ROYAL CANADIAN ARMY CADETS

SILVER STAR

INSTRUCTIONAL GUIDE

SECTION 3

EO M322.03 – IDENTIFY COMPONENTS OF THE GLOBAL POSITIONING SYSTEM (GPS)

Total Time: 30 min

PREPARATION

PRE-LESSON INSTRUCTIONS

Resources needed for the delivery of this lesson are listed in the lesson specification located in A-CR-CCP-703/PG-001, Chapter 4. Specific uses for said resources are identified throughout the instructional guide within the TP for which they are required.

Review the lesson content and become familiar with the material prior to delivering the lesson.

PRE-LESSON ASSIGNMENT

N/A.

APPROACH

An interactive lecture was chosen for this lesson to orient the cadets to the components of the GPS and to present background material.

INTRODUCTION

REVIEW

N/A.

OBJECTIVES

By the end of this lesson the cadet shall have identified the components of the GPS.

IMPORTANCE

It is important for cadets to be able to identify the components of the GPS so they have the background knowledge and information required to effectively operate a GPS receiver when navigating.

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Teaching point 1 **Discuss the GPS**

Time: 10 min Method: Interactive Lecture



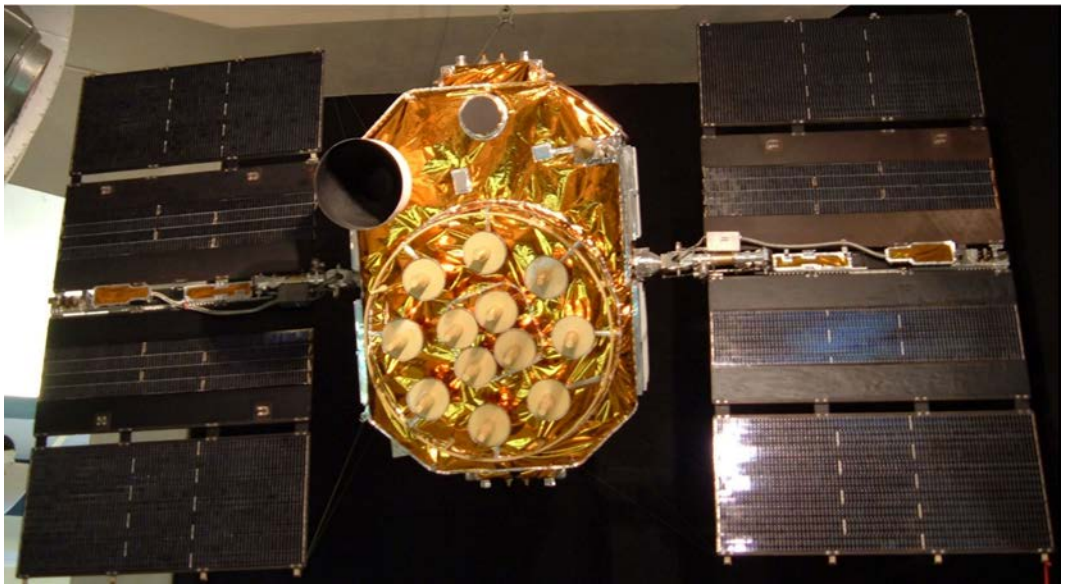
Determine the level of understanding cadets have of the GPS by carrying out a short discussion.

It is expected that most cadets will assume the GPS is the unit a person looks at to determine position. Prior to moving to TP 2 ensure cadets understand that the GPS is a constellation of satellites and is comprised of many components.

WHAT THE GPS IS

Global Navigation Satellite System (GNSS) is the generic term for satellite navigation systems that provide autonomous geo-spatial positioning with global coverage. The Global Positioning System (GPS) is a constellation of satellites, ground stations and receivers created, owned and operated by the United States. This system is used to navigate and enables anyone with a GPS receiver to know where they are 24 hours a day in any kind of weather.

The GPS is a group of 21 satellites (and three spares) that orbits the Earth and sends radio signals from their positions above the Earth back to Earth's surface. A GPS receiver is an electronic device that detects the radio signals from the satellites and calculates the receiver's position on the Earth. It is capable of giving location, speed, time and altitude.



"Wikipedia", Global Positioning System Satellite. Retrieved March 27, 2008, from http://en.wikipedia.org/wiki/Image:Global_Positioning_System_satellite.jpg

Figure 1 GPS Satellite

The United States GPS is not the only satellite navigation system currently deployed in space. Other nations that have begun or have established a similar satellite navigation system are:

- European Union – GALILEO Satellite System,
- Russian – GLONASS System, and

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- Chinese – Beidou System.

HOW THE GPS WORKS

The system is divided into three parts or segments: space, ground control and users. The space segment consists of 24 satellites that orbit 20 200 km above the Earth and send radio signals toward Earth. The radio signals broadcast the position of each satellite in the sky with an electronic code.

Each satellite performs a relatively simple primary task: it transmits a timing signal using its built-in atomic clock. When a device on the ground receives that signal, it can determine its distance from the satellite.

That single measurement alone does not accomplish much, but when a GPS receiver collects timing signals from three different satellites the receiver can determine two precise coordinates: latitude and longitude. With four satellite signals, the GPS receiver is able to determine altitude as well.



A GPS receiver is also capable of determining more than latitude, longitude, and altitude. It can also determine other variables such as speed and heading.

COMPONENTS OF THE GPS

Satellites

The GPS and its satellites have the following characteristics:

- The minimum number of satellites that are required to cover the entire Earth is 18, however the number of satellites in orbit fluctuates between 24 and 29 satellites due to spares and upgrading.
- Satellites orbit in a semi-synchronous orbit (orbits are coordinated, but not identical).
- Each satellite completes an orbit every 12 hours.
- Satellites orbit the Earth at 20 200 km (12 552 miles) (airplanes routinely fly at 11–13 km [37 000–43 000 feet], the shuttle orbits at 370 km [230 miles]).
- Each satellite has three key pieces of hardware:
    - **Computer.** Controls its flight and order functions.
    - **Atomic Clock.** Keeps accurate time within three nanoseconds (approximately three-billionths of a second).
    - **Radio Transmitter.** Sends signals to Earth.

Ground Stations

The ground control segment of the GPS is comprised of five ground stations that track the satellites, monitor their condition and make any necessary adjustments to keep the system accurate. The entire system functions and is monitored by the US Department of Defence. Information from the stations are sent to a master control station – the Consolidated Space Operations Centre (CSOC) at Schriever Air Force Base in Colorado where the data is processed and adjustments are made. The five ground stations are in Hawaii, Colorado, Diego Garcia, Ascension Island and Kwajalein.

Receivers

GPS receivers make up the user segment. It is the GPS receiver, whether it is in an airplane, a truck, a boat or in a hiker’s hand, that detects the radio signals from the satellites and calculates the receiver’s position.

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When a receiver is turned on, it interprets the radio signals and extracts the satellite location information. The GPS signal broadcasts information that tells the receiver the location of each satellite in the system. The receiver then interprets the radio signal to determine the exact time. This is required to calculate position.

The orbits of the GPS satellites ensure that there will be a minimum of four satellites covering any spot on the globe at all times. The receiver uses the signal from one satellite to continuously monitor and be synchronized with the time maintained by the other satellites. The receiver collects the signals from the other satellites and calculates the difference between them. This calculation positions the receiver from each satellite and triangulates its location. Based on a four satellite fix, the receiver will identify location giving the user latitude, longitude and altitude (altitude is only possible with a four satellite fix).

CONFIRMATION OF TEACHING POINT 1

QUESTIONS

Q1. What does GPS stand for?

Q2. What are ground stations responsible for?

Q3. How does a receiver calculate your position?

ANTICIPATED ANSWERS

A1. GPS stands for Global Positioning System.

A2. Ground stations are responsible for tracking the satellites, monitoring their condition and making any necessary adjustments to keep the system accurate.

A3. The receiver uses the signal from one satellite to continuously monitor and be synchronized with the time maintained by the satellites. The receiver collects the signals from the other satellites and calculates the difference between them. This calculation positions the receiver from each satellite and triangulates its location. This location gives the user latitude, longitude and altitude.

Teaching point 2 **Explain GPS Terminology**

Time: 5 min Method: Interactive Lecture



As cadets are introduced to and continue to use GPS receivers they may encounter the following terms. Explain the terms to the cadets and give examples where possible.

GPS. Global Positioning System, a constellation of 21 satellites (and three spares) used to determine location, speed, time and altitude.

Three-Dimensional (3D) Coordinate. Requires a four satellite signal lock, giving a position as determined by latitude, longitude, and altitude.

Assisted GPS (A-GPS). GPS with assistance from cellular technology. Found mostly in new GPS-equipped phones. A-GPS relies on cellular networks to help do some of the tracking because GPS signals will not penetrate indoors.

Differential GPS (DGPS). A stationary receiver working in conjunction with the satellites to correct errors in the timing signals, resulting in a more precise measurement of location.

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Latitude. Imaginary parallel horizontal lines encircling the Earth, measuring 90 degrees north and 90 degrees south from the equator. The line at the equator represents zero degrees of latitude.

Longitude. Imaginary vertical lines running from the North Pole to the South Pole. The prime meridian (zero degrees longitude) runs through Greenwich, England, and serves as the reference line from which longitude is measured. Latitude and longitude create a grid covering the planet from which one can extrapolate coordinates.

Triangulation. What GPS receivers do to determine position based on data received from three or more GPS satellites.

Wide Area Augmentation Service (WAAS). Improves GPS accuracy and availability. WAAS was designed with aviation in mind as it improves a GPS receiver's accuracy to within three metres.

Waypoint. An intermediate position between the starting and destination points along a navigational route. If one makes three stops along the route to the final destination, the GPS receiver will consider each one of these stops a waypoint.

CONFIRMATION OF TEACHING POINT 2

QUESTIONS

Q1. What is a 3D coordinate?

Q2. What is triangulation?

Q3. What is a waypoint?

ANTICIPATED ANSWERS

A1. A 3D coordinate is one's position as determined by latitude, longitude, and altitude.

A2. Triangulation is what a GPS receiver does to determine position based on data received from three or more GPS satellites.

A3. A waypoint is an intermediate position between the starting and destination points along a navigational route.

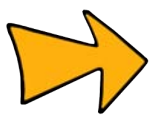
Teaching point 3 **Discuss GPS Receivers and the Information They Provide**

Time: 10 min Method: Interactive Lecture

The GPS receiver is a piece of equipment that processes the signals sent from satellites. The information the receiver calculates from the signals can be used in many ways.

ACCURACY

The accuracy of a GPS receiver depends on the number of satellites from which signals are being recieved, and the use of augmentation systems. A GPS receiver without WAAS measures to an accuracy of 5 m (16.4 feet) 95 percent of the time, and with WAAS to an accuracy of 3 m (9.8 feet).



WAAS is most often found on GPS receivers for aircraft. Landing safely in fog is difficult without an accurate location of the runway.

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TIME

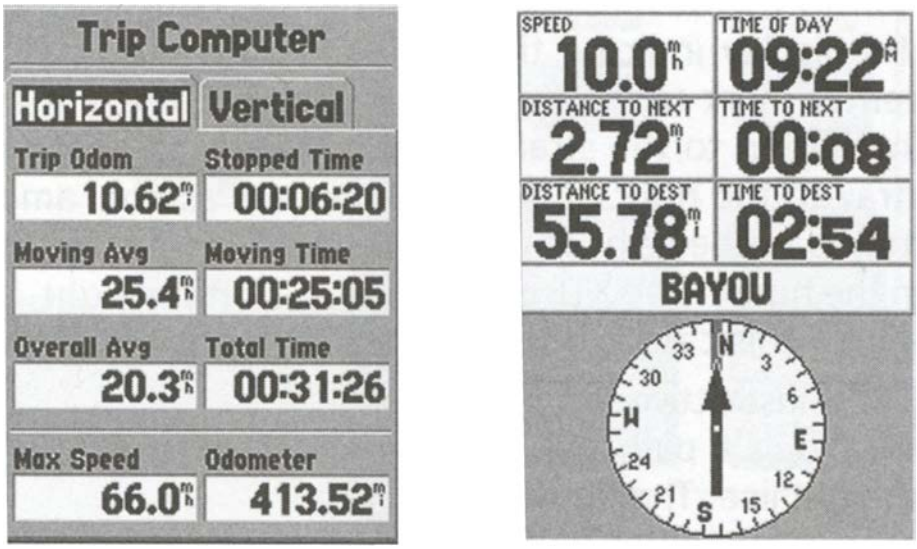
A GPS receiver receives time information from atomic clocks, so it is more accurate than a wristwatch. Receivers report a variety of times as navigation statistics, to include:

- **Estimated Time of Arrival (ETA).** The ETA is the time of day one will arrive at the destination (eg, 1230 hrs).
- **Estimated Time Enroute (ETE).** ETE tells how much longer one must travel before arriving at the destination and is measured in minutes or hours.



ETA and ETE are only useful when travelling in a straight line like in a boat or on a plane. However if a route is planned with waypoints to guide the route, the ETA and ETE timings will be accurate to follow.

- **Trip Time.** Also known as elapsed time, the trip timer measures time from the last time it was reset. This can be used to calculate average speed because it continues counting time regardless if a person is moving or not.
- **Time Moving.** The amount of time that speed is not zero. When you come to a stop, the timer stops counting. The time moving is used to calculate the average moving speed.
- **Time Not Moving.** The time not moving timer counts only when you are standing still. It represents the time you sit motionless. If the times on the time moving and the time not moving timers are added together, they should equal the trip timer.
- **Time of the Day.** All receivers provide the time of the day. The GPS satellites keep what is known as GPS time.



L. Letham, GPS Made Easy (4th ed.), The Mountaineers (p. 54–55)

Figure 2 Time Screens

LOCATION

GPS provides location in three dimensions:

- latitude (X-coordinate),
- longitude (Y-coordinate), and

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- altitude.

The location can be displayed in a number of coordinate systems (eg, latitude/longitude, Universal Transverse Mercator [UTM]).



The altitude calculation of a consumer GPS receiver is not very accurate (+/- 15 m [49.2 feet]).

SPEED

A receiver measures the time and distance between the point where a person is and the point where the person was a short time ago, then divides the distance by the time it takes to travel there (speed = distance/time). Some of the speed statistics are:

- **Speed Over Ground (SOG).** The SOG (also known as ground speed) is just like the speed displayed by the speedometer in a car. It measures how fast you are going at that moment. Speed does not take into consideration if you are on course. It is a measurement of speed regardless of direction.
- **Velocity Made Good (VMG).** The speed at which the destination is approached. VMG takes into account the present course and destination.
- **Average Speed.** Divides the distance by the amount of time it took to travel that distance.
- **Average Moving Speed.** The average speed excluding the time the receiver stands still.
- **Maximum Speed.** The fastest speed travelled during the trip.
- **Vertical Speed.** The instantaneous speed measured for up and down movements only.
- **Average Ascent and Descent.** Much like average speed, the average ascent and descent is the distance of vertical movement divided by the amount of time to make the movement. It is the average rate of change in altitude.
- **Maximum Ascent and Descent.** The maximum rate of a vertical change in position.

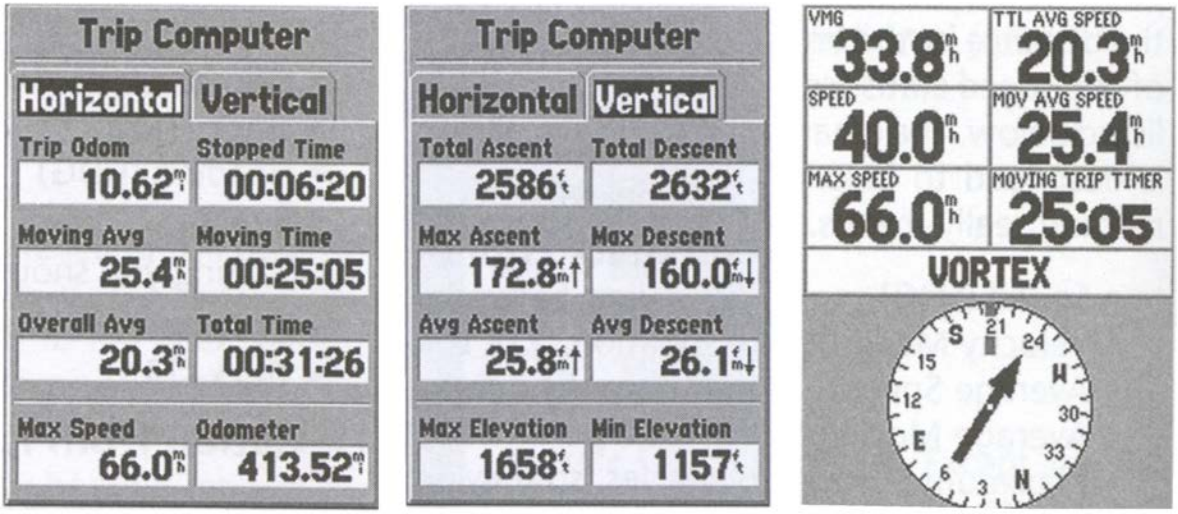

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Figure 3 Speed Screens

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DIRECTION OF TRAVEL

A GPS receiver can display the direction of travel if the receiver is moving. If the unit is stationary, it can not use satellite signals to determine which direction a person is facing.

Some GPS units have a electronic compass that shows the direction the receiver is pointed, whether moving or standing still. All directions calculated by a receiver can be expressed as a bearing or in degrees.

STORED LOCATION

Locations can be stored in the GPS receiver. It can store where a person has been and where a person wants to go. These location positions are waypoints. A GPS receiver can provide a person with directions and information on how to get to a waypoint.

CUMULATIVE DATA

A GPS receiver can keep track of information such as the route travelled, total distance travelled, average speed, minimum speed, elapsed time, and time to arrival at a specific location.

CONFIRMATION OF TEACHING POINT 3

QUESTIONS

Q1. What is the accuracy of a GPS receiver without WAAS?

Q2. What three dimensions will a GPS receiver report location in?

Q3. How does a GPS receiver calculate speed?

ANTICIPATED ANSWERS

A1. A GPS receiver without WAAS measures to an accuracy of 5 m, 95 percent of the time.

A2. A GPS receiver provides location in the following three dimensions:

- latitude (X-coordinate),
- longitude (Y-coordinate), and
- altitude.

A3. A GPS receiver measures the time and distance between the point where a person is and the point where the person was a short time ago then divides the distance by the time it takes to travel there (speed = distance/time).

END OF LESSON CONFIRMATION

QUESTIONS

Q1. What is the GPS?

Q2. What is triangulation?

Q3. What is a waypoint?

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ANTICIPATED ANSWERS

A1. The GPS is a constellation of 24 satellites orbiting the Earth, receivers and ground stations. They are used to determine location, speed and time.

A2. Triangulation is what GPS receivers do to determine their position based on data received from three or more GPS satellites.

A3. A waypoint is an intermediate position between the starting and destination points along a navigational route. If one makes three stops along the route to the final destination, the GPS receiver will consider each one of these stops a waypoint.

CONCLUSION

HOMEWORK/READING/PRACTICE

N/A.

METHOD OF EVALUATION

N/A.

CLOSING STATEMENT

GPS training will introduce cadets to a new tool to use while navigating. The GPS is a technological advancement that is continuously evolving to present new ways and methods of navigating. As these advances become available for the Cadet Program, cadets will be challenged to learn and apply them while navigating.

INSTRUCTOR NOTES/REMARKS

It is recommended that this EO be instructed outside.

REFERENCES

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