GPS

Global Positioning System - Basics

Introduction

The Global Positioning System (GPS) is a satellite-based radio-navigation system established by the U.S. Department of Defense for military positioning applications and as a by-product, has been made available to the civilian community.

Navigation, surveying and integration with Geographic Information Systems (GIS) are just a few of the fields which have seen the successful application of GPS technology.

GPS

GPS is a complex system which can be used to achieve position accuracies ranging from 100 m to a few millimetres depending on the equipment used and procedures followed.

GPS has drastically changed methods of navigation and is fast becoming important in everyday life.

GPS - BASIC CONCEPTS

The Global Positioning System (GPS) consists of a constellation of radio-navigation satellites, a ground control segment which manages satellite operation and users with specialized receivers who use the satellite data to satisfy a broad range of positioning requirements.

GPS Revolution

In 1973 the US Department of Defense developed new navigation system called the Navstar Global Positioning System. It has since come to be known simply as GPS.

The new system called for three components: ground stations that controlled the system, a "constellation" of satellites in Earth orbit, and receivers carried by users.

GPS Satellite

GPS satellite launches began in 1978, and a second-generation set of satellites ("Block II") was launched beginning in 1989. Today's GPS constellation consists of at least 24 Block II satellites. The system became fully operational in 1995.

GPS Satellite

GPS Goes Public

GPS was designed so that civilian users would not be able to obtain the same accuracy that the military could. Nevertheless, civilian as well as military applications were intended from the start.

Deployment of GPS continued at a steady pace through the 1990s, with growing numbers of civilian and military users. GPS burst into public awareness during the Persian Gulf War in 1991.

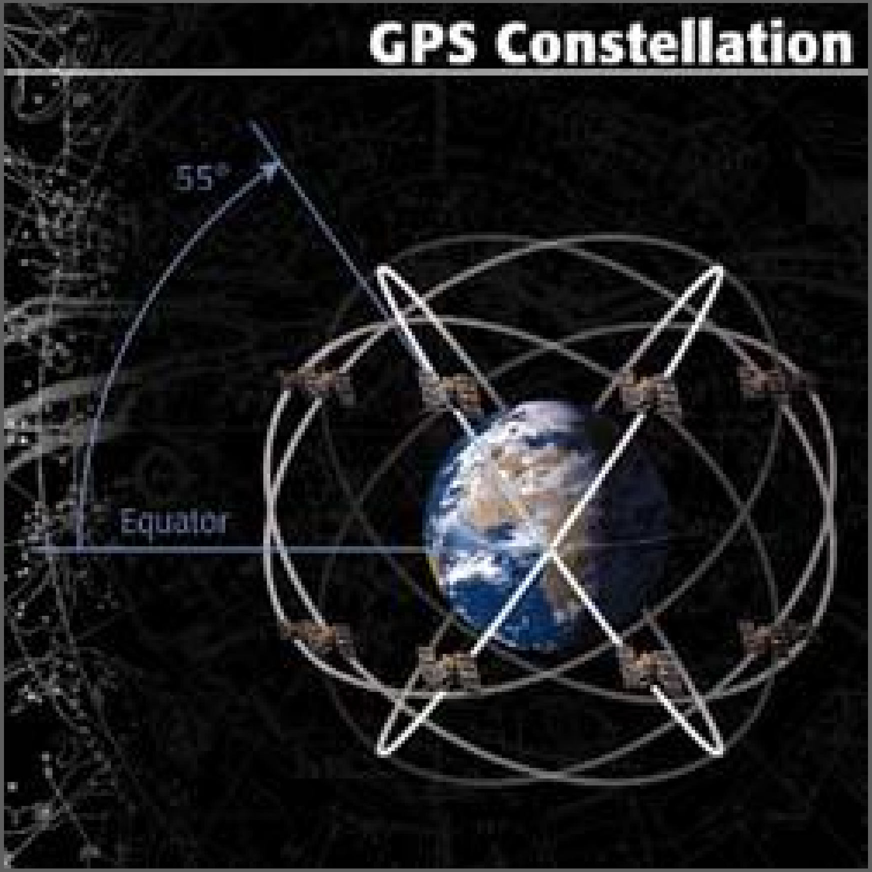
To satisfy demand, the Department of Defense acquired civilian GPS units and temporarily changed GPS transmissions to give civilian receivers access to higher-accuracy military signals.

How Does GPS Work ?

Global Positioning System satellites transmit signals to equipment on the ground. GPS receivers passively receive satellite signals; they do not transmit. GPS receivers require an unobstructed view of the sky, so they are used only outdoors and they often do not perform well within forested areas or near tall buildings.

GPS operations depend on a very accurate time reference, which is provided by atomic clocks at the U.S. Naval Observatory. Each GPS satellite has atomic clocks on board.

How Does GPS Work ?



There are at least 24 operational GPS satellites at all times. The satellites orbit with a period of 12 hours.

Ground stations are used to precisely track each satellite's orbit.

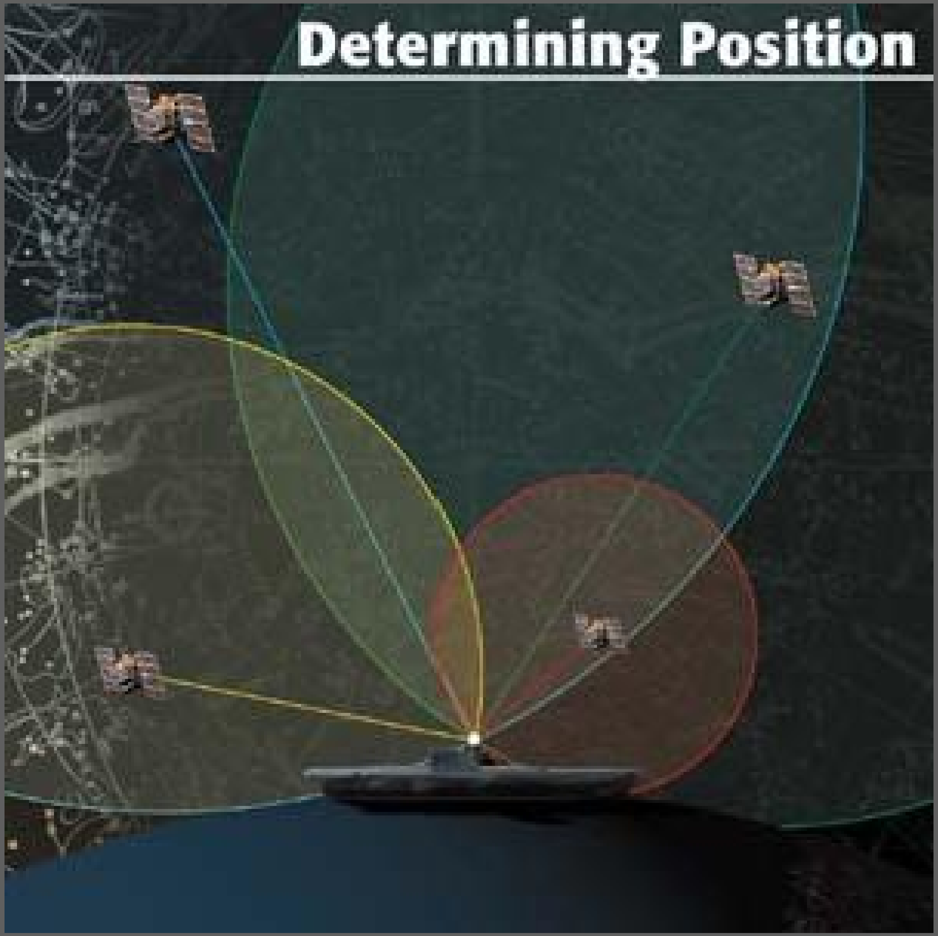
How Does GPS Work ?

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 signals, moving at the speed of light, arrive at a GPS receiver at slightly different times because some satellites are farther away than others. The distance to the GPS satellites can be determined by estimating the amount of time it takes for their signals to reach the receiver. When the receiver estimates the distance to at least four GPS satellites, it can calculate its position in three dimensions.

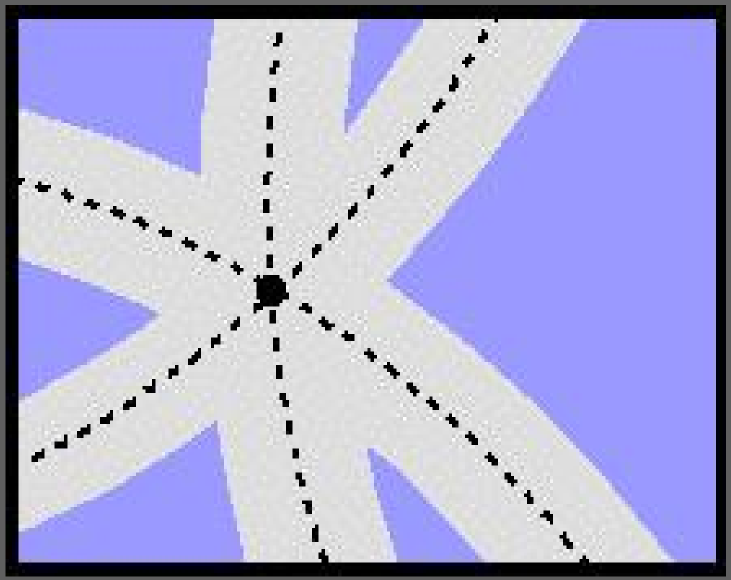
Determining Position

A GPS receiver "knows" the location of the satellites, because that information is included in satellite transmissions. By estimating how far away a satellite is, the receiver also "knows" it is located somewhere on the surface of an imaginary sphere centered at the satellite. It then determines the sizes of several spheres, one for each satellite. The receiver is located where these spheres intersect.

Determining Position

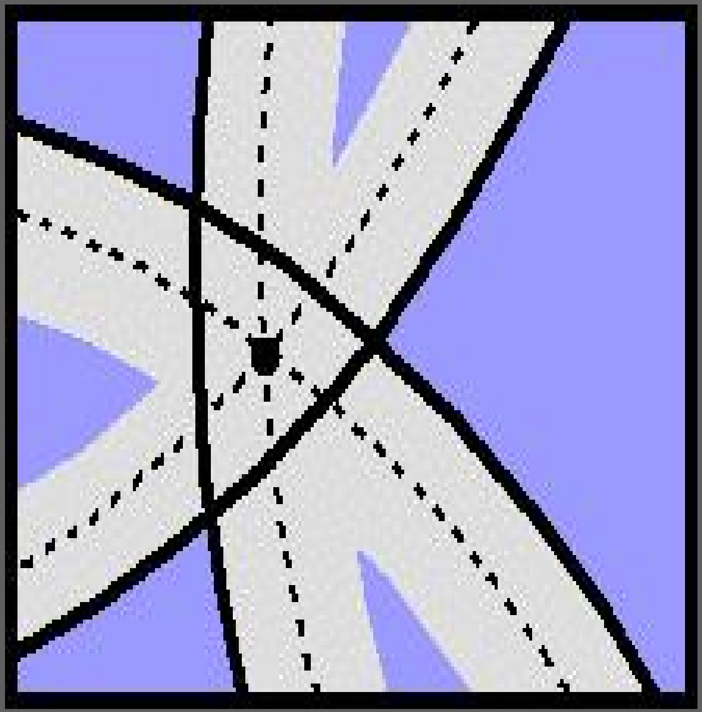


Determining Position



Because GPS receivers do not have atomic clocks, there is a great deal of uncertainty when measuring the size of the spheres shown in the diagram on the previous page. In the figure at left, the dashed lines show the actual intersection point, and the gray bands indicate the area of uncertainty.

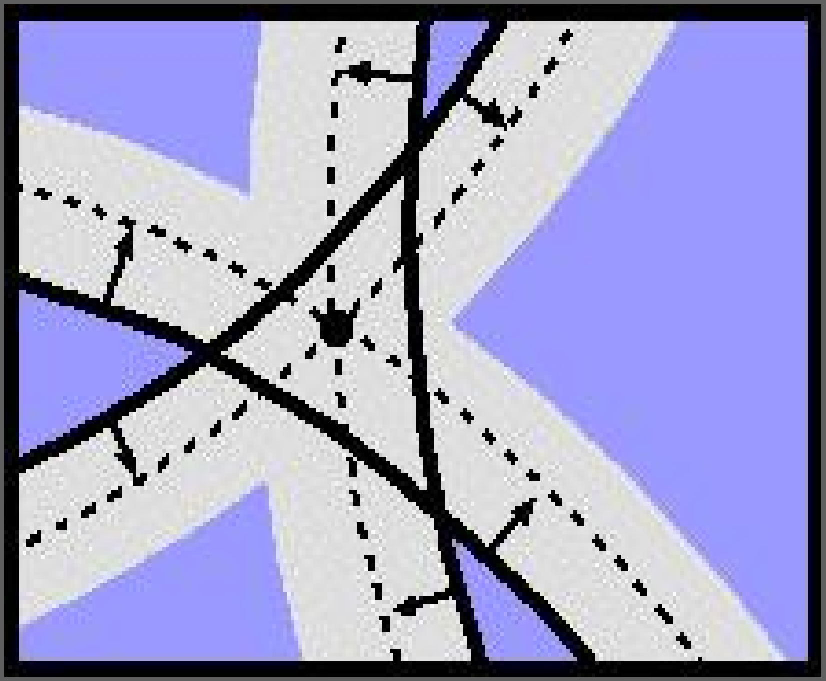
Determining Position



In this diagram, the solid lines indicate where the GPS receiver "thinks" the spheres are located.

Because of errors in the receiver's internal clock, these spheres do not intersect at one point.

Determining Position



The GPS receiver must change the size of the spheres until the intersection point is determined. The relative size of each sphere has already been calculated, so if the size of one sphere is changed, the other spheres must be adjusted by **exactly the same amount**.

Three spheres are necessary to find position in two dimensions, four are needed in three dimensions.

GPS Accuracy

The accuracy of a position determined with GPS depends on the type of receiver. Most hand-held GPS units have about 10-20 meter accuracy. Other types of receivers use a method called Differential GPS (DGPS) to obtain much higher accuracy. DGPS requires an additional receiver fixed at a known location nearby. Observations made by the stationary receiver are used to correct positions recorded by the roving units, producing an accuracy greater than 1 meter.

When the system was created, timing errors were inserted into GPS transmissions to limit the accuracy of non-military GPS receivers to about 100 meters. This part of GPS operations, called Selective Availability, was eliminated in May 2000.

Land and Sea Navigation

GPS has improved efficient routing of vessels at the sea and enhanced safety by making it possible to report a precise position to rescuers when disaster strikes.

GPS improves efficiency on land as well. Delivery trucks can receive GPS signals and instantly transmit their position to a central dispatcher. Police and fire departments can use GPS to dispatch their vehicles efficiently, reducing response time. GPS helps motorists find their way by showing their position and intended route on dashboard displays. Railroads are using GPS technology to replace older, maintenance-intensive mechanical signals.

Navigation In The Air

GPS offers an inexpensive and reliable supplement to existing navigation techniques for aircraft. Civil aircraft typically fly from one waypoint, to another. With GPS, an aircraft's computers can be programmed to fly a direct route to a destination. The savings in fuel and time can be significant.

GPS can simplify and improve the method of guiding planes to a safe landing, especially in poor weather. With advanced GPS systems, airplanes can be guided to touchdown even when visibility is poor. For the private pilot, inexpensive GPS systems provide position information in a practical, simple, and useful form.

Mapping The Earth

Surveyors and map makers use GPS for precision positioning. GPS is often used to map the location of such facilities as telephone poles, sewer lines, and fire hydrants. Surveyors use GPS to map construction sites and property lines. Forestry, mineral exploration, and wildlife habitat management all use GPS to precisely define positions of important assets and to identify changes.

During data collection, GPS points can be assigned codes to identify them as roads, streams, or other objects. These data can then be compared and analyzed in computer programs called Geographic Information Systems (GIS).

Mapping The Land

The use of GPS is widespread in field that require geospatial information for managing assets over large areas.

Forestry, mineral exploration, and wildlife habitat management all use GPS to precisely define positions of important assets and to identify changes.

GPS and Agriculture

GPS receivers installed in farm equipment provide accurate position information. This enables farmers to apply fertilizers and harvest crops with great precision.

New Frontiers In Science

GPS has made scientific field studies throughout the world more accurate and has allowed scientists to perform new types of geographic analyses.

Geologists use GPS to measure expansion of volcanoes and movement along fault lines. Ecologists can use GPS to map differences in a forest canopy. Biologists can track animals using radio collars that transmit GPS data. Geographers use GPS to define spatial relationships between features of the Earth's surface.

GPS Alternatives

The Russian Global Navigation Satellite System (GLONASS) has been an alternative to GPS.

Currently, the European Union is creating of a navigation system of its own, called Galileo, to avoid relying on the U.S. GPS and Russian GLONASS programs. Europe's satellite navigation system is planned to become operational in 2008.

THE END