intersect at a single point.

Which is the time held by the satellites' atomic clocks. The receiver then sets its clock to that time. Giving you atomic accuracy, right there on your car dashboard.