# ADVANCED: INSTRUMENT PANEL

## DESCRIPTION OF SESSION

In this session, participants will explore aviation instrumentation more deeply, examine how the Global Positioning System works, further explore the limitations and failures of instrument systems, and discuss human factors.

## CATEGORY

- Exploring, Aviation
- U.S. Department of Education, Transportation

## OBJECTIVES

By the end of this session, participants will be able to:

- Describe how GPS works, including explaining trilateration and finding out how pilots use this system for navigation.
- Understand human factors such as vision, perception, and denial.

## SUPPLIES

- Laptop computer with GPS simulator
- **GPS Overview** activity sheet (one per participant)
- Handheld GPS receiver (optional)
- Gyroscope

**ADVISOR NOTE:** Text in italics should be read aloud to participants. As you engage your post in activities each week, please include comments, discussions, and feedback to the group relating to **Character, Leadership,** and **Ethics**. These are important attributes that make a difference in the success of youth in the workplace and in life.

## ACTIVITIES

### Activity 1

### GPS Overview

Use a laptop computer with the Garmin 400 series (or another model) GPS simulator to further discuss GPS. Download the simulator for free at http://www8.garmin.com/support/download_details.jsp?id=3528.

Set the initial position to your airport and briefly explain the three-letter code for airports. Choose a nearby airport and ask participants to point to where they think it is. (If they answer incorrectly, tell them where north is and ask again.) Set a direct course to that airport, set the speed and altitude, and explain what’s going on as participants watch the plane fly along the pink line to the airport.

Point out that GPS is also useful for departures and approaches. Compare and contrast a GPS approach with precision and nonprecision approaches of other types. Ask: *What makes an ILS approach more accurate than a GPS approach? What are some of the problems with GPS? What is WAAS? Do you think GPS will someday take over all navigation for planes? Why or why not?*

Pass out the **GPS Overview** activity sheet and discuss trilateration. Note for participants that GPS receivers measure distance only. They receive a signal from a GPS satellite and, calculating using the speed of light, translate the time it takes to receive the signal into a distance from the satellite.

Aviation GPS receivers also contain a database of information about terrain and other navigational aids that are on the ground. Airplane GPS receivers give information relevant to pilots. Have participants compare the kind of information they might find on a car's GPS receiver versus an airplane's or a boat's. Taken together, the information about distance from the satellite and the information about terrain and ground-based navigation aids gives pilots a complete picture of where he or she is in space.

If a hand-held GPS receiver is available, use it to demonstrate these concepts as you discuss them.

**Activity 2**
**Airplane Systems**
Most instruments work together in a system. The gyroscopic, pitot-static, electrical, and vacuum systems are all examples.

Ask Explorers: *What is a system?* (The word "system" describes how different parts of a plane interact to form a complex whole. For example, the pitot system involves static air, ram air, altimeter, airspeed indicator, and vertical speed indicator, and sometimes includes an alternate static system. A plugged static or ram port would cause faulty indications in multiple instruments.)

Discuss airplane systems and how an airplane's instruments interact to create a system. You can also discuss redundancy and engineering constraints. (For example, there could be backups for all systems, but that might make the plane too heavy to fly.)

Discuss static ports and pitot tubes and how they work, as well as ram air versus static air and how the difference between the two helps determine altitude, airspeed, and vertical speed indicators. Discuss alternate static and why it works. Ask: *What do their purposes have to do with their placement on the plane? What engineering constraints dictate their placement? What would happen if the pitot tube were clogged? What if the static port were clogged?* (Static pressure measures outside air pressure and ram air measures moving air. The difference between the two pressures can determine altitude and airspeed. A blocked pitot tube will affect the airspeed indicator, with the indicator showing an increase with increased altitude and a decrease with decreased altitude. A blocked static port is more serious, which is why many planes have an alternate static source. The altimeter may indicate a higher than actual altitude, which means you might be too close to the ground or other obstacles. The vertical speed indicator will momentarily indicate a climb, then will settle back to the initial indication. The airspeed indicator will indicate greater than normal airspeed, which will cause the pilot to slow down, risking a stall.)

Discuss how a gyroscope works and how it works with the heading indicator and attitude indicator. Discuss the principles of a gyroscope (rigidity in space and precession) and Newton's First Law. If a gyroscope is available, use it to demonstrate the two principles.

Set a gyroscope in motion. As you tilt the gyroscope, have participants imagine that the airframe is tilting and notice how the inside wheel does not tilt. In an attitude indicator, the model plane is on the part of the gyroscope that stays upright, and as the plane around the wheel tilts, the model plane gives an indication of the plane's attitude with respect to the artificial horizon.

Wikipedia has an excellent explanation of how a gyroscope works, along with relevant animations. See [http://en.wikipedia.org/wiki/Gyroscope](http://en.wikipedia.org/wiki/Gyroscope).

Briefly mention other gyroscopic instruments, including the turn and slip indicator and the heading indicator.

Explain to participants that airplane instruments can be powered in one of several ways: mechanically, electrically, via lasers, or via solid state. On smaller aircraft, they're usually powered by the airplane's vacuum system. The vacuum system draws air in through a filter assembly, which then moves through turbines in the instruments, where it causes the gyros to spin at high speed. The air then continues on to the engine-driven vacuum pump, where it is expelled. A relief valve prevents the pressure from getting too high. Another, more expensive option used in many larger aircraft is electrically powered instruments. Despite the expense, some smaller aircraft are now employing these electrically powered gyroscopic systems as well. If desired, students can research laser and solid state technologies.

Discuss engineering constraints and opportunities and why some ideas are better for certain situations and certain aircraft.

**Activity 3**
**Human "Instruments" versus Mechanical Instruments**
Tell Explorers: *Because of human physiology and psychology, we are generally not as good at determining where we are in space or understanding what is going on with the airplane as the mechanical instruments are. Our senses of sight, hearing, and feeling are simply not that accurate, especially when we are flying in clouds.*

Discuss some examples:

- What the inner ear tells us when we are in unusual attitudes
- The misperception of clouds that might not be parallel to the ground
- The various psychological factors that play into decision making (i.e., denying that there might be a problem when an instrument shows that there is)

Say: *It's best to rely on the instruments, but it's important to understand the systems well enough to cross-check and verify what you are seeing and feeling with what the plane is doing.*

**ADVISOR NOTE**
Some sample questions are below. They are designed to help the participants apply what they have learned to their own interests. You are welcome to use these questions or develop your own questions that relate to your post or specific focus area.

**REFLECTION**

- *Consider what you learned in this activity. Can you speculate on how pilots navigated before the wide use of GPS? What do you think that would look like? Do you think there might be some advantages of learning additional ways to navigate?* (Mention pilotage, dead reckoning, NDB, VOR, and celestial navigation strategies.)
- *What might be a disadvantage to relying solely on instruments?* (Point out that its always best to cross-check instruments with one another as well as looking outside in visual conditions so that you don't lose situational awareness.)

**ADVISOR AND OFFICER REVIEW**

After the meeting, address the following:

- Identify what was successful about the meeting.
- Identify what needed improvement.
- Schedule an officer and Advisor planning meeting to prepare for the next post meeting or activity.

Content for this session provided by Youth Aviation Adventure (http://www.youthaviationadventure.org/yaa/).

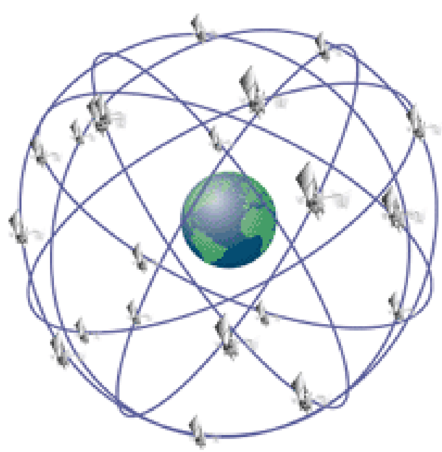
**RESOURCES**
**Activity 1**
**GPS Overview**
Following is more in-depth information for participants interested in further detail about GPS and its uses in aviation.

## What is GPS?

When people talk about "a GPS," they usually mean a GPS *receiver*. The Global Positioning System (GPS) is actually a constellation of 27 Earth-orbiting satellites (24 in operation and three extras in case one fails).

U.S. Air Force image

Each of these solar-powered satellites circles the globe, making two complete rotations every day. The orbits are arranged so that at anytime, anywhere on Earth, there are at least four satellites "visible" in the sky. The satellites continuously transmit signals that can be received by any GPS receiver such as a handheld GPS receiver or the one in a car or plane.



NASA image

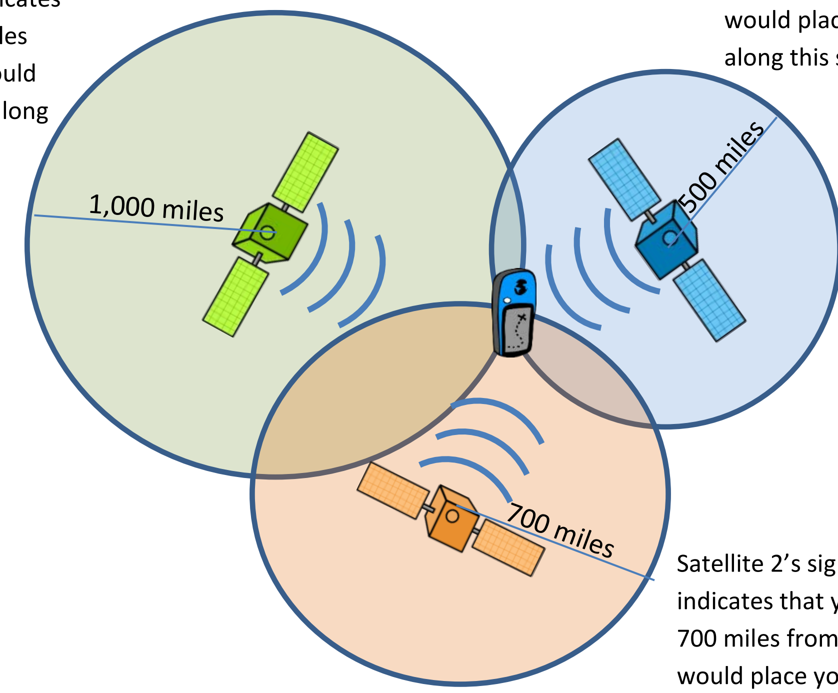
A GPS receiver's job is to locate four or more of these satellites, figure out the distance from each, and use this information to calculate its own location. This operation is based on a simple mathematical principle called *trilateration*.

**How does a GPS receiver help you locate where you are on Earth? Or, what exactly is trilateration?**

Below is an illustration that might help. Pretend you are holding the receiver in the center.

The signal from satellite 3 tells you that you are 500 miles away from it. That would place you anywhere along this small circle.

Satellite 1's signal indicates that you are 1,000 miles away from it. That would place you anywhere along this big circle.




Satellite 2's signal indicates that you are 700 miles from it. That would place you anywhere along this medium-sized circle.

The intersection of the three circles is your position on the surface of the Earth!

Of course, airplanes are usually not on the surface of the Earth. A fourth satellite signal is needed in order to calculate altitude. The intersection of three spheres is a circle; four spheres are needed to find the specific point where the plane will be.

Planes need at least five satellite signals to fly. The extra satellites are used for redundancy in case one satellite's signal is weak or bad. If a GPS receiver receives errant information, it simply ignores that signal.

**How do pilots use GPS?**

Below is an image of a typical GPS unit found in a small aircraft. The plane on the screen is navigating from the northwest to the southeast and has just passed the OSU airport (KOSU). It is on a 129-degree course and is traveling at a groundspeed of 115 knots at an altitude of 3,000 feet. Distance to the destination is 8.59 nautical miles. The straight line is the direct course between the starting and ending points that the pilot entered into the computer.