Introduction

Overview

A Global Positioning System (GPS) receiver is a hand-held device that receives data directly from overhead satellites. Using a GPS receiver, students can determine their location, as measured in latitude and longitude, almost anywhere in the world to an accuracy of ± 10 – 15 meters. If they average several measurements, typically they can determine their location to within ± 10 meters or less. Thus, students can determine the location of their GLOBE sites with sufficient accuracy to identify their individual pixel (30 m X 30 m) in Landsat images.

Yes, students can use satellite data. Although it was originally designed for military use, GPS is now used primarily in civilian applications. As a part of GLOBE, students will determine the latitude, longitude, and elevation of their school as well as of their GLOBE study sites. This information is critical for making GLOBE data useful for students and scientists around the world. The visualization of student data as GLOBE maps would not be possible if the latitude and longitude of each site where students collect their data were not available.

Satellites

An object in orbit around a larger body is called a *satellite*. When the Galileo spacecraft reached Jupiter and slowed down to enter into an orbit around the planet, it became a satellite of Jupiter. When we launch a satellite into orbit around Earth, it becomes an artificial satellite of Earth just as the moon is a natural satellite of Earth. These artificial satellites in Earth's orbit perform a variety of tasks including: long-distance telephone, television, and data communication, weather and natural-resource observations, military surveillance, and basic science measurements.

Our moon is 384,500 km from Earth, and it takes about one month to complete one orbit. Because of fuel limitations or a desire to perform close observations, space shuttles and some observation satellites are only a few hundred kilometers above Earth. These *Low-Earth-Orbit* satellites take a minimum of 90 minutes to complete one orbit. Communications satellites are in orbits 35,792 km above Earth. At this altitude, these satellites take exactly one day to circle Earth. This special orbit is called *Geosynchronous Orbit*. A satellite in geosynchronous orbit always appears to be at the same place in the sky to a terrestrial observer. Thus, an antenna pointed at a geosynchronous satellite need not move. Compare this to a space shuttle which may pass from horizon to horizon in minutes or our moon which may take a month to move across the sky.

GPS Satellites

The Global Positioning System consists of a series of satellites, ground control stations, and users with GPS receivers. See Figure GPS-I-1. These satellites are unmanned and are launched by expendable rockets that place them into orbit. There are 28 GPS satellites in orbit 20,200 km above Earth's surface. At this altitude, the satellites take about 12 hours to complete one orbit. The satellites are spaced in their orbits so that at least four are always in view of a terrestrial observer at any point on Earth. A ground-based system of tracking stations monitor the orbits of the satellites to an accuracy of ± 1 m, and encodes the satellite's location, along with the satellite-generated time signal, into the unique identification code transmitted by each satellite. The satellites transmit encoded signals approximately every 15 seconds. When received by a hand-held GPS unit, the data allow the calculation of the latitude, longitude and elevation (or altitude) of the receiver. The radio signals travel in a straight line from the satellite to the GPS receiver passing through clouds, light tree canopies, glass, and plastic, but not through solid structures such as buildings and mountains. When operating, the GPS unit is able to identify each satellite as they come into view, and evaluate the quality of the incoming signals. Modern GPS units may receive signals from up to 12 satellites

Figure GPS-I-1: A Global Positioning System Satellite (courtesy www.gps.gov)

at the same time. A minimum of three signals is required to give the latitude and longitude, while reception of a minimum of four signals is necessary to calculate the altitude. Reception of a larger number of signals produces a more accurate result.

The capabilities of the GPS system rely critically on the development of extremely accurate atomic clocks. The most accurate clocks are capable of neither losing nor gaining more than 1 second in 20 million years! The time given in the GPS receiver is accurate to within one billionth of a second! The combination of clocks in the GPS receiver and atomic clocks on each satellite allow the GPS receiver to record the transit time of each radio signal to within 1 nanosecond (one billionth of a second). Knowing the speed of light (about 1 foot per nanosecond) it is possible to use the time delay, between the transmission and reception of the radio signal, to calculate with extreme accuracy the instantaneous distance from each satellite to the GPS receiver. Converting the simultaneous time delay of signals from three or more satellites into distances, it is possible to calculate, by triangulation, the position (latitude, longitude, and elevation) of the receiver anywhere on the surface of Earth.