

UC Santa Barbara

GIS Core Curriculum for Technical Programs (1997-1999)

Title

Unit 24: Using GPS Data

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<https://escholarship.org/uc/item/94c2q8sw>

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Publication Date

1998

Peer reviewed

UNIT 24: USING GPS DATA

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A Global Positioning System (GPS) is a set of hardware and software designed to determine accurate locations on the earth using signals received from selected satellites. Location data and associated attribute data can be transferred to mapping and Geographical Information Systems (GIS). GPS will collect individual points, lines and areas in any combination necessary for a mapping or GIS project. More importantly, with GPS you can create complex data dictionaries to accurately and efficiently collect attribute data. This makes GPS is a very effective tool for simultaneously collecting spatial and attribute data for use with GIS. GPS is also an effective tool for collecting control points for use in registering base maps when known points are not available.

Unit Concepts

1. GPS Equipment and Definitions
2. Accuracy Considerations
3. Project Preplanning
4. Collecting and Correcting Data
5. Exporting Data

Section 1: Equipment and Definitions

The system hardware contains three parts; the antenna, the receiver, and the datalogger; sometimes called a data-collector. The datalogger is a hand-held computer that contains software to coordinate signal collection and storage, file manipulation, and file transfer to and from a Personal Computer (PC). Some systems might combine some of these elements into a single piece of hardware.

The system software, which normally resides on a PC, has four primary functions: preplanning, post-processing correction of the raw satellite data, display/editing of the data, and converting/exporting of the data.

Preplanning includes determining satellite availability for a particular place and time, and the preparation of data dictionaries for a particular job.

Correction involves the use of a base station file to apply corrections to the raw data collected from the satellites, greatly improving accuracy.

Editing and display can include averaging points, connecting points to form lines or areas, smoothing, measuring distance and area, and displaying the data to screen. GPS software programs are not meant to be map-making programs and usually most of the final editing will take place in a Computer-Aided Drafting and Design (CADD) program or a GIS program.

Data conversion and export include the capability to convert from the spherical Latitude/Longitude (Lat/Long) coordinates that the receiver collects into a variety of other coordinate systems and datums, and then exporting this data in a variety of formats used by different CADD and GIS programs.

Global Positioning Satellites

The GPS satellites circle the earth twice a day, 10,900 miles above the earth. There are 24 satellites in the GPS constellation. Twenty-one satellites can be called on at any time; the other three are spares in case one of the others becomes unhealthy.

Five or six satellites are above and visible (by radio wave) to any spot on the earth at any one time. Buildings, hills, trees, and other ground features may block one or more at one time, or one or two of the satellites may not be at their best. These problems will reduce the number of useful satellites above a position to two, and maybe even one, but three or four are commonly available. Often as many as five and six are visible.

The location in space of each satellite is known. The orbits are carefully planned and constantly updated so that actual location is never off by much from the intended location. Each satellite constantly announces its number, and the time that signal was sent.

The distance from each satellite to the receiver is calculated by comparing the time the signal says it was sent with the time the receiver picks up the signal. The time difference is multiplied by the speed of light to get the distance from satellite to receiver. This is done for each satellite the receiver can "see".

Satellite Triangulation

The known distances and locations of each visible satellite are used to locate the position of the receiver. We can place ourselves anywhere on a sphere around one satellite once we know the distance to the satellite. Known distances from two satellites will place us on a circle that is the intersection of two spheres. Known distances from three satellites will place us in two points, which is the intersection of three spheres. We may be able to eliminate one of these points as being impractical, such as out in space or deep underground. With one gone, the other must be correct.

Three satellites are sufficient, at least theoretically, to provide receiver location. More satellites simply add confirmation to the receiver location. In practice, the more satellites the better. Four satellites are the minimum to secure only one, absolutely technically, trigonometrically unambiguous location. Three work in practice since we can eliminate the

absurd location.

Satellite Distance and Location Errors

The exact location of any one satellite at any given time is not correct. The satellites are placed with extreme care and constantly monitored but factors such as gravity, influence from the earth, moon, sun, and even other stars move the satellites a little. The solar wind can also push the GPS satellites out of the intended orbits. Without absolutely accurate knowledge of the satellite locations the receiver position fix will not be correct.

Each satellite broadcasts its position in an "ephemeris". From a completely blank slate a receiver can target a satellite, receive the ephemeris, and determine its own position relative to the satellite. Therefore, a receiver doesn't have to be programmed with all the satellite location information because it picks up locations as needed. Receiving the ephemeris for a satellite takes about 30 seconds.

The clock in each satellite must be absolutely correct for the correct distance from each satellite to the receiver to be known. Even the tiniest fraction of a second error in time will throw off the distance calculation. Each satellite carries four atomic clocks, the most accurate timing device known, but small influences affect the accuracy of the clocks.

So, neither satellite location nor distance is exactly known, and the theoretical position by triangulation has to be adjusted.

If these were the only sources of error our problems would be small. But there are several other varieties that can further mess up distance and location. These other problems include errors from receiver clocks, atmospheric interference with the satellite signals, and government fuzzing.

The clock in the GPS receiver must be exactly in synch with the satellite clocks to eliminate all error in distance. Since the satellite clocks don't agree with each other, it is unrealistic to expect the GPS receiver to be dead on. Fortunately, consistency is sufficient.

Each satellite sends its time signal to the receiver. The receiver notes when the signals were sent and then calculates the distances. These distances are compared and any adjustments necessary to correct for a fast or slow receiver clock are calculated. The adjustment, however, is not exact, and some distance errors occur.

Atmospheric interference contributes to distance errors. Various layers of the atmosphere slow the speed of light. Without a constant speed of light the distance calculation is wrong. Atmospheric interference is small when a satellite is directly overhead since only one atmosphere is involved. Satellites low on the horizon are broadcasting through the equivalent of two or three atmospheres, causing the signal to slow and even bounce before coming to ground. Sunspot activity and the solar wind also affect the atmosphere and therefore the signals.

Another source of atmospheric error is signal bounce or multi-path error. This happens when the signal bounces off buildings, trees or other solid objects in the atmosphere before reaching the receiver. Atmospheric interference is the biggest source of uncontrolled and

uncontrollable error. Every other error can be averaged or weighted or otherwise accounted for.

Government fuzzing is the single largest cause of error in distance calculations. The fuzz is introduced for security reasons. The government fuzz is called Selective Availability, abbreviated SA. This is a deliberately introduced error in the satellite time signal that cannot be quickly corrected. When SA is on, the locations based on GPS are lousy unless they are corrected using some of the techniques described below

The government has one final trick, called Anti-Spoofing. With AS the satellite signals are coded and can only be read by someone with the code. Every now and then the satellite signals make absolutely no sense whatsoever. These periods are very brief and very rare. Perhaps these times are tests of the AS system.

Many people are horrified at the possible errors in GPS location. These same people will cheerfully draw a line on a topo sheet and use a dot grid to get area. The width of a pencil line on a 1:24000 topo sheet can easily be 50 feet wide. Even uncorrected GPS locations are nearly this good.

GPS Receivers

GPS receivers span a wide range of price and capability. Described below are the basic types with a brief description of the capabilities of each.

The basic split of receivers is based on the number of satellites the receiver can track at one time. Each tracked satellite requires a channel. Single channel satellites can track one satellite, two channel receivers can track two satellites, and so forth. Receivers usually have between one and twelve channels.

Since four satellites are required for an accurate position, any receiver with less than four channels must necessarily be a sequencing receiver. A sequencing receiver tracks one satellite, drops that one and goes to the next in sequence, and so on until at least four satellites have been tracked. The whole process then begins again.

Single-channel receivers are the cheapest and smallest. Two-channel receivers process the signal from one satellite while tracking the next satellite. Receivers with four or more channels are continuous receivers. Each channel tracks one satellite. No gaps or delays in tracking occur.

Six channels are better than four, since another satellite or two is a benefit, but eight channels is only a small step better than six. Five or six satellites within easy "viewing" distance are common. The seventh and eighth satellites are further afield and require a larger antenna to capture. Obstructions low on the horizon may block the farthest satellites and negate the advantage of eight or more channels. Ten- and 12-channel receivers are usually reserved for benchmark locations and other activities requiring similar accuracy.

GPS Dataloggers

The major differences between dataloggers are the amount of memory and the type of keypad.

GPS files are surprisingly small, but if you want to do a full day of collecting you should have at least 1 Mb of memory in the datalogger.

Some dataloggers don't have a full alphanumeric keypad. Because attribute data is key to GIS, the type of keypad is a consideration. You can create many codes within a data dictionary that allow the user to input most data on the screen. But if the attribute values you are collecting use unique codes or part numbers, having an alphanumeric keypad is very important.

GPS Software

Many of the less expensive GPS units, especially those meant just for navigation, do not come with software capable of exporting files or of using a data dictionary to define attributes. Without the ability to create data dictionaries and export files, these units are not functional for GIS.

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Section 2: Accuracy Considerations

There are two levels of accuracy mentioned in using GPS. One term is "Mapping Accuracy" which usually implies "corrected" accuracy within a few feet or less. This is usually sufficient for most GIS work. The other term used is "Surveying Accuracy" which is usually advertised as having "sub-centimeter" accuracy. These units are significantly more expensive.

Actually, one problem with GPS is that even at the map accuracy level, GPS is likely to be more accurate than your base map data. For example, if you use GPS to collect fire hydrant locations and then merge these points with digitized parcel maps, you might find the hydrants within the parcels instead of on the streets. The hydrants are more likely to be "correct", but depending on your needs it may be more effective to shift the hydrants than to shift the whole base map.

Satellite Geometry

Satellite geometry affects the accuracy of reported location. An unfavorable orientation can throw off accuracy even when satellite distance and location are excellent.

Errors introduced by satellite orientation are referred to as Position Dilution of Precision, or PDOP. PDOP is composed of two pieces: HDOP or Horizontal Dilution of Precision and VDOP or Vertical Dilution of Precision. One may be small and the other large. The final effect of HDOP and VDOP depends on whether you want good horizontal accuracy, vertical accuracy, or both.

PDOP affects reported position accuracy as a multiplier of the sum of all the other distance and location errors. If the sum of distance, timing, location, SA and other errors is 15 feet and PDOP is 4, the total error is $4 * 15 = 60$ feet. But it is the worst case on a one-time fix. A continuous receiver receives continuously, and constantly calculates and adjusts as more information becomes available. So the maximum error possible is not the likely error, and methods are available to remove most of the likely error.

Horizontal Error

HDOP is minimized when the position being located is in the middle of the satellites being tracked. With three satellites the best case is each satellite equidistant from the position and at 120 degrees from each other. Further, the satellites should be as low on the horizon as possible so that the elevation of the satellites above the position is zero. With four satellites the best case is in addition to the above three, a fourth directly overhead. The worst HDOP occurs when all the visible satellites are to one side of the position and high above the horizon.

Vertical Error

VDOP is minimized when one satellite is above the position and one satellite is below the position. This is impossible. The position can never be "between" the satellites, so elevation is more difficult to establish than position on the plane. The satellites will never be in a best orientation, just better or worse.

VDOP is not a severe problem since elevation is not usually as important as position on the plane. The accuracy is more than sufficient for most purposes, and if you're willing to wait a little longer for the position to be fixed, elevation can be known to a desired accuracy. Most receivers allow a maximum HDOP and VDOP to be selected. A rule of thumb is that vertical values are about one-third as accurate as horizontal values.

Differential Correction

Differential correction is the cure for most GPS errors except local errors such as multipathing. This correction should be applied to all reported locations when accuracy within 50 feet or less is required.

The basic idea is to use two receivers, one fixed and one roving. The fixed receiver is in a known position, established either by survey or by long term measurements of GPS signals. The fixed receiver compares its reported position to the position it knows it occupies, and stores the correction necessary to rectify reported and known position. The corrections are stored by date and time since the corrections are different for every second.

The roving receiver collects and processes signals and stores the reported positions, doing the best it can with the information available. This information is brought back to the office and the corrections calculated by the fixed receiver are applied to the rover's positions. The corrected positions from the roving receiver are easily accurate to within five feet. Since corrections are applied after the fact, this is called post-processing differential correction.

Corrections from the fixed receiver are applicable to an area within 200 or 300 miles of the fixed receiver. Therefore, only one fixed receiver is usually necessary within an operating area.

A newer type of fixed station correction is called "real-time" correction. This is an immediate, hence real-time, correction applied to the rover measurements. The fixed receiver calculates the correction necessary for this moment, and then sends the correction by radio to the rover.

The rover applies the correction to its current measurements and adjusts position accordingly.

Real-time correction is not as accurate as post-processing correction. There is a slight delay in the radio signal from fixed receiver to rover that must be accounted for, and all the atmospheric difficulties the original GPS signals must face also apply to the radioed correction. In addition, terrain features may bounce or block the correction. Since the fixed station and rover must be in radio contact, more fixed stations are required for real-time correction than for post-processing correction. Real-time correction adds to the cost of the GPS unit and is rarely necessary when collecting data for GIS. Post-processed differentially corrected data will always be more accurate than real time differentially corrected data.

Datum Plane

Height above a surface must be measured relative to that surface. For example, most elevations are reported as being some number of feet or meters above mean sea level. Unfortunately, mean sea level is an average that changes locally because of gravity, spinning force, sun-moon-planet orientation, and a dozen other things.

The surface of the earth is referred to as the "geoid". Most of the bumps and lumps can be modeled mathematically, but even the most comprehensive model can't get them all. If the geoid is chosen, a particular model for a particular place must be selected. A different geoid would automatically change all reported elevations.

The "ellipsoid" is an alternative to the geoid. The ellipsoid is a geometric figure fit around the earth that ignores most of the irregularities. Its smooth surface is excellent for determining elevation since it will be consistent from spot to spot.

Most GPS receivers allow you to specify the ellipsoid or the geoid for calculating elevation. Which one you choose depends on what you are going to do with the information. If you want relatively correct elevations that will be consistent over an area, use the ellipsoid.

The most commonly used geoid model for GPS work is the 1984 World Geodetic System--WGS84. Another common model is the 1927 North American Datum, called NADCONUS27, for North American Datum CONTinental US 1927. This is the model used for most USGS maps.

Many of the geoid and ellipsoid models can be translated mathematically from one to the other. Choosing one doesn't mean that another can never be used, but more time and effort are involved. Also, maps and other models using one set of elevations will have to be changed.

Geographic Information Systems have the same problem with the earth's surface. If your GPS information will be fed to a GIS, you should match the GIS datum, or at least make sure that a transformation to the needed datum is available.

Coordinate Systems

Horizontal location, the X,Y location on the earth's surface, changes with the way the earth's surface is represented. The common coordinate systems for GPS work are Latitude and Longitude, Universal Transverse Mercator, and State Plane Coordinate System. Most GPS

software converts the GPS data into the appropriate coordinate system.

Section 3: Preplanning - What to Collect, Creating a Data Dictionary, When to Collect

Preplanning involves determining what data to collect, creating a data dictionary to organize that data, and then determining the best time to collect the data.

What to Collect

There are two major types of data you will collect--Feature Data and Attribute Data. Feature data is locational data--points, lines, areas; and Attribute data is what is at or on those features.

Feature Data Types

Points: The location of one spot, such as a nest site, a fire hydrant, a well, etc. A single collected point will have the most inaccuracy, but by having the GPS make many individual readings and average this data, the accuracy can be improved. Since you want to average many readings, the interval setting for collecting points might be one second.

Lines: Lines are a series of connected points and are used for features such as streams, roads, boundary lines, etc. Since many points are collected at a set interval by the GPS to form the line, the accuracy is better than that with individual points. The time interval for collecting point readings on a line might be anywhere from one to five seconds. Some GPS units don't have a line option for collecting data. In this case data is collected as points, and then connected as lines when the data is post-processed.

Area: Areas are closed lines, and used for measuring property parcels, tree stands, vegetation areas, etc. Most GPS software will automatically close an area so that there is no need to return to the starting point. However, it is often more useful to have line features and use your CADD or GIS program to close the area. Then you can have separate line and area features.

Attribute Data

Attribute data is descriptive data attached to points, lines, locations on a line, or areas. If the point being collected is a tree location, the attributes might be *species*, *diameter*, or *height*. If the line feature is a road, attributes might be *pavement type*, *number of lanes*, or *speed limit*. Area attributes might be *soil type*, *vegetation cover*, or *land use*.

An attribute is the generic descriptor for the feature, while each feature has a specific *value*. In the point example above, likely *values* for the species *attribute*

would be Pine, Fir, and Aspen. It's important to distinguish between *attributes* and *values*. Think of *attributes* as the questions that would be asked and *values* as the answers. Attributes to be collected would be determined in the planning process, while specific values would be entered in the field.

Data Dictionary

A data dictionary is precisely that, a list of the types of data (both features and attributes) to be collected and the format in which they will be collected. This is determined before the collection begins and is usually created in the planning software and downloaded to the data logger. The software should allow you to design a data dictionary that will take the form of an input menu so that when the user is collecting data in the field, all he/she has to do is select the appropriate choice from the dataloggerinput screen. Properly designing a data dictionary is one of the most important steps for using GPS for GIS data collection.

When to collect data--Determining Satellite Availability and PDOP

This step involves using the GPS software's preplanning module, which will bring up charts showing satellite availability, PDOP levels, and other information for a selected location and time. This is necessary to ensure that enough satellites are available in a suitable orientation to collect the data. If the projected PDOP is lower than needed during the collection time, the spatial accuracy will be poor. It is important to also consider terrain so that the elevation mask can be properly set. The elevation mask is that angle, in degrees, below which satellites will not be considered for use in determining satellite availability and PDOP. In open terrain an elevation mask of 10 degrees might be acceptable, but in mountainous terrain, you might need to use a mask of 30 degrees. If the settings in the preplanning software don't match the conditions that are expected in the field, it is possible that you won't be able to collect spatial data with acceptable accuracy.

Section 4: Collecting Data

Once the preplanning is complete, the next two steps are collecting the data and using differential correction to correct the locational data.

Collecting Data

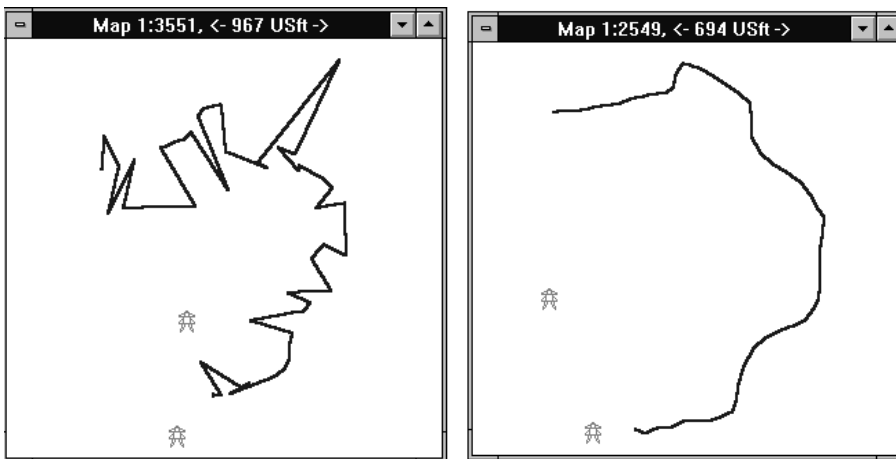
This step involves going out in the field with the receiver, antenna, and datalogger to actually collect features and attributes. This is the easiest part since it generally means turning on the unit, telling it a feature type and file name, and then walking, biking, or driving to collect points.

First check the settings on the data logger. One of the most important to set is the "logging interval" which is the amount of time between the positions the GPS is collecting. The logging interval is usually set to one second when collecting positions for point features and 5 seconds or longer when collecting line or area features. Other settings to check include the PDOP, elevation mask, time and the coordinate system used for display.

When collecting positions for point features, a recommended minimum is 180 positions, or 3 minutes if the logging interval is set to 1 position per second. If you are collecting line features, but also wish to collect point features along the line you can "nest" point features on the line data being collected. It is also possible to collect point features that are at a distance from the line by using an "offset." An example of this might be nesting a point feature that describes a viewpoint on a trail.

Differential Correction

Because of the inaccuracies described above and the intentional fuzziness introduced by the government, the data collected is probably only accurate to within 50 ft. To achieve better accuracy the file you collected needs to be compared to the data collected at a known point, called a Base Station. See examples below of uncorrected (on the left) and corrected data (on the right).



Many agencies such as the USFS, BLM, universities, and GPS vendors operate community base stations. They are usually accessible from the Internet or through a Bulletin Board Service (BBS) and are available anywhere from 10 minutes after the hour to 24 hours later. These can be downloaded for free or a nominal fee. The URL for a list of USFS and BLM sites is: *[outdated link removed]*; other places to check for base stations are on the Trimble site <http://www.trimble.com> or sites from other GPS manufacturers or dealers.

Section 5: Exporting Data

Most GPS software programs allow you to export the corrected data in several formats and coordinate systems. Make sure that your GPS can export the data in a compatible format. There are many variables to choose to match your requirements for output. The keys to exporting are to choose the appropriate format and coordinate system to match your GIS or CAD program.

Example Application--Using GPS to collect data for an irrigation district.

Irrigation districts deliver water to farmers in many areas of the west. An irrigation district needs to keep track of the irrigation canals and ditches, all the head gates and valves that control the flow of the water, and the location and amount of the area being irrigated. Often there will be base maps available for the main canals and the parcels where the water is delivered, but the irrigation districts usually need to map the other features. GPS is a perfect tool for this task.

The watermaster would determine what data needs to be collected and would work with the technician to create a data dictionary. The data dictionary would include items such as ditch name or number, head gate number and customer number. The head gate number and customer number would be used to link to the irrigation district's databases.

After checking for the best times to collect data, the technician would then start driving or walking along the canals and ditches. While collecting line features, he/she would also stop at head gates and valves and "nest" these in as point features. Along the way it might be necessary to pause the collection of these features and walk around the irrigated areas to verify the amount of land actually being irrigated.

Back at the office, the technician would differentially correct the data, and then convert it into a format that could be used with their base maps. Then the head gate numbers and customer numbers could be used to link these features with other in-house databases. The line and point features could also be overlaid with parcel data to verify ownership, and acreage could be calculated for all the irrigated areas and ponds. This could then be cross-checked with the customer database to check for errors. This data could now also be used for generating reports to regulatory agencies or to customers.

If there are parts of their service district that need to be registered to a base map, then the GPS could be used to find the coordinates of several control points. These would then be used to register those areas to the rest of the district's base map.

Learning Outcomes

The following list describes the expected skills which students should master for each level of training, i.e. Awareness/Competency/Mastery.

Awareness:

The expected learning goals of this section are to achieve a general understanding of how GPS operates and how it can be used as a data collection tool for GIS.

Competency:

The learning goals of this section are to develop the ability to plan a GPS session, collect the needed data and transfer that data to a GIS in the correct coordinate system and within

acceptable levels of accuracy, using existing standards and default settings.

Mastery:

Mastery of this topic would include a complete understanding of GPS operations including the various signal codes and how this affects data collection; being able to determine the acceptable PDOP, elevation mask and other settings for a particular project; being able to properly design a data dictionary; determining and locating the appropriate base station; and correctly using data filters when exporting the position data.

Preparatory Units

Recommended:

1. **Unit 19**--Plan a tabular database

Complimentary:

1. **Unit 9**--Convert digital spatial data between formats, systems, and software
2. **Unit 10**--Projecting Data
3. **Unit 11**--Registration and Conflation

Awareness

Learning Objectives:

1. Student can discuss the basic operations of a GPS unit.
2. Student can explain the limits of spatial accuracy inherent in using GPS and the importance of differential correction.
3. Student can discuss the types of data that can be collected for use with GIS.
4. Student can define basic vocabulary relating to the use of GPS.

Vocabulary

- Ephemeris
- Selective Availability
- Anti-Spoofing
- Receiver
- Datalogger

- PDOP
- VDOP
- HDOP
- Multi-path errors
- Differential Correction
- Real-time Correction
- Features
- Attributes
- Values
- Data Dictionary

Competency

Learning Objectives:

1. Student will be able to correctly preplan a GPS session, including creating a basic data dictionary.
2. Student will be able to verify, and if necessary change the default settings for the GPS unit.
3. Student will be able to collect the required data.
4. Student will be able to differentially correct the data
5. Student will be able to correctly export both the locational and attribute data to a GIS.

List of Tasks:

1. Use the preplanning software to determine times when PDOP and satellite availability are acceptable for data collection.
2. Create a Data Dictionary to identify specified attributes for the features to be collected and download this to the GPS datalogger.
3. Verify and if necessary change settings for PDOP, collection interval, etc. for the datalogger as needed.
4. Collect the data in the field making sure to note file names and starting and ending time of GPS files.
5. Download the files to the GPS software for post-processing
6. Download the correct base station files and perform differential correction.
7. Preview the data using the GPS software.
8. Perform any data editing such as deleting obviously aberrant points.
9. Export the data to a GIS in the correct format and correct coordinate system.

Sample implementation: Using GPS to collect utility data.

Project requirements: You are completing a map of the campus and need to create the utilities layer. You have maps showing the general location of water, sewer and power lines, but you do not have the power poles, light poles, phone junction boxes, transformers, etc. For this you need to determine what features to collect and what attributes should be collected for each feature. Do a pre-survey of the project area to decide what features and attributes to collect. Walk around the campus noting the type of data you'll need to collect and check for any obstructions such as large close-in buildings and heavy vegetation cover that might interfere with satellite sight lines. A pre-survey of the project area will save a lot of time and effort planning the data dictionary and organizing the data collection.

Note: The descriptions and steps that follow are meant to help you complete a basic GPS project, under fairly optimum conditions, from preplanning to inclusion in ArcView. This should be sufficient to understand the principles of GPS and to collect basic positional and attribute data for mapping and GIS projects. Depending on the particular project and settings you choose, you will see different choices and will need to respond appropriately.

This exercise is based on Trimble Navigation Limited hardware and software. The receiver is the **Trimble ProXL** and the Datalogger is the **TDC1** using **Asset Surveyor** software. Preplanning will be done using **Pathfinder Office** or **Quick Plan** software, and differential correction and data exporting will be completed using **Pathfinder Office** software. Other GPS hardware and software should have similar functions. While it is usually best to use one company's products for compatibility, this isn't always necessary.

Using Pathfinder Office to Create a New Project

1. Open **Pathfinder Office**. When Pathfinder Office opens, it displays a "Select Project" screen.
2. Select an existing project or select **New** at the bottom of the screen to open a new project. Answer the prompts for **Name**, **Comments**, and **Project Directory**. Create the project directory below the \Pfddata directory. Use the same name for the project name and project directory. This will create the project directory you specified and start a new project to store all the related files. When coming back into Pathfinder Office check to be sure you are working in the correct project. Pathfinder organizes all related files in a project so it's very important to create the project correctly.

Using Pathfinder Office to Create a Data Dictionary

A data dictionary allows you to pre-determine the structure for any data you'll be collecting. The datalogger has generic data dictionaries for Points, Lines, and Areas, but often you will want to create a specific structure and menu to aid data acquisition.

The most important part of designing a data dictionary is to understand the difference between

Features, Attributes, and the values/Attribute Menus. A **Feature** is the semi-generic type of object/data you are collecting, the **Attributes** are the types of values you want to collect for those features, and the **Attribute Menus** are the choices for the values themselves.

For example, if I'm collecting utilities along a road, the **Features** to collect are hydrants, power poles, transformers, and phone junction boxes. When I get to a hydrant, the **Attributes** might be the # of valves, the id #, the last date tested. For a power pole, the **Attributes** might be diameter of the pole, the material, the owner, and id#. The **Values** for the **Attribute** "valve" for the **Feature** "hydrant" would be the number of valves, such as 3; the **Value** for the **Attribute** "owner" for the **Feature** "Power Pole" might be Pacific Power & Light or Central Electric Co-op.

1. To create a data dictionary, select **Utilities>Data Dictionary Editor...** which will bring up a series of dialogue boxes. Creating a Data Dictionary is a multi-step iterative process and depending on your choices, the various options might not appear in the same order described in the following steps.

- a. The Data Dictionary Editor screen allows you to add, edit, or delete features or attributes. Fill in the data dictionary name and comment line. Then select "**New Feature...**".
- b. Then answer the prompts for the **Feature Name, Comments, Feature Classification** and press **OK** when finished.
- c. Then select **New Attribute** from the "Data Dictionary Editor" screen to bring up an **Attribute Type** dialogue box. Again, respond appropriately to the prompts. If you select **Numeric** data, you will be shown a dialogue box asking for width and precision. If you check **Character**, the program will ask for width. There is also an option to create a menu, so that you can pre-define likely values for the attributes. Menu is the most useful option. Selecting **Menu** will open the "New Menu Attribute" screen.
- d. After entering the attribute name, click on **New**.
- e. You'll get a screen to enter values for the attributes. Click **Add** when finished. After adding the last menu item, select **Close**. Continue the above operations until you've created all the features, attributes, and menu items needed for your data dictionary.

Transferring the Data Dictionary to the Datalogger

1. The Datalogger comes with a yellow cable with a 12 pin circular serial connector for the datalogger and a 9 pin connector for the computer. Using the yellow cable and any needed adapters, connect the datalogger to the computer. It's preferable to use the "Office Support Module" (the battery charger) when doing file transfers so that you save the Data Logger's internal batteries. File transfers use up the Data Logger's batteries quickly.

2. Turn on the Data Logger. The status line will report that it cannot find the GPS. Reply **No** using the "softkeys," (choices at the bottom of the TDC1's screen that are activated using the function keys).
3. On the Data Logger, select **File Transfer** in the Main Menu, and then it will look for the connection to the PC.
4. Select **Utilities>Data Transfer**. In the Data Transfer screen, select the appropriate **Data Type** and the correct file, click **Add...** and then click on **Transfer** to send the file to the Data Logger. When the transfer is completed, turn off the Datalogger to conserve batteries and then exit Pathfinder Office.

Using Quick Plan (Trimble's preplanning software) to Determine Satellite Availability and PDOP

1. Start Pathfinder Office if this isn't already open. Within Pathfinder Office, click on **Utilities>Quick Plan**.
2. Quick Plan will open with a calendar showing the current date. If this isn't the date you want, click on the calendar to select the desired date.
3. Quick Plan will then bring up a window asking location. Use the drop-down box for cities and select the closest city or enter the Lat/Long using the **Keyboard** option. It's best if you know the Lat/Long for the area you will be surveying, but since this is only checking satellite availability, if you're within a few miles you'll be OK.
4. You will now be in what Quick Plan calls a **Session**, with several menus displayed. The only menu we need to use is **Graphs**. This shows in graph form information about satellite availability, location, elevation, azimuth, PDOP, etc. The other menu you might need is **Options**, which will allow you to further define the selection set of satellites available. The most important option is setting an **Elevation Mask...**, which determines the elevation below which satellites aren't visible. The mask should be set to 15 or greater to match sight lines where you will be working. The mask setting has a major effect on satellite availability.
5. Select **Number SVs and PDOP** from the Graphs menu. This will show the number of satellites and the PDOP for different times for the day you selected. The number of satellites should be above four and PDOP should be below six for good data collection. Double click on the time bar to show more detail, then use **View>Refresh** (or a double right-click) to return to the full-day view. To look at other dates if that day will not work, select **Edit Session** from the Session menu and then select a new date.
6. After verifying that the time you will be surveying is going to work, exit Quick Plan and Pathfinder Office.

Using the ProXL Datalogger to Collect Data

1. Connect the Datalogger and the Antenna to the Receiver unit. The Datalogger has a small battery unit, but the receiver provides most of the power. The Receiver unit has two unconnected cables, one for the antenna and one for the Datalogger. The fittings are pretty obvious.
2. Turn on the Datalogger using the **on** key and the main menu should appear. The Datalogger will then check to see that it is connected to a GPS.
3. The next step is to check the configuration by pressing the **Function** key and then the **GPS/Config** button on the lower left corner of the Datalogger. Highlight **GPS** on the next screen and then press **Enter**. Select **Rover** to configure rover options. The configuration menu allows the user to configure the receiver and includes "Critical" and "Non-critical" settings. The critical settings should be checked, but the non-critical settings can be skipped.
4. There are about 20 critical settings but the only ones that generally need to be set are:
 - a. Logging Interval: Point features should usually be set for 1 second. Line feature interval should be set for 2-5 seconds. If you are walking use the longer interval, if driving, use a shorter interval.
 - b. PDOP mask: The PDOP should be set for 6 or less, but if Quick Plan showed a high PDOP for the time you will be collecting data you might want to increase the PDOP. Remember you will be getting poorer satellite geometry and less accuracy.
5. You're now ready to start collecting data. Select **Data Capture** by using the arrow keys to highlight it and then pressing **Enter**.
6. If there are existing data files, you will be given a choice of files to select. If there are no files, you'll have to create a file. Use the **Create** soft-key to create a new file.
 - a. The "create file" screen will show a default file name showing something like "RO20315a." The "R" stands for Rover, the "020315" is the month/date/time, and "a" is sequential identifier, with the letter incremented for each new file started during that hour.
 - b. When finished with the above step you'll be returned to the Select file screen. Select the file you just created.
7. After a data file is selected, you will be given a choice of feature types to log and an option for which data dictionary to use. To specify data type, select a dictionary or arrow down and hit **Enter** and then choose the data dictionary. If you haven't created a data dictionary, the program will use the Generic data dictionary, which is sufficient if you are only collecting spatial data and not attributes. You will be given a screen to add notes and comments if desired. The Datalogger will now start collecting data.
8. The status line at the bottom of the screen will show number of satellites, and the PDOP level. There will be a warning if the PDOP exceeds the level set during configuration. Usually the PDOP only goes out for a few seconds and this shouldn't cause any problems.

9. There will also be options to **pause** the logging using the softkeys. This is a toggle that will switch to **resume** when selected. You would pause when you need to move away from a position, or perhaps when stopped at a traffic light while driving. A point is added when **pause** is pressed, then when **resume** is pressed another point will be added and the logging will again start with the interval selected.
10. You can use **Nest** or **Quick** to add point features to line or area data as you are collecting the line or area data.
11. To save a feature, such as a point feature, select **OK**. This will save a set of points as one feature within the file.
12. To exit the file and save the data, hit the **Clear** button. You'll be given a warning message to be sure you really want to exit. Select **Yes**.

Repeat the above steps if you are collecting other data files. When you are done with all the collection turn off the Datalogger and disconnect it and the antenna from the receiver.

Downloading Data to a PC

The next step is to bring the data collected into the Pathfinder Office software on your PC for correction and then exporting to CADD or GIS.

1. Open Pathfinder Office and open your project, then select **Utilities>Data Transfer**.
2. Connect the datalogger to the PC as before and turn on the data logger. Select **File transfer** from the main menu of the Datalogger.
3. Check the correct data type. Then check the **PORT** drop-down box in the upper left to be sure that the correct com port has been selected. The Pathfinder Office program will check to see if it's linked to the Datalogger and then give you a choice of files to transfer.
 - a. Click on **Receive**.
 - b. Select the appropriate files and click on **Transfer**.
4. Make sure all data is downloaded. Pathfinder Office may tell you "100% transfer" while the datalogger is still downloading. When the datalogger display window indicates that the downloading is finished, turn off the datalogger and disconnect the cables.
5. Select **View>Map** to choose the file for display. Choose the file or files from the **Open Data File** screen and hit **OK**.
6. Then select **View>Layers>Features**. This opens a dialog box that allows you to set colors, symbol, line type, etc. depending on the type of feature selected. Both generic and user-specified features are available.

7. To clear the display, select **Files>Close**.

Differential Correction Using Base Station Files

Differential correction can be performed when you have a file from a base station that was taken during the same time as your data collection using the same satellites. Plan ahead to be sure that the base station will be collecting data.

From the Internet, access the Burns Community Base Station at this address:
[outdated link removed] (you will need to select a base station for your area).

Select the appropriate files to download (see following section) and send them to your Pathfinder Office working directory. Remember that if a rover file was collected over a span of two hours, for example from 9:45 to 10:15, you will need the base station files for 9 o'clock and 10 o'clock. Below is a typical file naming convention for base station files.

B for Burns

7 for year as in 1997

01 as in 1st month

14 as in 14th day of the month

19 for GPS time which is Greenwich Mean Time: (add or subtract from your local time to get GMT)

.exe for the file extension (this extension is for a self-extracting files, other file types might be ".zip" or ".ssf")

Example: The name for a file for 11am on January 14, 1997 for Pacific Standard Time would be B7011419.exe. The file name for 4pm on November 1st (PST) would be B7110200.exe. Midnight becomes "00" for the next day.

Uncompress the .EXE file. This might need to be done in DOS or a file manager. The resulting files will have a .SSF extension.

Performing Differential Correction in Pathfinder Office

1. Open Pathfinder Office and select **Utilities>Differential Correction**, which will bring up a dialogue box for Base station file, input file, and the name of the corrected output file.
 - a. Click on the **Browse** button to select the Rover file upon which to perform the differential correction. **Browse** the Base files and select the appropriate files with

regard to time of data collection.

- b. Click on the **Settings** button to bring up several settings options from which to choose. Choose **Output** and select "Corrected and Uncorrected" for line data output positions. If you don't have the uncorrected data output, the program connects only the corrected points, which could result in undesirable gaps. For point data, choose "Corrected Only".
- c. You can also check the setting for **Base Controls**, **Rover Controls**, and **Options** but these settings can usually be left at the default. The next three screens show the default settings for these options.
- d. After selecting the Differential Correction Settings, click on **OK** to process the rover file. A screen will report the number of files processed, how many positions were corrected, and the name of the .TXT file containing the detailed log.

Exporting to ArcView

These directions are for exporting to ArcView. The process is similar for other formats, but the exact choices will vary depending on your export format.

1. Select **Utilities>Export** from the main Pathfinder Office module; this will open the GPS output module.
2. Select the file to export by clicking **Browse** on the export screen and then specify the **Output Directory**. Next **Choose an Export Setup**, in this case "ArcView Shapefile sample" format.
3. Click on **Change Setup Options** to bring up screens for specifying **Format**, **Attributes**, **Position Filter**, **Coordinate System**, **System** and **Units**.
 - a. Under **Format**, specify whether you want **Features - Positions and Attributes** or **Positions Only**. If you used a Data Dictionary, select **Features - Positions and Attributes**.
 - b. The default settings for "GPS Position Criteria" on the **Position Filter** screen work best for most export files.
 - c. If attributes were collected, select **Attributes** and check the appropriate options
 - d. Select **Coordinate System** and check "Use Export Coordinate System" to change to the appropriate coordinate system. Again, it's critical to know the other data sources you are working with and the parameters of your base map. If you select UTM you will be given choices again for Geodetic Datum; if you select a State Plane option you will be given specific state plane options. After selecting the specific state plane, you will be given Datum options again.
 - e. Select **Units**. This will display a dialogue box so you can select the appropriate units.
 - f. When the settings are correct, click on **OK** to return to the Main Export screen.
4. From the main Export screen, click on **OK** to complete the export. This will then create a shape file for features and a separate file for positions that are not included in features.

Mastery

Learning Objectives:

1. Student will be able to discuss the effect of CA and P codes on GPS accuracy.
2. Student will be able to determine the maximum acceptable PDOP for a given accuracy for a project.
3. Student will be able to determine the appropriate elevation mask for the terrain for a given project.
4. Student will be able to create a data dictionary and write the metadata for the data dictionary.
5. Student will be able to locate available base stations and determine the best base station for a project.
6. Student will be able to determine which position filters to use when correcting the GPS data.

Tasks:

1. Given an acceptable level of accuracy for a project, determine the maximum PDOP level. If point features are being collected, determine the minimum number of positions that should be collected for each feature.
2. Using a topo map or other terrain data of the project area, determine the required elevation mask to use when checking for satellite availability. Consideration should be given not just to slope, but also the aspect of the terrain in respect to satellite locations.
3. Determine the types of features, attributes, and likely values and create a menu driven data dictionary to collect this data. Write metadata that describes the features, attributes, and values, including whether the data is numeric (including the number of decimal places), character, etc. to match FGDC metadata standards.
4. Locate available base stations for the project area. This might involve internet searches for state and federal agencies, contacting GPS vendors, and checking with universities and other agencies that might be near the project area or doing research in the project area. If a base station is not available, determine if there is a known point near the project area that can be used for creating a base station, if two GPS units will be available.
5. Determine the position filters that are appropriate for the project. This includes whether to select 2d or 2d/3d positions, number of satellites, PDOP level, etc.

Resources:

[Outdated link removed] This is the Web site for Kansas State University's GPS/GIS program.

[Http://www.trimble.com](http://www.trimble.com) This is the site for Trimble Navigation Limited web site. There is a lot of information on GPS, including tutorials and a list of community base stations.

[Http://www.gpsworld.com](http://www.gpsworld.com) GPS World magazine web site.

[Http://www.ashtech.com](http://www.ashtech.com) Ashtech is another GPS manufacturer. This web site also has good explanations on GPS and many links to other sites.

[Outdated link removed] This is the web site for American Congress on Surveying Mapping.
and

Created: May 14, 1997. Last updated: October 5, 1998.