

Aerospace Dimensions

AIRCRAFT SYSTEMS AND AIRPORTS



2 MODULE



Civil Air Patrol

Maxwell Air Force Base, Alabama

Aerospace Dimensions
**AIRCRAFT SYSTEMS
AND AIRPORTS**

MODULE
2

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INTRODUCTION

The Aerospace Dimensions module, *Aircraft Systems*, is the second of six modules, which combined, make up Phases I and II of Civil Air Patrol's Aerospace Education Program for cadets. Each module is meant to stand entirely on its own, so that each can be taught in any order. This enables new cadets coming into the program to study the same module, at the same time, with the other cadets. This builds a cohesiveness and cooperation among the cadets and encourages active group participation. This module is also appropriate for middle school students and can be used by teachers to supplement STEM-related subjects.

Inquiry-based **activities** were included to enhance the text and provide concept applicability. The activities were designed as group activities, but can be done individually, if desired. The activities for this module are located at the end of each chapter.



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A horizontally opposed avco lycoming aircraft engine

National Academic Standard Alignment

Science Standards	Mathematics Standards	English Language Arts Standards	Social Studies Standards	Technology Standards
Science as Inquiry	1. Number and Operations Standard: <ul style="list-style-type: none"> Understand numbers, ways of representing numbers, relationships among numbers, and number systems 	1. Reading for Perspective	8. Science, Technology, and Society	8. Understanding of the attributes of design
Physical Science: <ul style="list-style-type: none"> Motions and Forces 	4. Measurement Standard: <ul style="list-style-type: none"> Understand measurable attributes of objects and the units, systems, and processes of measurement 	3. Evaluation Strategies	9. Global Connections	9. Understanding of engineering design
Science and Technology: <ul style="list-style-type: none"> Abilities of technological design 	6. Problem Solving Standard: <ul style="list-style-type: none"> Solve problems that arise in mathematics and in other contexts 	4. Communication Skills		13. Ability to access the impact of products and systems
Science in Personal and Social Perspectives: <ul style="list-style-type: none"> Science and technology in society 	9. Connections Standards: <ul style="list-style-type: none"> Recognize and apply mathematics in contexts outside of mathematics 	12. Applying Language Skills		18. Understanding of and ability to select and use transportation technologies
	10. Representation Standard: <ul style="list-style-type: none"> Use representations to model and interpret physical, social, and mathematical phenomena 			

AIRPLANE SYSTEMS

Learning Outcomes

- Explain how a reciprocating engine operates.
- Identify parts of the airplane engine when viewed externally.
- Describe how a jet engine operates.
- Identify basic cockpit-mounted powerplant controls.
- Identify basic flight instruments.

Important Terms

combustion - the chemical process of burning

combustion chamber - an enclosed container in which fuel and air are burned for the production of energy

compression - the act of making a given volume of gas smaller

cycle - a recurring series of events; the airplane engine has four cycles, intake, compression, power, and exhaust

fuel - a chemical substance which is used as a source of energy; aircraft fuels include gasoline, kerosene, and propane

lean mixture - a mixture of gasoline and air in which there is less fuel and more air

magneto - an electrical generator that produces power when rotated

meter/metering - in terms of fuel for an engine, this is the process of allowing a precise amount of fuel to pass (An example would be a passageway that allows only so many molecules of gasoline to pass in a given unit of time.)

powerplant - a term which applies to the airplane engine and accessories

reciprocating - a type of engine that processes air and fuel by a back and forth movement of its internal parts

rich mixture - a mixture of gasoline and air in which there is more gasoline and less air than needed for normal combustion

stoichiometric - a ratio of fuel to air in which, upon combustion, all of the fuel is burned (In energy terms, it is 15 parts air to 1 part gasoline.)

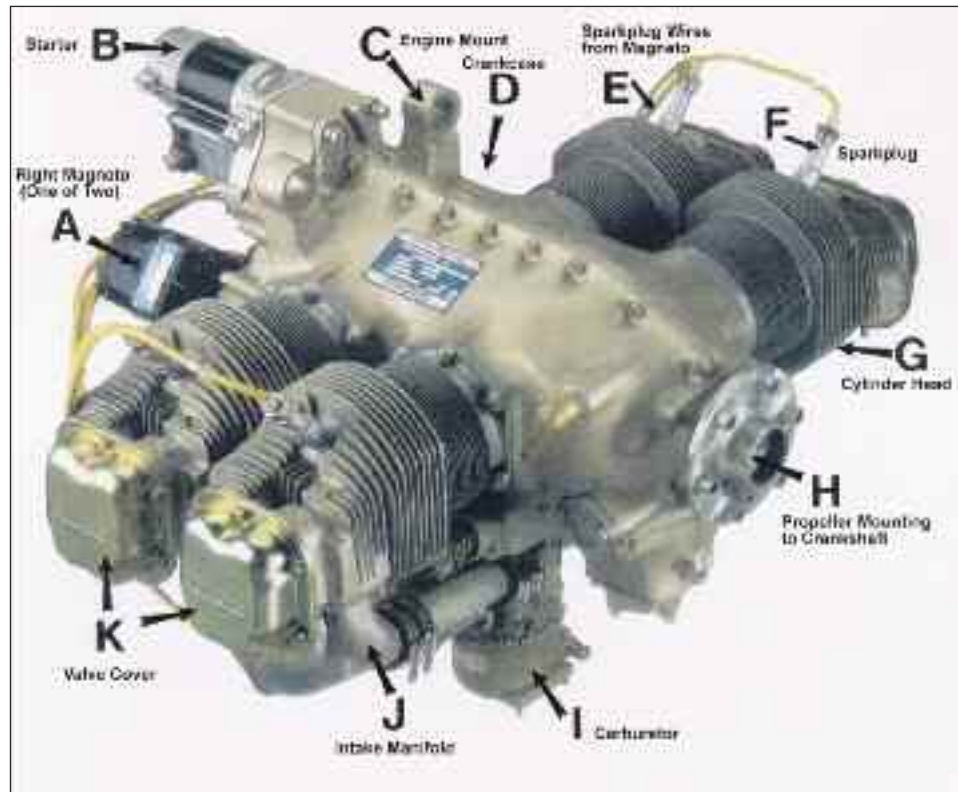
stroke - in the example of an airplane engine, it is the movement of the piston to its limits within the combustion chamber

THE AIRPLANE ENGINE

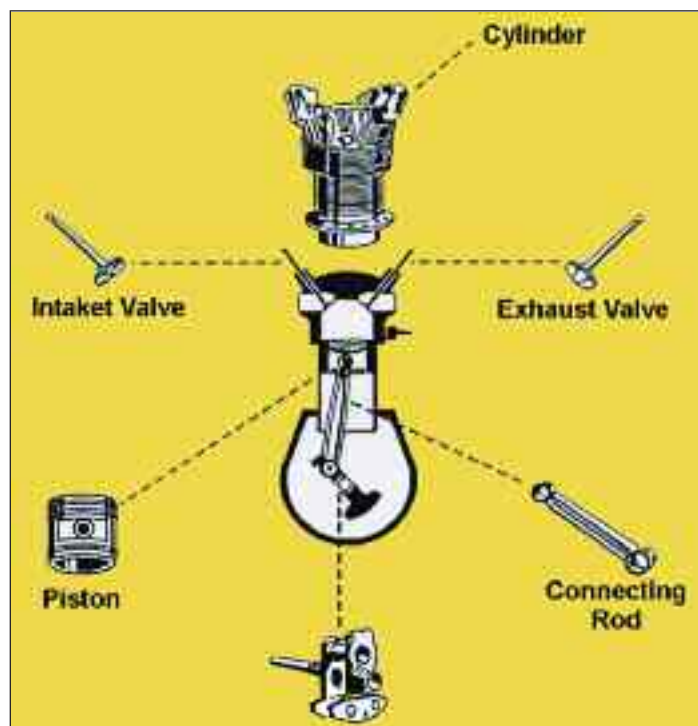
An airplane engine is the propulsion system for the aircraft. It supplies the power for the airplane and is called a powerplant when a portion of its energy is used to run other accessories, such as the electrical system and cockpit heating and air conditioning.

On the right is a picture of the external components of an airplane engine, but what's on the inside? The internal components of a reciprocating engine are mentioned in the picture at the bottom of the page. A **reciprocating** engine is also known as an internal **combustion** engine because a fuel mixture is burned within the engine. To understand how a reciprocating engine works, we must take a look at the engine's major parts and their functions.

Every internal combustion engine must have certain basic parts in order to change heat into mechanical energy. The cylinder forms a part of the chamber in which the fuel is compressed and burned. An intake valve is needed to let the fuel/air into the cylinder. An exhaust valve is needed to let the exhaust gases out. The piston, moving within the cylinder, forms one of the walls of the combustion chamber. The piston has rings which seal the gases in the cylinder, preventing any loss of power around the sides of the piston. The connecting rod forms a link between the piston and the crankshaft.



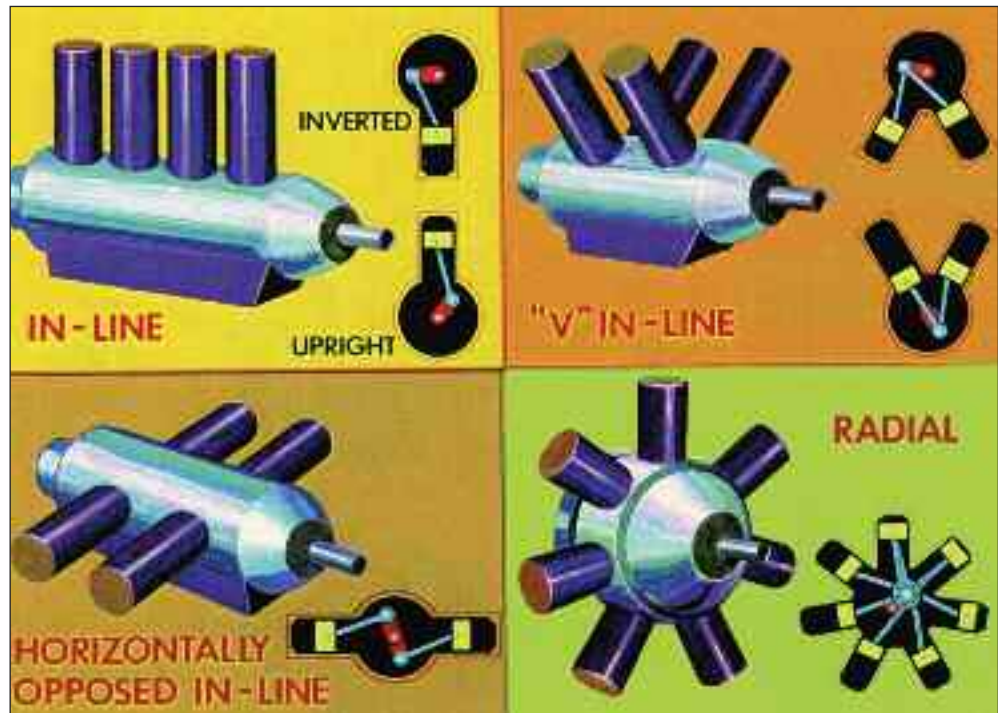
The external components of a Teledyne Continental 0200 Aircraft Engine
Courtesy of Teledyne Continental



The internal components of a reciprocating airplane engine

Cylinder Arrangements

Cylinders can be arranged so that engines may be mounted in different airframes. In-line engines are tall and the nose of the airplane can be slim for aerodynamic efficiency. The “V” and horizontally opposed in-line arrangements are compact and ideal for small aircraft. The radial design presents each cylinder to the oncoming air for maximum cooling efficiency.



Most reciprocating engines have one of these four cylinder arrangements.

Modern Aircraft Powerplant Operation

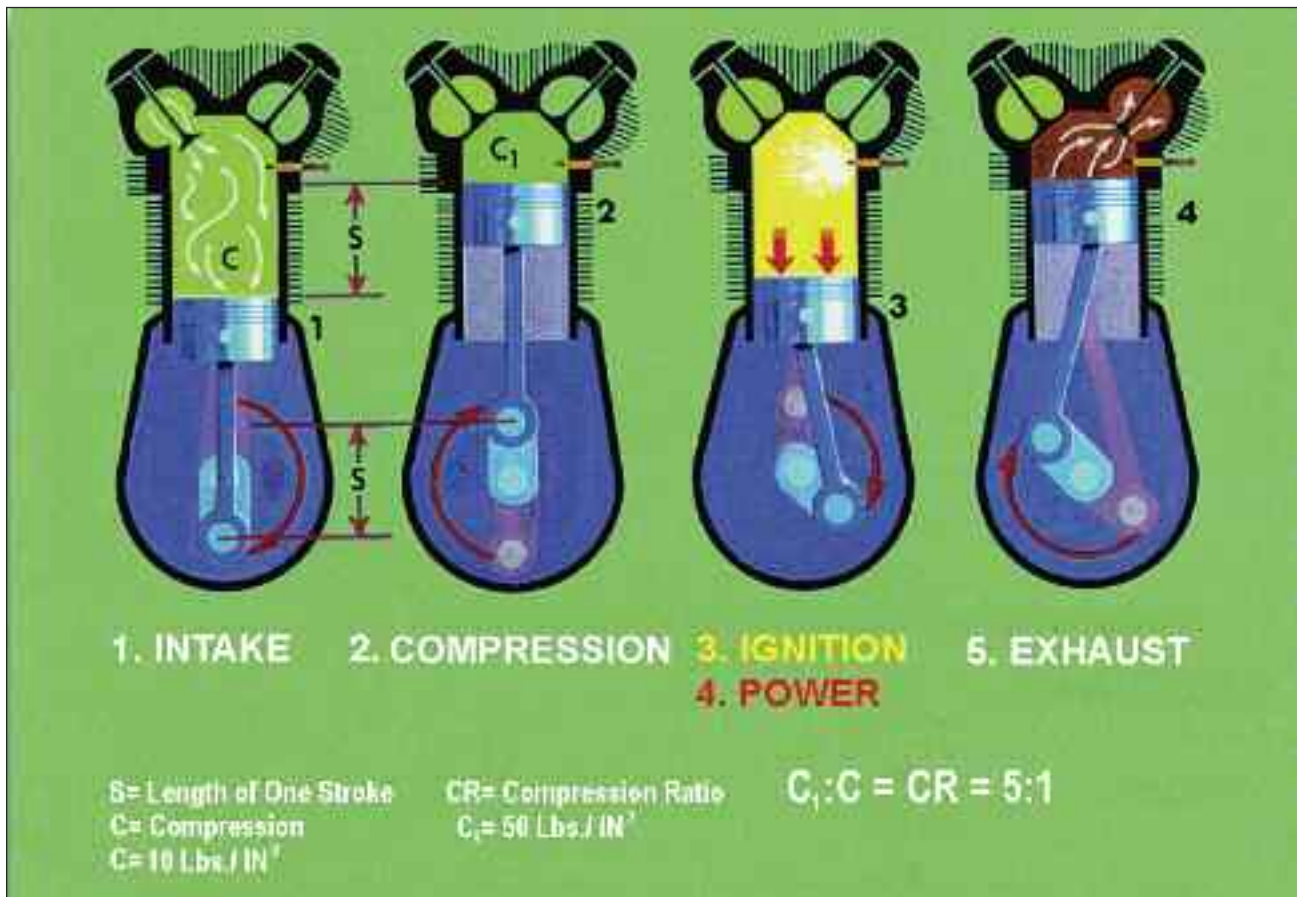
A modern airplane engine is a device that converts chemical energy into mechanical energy. Air mixed with gasoline is drawn into a cylinder, then compressed by a piston moving up and down inside a combustion chamber. A small bolt of lightning from a spark plug ignites the mixture of fuel and air and this causes an explosion that drives the piston downward, creating power. The next step is to get the burned-up gases out of the cylinder. This is done by opening a mechanical “door” called a valve. This “door” momentarily opens and the piston pushes the gases out past the valve into an exhaust pipe. The process starts all over again, hundreds of times a minute. This is known as a four-stroke operating **cycle**.

The standard configuration for a general aviation aircraft engine is to have four or six cylinders opposite each other. There are two “banks” of cylinders and this design is called horizontally opposed. The opposed engine has a very narrow silhouette and this allows aircraft engineers to design cowlings, or engine covers, with a low aerodynamic frontal area drag. This shape also allows engineers to install engines on wings with a minimum of drag. The wing-mounted engine is usually covered with a streamlined enclosure called a nacelle.

Converting Chemical Energy to Mechanical Energy

In a reciprocating engine, the piston moves up and down converting air and fuel to energy and exhaust. The first **stroke** occurs when the piston moves downward and simultaneously an intake valve opens. This is called the “intake” stroke and a mixture of air and fuel is sucked into the engine. A squeeze, or “**compression**,” occurs after the intake valve closes and the piston moves upward com-

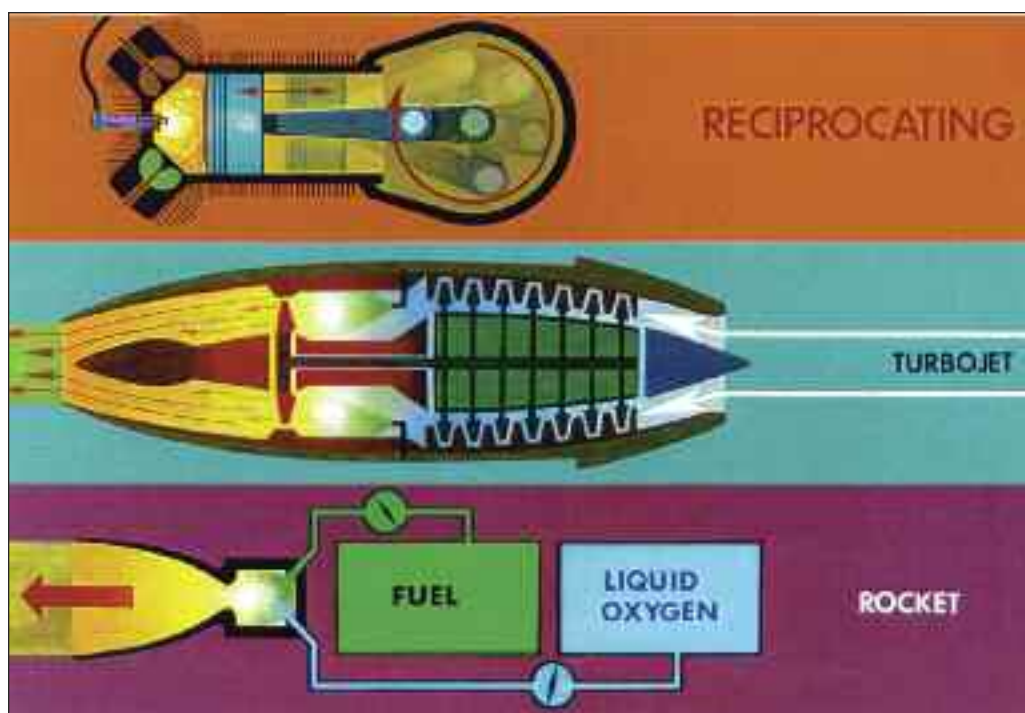
pressing the mixture of fuel and air. Then when the piston has reached its full upward travel, known as “top dead center,” a spark ignites the mixture of fuel and air. This is the ignition or “power” phase. The explosion pushes the piston downward and this energy is then transmitted to the crankshaft, which in turn powers the propeller. The propeller rotates providing forward thrust. The piston keeps on going and in a final stroke, pushes the “exhaust” gases out of the cylinder. An exhaust valve opens simultaneously and the gases are expelled.



The four-stroke (5 event) operating cycle of a reciprocating engine: (1) Fuel and air are drawn into the cylinder during the intake stroke. (2) The fuel/air mixture is compressed by the upward stroke. (3/4) A spark ignites the mixture forcing the piston downward producing power that turns the propeller. (5) The burned gases are expelled by the upward stroke.

Comparing the Reciprocating, Jet, and Rocket Engines

In both the reciprocating and jet engines, air enters during an intake phase. It is then compressed by a piston or by a set of compressor fan blades in a jet. The reciprocating engine has a spark plug for ignition. Once started, a jet engine maintains its combustion by the extremely hot gases. When the explosion occurs, gases are expelled from both through an exhaust pipe. A rocket, on the other hand, carries its oxygen with it. As shown in the illustration on the following page, fuel and oxygen are mixed together and ignited. This provides an enormous amount of power.



A comparison of the three most commonly used aircraft engines

The Chemistry of Power

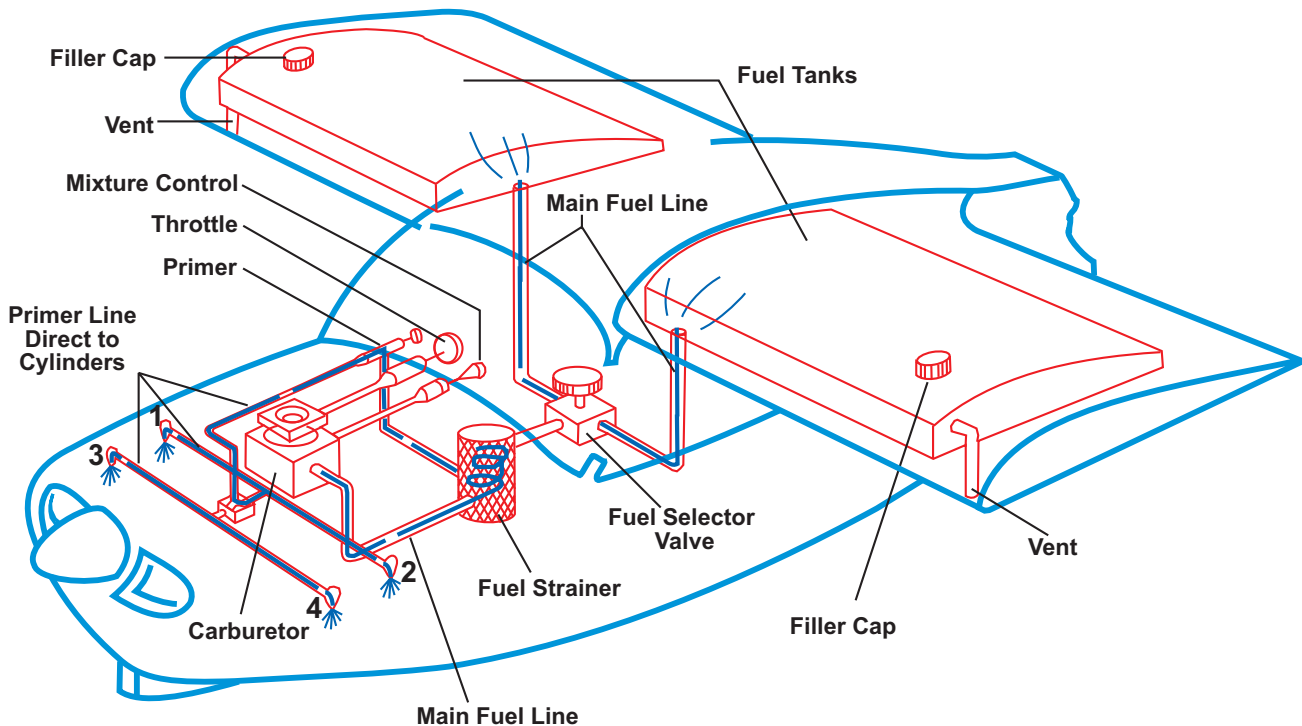
Before getting into the control system that enables a pilot to regulate power to an engine, let's look at the “chemistry” of power. An airplane engine is a “heat” engine. It converts heat energy into mechanical energy, and it is this mechanical energy that turns the propeller. Millions of years ago, the Sun provided energy to billions of plants and prehistoric animals, and over long periods of time their remains have been converted into what we now call “fossil fuels.” When these fossil fuels are refined into gasoline, it becomes a source of energy for airplane engines.

A mixture occurs when two chemical compounds come together, yet are not chemically combined. Gasoline and air are mixed in the carburetor, but don't chemically combine until they get inside the closed cylinder. In scientific terms, the air molecules do not become part of the gasoline molecules until they are burned. When they are ignited, a chemical reaction, known as oxidation, occurs and energy is released. That's what drives the propellers and jet turbines. After this **combustion** occurs in the **combustion chamber**, the gasoline molecules are converted into other compounds like carbon monoxide, carbon dioxide, and water, and are expelled as exhaust.

One of the most efficient mixtures of gasoline and air is called the **stoichiometric** ratio. This is 15 parts air to one part gasoline and, theoretically, when ignited, all of the **fuel** is burned. Sometimes, however, this ratio is not desirable. An example would be during initial engine startup when the outside temperature is cold. A **rich mixture** works better because there is more gasoline and less air. A **lean mixture** contains less fuel and more air. A leaner ratio works better after the engine is warmed up. One problem exists with a stoichiometric mixture. It can get very hot, and over prolonged periods too much heat can damage an engine. Modern engines are designed to operate most efficiently with a mixture near 12 parts air to 1 part fuel. Pilots can control this in the cockpit with the mixture control.

Gravity-Feed Fuel System

This is a greatly simplified diagram of a gravity-feed fuel system in a high wing aircraft. Stylized renderings of only the major parts are shown. Drain valves and plugs, fuel line strainers, interconnect vents, etc. have been deleted for clarification of the system and its function.

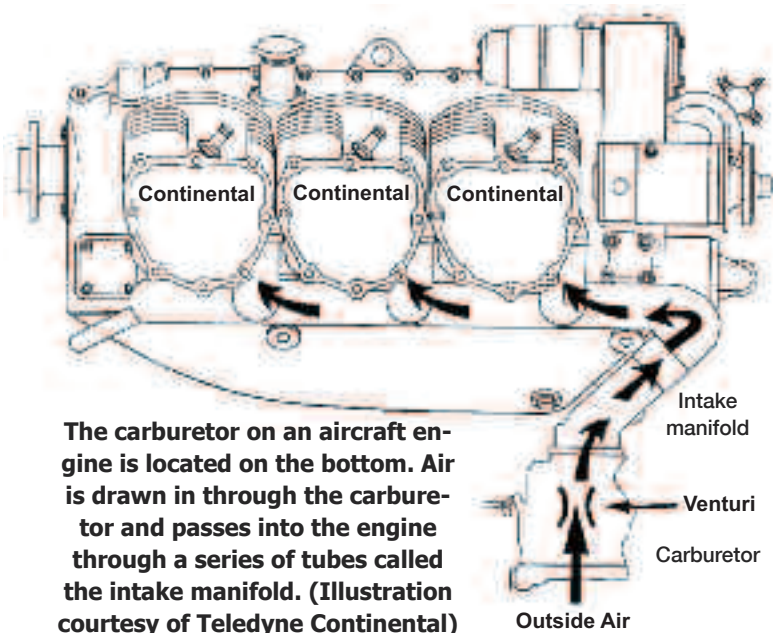


Fuel-Metering Carburetors

To develop the maximum amount of power, an engine must have the right mixture of gasoline and air supplied to it during the intake or suction phase. The volume of fuel and air is controlled by the throttle which operates the carburetor.

A carburetor functions because of the lower pressure created when a piston moves down on the intake stroke. When the air is sucked into engine, it comes in through a tube system and the carburetor is located between the outside air and the inside of the engine.

The carburetor has a restriction in it called a venturi. This causes air from the outside to accelerate as it passes through the restriction. A drop in pressure occurs inside the venturi and this sucks gasoline out of the carburetor



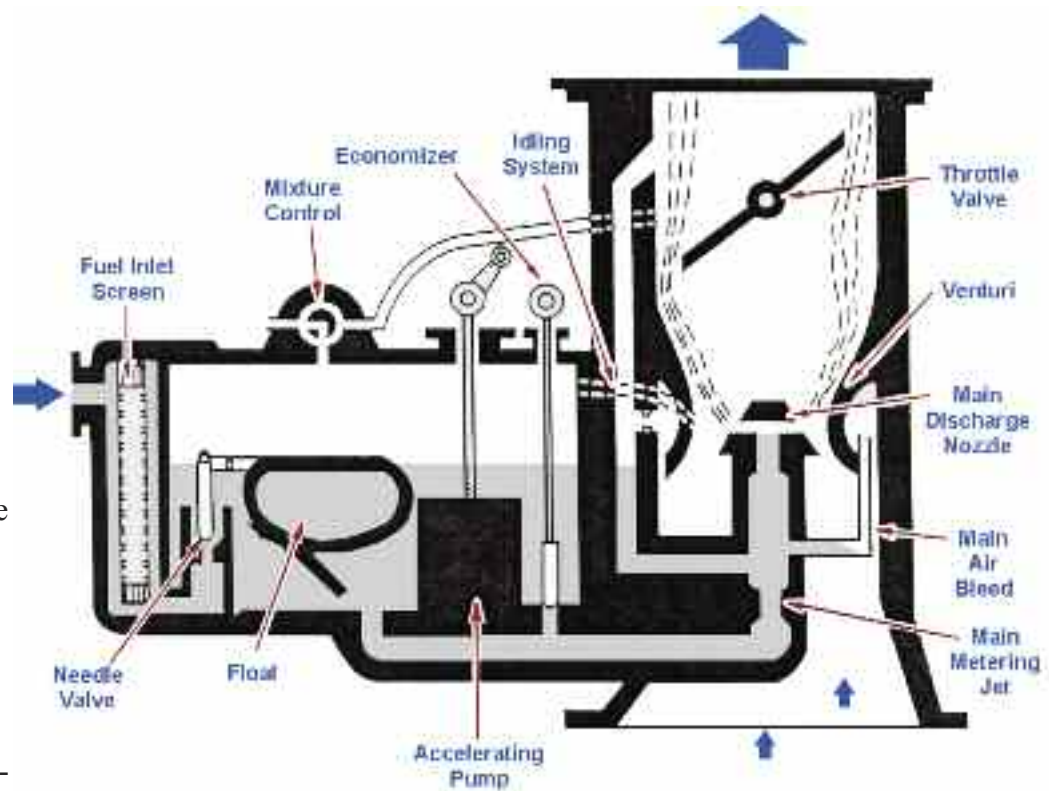
into the airflow. There is a small “gate” in the carburetor that controls the amount of air going into it. This gate is called the throttle valve and is controlled by the pilot in the cockpit. It is a hand-operated control and it’s called the throttle.

When the throttle is closed, the throttle valve seals the carburetor. As the pilot pushes the throttle forward, it opens the throttle valve in the carburetor. The engine is started and the pistons start moving, creating a suction.

The air is sucked in from the outside, and as it passes through the venturi in the carburetor, it speeds up. When this acceleration occurs, the pressure drops and fuel is sucked into the air flow. The air and fuel mixture then travels down into the engine past one of the intake valves. When the intake valve shuts, the trapped fuel and air gets compressed.

Every time a little fuel is sucked out of the carburetor into the stream of air, it has to be replaced or the cylinders will starve. Inside the carburetor, there is a chamber that holds gasoline until it is needed. This is called the float chamber. There is a float (somewhat like those found in a toilet tank) that monitors the amount of gasoline in the chamber. When the gasoline is drawn into the venturi of the carburetor, the float drops. A gate in the float chamber opens and allows gasoline from the fuel tanks to fill up the float chamber. Either a fuel pump or gravity is used to get the gasoline from the fuel tank to the carburetor. This force puts pressure on the line and keeps the float chamber supplied with fuel.

There is a very important component in the carburetor “system” and it’s known as the carburetor heat. Under certain flying conditions, air passing into a carburetor will form ice in the venturi. This can be dangerous since it can make the carburetor inoperative. If icing chokes the carburetor, the engine will quit. To solve this problem, pilots are taught how to use the carburetor heat control so that it melts the ice. Carburetor heat is made available by using the hot air that surrounds the exhaust system. When the pilot pulls the carburetor heat control, heated air is channeled into the carburetor. This closes off normal filtered air and directs exhaust-heated, unfiltered air into the carburetor. When the hot air goes through the carburetor, existing ice is melted and the water passes through the engine. Momentarily, this creates a problem because hot air is much less dense than cold air. The engine will run rough due to a fuel/air mixture that is too rich. After the ice is removed, it is proper pilot procedure to close the carburetor heat and return to colder air.



A simplified illustration of a carburetor

Powerplant Controls

In most training airplanes used by the Civil Air Patrol, there are only two engine controls, the throttle and mixture. In airplanes, the throttle is hand-operated and it controls engine speed by regulating the amount of air and fuel that flows into it during the “intake,” or suction phase.

Normally, at sea level, there is a considerable amount of oxygen and nitrogen in the air; however, as we climb higher and higher into the atmosphere, the number of air molecules decreases. (Research has found that 50% of all of the atmosphere’s air is located below 18,000 feet above sea level.)

Although the percentage composition of nitrogen and oxygen remains basically the same, the amount of nitrogen and oxygen is less at higher altitudes. As a result of less air (fewer air molecules), less fuel is needed. For that reason, a pilot must control the amount of fuel during the *suction* phase of engine operation. This is done with the mixture control in the cockpit. It is used to “**meter**” the amount of fuel available to the carburetor.



The throttle and mixture controls

Electrical Power to the Spark Plugs

Electrical energy is required to operate radios, lights, and other aircraft equipment. However, the electrical power to the spark plugs is supplied by **magnetos**, which are separate from the aircraft’s main electrical system. If a pilot were to shut off all electrical power during flight, the engine would continue to operate.

In the early days of aviation, airplanes were not equipped with an electrical system, yet the engines had spark plugs that required continuous energy. This power was supplied by magnetos. A magneto is an electrical generator that produces power when it is rotated. The airplane’s engine rotates the magneto mechanically and this produces the spark for the spark plugs.



Twin magnetos are located at the back of the engine
Photo courtesy of Teledyne Continental

When watching a movie or video about an early aviation pioneer, you may see a pilot sitting in the cockpit and someone in front manually spinning the propeller. This procedure has been around for years and is a mechanical method of getting spark to the airplane's engine. Here's how it works: The person in front of the airplane spins the propeller; the crankshaft turns and this mechanically rotates the magneto. When the magneto turns, electrical energy goes to the spark plugs, and the engine starts. Once started, the rotation of the crankshaft keeps the magneto going and this supplies the spark plugs with power.

The Electrical System

Most airplanes are equipped with a 14-28 volt electrical system and the electrical power is supplied by an engine-driven alternator. This component also keeps the battery charged. The battery is especially important for starting the airplane.

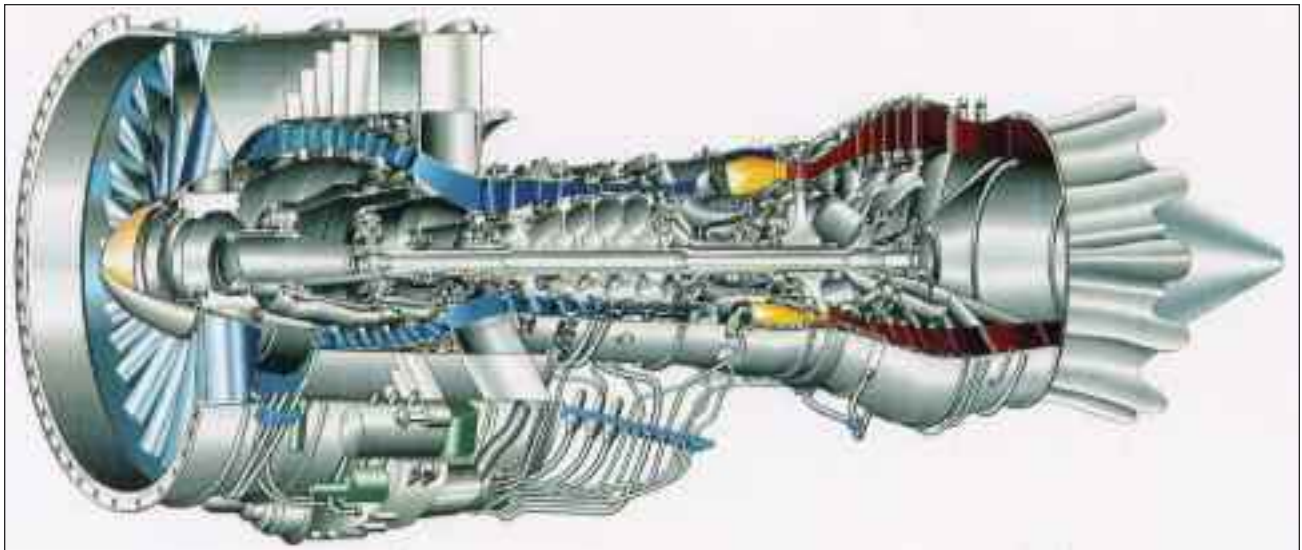
Alternators produce alternating current, which is then converted to direct current. Electrical power is supplied to the bus bar (see schematic on page 10) which distributes this energy to the accessories.

In the cockpit, there is an instrument that monitors the electrical current, or flow, called the ammeter. Another important electrical component in the system, which is located in the cockpit, is the master switch. The master switch has to be "on" to engage the starter, and, in the event of an alternator malfunction in flight, the master switch can be turned "off" to isolate the alternator from the rest of the system.

As the schematic shows, there are many circuit breakers and fuses that protect the system from electrical overloads. When a circuit breaker "pops," the electrical power to that accessory is stopped. Resetting the breaker will usually reactivate the circuit; however, if there is still an overload, or an electrical short, the breaker will continue to pop until the problem is fixed. A fuse, on the other hand, is an electrical device that has a thin metal piece between two metal connections. The thin metal piece is designed to break when an electrical overload, or short, occurs. Unlike the circuit breaker, a fuse must be replaced once the metal connection is broken.



**The alternator on an airplane engine looks much like the one on an automobile.
Photo Courtesy of Teledyne Continental**



**On the left side, (front), you will see the large fan section. Air enters there, is compressed (blue) in the compressor section and ignited in the burner section (yellow). This spins the turbine (red) and part of this energy is used to turn the center shaft. The rest is expelled out the tail pipe (in rear) as thrust.
(Artwork of PW6000 engine courtesy of United Technologies, Pratt & Whitney Division)**

ENGINE INSTRUMENTS

One of the most important operations inside an engine is lubrication. This is accomplished by oil, which allows metal parts to work together. Oil is as important to an internal combustion engine as blood is to the human body. Oil has two primary functions in an engine: (1) to lubricate moving parts; and (2) to carry away heat.

In most training aircraft, a pilot has two instruments that give information about the operation inside the engine. One of the most important is the oil pressure gauge. The oil is circulated through the engine by a pump and it is the oil pressure gauge that monitors this operation. Close to the oil pressure gauge is the oil temperature gauge. This allows the pilot to monitor the temperature and take corrective measures to avoid possible engine damage due to overheating.

Engine speed is monitored by the tachometer. The “tach,” as it is commonly called, also displays the speed of the propeller. Since the propeller is connected directly to the crankshaft of the engine, changes in the speed of the engine mean like changes in the speed of the propeller.



The temperature and oil pressure gauges in the cockpit



The tachometer, displaying engine speed in revolutions per minute

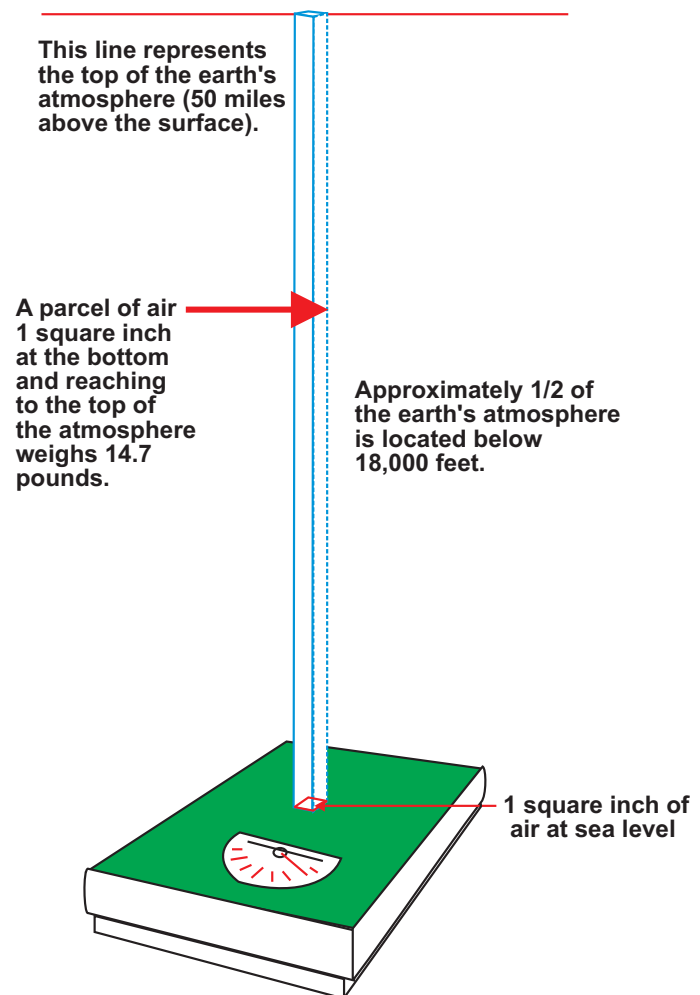
FLIGHT INSTRUMENTS

There are special instruments that allow the pilot to monitor an airplane's operation in flight. Three of these work on the principle of differences in pressure, also known as pressure differential. The other three work on the principle of gyroscopes, maintaining their position while spinning.

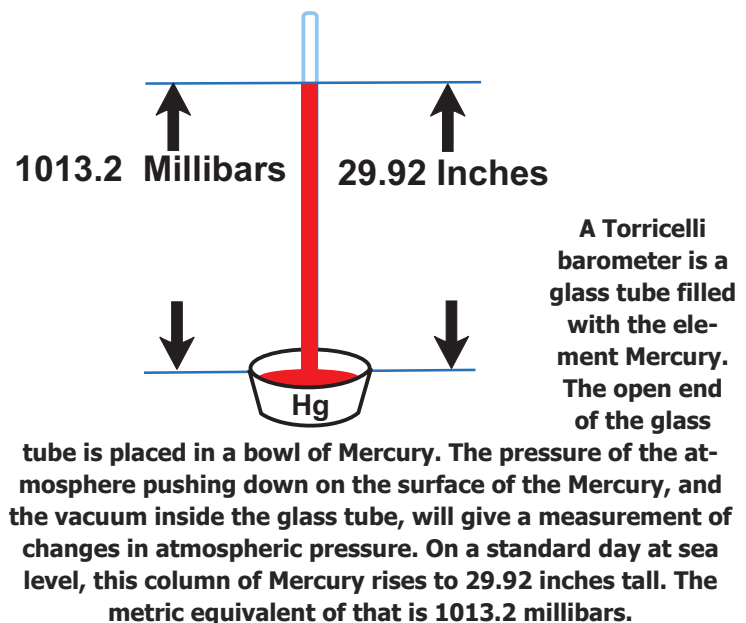
To more clearly understand these instruments, let's first examine pressure differential. Think of a parcel of air, one square inch (about the size of a postage stamp), and 50 miles tall. If you could somehow weigh that space of air anywhere in the world, it would average 14.7 pounds. If you could take weight samples at various levels, up to the top of the parcel, the air would weigh progressively less, and, at the top, it would be virtually weightless.

What does this have to do with altitude measurement in an airplane? If the pressure becomes progressively less as we go higher above the Earth, we can use it to give us precise height information. Think of it this way; if you had an ultra-sensitive pressure gauge, you could get an accurate reading of the altitude gained by going upstairs in a house, or a school, or even up on a chair.

Engineers who build airplane instruments have a set of standard references based on information that scientists have gathered. There are standard references for pressure, temperature, etc. For pressure, at sea level, the standard is 29.92 inches of Mercury, or 1013.2 millibars. This means that our 50 mile-tall column of one square inch of air would cause a mercury barometer to stand 29.92 inches tall. As stated earlier, when we go higher in altitude, the air weighs less and the pressure drops. Scientists found that the average pressure drop, for every 1000 feet of altitude gained, is one inch. See the diagram to the right. **(It must be noted that the element Mercury is dangerous, and only a trained and highly-qualified scientist should experiment with it.)**



The weight of the air upon every square inch of the Earth's surface is approximately 14.7 pounds at sea level and decreases to nearly zero at 50 miles above the surface.



The Altimeter

Since pressure is related to altitude, we are able to tell how high we are by monitoring the pressure in an airplane compared to a pressure reference on the ground or at sea level. That is how altimeters work. Just before take-off, a pilot sets the altimeter to the local pressure. Then as the airplane climbs, the pressure begins to drop. The altimeter senses this change and displays it as altitude.

The Vertical Velocity Indicator

When the airplane levels off at a given altitude, and the pressure stabilizes, another instrument reads this as zero. If the airplane goes up or down from this point, the instrument senses the change and gives the pilot a rate of climb, or ascent. This instrument is known as the VVI or Vertical Velocity Indicator. You may also hear it referred to as the “rate of climb.”

The Airspeed Indicator

Another very important instrument records the difference between still air (static) and air that is being rammed into the system. Compared to a car, it is the airplane’s “speedometer.” In the language of instruments, it is called the airspeed indicator. Outside, usually located on a wing, is a small, hollow tube called the pitot. As the airplane moves forward, the relative wind flows into the pitot tube and this creates a ramming effect that is registered as pressure. When this ram air is compared to still air, it can be displayed as speed. The difference between the ram air and the still air gives what is known as a pressure differential. A static port provides the system with information from an area of undisturbed air.

Indicated airspeed is the information you get when you read the airspeed indicator, directly. Another, known as the calibrated airspeed, is the indicated airspeed corrected for errors that may occur in the instrument itself. The next kind of



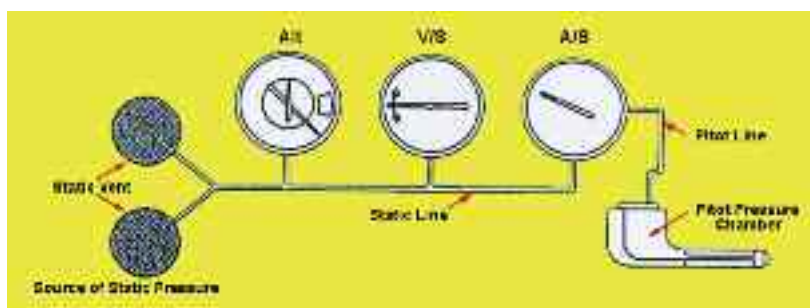
The altimeter measures pressure and displays this as height above sea level



The vertical velocity indicator displays a rate of change in altitude



The all-important airspeed indicator



The Pitot Static System Schematic

airspeed is known as true. True airspeed is the actual speed of the airplane through the air. This kind of airspeed is corrected for pressure and non-standard temperature. In “language” terms, pilots will say, “...my airplane *trued out* at 180 knots.” It means that after adjusting the airspeed indicator, at a given altitude, the airplane is traveling at 180 knots. Finally, there is the speed over the ground. This is referred to as ground speed and can be calculated by the time it takes for the airplane to fly between two or more points on the ground. For your information, a regular mile is known as a statute mile and is 5,280 feet long. A nautical mile, often referred to as a “naut,” or “knot,” is 6,076 feet.

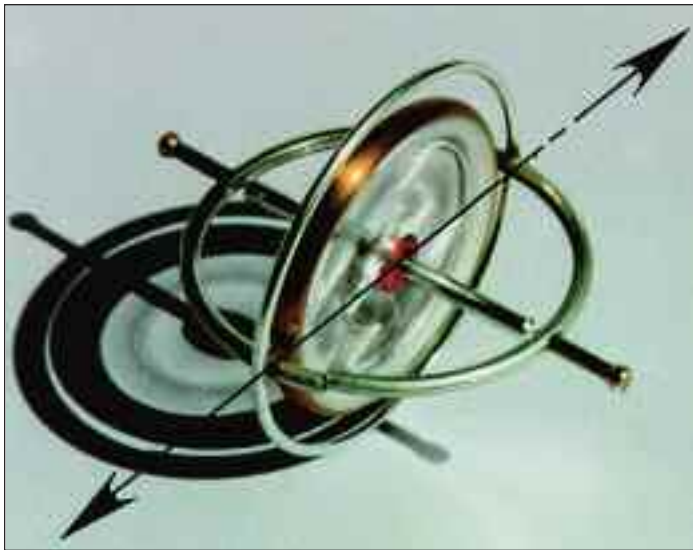
Flight Instruments-Gyro Power

These instruments are based on the principle of a spinning gyroscope. The gyroscope has a small rotating wheel, called a rotor, that is mounted on an axle. The rotor will maintain its position in space while spinning at a very high speed. This principle is called rigidity in space and means that once the rotor starts to spin at high speed, it strongly resists changes and forces applied to it. As long as it remains in one place, and the rotor spins, it will give the pilot valuable information about direction, banking, and attitude. Note that the gyro is mounted in two rings, called gimbal rings. These rings allow the gyro to rotate freely, or universally. By various methods of mounting, gyros are an energy source in three very important flight instruments: altitude indicator, heading indicator, and turn coordinator.

Let’s take a look at the gyroscope as an “experiment.” A toy gyroscope (gyro for short) can be made, but it is much more convenient to buy one at a hobby, craft, or toy store. Here’s how they work: A string is first inserted into a hole in the gyro’s axle. The string is wound tightly around the axle. A hard pull on the string will spin the axle at high speed and that’s when Newton’s First Law of Motion takes over. This law states, “a body at rest will remain at rest unless acted upon by some outside, unbalanced force, or a body in motion will remain in motion unless acted upon by some outside, unbalanced force.” Now, when it’s spinning you can actually balance the gyro on the tip of a pencil! Amazing, but true! If it is standing up, that’s the principle behind the airplane’s attitude indicator; if it is on its side,



A toy gyroscope shows how it can maintain its position while spinning. When the rotor is spinning perpendicular to the surface, it is parallel to the horizon. The attitude indicator is based on this principle. It gives the pilot an “artificial horizon.”



Once a vertically-mounted rotor starts to spin, it tends to stay in that alignment. The heading indicator becomes an artificial compass and gives the pilot directional information.

and the rotor is spinning perpendicular to the surface, that's the principle behind the airplane's heading indicator and turn coordinator.

If a rotor is aligned vertically, it can give direction information. Imagine that the airplane is sitting on the ground with its nose pointed north. When the airplane is started, the rotor starts to spin. No matter what direction the airplane goes, the rotor will continue to spin still aligned to north. This is the basis of a heading indicator, an instrument also known as the "directional gyro."

The heading indicator can be set without the airplane facing north. An example of this may be that the airplane is headed west when the engine is started. The pilot rotates a small knob on the face of the instrument so that it shows west, or 270 degrees. The instrument is now automatically corrected for all other headings. The pilot uses a precision magnetic compass, located usually above the instrument panel, for these corrections. (See associated Activity One at the end of the chapter.)



The turn coordinator uses the gyro principle for banking information.

Also displayed with the turn coordinator is a simple instrument called an inclinometer. This is nothing more than a curved, liquid-filled glass tube with a ball inside. If a turn is not being executed properly by the pilot, the ball will give a clear indication of poor technique. If the banking maneuver is done properly, the ball will stay in the center throughout the procedure. The inclinometer shows whether the airplane is slipping or skidding in a turn. Slipping means that the airplane is moving toward the inside of the turn and skidding means it's moving away from the radius of the turn.

THE GLASS COCKPIT – A New Generation of Aircraft Instrumentation



This image gives you a closer look at the Captain's panel of a Cessna 172 airplane. The display in front of the pilot is referred to as the PFD, or Primary Flight Display. The upper ADI, or Attitude Director Indicator, is bracketed on the left by the "Speed Tape" Indicator and on the right by the "Altitude Tape" Indicator. The bottom half is the Horizontal Situation Indicator and shows a full compass rose presentation with a terrain mode overlay.

What is a "Glass Cockpit?"

A glass cockpit is an airplane cockpit that features electronic instrument displays. The glass cockpit has become standard equipment on most aircraft today, including airliners, military aircraft, and general aviation aircraft. The glass cockpit was even fitted on several of the recent Space Shuttles.

Aircraft used to rely on mechanical gauges, but over the years as more instruments and controls were added, the cockpit became very crowded. The growing number of instruments competed for space and the pilot's attention. The introduction of electronic displays and digital information changed that. The glass cockpit represented a huge technology update and an improvement.

The glass cockpit displays the information in an easily understood picture of the aircraft situation and position. It does this, not only in horizontal and vertical dimensions, but also in regard to time and speed. The glass cockpit reduces the pilot's workload and at the same time gives the pilot situational awareness. The multi-colored, multi-functional flat screens are much easier to read and understand. The glass cockpit has improved pilot efficiency and airplane safety.

NASA, the aerospace industry, and the Department of Defense are all using glass cockpit technol-



The glass cockpit of a Cessna CJ2 Citation – Image by Alex McMahon

ogy to increase performance of their aircraft and the pilots who fly them. Additionally, both airlines and passengers are benefitting from this new technology. The cost of travel is less than it would be with the old technology and more flights arrive on time.

Future Developments

The newest developments in cockpit displays look and behave a lot like other computers, with windows and data that can be manipulated with point-and-click devices. They also add terrain, approach charts, weather, vertical displays, and 3D navigation images.

The improved concepts enable aircraft makers to customize cockpits to a greater degree than was previously done. All of the manufacturers involved have chosen to do so in one way or another—such as using a trackball, thumb pad, or joystick as a pilot-input device in a computer-style environment. Many of the modifications offered by the aircraft manufacturers improve situational awareness and customize the human-machine interface to enhance safety.



Glass cockpit of a Piper Saratoga

As aircraft displays have modernized, the sensors that feed them have modernized as well. Traditional gyroscopic flight instruments have been replaced by Attitude and Heading Reference Systems (AHRSs) and Air Data Computers (ADCs), improving reliability and reducing cost and maintenance. (GPS) receivers are frequently integrated into glass cockpits.

Modern glass cockpits

might include the Synthetic Vision System (SVS) or the Enhanced Vision System (EVS). Synthetic Vision Systems display a realistic 3D depiction of the outside world (similar to a flight simulator), based on a database of terrain and geophysical features in conjunction with the attitude and position information gathered from the aircraft navigational systems. Enhanced Vision Systems add realtime information from external sensors, such as an infrared camera.

All new airliners, such as the Airbus A380, and Boeing 787, as well as private jets, such as Bombardier Global Express and Learjet, use glass cockpits. Certain general aviation aircraft, such as the 4-seat Diamond Aircraft DA40, DA42, and DA50, and the 4-seat Cirrus Design SR20 and SR22, are available with glass cockpits. Systems, such as the Garmin G1000, are now available on many new General Aviation (GA) aircraft, including the classic Cessna 172, one of CAP's two major airplanes used for aviation missions. The other major CAP airplane, the Cessna 182, has a glass cockpit.

Glass cockpits are also popular as a retrofit for older private jets and turboprops, such as Dassault Falcons, Raytheon Hawkers, Bombardier Challengers, Cessna Citations, Gulfstreams, King Airs, Learjets, Astras, and many others. Aviation service companies work closely with equipment manufacturers to address the needs of the owners of these aircraft.

GPS – A NEW TECHNOLOGY FOR AEROSPACE NAVIGATION

GPS – Where Did It Start?

The Global Positioning System (GPS) is a navigation and precise-positioning tool. Developed by the Department of Defense in 1973, the GPS was originally designed to assist soldiers and military vehicles, planes, and ships in accurately determining their locations world-wide. Today, the uses of the GPS have extended to include both the commercial and scientific worlds. Commercially, the GPS is used as a navigation and positioning tool in airplanes, boats, cars, and for almost all outdoor recreational activities such as hiking, fishing, and kayaking.

In the scientific community, the GPS plays an important role in the earth sciences. Meteorologists use it for weather forecasting and global climate studies. Geologists can use it as a highly accurate method of surveying and in earthquake studies to measure tectonic motions during, and in between, earthquakes.

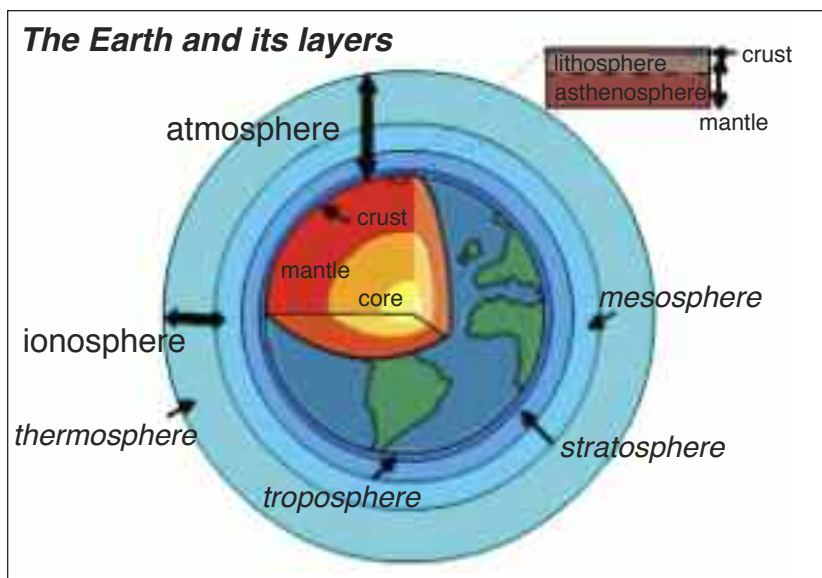


The GPS is a “constellation” of satellites that orbit the earth.

How Does It Work?

Three distinct parts make up the Global Positioning System. The first segment of the system consists of 24 satellites, orbiting 20,000 km above the Earth in 12-hour circular orbits. This means that it takes each satellite 12 hours to make a complete circle around the Earth. In order to make sure that they can be detected from anywhere on the Earth's surface, the satellites are divided into six groups of four. Each group is assigned a different path to follow. This creates six orbital planes which completely surround the Earth.

These satellites send radio signals to Earth that contain information about the satellite. Using GPS ground-based receivers, these signals can be detected and used to determine the receivers' positions



(latitude, longitude, and height). The radio signals are sent at two different L-band frequencies. L-band refers to a range of frequencies between 390 and 1550 MHz. Within each signal, a coded sequence is sent. By comparing the received sequence with the original sequence, scientists can determine how long it takes for the signal to reach the Earth from the satellite. The signal delay is useful in learning about the Ionosphere and the Troposphere, two atmospheric layers that surround Earth's surface. A third signal is also sent to the receivers from the

satellite. This signal contains data about the health and position of the satellite.

The second part of the GPS system is the ground station, comprised of a receiver and antenna, as well as communication tools to transmit data to the data center. The omni-directional antenna at each site, acting much like a car radio antenna, picks up the satellite signals and transmits them to the site receiver as electric currents. The receiver then separates the signals into different channels designated for a particular satellite and frequency at a particular time. Once the signals have been isolated, the receiver can decode them and split them into individual frequencies. With this information the receiver produces a general position (latitude, longitude, and height) for the antenna. Later, the data collected by the receiver can be processed again by scientists to determine different things, including another set of position coordinates for the same antenna; this time with millimeter accuracy.

The third part of the system is the data center. The role of the data center is two-fold. It both monitors and controls the global GPS stations, and it uses automated computer systems to retrieve and analyze data from the receivers at those stations. Once processed, the data, along with the original raw data, is made available to scientists around the world for use in a variety of applications. Since global GPS sites are constructed and monitored by different institutions all over the world, there are many different data center locations.

The Global Positioning System (GPS) was designed as a dual-use system with the primary purpose of enhancing the effectiveness of U.S. and allied military forces. GPS is rapidly becoming an integral component of the emerging Global Information Infrastructure, with applications ranging from mapping and surveying to international air traffic management and global change research. The growing demand from military, civil, commercial, and scientific users has generated a U.S. commercial GPS equipment and service industry that leads the world. Augmentations to enhance basic GPS services could further expand these civil and commercial markets.

The GPS is managed by the National Space-Based Positioning, Navigation, and Timing (PNT) Executive Committee, supported by the PNT Executive Secretariat (<http://www.pnt.gov>). The PNT manages GPS and US Government augmentations to the GPS, consistent with national policy, to support and enhance US economic competitiveness and productivity while protecting national security and foreign policy interests.

The basic GPS is defined as the constellation of satellites, the navigation payloads which produce the GPS signals, ground stations, data links, and associated command and control facilities which are



One of 24 Global Positioning Satellites – Image courtesy of NASA

operated and maintained by the Department of Defense; the Standard Positioning Service (SPS) as the civil and commercial service provided by the basic GPS; and augmentations as those systems based on the GPS that provide real-time accuracy greater than the SPS. The GPS permits land, sea, and airborne users to determine their three dimensional position, velocity, and time, 24 hours a day, in all weather, anywhere in the world.

The GPS is one technology that allows pilots to accurately determine their position anywhere on the Earth within seconds. The GPS is becoming the primary means of navigation worldwide. The GPS units in the aircraft finds the nearest two satellite signals. This process is called “acquisition.” The time it takes for the signals to travel creates a precise triangle between the two satellites and the aircraft, telling the pilot his latitude and longitude to within one meter.

Despite these advances, pilots can still crash because they get lost or lose track of hazards at night or in bad weather. On December 29, 1970, the Occupational Safety and Health Act came into effect. It requires most civilian aircraft to carry an emergency locator transmitter (ELT). In the event of an accident, an ELT is designed to transmit a distress signal and then lead rescuers to the site. The ELT becomes active when a pilot tunes to an emergency radio frequency or activates automatically when the aircraft exceeds a certain force in landing, called the g-force, during a crash. (See associated Activity Two at the end of the chapter.)



Emergency locator transmitter

ACTIVITY SECTION 1

Activity One - Gyroscope: Earthly Spinning

Purpose: After discussing the use of the gyroscope in airplane instrumentation, this activity will demonstrate how the gyroscope works within the force boundaries of Earth, and what principle occurs when the gyroscope is spinning.

Materials: Acquire a toy gyroscope from a hobby, craft, or toy store. The cost is around \$5.00. (Science museums are also usually a good place to locate one, as well as the internet.)

Procedure:

1. Run the gyroscope's string through the hole in the gyroscope rotor's axle.
2. Wind the string onto the axle.
3. Holding the gyroscope, pull the cord with a steady but strong motion.
4. Once the rotor starts spinning, let the gyro rest on its stand.
5. Touch the upper part of the gimbal rings and notice how it wants to stay in position.
6. Let it spin down or stop it with your fingers.
7. Repeat the steps 1-3 and see how many places a gyro will maintain its position, even continuing to work sideways. With careful placement, the gyro will sit on a pencil point!

Summary: Newton's First Law of motion applies here. This law states: "a body at rest will remain at rest unless acted upon by an outside, unbalanced force, or a body in motion will remain in motion unless acted upon by an outside, unbalanced force." On Earth, gravity acts on the gyro. But, in space, without the forces found on Earth, the gyroscope will spin endlessly. Thus, a spinning gyroscope could help demonstrate the principle of rigidity in space, which means that once the gyro is spinning at a high speed, it resists change.



The principles of a gyroscope are amazing

Activity Two - Geocaching

Purpose: To introduce students to a fun reading, geography, math, and technology activity using the Global Positioning Satellite (GPS) technology available for use in the aviation and space programs.

Materials: computer with internet to access information from the Geocaching website <http://www.geocaching.com/>, which includes information on where caches are located; a GPS; note pad; pen or pencil; drinks; and first-aid kit for trip; bug spray; walking stick (optional depending on terrain); small items to use as trade items in the located caches (such as marbles, keychains, special coins, or other significant items);

Procedure:

What is geocaching? Geo stands for Earth and cache stands for container. Geocaching is a high-tech treasure hunting game played throughout the world by adventure seekers equipped with handheld GPS devices. The basic idea is to locate outdoor hidden containers, called geocaches, and then log your find and experiences online. Geocaching is enjoyed by people from all age groups, with a strong sense of community and support for the environment. There are hundreds of thousands of registered geocaches hidden around the world. One of the big surprises is how many geocaches there are in virtually all vicinities (some even in the places people regularly walk their dogs). This would be a great way to enliven a long boring car journey, adding extra interest to a unit or school field trip.

Follow the guidance below.

1. Give yourself or your team a name to use online at geocaching.com and to log your find at the cache location.
2. While online select and print at least one cache you want to find by searching the zip code of the desired area. You may want to select a cache with a larger container size in hopes of being able to trade items for your group.
3. Read your selected cache description, checking cache size and terrain. You can pull up the goggle map to get a general idea of the area where it is located. Caches can be in parking lots or deep in the woods. Print out your selected cache page information and take it with you.
4. Use the coordinates given by the hider to find the cache. Put these coordinates in your GPS and hit go on the GPS.
5. Once you arrive, use stealth in finding the cache. Not all people are in the game. You don't want



This find was a larger size container in the woods. The kids enjoy the trade items and the log gets signed.

others seeing you find the cache or they may not respect the game and may move it or take it. Use your GPS to get as close to the exact location as you can. Hopefully this will bring you within 10 feet or closer.

6. Start your hunt. The cache can be a large Tupperware container full of fun trade items hidden under branches or it can be a small magnetic cache stuck on something metal so small it only holds a small piece of paper to sign. Many are very creative and are something you would never think was even a container.
7. Inside the cache is a log. Enter your cache name on the log so you can show that you have found it. The first cacher to find a newly published cache gets “first to find” (FTF) honors. And will sign the log FTF. Others might put TFTC which means “thanks for the cache”.
8. Use your paper to make any notes to describe your find and to record back at your computer. You will log it as a “find” and get a smiley or a “did not find” (DNF) and maybe a fun story about your adventure without giving information about what the container was or the exact location. It takes the even the most experienced geocacher a few times to find some of the harder ones, so don’t get discouraged.
9. Larger cache containers often have small trade items. If you take something it is nice to leave something for the next person to enjoy or use for trade. You may find a geocoin or travel bug (which are trackable items described on the website). If you take one, you must find another cache to leave it in and log where you moved it to on the website. The owner has written a mission or goal and watches its movement online.

Summary: This activity familiarizes you with a GPS. Some GPSs have geocaching programs so you can read the information while you are geocaching.



This Geomate Junior Geocaching GPS is great for kids. But any GPS can be used.

AIRPORTS

2



During the last week in July and the first week in August, Wittman Field, in Oshkosh, Wisconsin, becomes the busiest airport in the world. This occurs during the annual Experimental Aircraft Association (EAA) fly-in called AirVenture.

Learning Outcomes

- Explain the basic layout of a general aviation airport.
- Identify taxiway and runway signs and markings.
- Explain the role of the Federal Aviation Administration in controlling air traffic.
- Identify the different phases of the flight profile.
- List the phonetic alphabet.

Important Terms

ATC - air traffic control

beacon - a tower-mounted, large, rotating light located at an airport that gives pilots a guide to the type of airport and the airport's location

controlled airport - an airport with an operating control tower

control tower - a structure that houses air traffic controllers

course - the intended path of flight, which is measured in angular degrees from true or magnetic north on a compass

FAA - Federal Aviation Administration, which is the regulatory authority for all aviation

flight profile - a standardized series of steps the pilot takes from take-off to landing

FSS - Flight Service Station - a FAA facility that provides pilots with weather briefings and flight planning (opening and closure)

heading - the direction that an airplane points with respect to true, or magnetic, north including any wind displacement; based on its longitudinal axis

noise abatement - a policy set forth by a governing body that controls the noise impact upon a community surrounding an airport

ramp - the airport's "parking lot"

runway - a dedicated pathway for taking off and landing airplanes

runway heading - a number labeling a runway, which is based on corresponding degrees from true, or magnetic, north

segmented circle - a set of indicators, usually surrounding an airport's wind sock, that provide traffic pattern information to a pilot in the air

taxi - ground movement of an airplane

taxiway - a passageway between the parking area and the runways of an airport

tetrahedron - a device that gives an indication of the landing direction at an airport

traffic pattern - a rectangular virtual path above an airport that facilitates the coordination of the flow of aircraft in the air

uncontrolled airport - an airport without an operating control tower

wind direction indicators - several types of devices that give a pilot an indication of wind direction

wind sock - a fabric tube that shows which direction the wind is from



Naples, Florida Airport – Images by Alex McMahon

THE FLIGHT PROFILE

There are basically two kinds of airports, **uncontrolled** and **controlled**. An airport can be a small grassy field, located in a pasture, or it can be a large center for commercial or military aviation.

When an airplane departs an airport, large or small, it normally follows a standard **flight profile**. Whether it's a Piper Cherokee with a student pilot at the controls or a Lockheed SR-71 on a routine mission, it follows basically the same procedure every time. Refer to the illustration below to follow the listed profile:



Not all airports are acres of concrete and asphalt. In many parts of the world, grassy fields are home for airplanes like this Australian Tiger Moth.

(A) While the airplane is parked, the pilot walks around and examines it externally. This is called the preflight inspection. Fuel & oil levels, control surface freedom-of-movement, flaps check and landing gear condition are just a few of the many important items a pilot examines before starting the airplane.

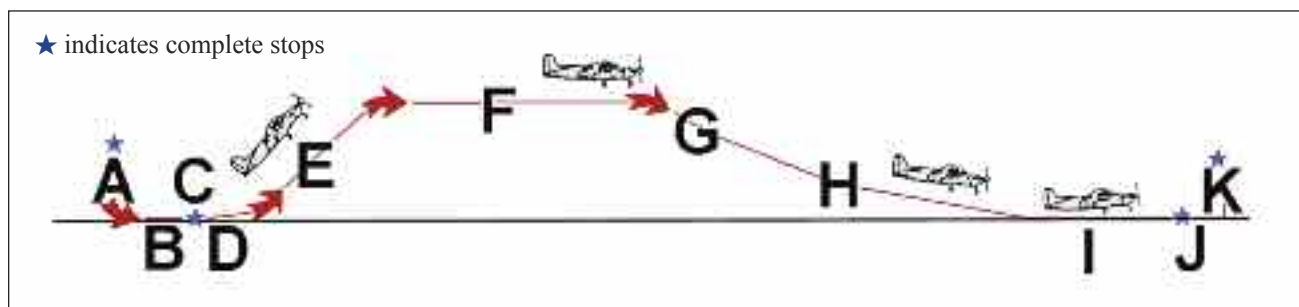
(B) Using the example of a controlled airport, the pilot gets movement clearance from the ground controller in the airport control tower. This is the **taxi phase** of the profile. The pilot taxis the airplane along a **taxiway** and then stops before entering a **runway**.

(C) The pilot sets the parking brake, does an engine run-up, checks magnetos, sets mixture, checks carburetor heat, checks engine instruments, checks flight instruments, and makes sure that all flight controls are moving properly. Passengers are briefed, seat belts and shoulder harnesses are checked, and the pilot calls the **control tower** for clearance to take off.

(D) Once cleared by the tower controller, the pilot enters the runway and the takeoff portion of the flight profile begins.

(E) After takeoff, the pilot puts the airplane into the climb portion of the profile. During this period, the air traffic controller may ask the pilot to follow a specific **traffic pattern**. Once clear of the airport traffic, the pilot may continue climbing until a desired altitude is reached.

(F) The pilot then levels off and the aircraft enters the cruise part of the profile. Depending upon preflight planning, the pilot may elect several options for the rules that govern flying. An example of this is VFR, or Visual Flight Rules. If the pilot elects to go from point to point using these rules, all



The flight profile—from takeoff to touchdown

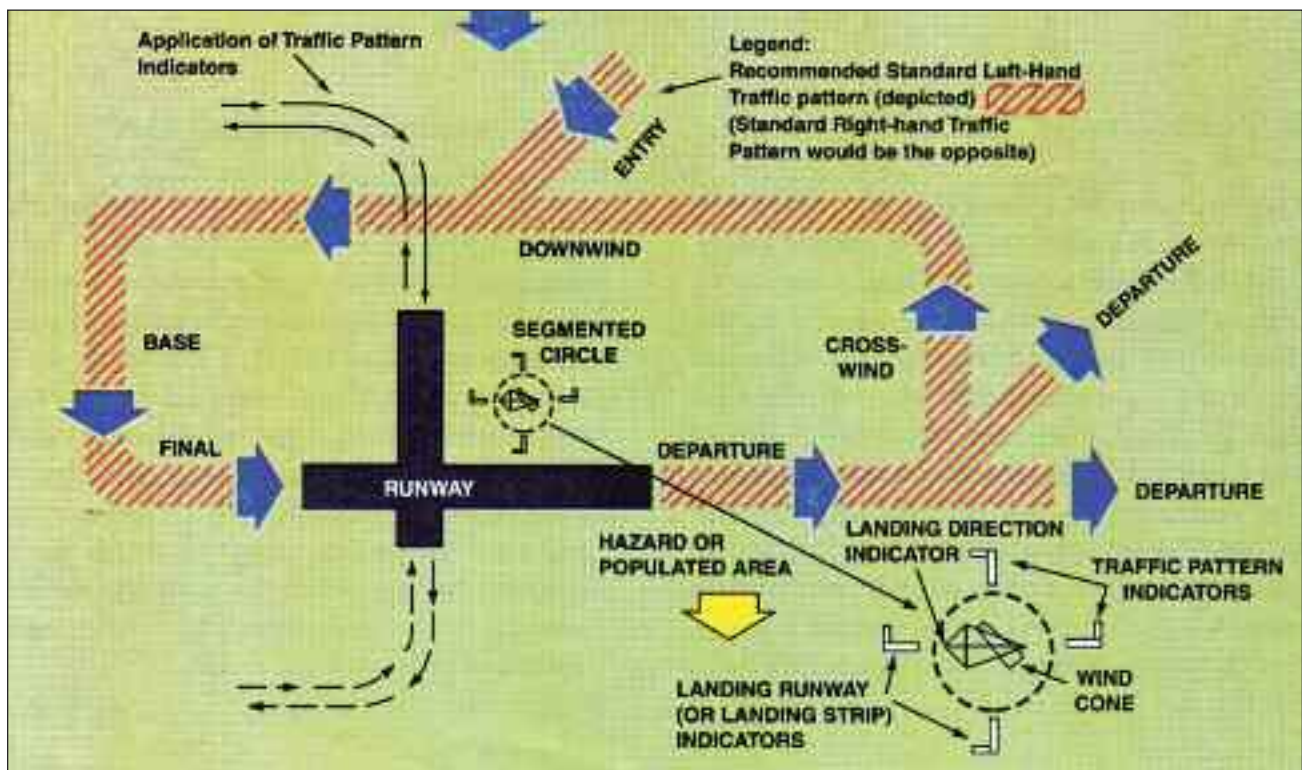
movement is done on a “see and be seen” basis. A very important part of learning to fly an airplane is knowing where you can and can not go when flying by the rules. Visual Flight Rules are directly connected to weather and visual conditions within the airspace system. A pilot may elect to go by IFR, or Instrument Flight Rules, wherein the pilot uses the instruments to guide flight. IFR are used in poor visibility conditions, such as bad weather or darkness. In either case, the pilot must first be trained in and rated by the **Federal Aviation Administration** (FAA). Unlike VFR, IFR is a system of carefully-controlled directions and altitudes that enables the pilot to fly into weather conditions where visibility is limited. Under these rules, strict control is maintained by Air Traffic Controllers who monitor the system by radar, and IFR requires that a pilot fly an airplane with great precision.

(G) The next phase from cruise is descent. In this phase, the pilot decreases altitude and prepares for landing at another destination, or returns to the airport where the flight originated. If the pilot is approaching a controlled airport, radio contact must be made with the air traffic **control tower**, or an **ATC** radar facility called “approach control.” The controller will then direct the pilot to position the airplane on a specific **course** so that it enters the airport without disrupting the existing flow of traffic.

(H) Once the pilot enters the proximity of an airport, a traffic pattern is followed in preparation for landing. This is all part of the approach-to-landing phase.

(I) The next step is landing. Once the pilot has positioned the airplane into alignment with the runway, a glide slope angle is maintained until touchdown. The object is to get the airplane to land straight ahead at a relatively slow speed. Most flight training schools teach pilots to land just above stall speed. This puts the least amount of stress on the airplane and does the least damage to tires. The pilot slows the airplane down and exits the runway onto a taxiway.

(J) The airplane is then stopped and the pilot contacts the ground controller for permission to continue on a taxiway to a parking spot on the **ramp**. Once cleared, the pilot taxis the aircraft to the parking area.



The airport traffic pattern

(K) The pilot positions the airplane at or near the tie-down chains and the airplane is **shut down**. A post-flight procedure is followed including shutting everything off properly and recording the flight in the necessary log books.

RUNWAY MARKINGS

The Federal Aviation Administration controls the airway system over the United States and it has certain standards that govern airports. These standards are quite different from the familiar automobile street, avenue, boulevard, and freeway markings.

Several factors are taken into consideration when airport designers are in the planning stages. If there is to be only one runway, careful consideration is given to the prevailing winds surrounding the airport. Since wind is a major factor in the takeoff and landing performance of an airplane, airport designers try to position a runway so that pilots will be taking off and landing into the wind most of the time.

The numbers at the ends of the runways are actually shortened **headings** as noted on a Compass Rose. (See photo to the right.)

Runways are given numbers between 01 and 36. This indicates the **runway heading**. A runway with the number 36 point to the north, at “magnetic north,” or “true north,” which is 360°.

A runway with the number 18 is south, or 180°, which is actually 180° clockwise from magnetic north on a compass.

Thus, the runway number is one tenth of the runway’s magnetic heading. In other words, a runway with a 270° will be recorded as 27 (the zero is dropped to denote one tenth of the actual heading). Looking at the Compass Rose photo to the right, in what direction would a 270° (or runway 27) be headed? Yes, it would be west. Look at 290° (or runway 29). In what direction would that runway be headed? You will see WNW on the compass, and that means West North West.



Compass Rose

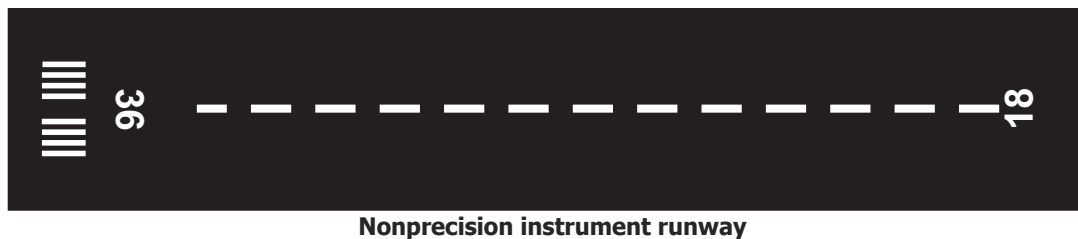


A typical VFR runway where the numbers "29" and "11" are based on magnetic headings of 290° and 110°

Looking at the runway image above, imagine that you are in the cockpit of an airplane coming in for a landing. When you look out, you see runway 29 directly ahead. If you were to glance at the airplane’s compass, you would note that it also reads 29 (the shortened, or one-tenth version of 290°). Now, if you were to come into the same airport from the opposite direction, you would see the number 11 on this runway. Again, a glance at the compass would show the number 11, the magnetic heading of 110°. In what direction is runway 11’s course? The compass says ESE, which means East South East, which is the opposite direction of runway 29- WNW.

Often there will be two parallel runways (runways running side-by-side with the same magnetic heading). Their numbers will be the same at both ends. In this case, they are designated “R” for the right one and “L” for the left one. Using the “20” above, you would see 20R on one runway and 20L on the other. If three runways are in parallel, the center would be 20C (for center).

Nonprecision Instrument Runways



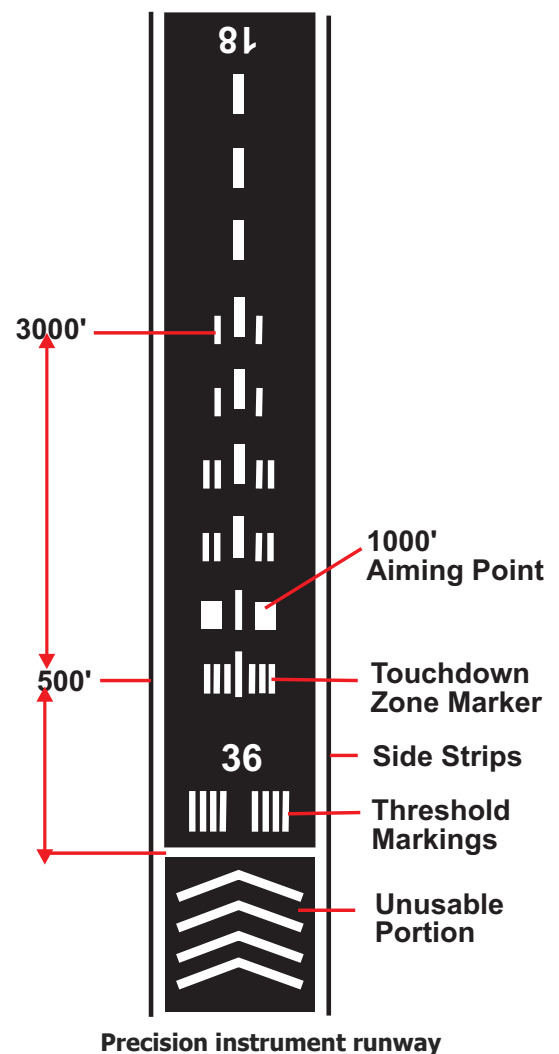
Some airports have the capability to conduct nonprecision instrument approach operations during inclement weather. Nonprecision runways only provide pilots with lateral (left or right) or alignment markings to help the pilot land. There are no markings to determine vertical (altitude) or glide angle and the pilot has to rely on instruments for this information. At airports where they have this instrument landing capability, you may see nonprecision instrument markings, as in the illustration below. These threshold markings are the two sets of four stripes ahead of the number 36.

All the Bells and Whistles- Precision Instrument Runways

If an airport is an important hub in the airway system, it will usually have a runway that is designed to accept aircraft under bad weather conditions. This type of runway is in full compliance with IFR, or Instrument Flight Rules. When a pilot is in the approach phase of the flight profile, he/she will use an electronic "Instrument Landing System" (ILS) glide slope instrument in the cockpit for guidance to a precision runway.

A precision runway has both lateral (left to right) and vertical (altitude) informational markings to assist the pilot in precise alignment (lateral) and glide angle (vertical) control.

Since the pilot often cannot see the runway, the visual markings, shown to the right, assist in getting the airplane onto the runway safely.



AIRPORT SIGNS

At some point, it is hoped that you will get the opportunity to go on an orientation flight. When the pilot is taxiing out for departure, you will notice signs along the route and near the runway. Part of the “language” of an airport is understanding the meaning of these signs. The six categories of signs are depicted below and are described on next page.

U.S. Airport Signs			
Sign & Location	Pilot Action/Sign Purpose	Sign & Location	Pilot Action/Sign Purpose
 On taxiways at intersection with Runway and at Runway/Runway Intersection	Do not cross unless clearance has been received (towered airport) or until clear (nontowered airport). At runway/runway intersections, hold short if land and hold-short clearance has been accepted.	 Edge of ILS Critical Area	These signs are used on controlled airports to identify the boundary of the ILS critical area. It is intended that pilots exiting this area would use this sign as a guide to judge when the aircraft is clear of the ILS critical area.
 Hold Position on Taxiway Located in Runway Approach or Departure Area Hold	Controlled Airport — Hold when instructed by ATC. Noncontrolled Airport — Proceed when no traffic conflict exists.	 Taxiways and Runways	On Taxiways — Provides direction to turn at next intersection to maneuver aircraft onto named taxiway. On Runways — Provides direction to turn to exit runway onto named taxiway.
 ILS Critical Area	Hold when instructed by ATC when approaches are being made with visibility less than 2 miles or ceiling less than 800 feet.	 Taxiway	Provides general taxiing direction to named runway.
 Areas where Aircraft are Forbidden to Enter	Do not enter. Identifies paved areas where aircraft entry is prohibited.	 Taxiways and Runways	Provides general taxiing direction to identified destination. Other destination signs include direction to taxiway, runway.
 Taxiway	Identifies taxiway on which aircraft is located.	 Runway	Provides remaining runway length in 1,000 foot increments.
 Runway	Identifies runway on which aircraft is located.	 HS-1	Land and Hold Short point for other than intersecting runways as instructed by ATC.
 Edge of Protected Area for Runway	These signs are used on controlled airports to identify the boundary of the runway protected area. It is intended that pilots exiting this area would use this sign as a guide to judge when the aircraft is clear of the protected area.	 Taxiway Ending Marker	Indicates taxiway does not continue.

Airport signs

1. **Mandatory Signs** - These have a red background with white numbers/letters. These signs denote an entrance to a runway, critical area, or a prohibited area.
2. **Location Signs** - These are black with yellow inscription and usually a yellow border. They don't have arrows. They are used to identify a taxiway or runway location, boundary of the runway, or an instrument landing system (ILS) critical area.
3. **Information Signs** - These are yellow signs with black lettering and symbols that give information on such things as areas that cannot be identified by the tower, **noise abatement** procedures, and applicable radio frequencies.
4. **Direction Signs** - These are yellow signs that give a pilot directions. The black inscription and arrow identifies the designation of the intersecting taxiways leading out of an intersection.
5. **Destination Signs** - These are yellow signs with black letters and a distinctive black arrow, like the direction signs. They give direction to special locations like military, international, and fixed-based operator (FBO) sites.
6. **Runway Distance Remaining Signs** - These are large black signs with a white number that tell pilots the distance remaining during takeoff or landing.

AIRPORT LIGHTING

During flight training, you will discover that one of the most challenging, yet fascinating, experiences is flying at night. Moonlit landscapes and city lights are sometimes breathtaking. From a distance, airports tend to blend into big city lights; however, if you know what to look for, they are easy to spot. Airport lighting is a kaleidoscope of color and each light has both purpose and meaning. Since the Federal Aviation Administration controls the airway system, airport lighting is standardized.

Who Controls Airport Lighting?

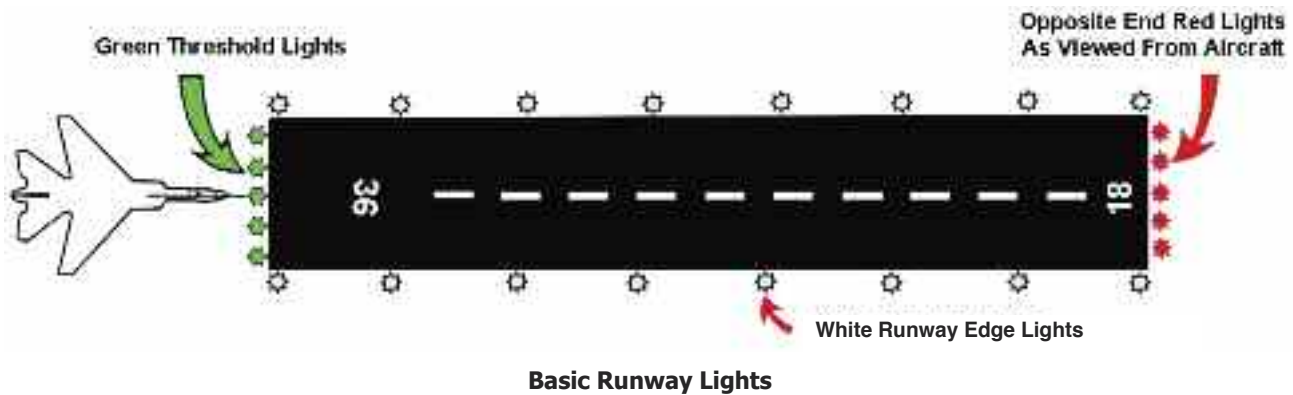
Airport lighting is controlled by air traffic controllers at controlled (tower) airports. At uncontrolled (no tower) airports, the lights may be on a timer, or if there is a **Flight Service Station (FSS)** located at an airport, the FSS personnel may control the lighting. A pilot may request various light systems be turned on or off and also request a specified intensity. At selected uncontrolled airports, pilots in flight can control the intensity of these runway edge lights from the cockpit. It's done by using a specified radio frequency and clicking the microphone. This procedure is called "pilot controlled lighting."

AIRPORT LIGHTS

Most airports have some type of lighting for night operations. The type of lighting systems depends on the volume and complexity of operations at an airport. Airport lighting is standardized so that airports use the same colors for lights on the runways and taxiways. Below are examples of some of the lights at airports:

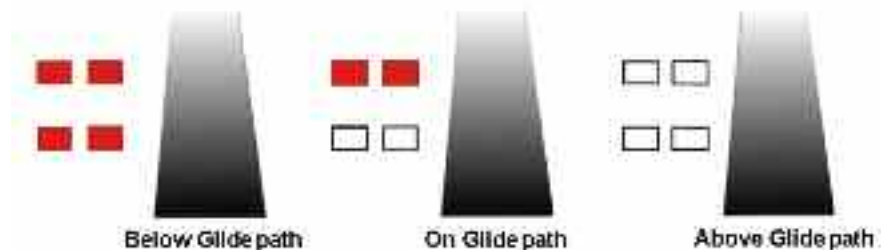
1. **Runway edge lights** - Lights used to outline the edges of runways at night or during low visibility conditions. They are classified according to the intensity they are capable of producing: (1) Low Intensity Runway Lights (*LIRL*); (2) Medium (*MIRL*); and (3) High (*HIRL*). These lights are white except on instrument runways where amber lights are used on the last half the length of the runway (or the last 2,000 feet, whichever is less).

2. **Threshold Lights** - Green lights that show the beginning of the runway.
3. **End of runway lighting** - Red lights that mark the end of the runway you are facing.
4. **REIL - Runway End Identifier Lights** - High intensity white strobe lights placed on each side of the runway, especially helpful with reduced visibility, contrasting terrain, and much other lighting.

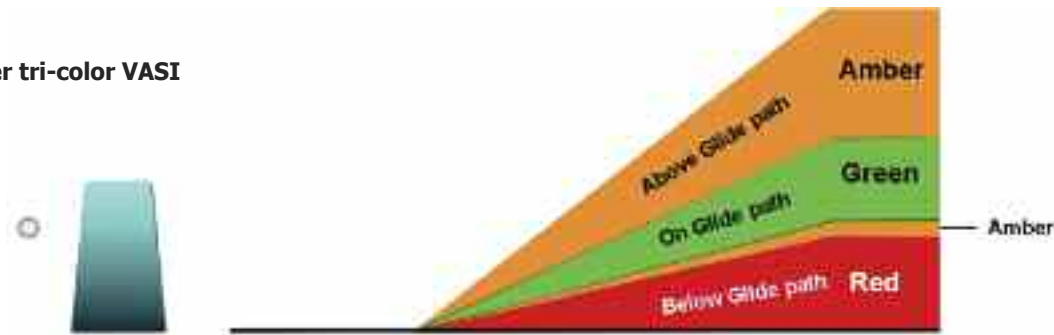


5. **In-Runway Lighting** - Touchdown zone lights (TDZL), runway centerline lights (RCLS), and taxiway turnoff lights are installed on some precision runways to facilitate landing under adverse visibility conditions. TDZLs are two rows of transverse light bars disposed symmetrically about the runway centerline in the runway touchdown zone. RCLS consists of flush centerline lights spaced every 50 feet beginning 75 feet from the landing threshold. Taxiway turnoff lights are flush lights which emit a steady green color.
6. **ALS - Approach Lighting System** - If an airport has a precision landing system, there is a good possibility that it will also have an ALS, or approach lighting system. The ALS is primarily intended to provide a means to transition from instrument flight to visual flight for landing. It depends on whether the runway is designated as "precision" or "nonprecision." Sometimes beginning as far away as 3,000 feet, some of the more complex systems include sequenced flashing lights which appear to the pilot as a ball of light traveling toward the runway at high speed. Approach lights can also aid VFR pilots operating under normal conditions.
7. **VASI - Visual Approach Slope Indicator** - The VASI lighting system is the most common visual glide path system and gives pilots a visual indication of the proper approach angle during the landing. The VASI provides obstruction clearance within 10° of the extended runway centerline, and to 4 nautical miles from the runway threshold. A VASI consists of light units arranged in bars. There are 2-bar and 3-bar VASIs. The 2-bar VASI has near and far light bars and the 3-bar VASI has near, middle, and far light bars. Two-bar VASI installations provide one visual glide path which is normally set at 3° and the upper glide path one-fourth degree above the lower glide path. The basic principle of the VASI is that of color differentiation between red and white. Each light unit projects a beam of light having a white segment in the upper part of the beam and a red segment in the lower part of the beam. The lights are arranged so the pilot will see the combination of lights.

A standard two-color VASI



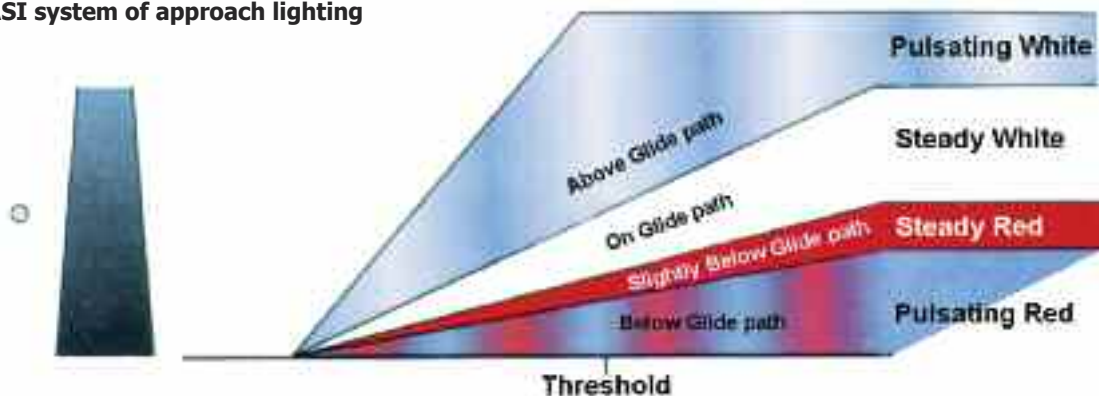
The newer tri-color VASI



When an aircraft descends from green to red, the pilot may see a dark amber color during the transition in colors.

8. **Tri-Color VASI** - This is a system with a single light giving three separate indications. When a pilot is above the recommended glide path, there will be an amber color displayed. If the pilot is below the glide path, a red color will be observed. When the pilot makes the necessary corrections and the airplane is on the recommended glide path, a green colored light will be indicated.
9. **Pulse Light Approach Slope Indicator (PLASI) and Precision Approach Path Indicator (PAPI)** - A newer version of a two color visual approach involves a pulsating red light when the pilot is below and a pulsating white light when the pilot is too high above the recommended path. This is referred to as the *PLASI* system. The *PAPI* lights are usually located on the left side of the runway and consist of a row of four lights. If the pilot is too high, all four lights will be white. When the recommended glide path is obtained, the left two will be white and the right two will be red. All four lights will be red if the pilot is too low on the glide path.

The PLASI system of approach lighting



10. **Taxiway Lights** - Blue lights are the norm for taxiway edge lights. However, some airports have green taxiway centerline lights that may include portions of the ramp. Lights that shine in all directions are called *omnidirectional* and can be observed at the edge of taxiways.
11. **Beacons** - These **beacon** lights guide pilots to airports at night. From a distance, pilots can see what appears to be flashing colors. If it is a civilian airport, the beacon will flash alternating colors of white and green. If it's a water airport, the colors will alternately be white and yellow. Helicopter airports, called heliports, have a three color display of green, yellow, and white. Military airports have a distinctive "white-white-green" display.

WIND DIRECTION INDICATORS

Wind is a key factor in flying, especially in takeoff and landing. At controlled airports, the tower operators provide this information to pilots in voice and recorded communications. However, when this service is not available, standardized, visual **wind indicators** become one of the pilot's best sources of wind information. These indicators include a wind sock, a wind tee, and a tetrahedron.

Wind socks have been around for decades and they are still a reliable source of wind direction and speed. Because the wind sock is large on one end and small on the other, and can swivel around its pole, it gives the direction and a good indication where the wind is from and how hard it's blowing. The wind enters the larger end of the sock, inflates it, and rotates it so that the sock aligns itself to the wind. From the air, a pilot can see this inflated sock and estimate the speed of the air flow.

Wind tees and tetrahedrons can swing freely, and will align themselves with the wind direction. The wind tee and tetrahedron can also be set manually by some authority at the airport. Both the tetrahedron and wind tee point into the wind.



The airport beacon

Wind Indicators

At most airports, there is a **segmented circle** surrounding the wind indicator. These can be as simple as half-buried car tires that are painted so they can be seen from the air.

Other markings around the segmented circle include traffic pattern direction indicators or landing runway indicators. These markers tell the pilot which way the normal traffic pattern flows around an airport. (See associated Activity Three at the end of the chapter.)



Wind indicators

Airport Communication

As we have learned, the airport has special lighting, markings, indicators, and signals to ensure safe take off and landing. The FAA has coordinated these safety features, but has also designated special communication codes between the Air Traffic Controllers and the pilots. A unique alphabet vocabulary is used so that all oral communication at the airport is clear. **This phonetic alphabet is presented in Activity Four at the end of the chapter.** Try this associated activity to help you understand how aviators clearly communicate to avoid misunderstandings that could cause disasters in take off and landing.

ACTIVITY SECTION 2

Activity Three - Look Down; What Are You Seeing?

Purpose: Identify parts of an airfield and where each is located from an aerial view.

This is an actual photograph taken of Jefferson County Airport, Broomfield, Colorado. Imagine that you are flying over this field, or a similar airport, and you are being quizzed by a flight instructor on what you're seeing. Identify as many parts of the airfield as you can. The answers are on the next page.

- | | | |
|-----------------------|-----------------|--------------------|
| 1. Taxiway | 2. Ramp | 3. Runway 29 Right |
| 4. Threshold Markings | 5. Aiming Point | 6. Side Strip |

Notice that there is a runway crossing Runway 29R. It is exactly perpendicular, or 90° , to Runway 29R. There is also a runway to the left of runway 29R. It is also at 270° . What would this runway be called? The answer is on the next page.



Jefferson County Airport, Broomfield, Colorado Courtesy of Raytheon Airport Services

Summary: This activity gives you the opportunity to identify the various parts of an airport. The answers for questions 1-6 are labeled on the map below. Match the numbers to the names on the previous page. The runway that is to the left of runway 29R is 29L.



Jefferson County Airport, Broomfield, Colorado Courtesy of Raytheon Airport Services

Activity Four - Hey You, Bravo-Oscar-Bravo!

Purpose: Increase your knowledge of the phonetic alphabet used by pilots and Air Traffic Controllers.

Materials: Standard phonic alphabet below

A	Alfa	“Al-fa”
B	Bravo	“Bra-vo”
C	Charlie	“Char-lee”
D	Delta	“Del-tah”
E	Echo	“Eck-o”
F	Foxtrot	“Fox-trot”
G	Golf	“Golf”
H	Hotel	“Hoh-tell”
I	India	“In-dee-a”
J	Juliet	“Jew-lee-et”
K	Kilo	“Key-lo”
L	Lima	“Lee-ma”
M	Mike	“Mike”
N	November	“No-vem-ber”
O	Oscar	“Ahs-ker”
P	Papa	“Pah-pa”
Q	Quebec	“Keh-beck”
R	Romeo	“Row-me-o”
S	Sierra	“See-air-a”
T	Tango	“Tang-go”
U	Uniform	“Yew-nee-form”
V	Victor	“Vic-tah”
W	Whiskey	“Wiss-key”
X	X-Ray	“Ecks-ray”
Y	Yankee	“Yang-key”
Z	Zulu	“Zoo-loo”

Procedure: You've probably heard someone try to spell out a word using other words like “...that's N, as in Nancy,” or “B...like boy.” In the world of aviation, there is an organization called the ICAO, or International Civil Aviation Organization, and they have established English as the world-wide language of aviation. Along with this, they have selected 26 words which help in transmitting clear communications. This is known as the phonetic alphabet.

Have each participant stand and give his/her name in phonetic alphabet. It's quick, it's fun, and it's a learning experience. But, first try these just for grins!

1. Who am I? Juliet, Oscar, Sierra, Hotel, Uniform, Alfa
2. Who am I? Tango, Uniform, Romeo, Kilo, Echo, Yankee
3. Who am I? Sierra, Papa, Alfa, Charlie, Echo, Charlie, Alfa, Sierra, Echo?

Summary: This activity helps to familiarize you with the phonic alphabet which many people outside the aviation field use to clearly communicate orally. Hopefully this will be helpful to you in the future.

AIRPORT TO AIRPORT- AERONAUTICAL CHARTS

Learning Outcomes

- Describe the basic layout of a sectional chart.
- Explain the sectional chart legend.
- Identify latitude and longitude lines.
- Identify features such as railroads, pipelines, obstructions, and highways.
- Identify all of the information given about an airport.



An excerpt from an aeronautical sectional chart

Important Terms

cartography - the art and science of creating charts and maps

chart - a projection, usually on paper, showing a body of land and other features, such as water, that gives information, usually in the form of symbols, graphs, or illustrations

latitude - a system of lines that run parallel to the equator, also known as parallels

legend - an illustration showing the symbols that are used on charts

longitude - a system of lines, known as meridians, between the north and south poles

map - a representation of the surface of the Earth (or of the sky/space above)

nautical mile - a unit of length that is approximately 6076 feet

projection - a method of transferring a portion of the Earth's surface onto a flat chart; the most widely used in aeronautical charts being the Lambert Conformal Conic Projection

relief - a term used to describe elevations, which is depicted by color tints, contour lines, and shading on maps

sectional - a chart specifically designed for aviation use and Visual Flight Rules, with the scale being 1:500,000 or approximately 8 statute miles to one inch

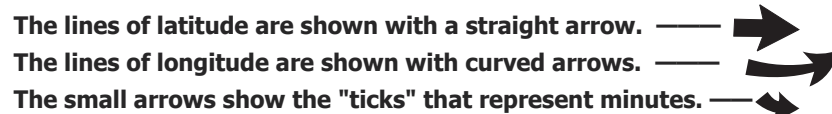
scale - the size of an item, or area, on a chart, compared to it in actuality

statute mile - a unit of length that is 5,280 feet

tick - a small, or abbreviated mark on a line

WAC - The World Aeronautical Chart, which covers a much larger area than the sectional chart; the scale of the WAC being 1:1,000,000 or approximately 16 statute miles per one inch

The most commonly used aeronautical “**map**” is known as the **Sectional Chart**. It has a scale of 1 inch to 500,000 inches, or approximately 8 **statute miles**. The **nautical mile** equivalent is approximately 6.85 miles. These charts are based on the principle of a **Lambert Conformal Conic Projection** and locations are positioned according to lines of **latitude** and **longitude**. The **World Aeronautical Chart** is even larger than the sectional chart, but in this chapter we will focus on the sectional chart.

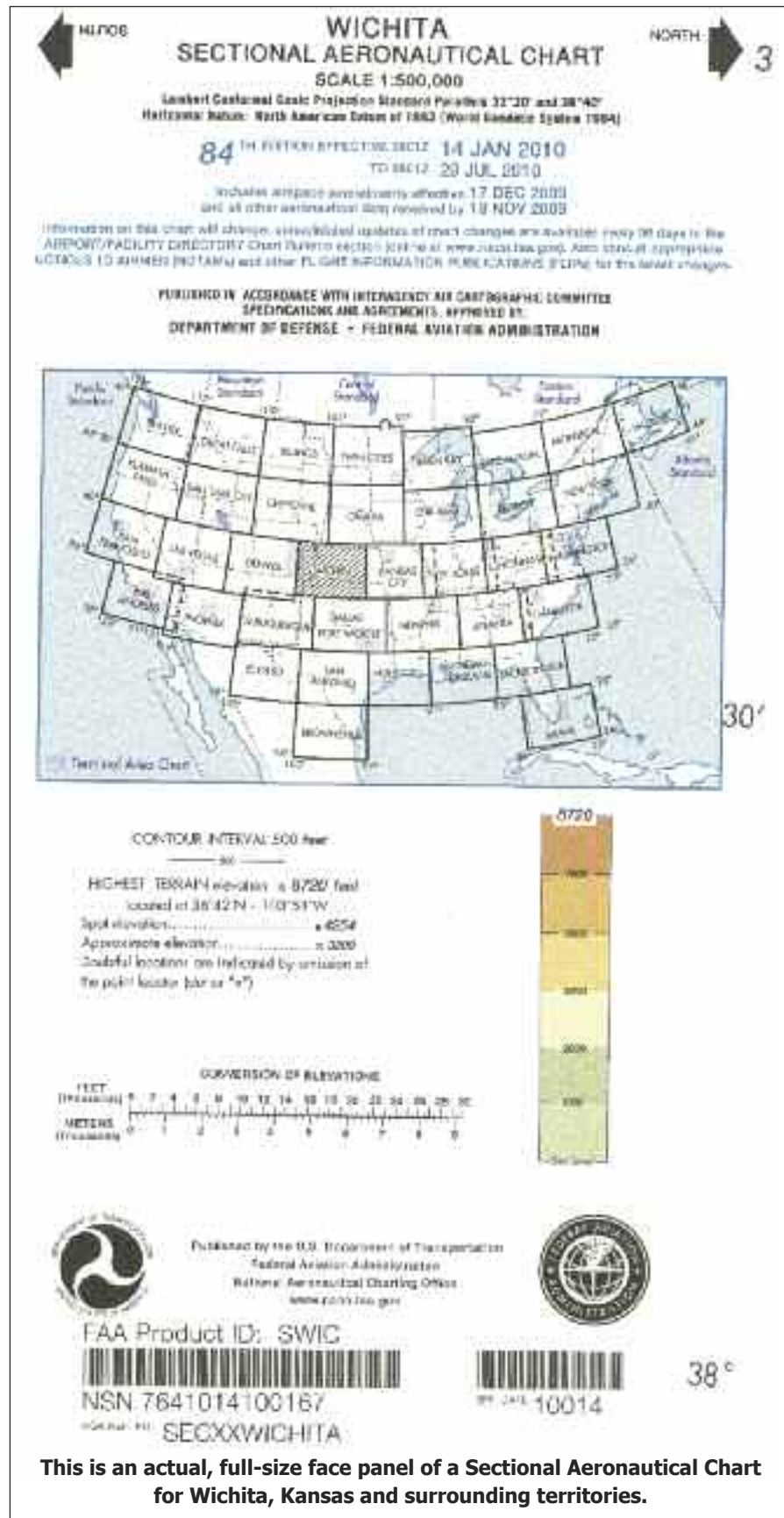


SECTIONAL AERONAUTICAL CHARTS

The Sectional Aeronautical Charts are shown in this illustration. The **cartography** used to create these charts is revised every 6 months, but there are a few located outside of the 48 contiguous states that are revised annually. The **scale** of this chart is 1:500,000 and it is based on the Lambert Conformal Conic Projection.

In the illustration, you will see the chart title and that refers to a primary city within the coverage of the sectional. Note the one we are using is Wichita, a large city located in the state of Kansas. Others, like Las Vegas, Chicago, Miami, Dallas-Ft. Worth, Phoenix, and Houston, all have small blotches within their area. This means that there is additional information available for their large airports in the form of Terminal Area Charts.

The black arrows in the upper right and left corners indicate which side of the sectional is north and which is south. There is a band of color (vertical) just below the illustration of the United States. This graphic shows the gradient tints assigned to each one thousand feet of elevation, called **relief**. Colors range from a green at sea level to a golden tint, at high areas. The “8720” is the maximum height that is represented on the Wichita sectional.

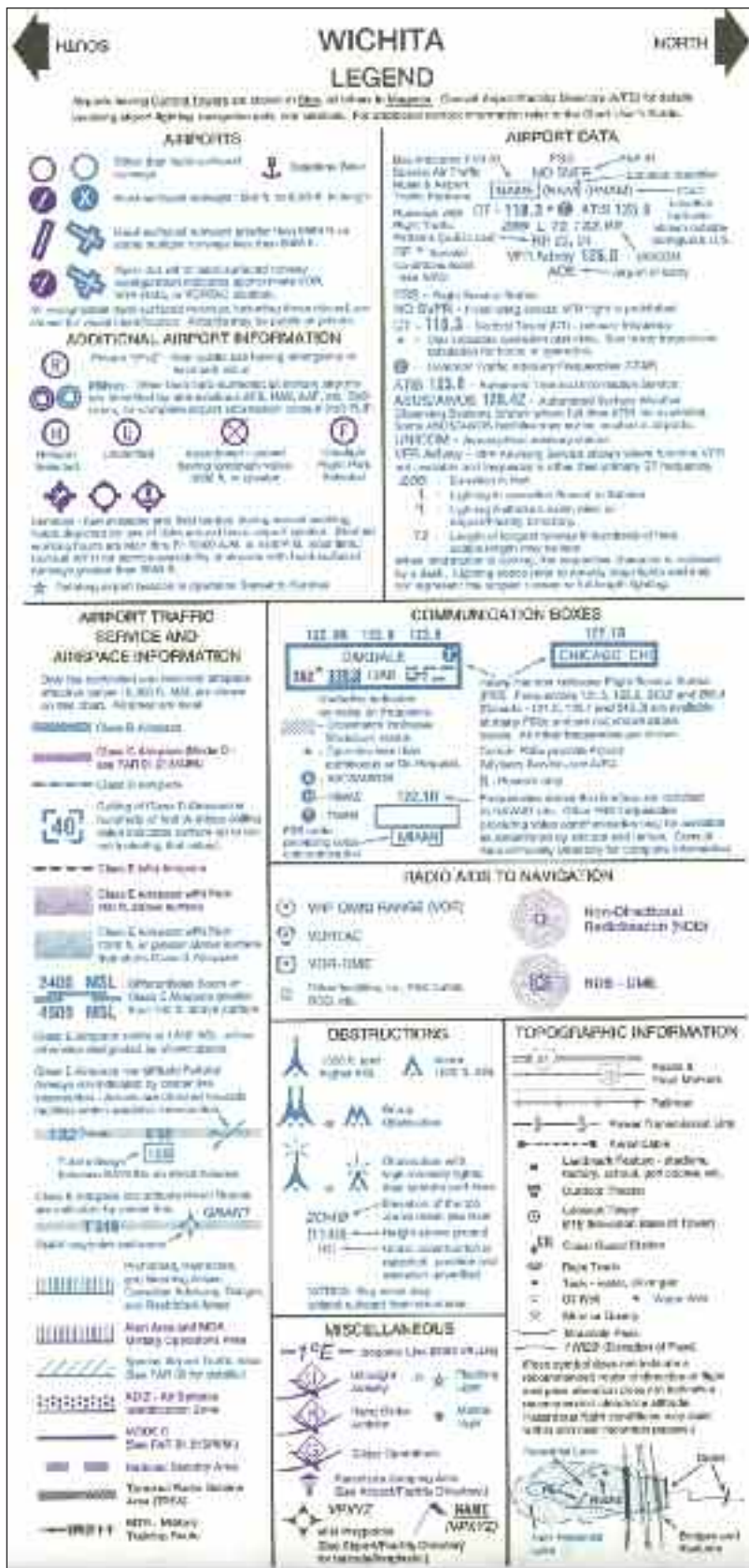


THE LEGEND AND ITS SYMBOLS

The sectional chart not only displays airports, it has cities, towns, railways, rivers, radio navigation aids, power lines, obstructions, and other landmarks that pilots can use as visual checkpoints along a route of flight. All of these features are depicted in various colors and forms. To learn how they are represented, you must become familiar with the chart's **legend**. This is a colorful array of symbols and graphics that represent features of interest to pilots.

Using the legend shown here, try to locate the following symbols on the Wichita sectional excerpt shown on page 42. This activity will give you a challenge that will help promote a better understanding of the legend. Work with a partner to assist each other in locating each symbol.

- Obstruction below 1000 ft. AGL
- Mines and quarries
- Small town shown in yellow
- Private-non public use airport
- Power transmission line
- Interstate Highway 80
- Nondirectional radio beacon
- Railroad track
- Visual check point
- Parachute jumping area
- Class C airspace
- Group obstruction
- Outdoor theater
- Small river
- Wichita VORTAC
- A longitude line
- A latitude line
- Golf course
- Sand pit
- Race track



The legend for the Wichita Sectional Aeronautical Chart



This is an excerpt from the Wichita sectional and it covers an area in northern Oklahoma.
The Kansas border is 37° Latitude and just west of Enid is 98° Longitude.

You will notice that the legend has “blocks” of information. Using the two airport blocks, notice how a symbol relates to an actual symbol on the excerpt. Often times, the legend symbol doesn’t exactly fit the one in the block. That’s when you have to look around for other related graphics. Here’s an example: Go to block marked Airports that has been superimposed upon the excerpt. The second line down is a blue symbol with an “x” in it. This is the symbol for a tower-controlled airport with a hard-surfaced runway between 1500’ and 8069’ long. There is a black line that connects that symbol to the one on the chart. This is Enid Woodring Airport. Its longest runway is 6400 feet and it falls between the 1500-8069 limits. The runway is hard-surfaced. Notice that there is a small star on top of the Enid-Woodring symbol and tabs sticking out. Go back to the block of information and you’ll see a little blue star at the bottom. It says, “* Rotating airport beacon in operation Sunset to Sunrise.” Enid-Woodring Field has a beacon and it is shown on the symbol.



Now look down at the lower portion of the box and you will see symbols, although the wrong color, that have tabs. The information says, “Services: fuel available and field tended during normal working hours depicted by use of **ticks** around basic airport symbol.” They call them ticks, but they look like tabs.

In order to get the meaning of the symbols used, you have to do a little digging. If you carefully examine the Enid-Woodring Airport symbol, you will notice a small dot in about the 5 o’clock position. To solve the mystery of the dot, it’s buried in the AIRPORTS block of information. Can you find it?

Looking back at the Airport Data block on the excerpt on page 43, you will see a black line going from the text to the magenta information around “Cherokee.” Note that the information in the AIRPORT DATA is blue and the information around Cherokee’s airport is purple. Now, look back at the information around Enid-Woodring Airport. It is blue. Woodring has a control tower and Cherokee does not. It is said to be uncontrolled. Note also that the Cherokee airport symbol has a tiny star on top of it. This means that it has a rotating beacon operating from sunset to sunrise.

Let’s take a look at the airport data and see what it’s all about. Of course, CHEROKEE is the name of the airport and the name of the town. Notice right after the name CHEROKEE, there is (OK 6). If you will look back up into the data block, you will see (NAM) and a small arrow pointing to it with “Location Identifier” written. This means that Cherokee airport is identified with that symbol. If it were Los Angeles International Airport, it would be LAX, Dallas-Ft. Worth would be DFW, Seattle, SEA, etc.




The Cherokee, Oklahoma Airport symbols and information

Remember-Uncontrolled Airports Are Magenta, Controlled Airports Are Blue

Under the first line of information about Cherokee is “1177 L 38 122.9.” Again, looking back at the information block, you will see that the 1177 relates to the “elevation in feet.” So Cherokee has an elevation above sea level of 1,177 feet. The L is “Lighting in operation Sunset to Sunrise.” The 38 is the “Length of the longest runway in hundreds of feet.” Cherokee has a runway that is 3800 feet long. Now, look at the Cherokee airport symbol. It is magenta and there is a line in the middle of it. If you go back down to the AIRPORTS block, you will see the second symbol, again shown in magenta, and this says it is a hard-surfaced runway between 1500’ to 8069’ in length. Cherokee has a hard-surfaced runway that is 3800’ long. You can see that information is often buried in another block and you have to hunt for it.

Once You’ve Mastered Cherokee, Try All of the Airports on the Sectional!

The next information in the Cherokee airport data is the 122.9. This is the UNICOM and it is identified in the AIRPORT DATA block with a small arrow. Down in the lower portion of the AIRPORT DATA block, you will see a definition for UNICOM. It is an “Aeronautical advisory station” and not a control tower. It means that the airport has an advisory on items such as wind direction, services available, and traffic pattern directions. The  at the end of the information means this is a “Common Traffic Advisory Frequency.”

Airports- Time to Visit One!

Now that you have learned a good deal about airports, it is time to go and visit one. You can arrange a visit through an adult with whom you are working on this module. If you are lucky, you will be able to take an orientation flight to see the airport from the air, hear the communications of the Air Traffic Controllers, and observe the final approach for landing. Blue skies to you! (See associated Activity Five at the end of the chapter.)



This is what is seen when you fly in an airplane. Once the runway is lined up, full power is added for take-off. It is one of the most exciting moments of flight.

2 ACTIVITY SECTION

Activity Five - The Final Approach!!

Purpose: Simulate the final approach and landing of an airplane.

Materials: a plastic toy airplane with fixed landing gear, two eye screws, 30-40 feet of fishing line, a stick or broom handle 18-24 inches long, masking tape, and two people. Note: The model airplanes can be purchased in most variety stores. The nylon fishing line and eye screws can be found at any hardware store, or large center, like Wal-Mart.

Procedure:

1. Put the two eye screws in the back of the toy airplane so that it hangs straight and level on the fishing line.
2. Tie one end of the fishing line up high in a room.
3. Thread the fishing line through the eye screws on the back of the plane.
4. Tie the other end of the fishing line to the stick, which becomes the pilot's "joystick."
5. Lay out the runway on the floor with masking tape. Place the joystick at the far end of the runway.
6. One person takes the airplane to the top of the line and releases it while the pilot, seated just beyond the runway, moves the joystick forward and backwards to adjust the speed in order to land on the runway.

If the pilot pulls back too tightly on the stick, the plane will overshoot the runway. Pushing forward increases the speed of the plane coming down the fishing line. The object is to land the plane inside the runway limits. Practice makes perfect on this activity!

Summary: This is a great activity for simulating a landing and the difficulty involved in judging both speed and angle upon final approach, descent, and landing.



