22

Air Vehicular Systems

Basic Concepts

- Cite the uses of each type of jet engine.
- List common types of aircraft instruments.
- Identify the three types of stability of an aircraft.
- State how an airplane flies.
- Name the parts of an airfoil.
- Define the structural parts of an airplane.
- Cite the support systems used in air transportation.

Intermediate Concepts

- Figure gearbox ratios for different applications.
- Give examples of how moving surfaces control stability.
- Describe the control of a helicopter.

Advanced Concepts

- Plan a flight using an aeronautical chart.
- Discuss the various explanations of the creation of lift.
- Calculate the lift coefficient for various aircraft.

Aircraft require the use of several systems in order to transport people and goods. Propulsion systems provide thrust, which moves the aircraft forward. Many instruments and gauges that provide the pilot with navigation information are onboard the aircraft and are part of the guidance system. Aircraft control systems allow the pilot to steer and land the craft. Suspension systems, such as the wings, provide lift and keep the aircraft in flight. The structural system includes the trusses that keep the aircraft intact and flightworthy. These systems are all contained onboard the aircraft, while the support system is on the ground and includes airports, runways, and flight control towers.

Radial engine: An engine in which all the pistons are connected to a hub in the center of the engine.

Airfoil: The shape of a propeller blade or an airplane's wing.

Angle of attack: The angle at which a propeller blade hits the air or the upward tilt of a wing's leading edge.

Propulsion Systems

Aircraft propulsion systems are used to generate thrust. They create thrust by accelerating the oncoming air. Engines are the propulsion systems used to generate thrust for most aircraft. The only other types of propulsion systems used are the wind, in the case of hot air balloons, and human power, in the case of hang gliders and pedal-powered gliders. See **Figure 22-1.** Aircraft engines are divided into two categories: reciprocating and jet.

Reciprocating Engines

Reciprocating engines were used on the Wrights' *Flyer* and are still used today on general aviation craft. They are named for the motion the piston follows while in operation. These engines are also known as internal combustion engines because they rely on the combustion of gases inside a cylinder to create motion.

Several internal combustion engine shapes have been used in aircraft throughout aircraft development. Early aircraft used radial internal combustion engines. ***Radial engines*** are configured in a way in which all the pistons are connected to a hub in the center of the engine. See **Figure 22-2.** The pistons fan out from the center to form a circle.

Figure 22-1. The wind is the propulsion system for a hot air balloon. Air heated by a propane burner provides the lift to get the balloon into the air, but horizontal movement depends completely on the wind.

Today, the internal combustion engines used on aircraft are either in a horizontally opposed (flat) or *V* shape. In flat engines, all the cylinders share a crankshaft and are set in opposite directions from each other. In *V*-shaped engines, the cylinders form a *V* and also share the same crankshaft. Typical aircraft engines have four or six cylinders.

The reciprocating engine is used to drive propellers. The propellers provide the aircraft with thrust in the reciprocating engine systems. See **Figure 22-3.** A propeller is made up of long blades rotated around a center hub. Its blades have a shape that is very common in both air and marine transportation—the ***airfoil.*** A propeller can be compared to a set of rotating airplane wings. It provides thrust by accelerating the velocity and changing the pressure of the air passing through the blades.

The amount of thrust a propeller creates is determined in part by its pitch and rotation speed. The pitch determines the angle of attack. The ***angle of attack*** is the angle at which the propeller blade hits the air. Propeller blades are twisted, so the angle of attack decreases as the distance from the center increases. Refer to Figure 22-3, noting the shape of the propeller blade. This idea was first developed by the Wright brothers and is used to make the propeller more efficient. The speed of the connected engine's crankshaft determines the rotation speed of the propeller. The crankshaft of the engine often rotates too fast, however, for the propeller to be efficient. In this case, a gearbox is used to reduce the revolutions per minute (rpm).

Propellers are very efficient propulsion systems. They are able to provide good fuel economy. The efficiency is, however, a trade-off for speed. Propeller propulsion systems have a top speed well under the speed of sound, or as referred to in aviation, ***Mach 1*** (760 miles per hour).

Jet Engines

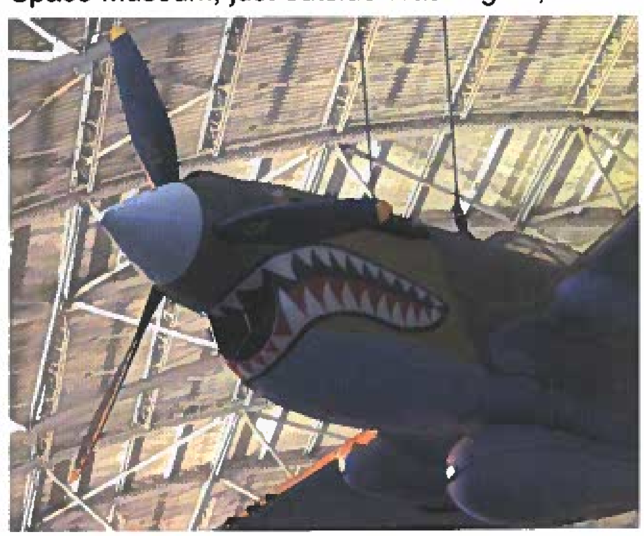
Jet engines are able to travel at much higher rates of speed than reciprocating engines. They operate on the principle defined in ***Isaac Newton's third law of motion***. This law states that "for every action, there is an equal and opposite reaction." A simple example of the third law of motion can be conducted with a balloon. If you blow up a balloon and release it without tying the opening shut, all the air rushes out. The air that rushes out is sent in one direction, and the balloon flies in the opposite direction. The air rushing out is the action, and the balloon's movement is the reaction. See **Figure 22-4.** This release of air (and the opposite movement) is very similar to the action of a jet engine. Jet engines force hot gases from the rear of the engine. The reaction to the hot gases moves the engine forward, producing thrust.

Ramjet engines

Ramjet engines are the simplest type of all jet engines. They have no moving parts. See **Figure 22-5.** Ramjets can only operate at high speeds because they require moving air to enter the engine. They cannot be used for takeoffs and will not work at low speeds. Aircraft with ramjets are often experimental craft launched from other aircraft. Once the craft are launched, the ramjets are used to produce a great amount of thrust. This type of engine is often used on missiles and other weapons that can be fired from moving aircraft.

Figure 22-2. Radial engines consist of a series of cylinders around a central hub. The pistons are connected to the hub, causing it to rotate and spin the propeller. Because the cylinders are all at the front of the engine, the air rushing by the airplane cools the engine. Radial engines are able to produce a large amount of horsepower (hp) at relatively few revolutions per minute (rpm).

Figure 22-3. Airplane propellers are airfoils, providing thrust by accelerating and changing the pressure of the air passing over the blades. This World War II fighter aircraft is on exhibit at the Smithsonian Institution's Udvar-Hazy Air and Space Museum, just outside Washington, D.C.



STEM Connection

Math: Gearbox Ratios

Gearboxes use ratios to express the amount of reduction they produce. A ratio is the relation between two numbers. In a gearbox, the first number of the ratio is the input value. The second number is the output value. A gearbox that slows down the revolutions has a larger number first. For example, a crankshaft may rotate at 2400 revolutions per minute (rpm), and the connected propeller may be most efficient at 1200 rpm. The input value is 2400 rpm, and the output value is 1200 rpm. This ratio would be written as 2400:1200. Expressed in the lowest value possible, this example reduces to 2:1.

If the crankshaft (input) rotates at 3825 rpm, and the desired propeller rpm is 2550 rpm, what is the ratio of the needed gearbox? The initial ratio would be 3825:2550. Divide 3825 by 2550, which equals 1.5. The ratio would be 1.5:1. Ratios should not, however, be left with decimal points. Multiply both sides by 2. The needed gearbox is 3:2.

Mach 1: The speed of sound (760 miles per hour).

Isaac Newton's third law of motion: For every action, there is an equal and opposite reaction.

Gas turbine engines

The four types of gas turbine engines are turbojet, turbofan, turboprop, and afterburning turbojet engines. See **Figure 22-6.** Each type of gas turbine engine has specific functions and designs.

Turbojet engines are used on commercial aviation vehicles. The compressor is used to increase the pressure of the air entering the engine. It has several rows of blades that spin around a central shaft. The air is compressed by the blades, known as rotors and stators, and sent to the

Figure 22-4. If an inflated balloon is tied shut, nothing happens. If it is left untied, the air escapes when the balloon is released. The balloon reacts by moving in the direction opposite the opening.

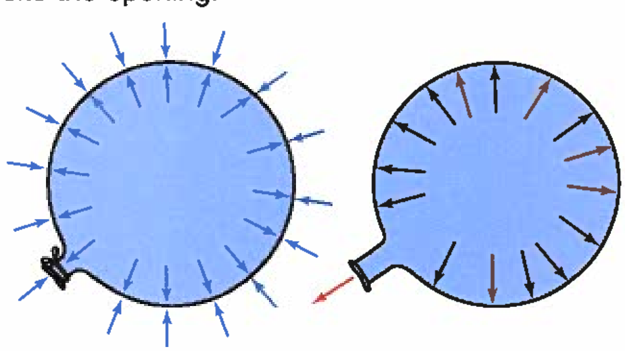
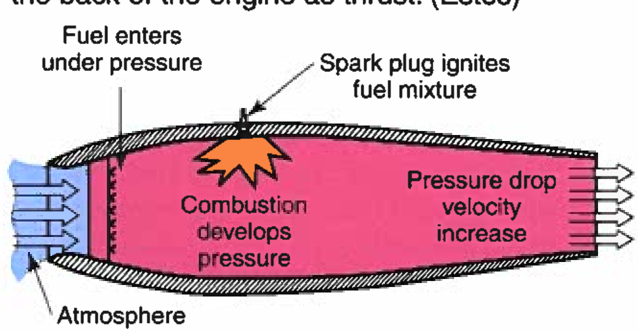


Figure 22-5. A ramjet engine can operate only when moving at high speed, since it has no moving parts and no device for drawing in air. Air enters the front of the engine as the vehicle is moving at a high rate of speed. The internal shape of the engine causes the air to be compressed. When this happens, fuel is sprayed into the combustion area so it mixes with the compressed air. This mixture is then ignited. It expands rapidly as it burns, and it is forced out the back of the engine as thrust. (Estes)



combustion chamber. It is packed into a combustion chamber in the middle of the engine. There, fuel is injected so it can mix with the compressed air. After mixing, the fuel and air are burned and forced toward the back of the engine. Once ignition has started, it becomes a continuous process inside the engine. Before the hot gases leave the rear as thrust, they pass through a turbine section. The gases spin the turbine blades at high speed. The turbine powers the compressor section and adds to the thrust the hot gases leaving the rear of the engine provide. The hot gases then escape through the exhaust nozzle at the rear.

Turbofan engines are sometimes called fan-jets or bypass engines. Turbojets produce small streams of fast air. Turbofans utilize large amounts of slower-moving air. The turbofan brings more air to the compressor section. This allows for a more efficient combustion process. The fan also forces air around the outside of the engine. This adds to the total thrust output of the engine. Turbofan engines are widely used on commercial passenger airplanes because they are efficient, as well as powerful, at low speeds.

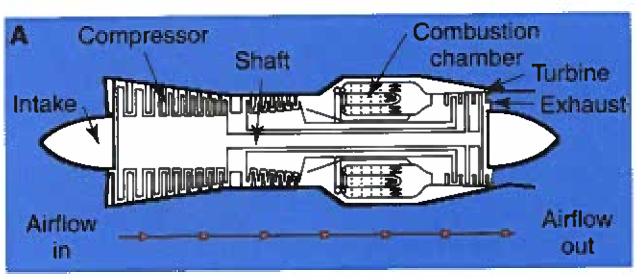
Turboprop engines are basically turbojets that have a propeller mounted on the front. These engines use the product of the combustion to turn the propeller. Thrust from the rear of the engine is not relied on as propulsion. It is used to turn the propeller, which, in turn, moves the vehicle forward.

Ramjet engine: An engine that can operate only when moving at high speed, since it has no moving parts and no device for drawing in air.

Turbojet engine: An engine used on commercial aviation vehicles.

Figure 22-6. A—A cross section of a turbojet engine. Airflow and combustion are continuous. Notice that the engine has internal parts rotating on a shaft. Arrows show airflow from the front of the engine through the back. At the front, there is a compressor section. (Pratt and Whitney, Canada) B—The turbofan engine is a variation of the turbojet, with a fan placed in front of the compressor section. The action the engine causes supplies power, in addition to thrust. C—This cutaway view of a turboprop engine shows the gear assembly connecting the propeller shaft on the left with the turbines on the right. Notice the gearbox between the propeller shaft and the main engine shaft. (Allied Signal Aerospace, Garrett Engine Division) D—With the aid of its afterburner, a U.S. Navy F-18 Hornet fighter plane takes off from the deck of the aircraft carrier USS *Harry S. Truman*. (U.S. Navy)

A



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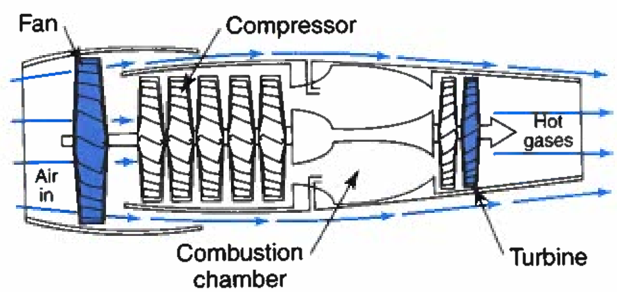

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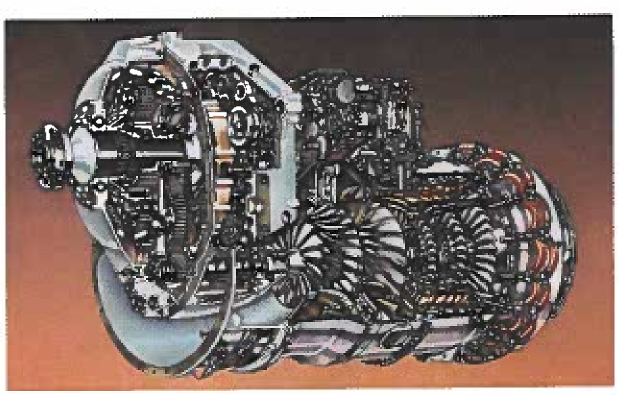


D

Turbofan engine: An engine widely used on commercial passenger airplanes because it is efficient, as well as powerful, at low speeds. Sometimes called a fan-jet or bypass engine.

Turboprop engine: An engine that is basically a turbojet with a propeller mounted on the front.

Afterburning turbojet engine: A turbojet or turbofan engine with an additional burner added to the nozzle.

Aeronautical chart: A chart that provides important data for airplane pilots and navigators. It is basically a topographic map on which special guidance information has been added.

The ***afterburning turbojet engine*** is a turbojet or turbofan engine with an additional burner added to the nozzle. The afterburner includes a port that allows fuel to be injected into the hot exhaust gases. When this fuel is burned, it provides additional thrust. The afterburner is, however, very inefficient. Afterburners are only used on aircraft that would, at times, need additional thrust. Common applications are on fighter jets and supersonic transports (SSTs).

Guidance Systems

Guiding an aircraft is similar to guiding a boat or ship because there are not fixed paths to follow. Pilots must use charts and instruments to plot and follow their desired course. Piloting aircraft is much different from simply driving a car and following roads. Because it is much more difficult to guide or navigate a plane, pilots must go through a great amount of training and obtain a series of licenses before they are allowed to fly. This training helps pilots learn how to use charts, instruments, and navigation systems.

Aeronautical Charts

Aeronautical charts are charts that provide important data for airplane pilots and navigators. These charts are basically topographic maps on which special guidance information has been added. Aeronautical charts show elevations of hills and mountains, as well as the locations of airports and other landing areas. They have special markings that locate prohibited areas where aircraft cannot fly legally, such as around military installations. Other areas are labeled as restricted. These are not prohibited, but they could be dangerous. Artillery ranges are marked as restricted areas.

When plotting a course for an aircraft, the pilot or navigator uses a navigation plotter. See **Figure 22-7.** It is used to measure distances, as well as directions, when placed on top of an aeronautical chart.

Instruments

The cockpits of aircraft are filled with guidance and navigation equipment. See **Figure 22-8.** The number and types of instruments required depend on the type of flying being done. Pilots follow ***visual flight rules (VFR)*** when weather conditions allow them to navigate by what they are able to see outside the cockpit. ***Instrument flight rules (IFR)*** are followed when weather conditions do not allow pilots to navigate visually. There are several essential instruments that can be found on any airplane, whether the pilot operates by IFR or VFR. See **Figure 22-9.**

Airspeed indicators measure the difference between two pressures acting on an aircraft. As the plane starts flying, air rushes into a small tube on the outside of the aircraft. There is another tube inside the plane's ***fuselage***, or the

Figure 22-7. A navigation plotter is used with an aeronautical chart to plot the course of an aircraft. The plotter is made from clear plastic, and it combines a protractor with a straight edge marked with different scales.

Figure 22-8. The cockpit of a modern airliner has nearly 1000 instruments, controls, and gauges filling almost every possible space. Smaller aircraft have many less instruments. Note that all the controls are duplicated on each side of the cockpit. The command pilot sits on the left, with the copilot on the right. Either can fly the aircraft. (Airbus)

Figure 22-9. Essential instruments found on aircraft of all sizes. This aircraft combines traditional gauges with electronic display screens. (Cessna Aircraft Company)

Visual flight rules (VFR): Rules followed when weather conditions allow pilots to navigate by what they are able to see outside the cockpit.

Instrument flight rules (IFR): Rules followed when weather conditions do not allow pilots to navigate visually.

Airspeed indicator: An instrument that measures the difference between two pressures acting on an aircraft.

Fuselage: The main body of a plane.

main body of the plane. Both tubes lead to the airspeed indicator. The difference in pressure between the two tubes activates a small diaphragm. The motion of the diaphragm is displayed on the face of the instrument in miles per hour (mph) and knots. The ***vertical speed indicator*** works similarly to the airspeed indicator. This instrument, however, displays the rate at which the airplane is ascending or descending. ***Altimeters*** are used to display the altitude, in feet, of the aircraft from the ground. ***Artificial horizon*** instruments, also called attitude indicators, display the amount of pitch and roll of the aircraft, compared to the horizon. The ***heading indicator*** shows the pilot the direction the plane is headed.

Vertical speed indicator: An instrument that displays the rate at which the airplane is ascending or descending.

Altimeter: An instrument used to display the altitude, in feet, of the aircraft from the ground.

Artificial horizon: An instrument, also called an attitude indicator, that displays the amount of pitch and roll of an aircraft compared to the horizon.

Heading indicator: An instrument that shows the pilot the direction the plane is headed.

Electronic Navigation Equipment

Instruments allow pilots to find their current direction, speed, attitude, and altitude. Most pilots use the instruments in combination with electronic navigation equipment to ensure efficient travel from one place to another. Electronic navigation equipment is based on the use of radio waves. Radio transmitting stations used for guidance are usually land based. They are mostly government owned and operated.

Radio waves are distinguished by their frequencies. High-frequency waves are very accurate for navigation, but they cannot travel past the horizon. Low-frequency waves are still accurate, and their signals carry for thousands of miles. The type of frequency used is determined by the function of the transmitting station. High frequencies are employed if the waves are to be sent only short-range. If the waves are to be sent over very long distances, lower frequencies are used.

Radio Direction Finding

Radio direction finding is one of the early methods for guiding airplanes and ships. Electronic equipment aboard the vehicle receives transmissions sent by radio transmitters (beacons). The navigator adjusts the antenna until it signals it is locked onto the direction of the incoming signals. The course of the vehicle can then be adjusted according to the position of the beacon.

The Very-High-Frequency Omnidirectional Radio Range (VOR) Navigation System

Very-high-frequency omnidirectional radio range (VOR) navigation was developed in the 1940s. This is a commonly used guidance system for air transportation. Each VOR station transmits a series of beams in all directions. The beams of radio waves are called ***radials***. See **Figure 22-10.** The locations of VOR stations make up typical air routes. They are easy to find using a VOR instrument. The VOR instrument shows the heading of the next VOR station. See **Figure 22-11.** Because the systems send out signals in all directions, pilots can navigate in any one of 360 verified directions toward or away from the VOR transmitter.

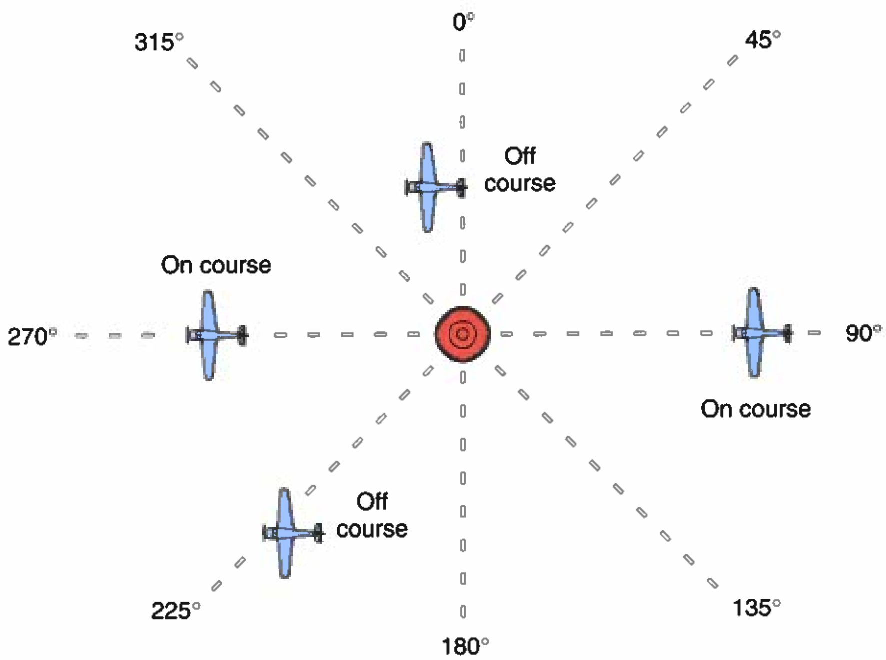
Very-high-frequency omnidirectional radio range (VOR) navigation: A commonly used guidance system for air transportation. Each VOR station transmits a series of beams of radio waves in all directions. A VOR instrument shows the heading of the next VOR station.

Radial: A beam of radio waves.

The Instrument Landing System (ILS)

The ***instrument landing system (ILS)*** is a system allowing pilots to land in all types of weather conditions. It uses two radio waves to mark the approach of a ***runway***, or a flat, straight path specially lit and marked

Figure 22-10. A very-high-frequency omnidirectional radio range (VOR) station sends out radio signals in all directions for aircraft to home in on. There are presently over 1000 VOR transmitting stations in the United States. The pilot selects a signal (also called a radial) and locks onto it. Each radial is different from the others so they can be kept apart and identified. The airplane has a VOR-detecting device that locks onto the signals and tells the pilot or navigator which radial it is following.



Instrument landing system (ILS): A system allowing pilots to land in all types of weather conditions. It uses two radio waves to mark the approach of a runway.

Runway: A flat, straight path specially lit and marked to aid pilots.

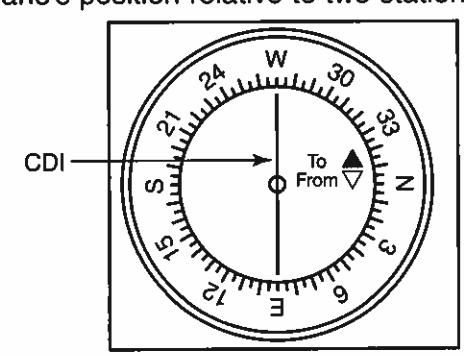
GREEN TECH
GPSs can also be used to help determine environmental issues. The government can use GPSs and send data to geographic information system software for analysis.

to aid pilots. The first wave is a localized beam marking the center of the runway. The second beam is the guide-slope beam that designates the path to be followed by the approaching aircraft. There are also three beacons indicating the beginning, middle, and end of the approach. The first is anywhere from 4 to 7 miles from the runway. The final beacon is near the end of the runway. The aircraft is equipped with an ILS indicator showing the location of the plane within the two beams and three beacons. In bad weather conditions, the ILS can be relied on to land the plane.

Global Positioning Systems (GPSs)

It is estimated that VORs and ILSs will eventually be phased out, due to the advances in satellite technology. Global positioning systems (GPSs) will ultimately be used for navigation and landing of aircraft. They use a collection of satellites that work together to locate any position on or above earth. There are two types of GPSs available to aircraft

Figure 22-11. The very-high-frequency omnidirectional radio range (VOR) instrument on the cockpit control panel. The course selector turns the compass card so the desired heading is at the top, or 12 o'clock position. The course deviation indicator (CDI) points at the desired heading when the plane is on course. Deflection to the left or right indicates the plane has gone off course. This instrument can also show the plane's position relative to two stations.



pilots. GPS receivers can be purchased as handheld or in-dash systems. The in-dash systems are installed in the aircraft and are typically more sophisticated than the handheld receivers. See **Figure 22-12.**

GPSs can be used to navigate from one point to another by placing way points. A ***way point*** is the location of the destination. Once the way point is set, the receiver can calculate the information needed to keep the aircraft on the correct heading. With the use of the Wide Area Augmentation System (WAAS) and the Local Area Augmentation System (LAAS), which make GPSs more accurate, GPSs will eventually be used to land aircraft.

Way point: The location of a destination in a global positioning system (GPS).

Attitude: The position and orientation, or directional control, of an aircraft.

Control surface: A moveable airfoil designed to change the attitude of an aircraft.

Envelope: The inside of a hot air balloon.

Control Systems

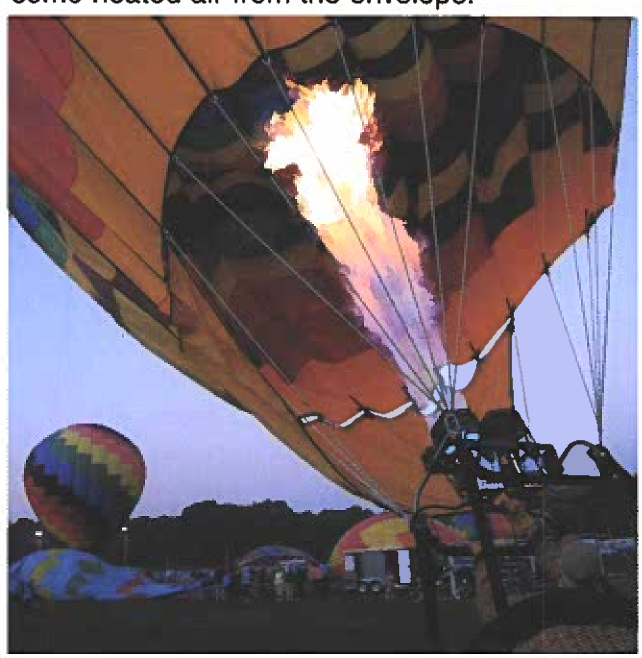
Aircraft are controlled in two ways. First, the attitude of the aircraft must be controlled. The ***attitude*** is the position and orientation, or directional control, of the aircraft. This is controlled by the use of control surfaces on the aircraft. ***Control surfaces*** are moveable flaps that deflect wind and help to steer the aircraft. Second, the speed of the aircraft must be controlled. Speed can be controlled in several different ways.

Lighter-Than-Air Vehicle Control Systems

The amount of control a pilot has of a lighter-than-air vehicle depends entirely on the type of vehicle. Hot air balloon pilots can only control the vertical flight of the balloon. Changing the temperature of the air inside the balloon controls the altitude of the hot air balloon. To raise the balloon, the pilot turns on the burner and heats air inside the balloon, or ***envelope***. See **Figure 22-13.** To lower the balloon, the pilot allows the air to cool or

Figure 22-12. An in-dash global positioning system (GPS) receiver. Chart displays pinpoint the aircraft's position and can be changed in scale to show wider or more detailed views. In-dash systems can be integrated with weather maps, terrain charts, and aeronautical charts. (Cessna Aircraft Company)

Figure 22-13. Heated air from a propane burner is directed into the envelope of the hot air balloon, providing lift, which causes the balloon to rise. To descend, the pilot can vent some heated air from the envelope.



opens a vent at the top of the balloon. The direction and speed the hot air balloon travels are not as easily controlled by the pilot. Balloon pilots are at the mercy of the wind. Pilots must raise or lower the hot air balloon to take advantage of wind currents and directions.

Blimps and dirigibles are lighter-than-air vehicles that are able to control both vertical and horizontal dimensions of flight. See **Figure 22-14.** These airships use both horizontal and vertical stabilizers to steer the craft. These ***stabilizers*** are similar to rudders used on boats. By manipulating the rudder, pilots control the flow of air. Airflow, in turn, influences the direction of travel. By raising or lowering the horizontal stabilizer, a blimp ascends or descends. Turning the vertical stabilizer right or left steers the rear of the airship sideways in either direction. The components of the propulsion systems can control some lighter-than-air vehicles. Thrust in a different direction reorients the position of the craft. Propulsion fans driven by engines swivel in order to swing the blimp in the desired direction. See **Figure 22-15.**

Heavier-Than-Air Vehicle Control Systems

Different control systems control the different types of heavier-than-air vehicles. Airplanes rely on surfaces to steer the aircraft. Instead of surfaces, helicopters use two rotating blades to control the movement of the aircraft.

Airplane control systems

Airplanes are heavier-than-air vehicles capable of great speed and control. See **Figure 22-16.** In order for an airplane to be controlled, the vehicle must be stable. There are three types of stability of great concern to all pilots: directional, lateral, and longitudinal stability. Each of these types of stability is concerned with one axis of the aircraft. See **Figure 22-17.** The axes are all 90° from each other, like the X, Y, and Z axes you may have studied in a mathematics course. Each axis is stabilized by a ***stationary surface,*** which is a surface that is fixed in one position, such as an airplane wing, and can be controlled by a moveable control surface. See **Figure 22-18.**

Figure 22-14. Horizontal and vertical stabilizers on a blimp function like rudders on a boat, turning the vehicle or making it rise or descend. (The Goodyear Tire & Rubber Company)

Figure 22-15. Propulsion fans mounted on the blimp's control cabin provide forward (or backward) motion and also can be swiveled to provide directional control. (The Goodyear Tire & Rubber Company)

Figure 22-16. Airplanes control three degrees of freedom and can be precisely maneuvered at high speed, as in this example of precision formation flying. (U.S. Air Force)

Directional stability allows the airplane to fly in a straight line. The horizontal stabilizer, or tail fin, is used to provide directional stability. While the plane is in motion, wind currents that push the tail of the aircraft off course can affect the directional stability. This side-to-side motion is known as ***yaw***. A rudder placed at the back of the tail fin controls yaw. See **Figure 22-19.**

Ailerons are moveable control surfaces placed on the main wing. The wing of the plane is the stationary stabilizer for lateral stability. ***Lateral stability*** is used to overcome the tendency of the plane's wings to dip on either side. This motion is known as ***roll***. When the ***control stick***, or the airplane lever operating the elevators and ailerons with the power to guide the aircraft, is pushed right, the right aileron is angled up, and the left aileron is angled down. This causes the plane to roll to the right.

Longitudinal stability is the ability to fly the airplane without the nose moving up or down. The ***horizontal tailplane*** is used to achieve longitudinal stability. ***Elevators*** are the moveable surfaces placed on the tailplane to control changes in this stability. Movement in this direction is known as pitch. ***Pitch*** is the up and down movement of the nose of the aircraft.

A turn, or bank, in an aircraft is known as a ***coordinated turn*** because all three control surfaces must work together. The rudder orients the nose of the plane. The ailerons roll the plane into the turn. The elevators are used to maintain altitude.

The speed of most aircraft is controlled by changing the amount of thrust the engine produces. Large aircraft have additional control surfaces to slow themselves down during landing. These control surfaces are known as ***spoilers***. When the spoilers are raised, they help to slow the aircraft down by increasing the amount of drag.

Stabilizer: A device, similar to a rudder on a boat, used by a pilot to steer an airship. It controls the flow of air.

Stationary surface: An immobile, exterior boundary of an object.

Directional stability: The ability to fly an airplane in a straight line.

Yaw: The side-to-side motion of an aircraft.

Figure 22-17. Yaw, pitch, and roll are the three motions affecting stability of an aircraft. (Estes)

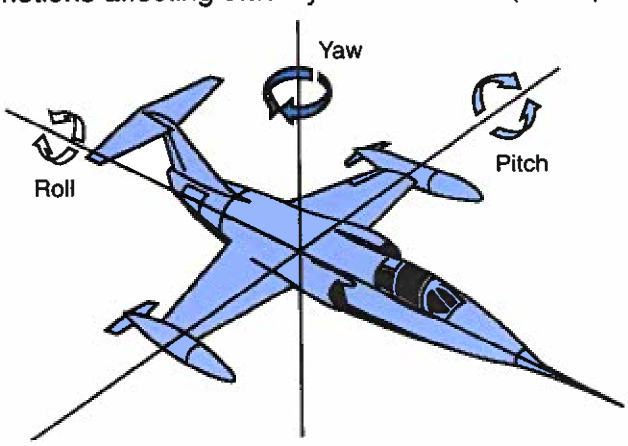
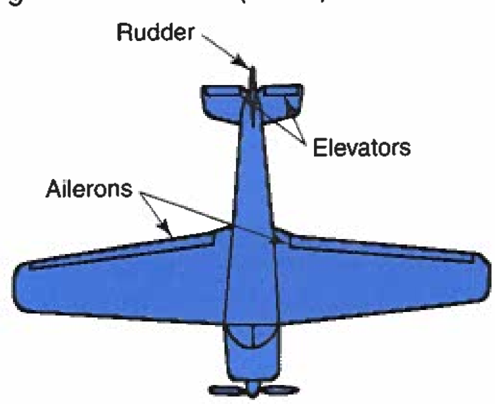


Figure 22-18. The ailerons, elevators, and rudder are moveable surfaces that help control the flight of an aircraft. (Estes)



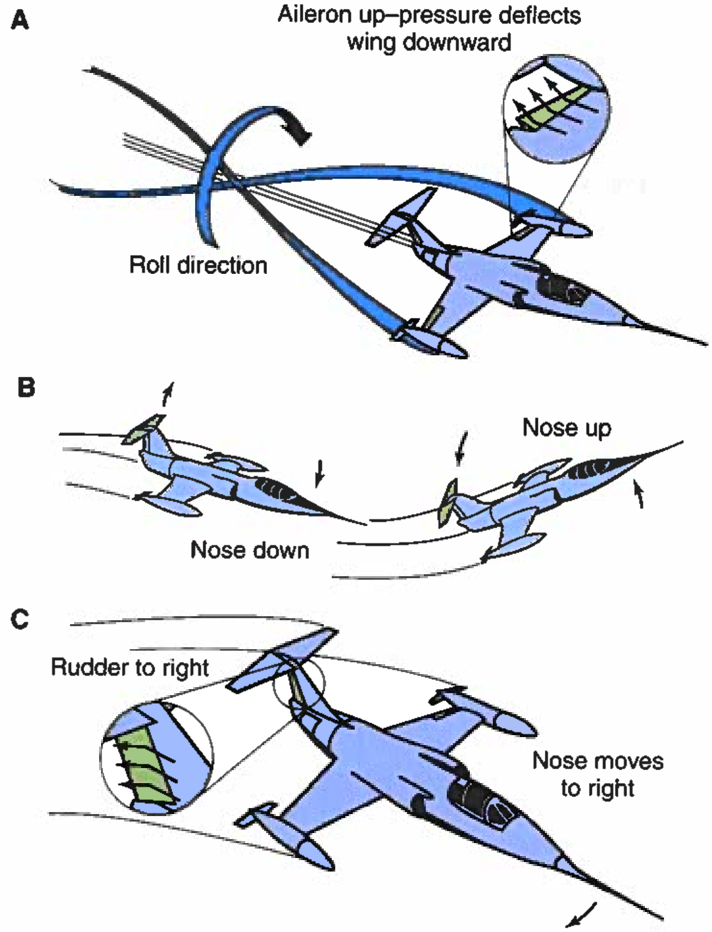


Figure 22-19. Functions of the moveable control surfaces. A—Ailerons. These surfaces can be raised or lowered to bank the plane in either direction. Moving the control stick of the airplane from right to left controls roll. B—Elevators. Moving the control stick forward or backward controls the aircraft pitch. Moving the stick backward raises the elevator and angles the nose of the plane upward. This allows the airplane to climb. C—Rudder. By turning the rudder using rudder pedals, the pilot can correct the yaw and direct the nose of the plane in the right direction. The rudder is only used to correct yaw, however, and cannot be used to turn the aircraft itself. (Estes)

Helicopter control systems

Helicopters are rotary-wing aircraft that can move in different directions with greater speed and agility than airplanes. They are more maneuverable. A *swash plate* located on the main rotor makes control possible. See **Figure 22-20.** Two hand levers, known as the collective pitch control lever and the cyclic control stick, control the swash plate. See **Figure 22-21.** The ***collective pitch control lever*** directs the swash plate to change both blades evenly. This allows the helicopter to ascend or descend. The ***cyclic control stick*** changes only one side of the swash plate. This changes the pitch of the blades on only one side of the rotor. The pilot can steer in any direction. By controlling cyclic pitch, pilots determine the vehicle's direction of flight forward, backward, and laterally (to the left or right).

To turn the helicopter, the pilot uses the directional control pedals at his feet. The directional pedals control the thrust of the tail rotor. In straight flight, the thrust of the tail rotor is equal to that of the main rotors. When turning, the pilot either increases or decreases the amount of tail rotor thrust to spin the helicopter in either direction.

Aileron: A moveable control surface placed on the main wing of a plane.

Lateral stability: The ability to overcome the tendency of a plane's wings to dip on either side.

Roll: The tendency of a plane's wings to dip on either side.

Control stick: The airplane lever operating the elevators and ailerons with the power to guide the aircraft.

Longitudinal stability: The ability to fly the airplane without the nose moving up or down.

Horizontal tailplane: The tail surfaces of an airplane that are parallel to the horizon, including the stabilizer and the elevator.

Elevator: The moveable surface placed on the tailplane to control changes in longitudinal stability.

Pitch: The up-and-down movement of the nose of an aircraft.

Coordinated turn: A turn, or bank, in an aircraft in which all three control surfaces work together.

Spoiler: A control surface on a large aircraft designed to slow the aircraft down during landing by increasing the amount of drag.

Swash plate: Part of a helicopter that controls the pitch of the blades on the main rotor, controlling the aircraft's horizontal and vertical movements.

Collective pitch control lever: A helicopter control that directs the swash plate to change both blades evenly, allowing the aircraft to ascend or descend.

Figure 22-20. The swash plate (see inset) controls the pitch of the blades on the main rotor of the helicopter, controlling the aircraft's horizontal and vertical movements. (Sikorsky Helicopter)

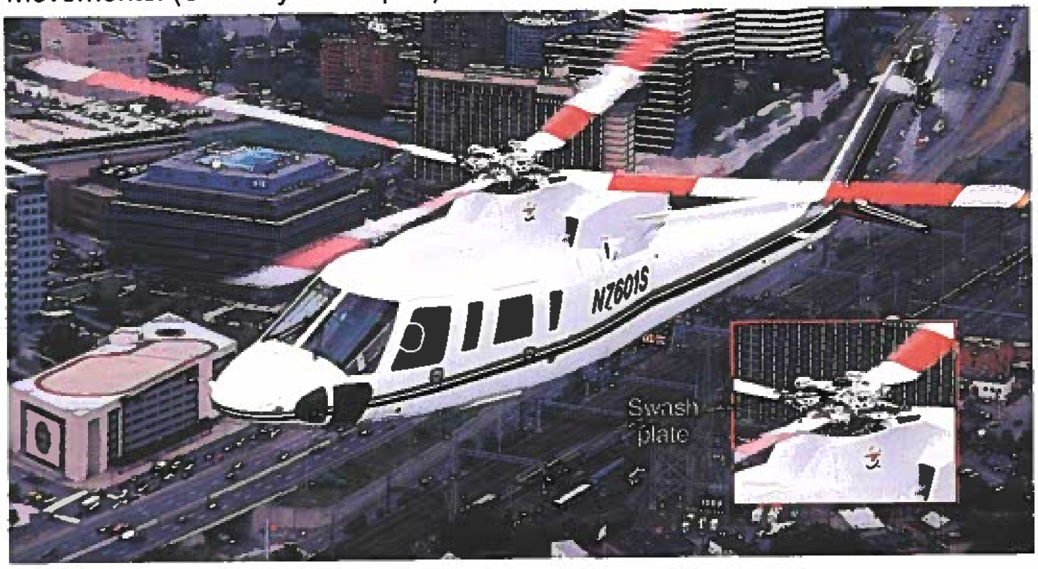


Figure 22-21. The collective pitch control lever controls upward and downward movement of the helicopter. The cyclic control stick is used to steer the aircraft. (Sikorsky Helicopter)

Suspension Systems

Airplanes must have suspension systems so they can take off, land, and maneuver on the ground. Usually, airplanes have wheels. The wheels are called landing gear.

Small aircraft usually have their landing gear arranged in one of two ways. See **Figure 22-22.** In the conventional arrangement, the single wheel is at the tail of the plane, and the two main wheels are under the cockpit.

Figure 22-22. Landing gear arrangements. A—A taildragger system with two main wheels under the wings and a small wheel beneath the tail. This arrangement was one of the first ways wheels were positioned onto planes. B—Tricycle gear, with a nose wheel and two main wheels. This arrangement keeps the plane more or less level when it is at rest and gives the pilot better visibility when taxiing and taking off.

A

B

A plane with this arrangement is known as a taildragger. It has a disadvantage in the fact that the pilot has poor visibility when the plane is on the ground. This is because the fuselage of the plane tends to point upward when at rest. This also makes takeoffs more difficult and even requires special training from the Federal Aviation Administration (FAA). In the tricycle-style landing gear arrangement, the two main wheels are placed just behind the cockpit area. The single wheel is in the plane's nose, usually under the engine area.

Cyclic control stick: A helicopter control that changes only one side of the swash plate. This changes the pitch of the blades on only one side of the rotor.

Large commercial passenger planes use the tricycle-style landing gear. Instead of three wheels, they have multiple sets of wheels. See **Figure 22-23.**

Wheels are attached to the aircraft with struts. Struts are designed so they absorb the shock of the airplane touching the ground. They are made differently, depending on the size of the vehicle they must support. Small planes can use one-piece metal struts. Large planes use hydraulic shock-absorbing devices similar to the ones used on automobile suspensions. Of course, the shock absorbers on large planes must be stronger than those used on cars.

Some airplanes are designed to land on water. Their suspension systems use pontoons instead of wheels. See **Figure 22-24.** Some planes can land on solid ground or water. These use wheels attached to the insides of the pontoons. Planes used on snow and ice can be fitted with skis.

The components of airplanes that enable flight are also parts of the suspension system. Airplanes are suspended by air flowing over and under specially shaped wings. Even though the function of wings as part of the suspension system is not easy to understand, the wings are just as important as wheels on a car. The main force we are concerned about when studying suspension is lift. The shape of the wing, speed of the airplane, and angle of attack affect lift.

Figure 22-23. To support the heavy weight of large airliners during takeoff and landing, multiple sets of wheels are used. (Airbus)

Figure 22-24. Floats called pontoons are used, instead of wheels, to allow aircraft to land on water. The pontoons are hollow cylinders, so they float. This type of aircraft is used extensively to provide transportation to remote areas of Alaska and Canada. (Howard Bud Smith)

The shape of a plane's wing is called an airfoil. See **Figure 22-25.** The front of the airfoil is called the ***leading edge***. The point at the back of the airfoil where the top and bottom meet is known as the ***trailing edge***. The line drawn between the leading and trailing edges is the ***chord line***. If you were to divide the airfoil in half between the top and bottom, the resulting curve is the mean camber line. The distance between the top of the mean camber line and the chord line is the ***camber***. The length, or span, of the wing is also an important variable. The ***span*** is the length of the wings, from tip to tip. With the span and chord line, the aspect ratio of the wing can be figured. The ***aspect ratio*** is the span divided by the chord line (aspect ratio = span/chord). For wings that do not have a constant chord line length—for example, wings that get smaller at the tips—a different formula is used. In these cases, the aspect ratio is equal to the span, squared, divided by the area of the wing. The chord line, mean camber line, span, and camber of the airfoil affect the amount of lift possible.

Leading edge: The front of an airfoil.

Trailing edge: The point at the back of an airfoil where the top and bottom meet.

Chord line: The line drawn between the leading and trailing edges of an airfoil.

Camber: The distance between the top of the mean camber line and the chord line of an airfoil.

Span: The length of a plane's wings, from tip to tip.

The way in which airfoils actually generate lift is an area of great discussion. There are two popular theories of lift: the Bernoulli theory and the Newtonian theory. Both theories were originally meant to describe phenomena, rather than lift. They have both been used, however, to describe how lift occurs. Each theory has both correct and incorrect aspects.

The Bernoulli theory states that the air traveling over the airfoil is forced to travel farther than the air traveling below. See **Figure 22-26.** This generates a higher speed of airflow across the top, which creates an area of low pressure. The area of lower pressure then lifts the airfoil up. This popular theory is incorrect for several reasons. First, not all airfoils are longer on the top. Some have either the same or less distance on the top of the airfoil than the bottom of the airfoil. Secondly, the air across the longer section of the airfoil travels too fast for this theory to be accurate. One part of the theory is, however, correct. There is an area of lower pressure created above the airfoil. It is not, however, created due to a difference in air velocity.

Figure 22-25. The major parts of an airfoil.

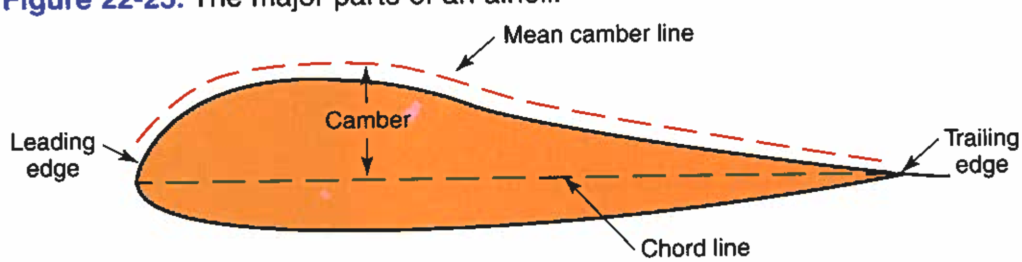
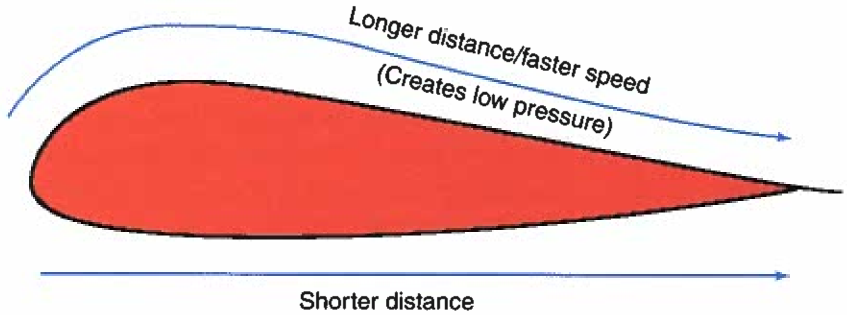


Figure 22-26. The Bernoulli theory of lift.



Aspect ratio: The span divided by the chord line.

The Newtonian theory is based on the ideas of Newton's third law of motion. The idea of this theory is that, as the air particles hit the bottom of the airfoil, the particles are deflected downward. See **Figure 22-27.** This deflection then causes the airfoil to react in the opposite direction, generating lift. This theory is also incorrect because it assumes that the top of the airfoil makes no difference in the amount of lift generated. It has been proven in tests that both the top and bottom of the airfoil affect lift.

The actual creation of lift is a complicated lesson in physics. The basic theory of lift is that lift is created by turning the flow of a gas. Both the top and bottom of the airfoil are used to change the direction of the air as it flows around the airfoil. By turning the flow of air, all parts of the airfoil work together to generate lift. The speed of the plane is also an important part of the creation of lift. Lift is a force, and force equals mass multiplied by acceleration ($F = M \times A$). Acceleration is a measurement of velocity (speed and direction) and time. Therefore, the greater the speed, the more lift generated.

The final variables in the factors of lift are the angle of incidence and angle of attack. The ***angle of incidence*** is the angle of the wing as it is attached to the aircraft. It is measured from an imaginary line running from the nose of the aircraft to the tail of the aircraft and cannot be changed once the aircraft is built. The angle of attack refers to the position of the wing as it hits the air. See **Figure 22-28.** As the front of the wing tips

Angle of incidence: The angle of the wing as it is attached to the aircraft.

Figure 22-27. The Newtonian theory of lift.

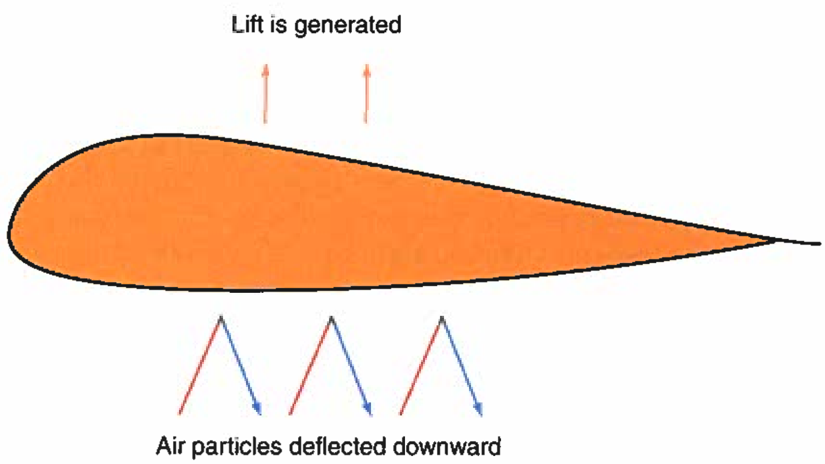
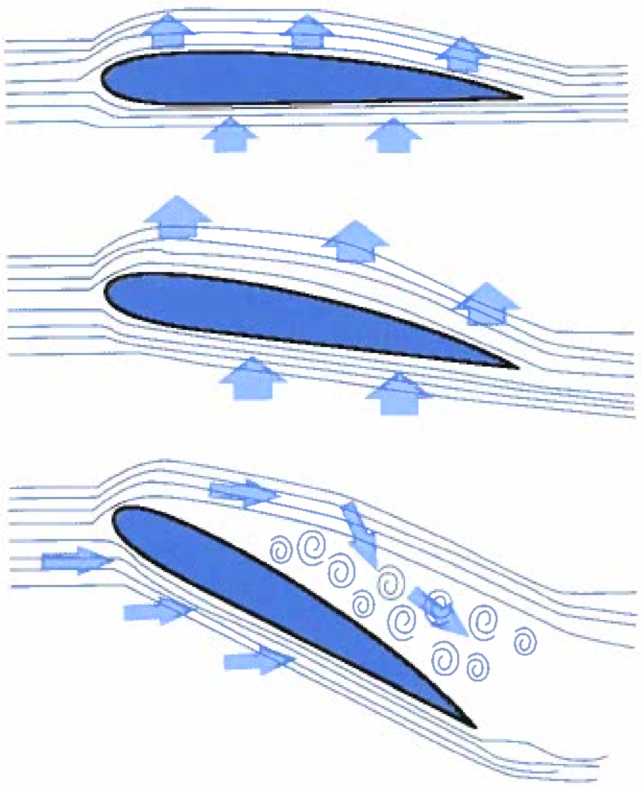


Figure 22-28. The upward tilt of the wing's leading edge is referred to as the angle of attack. As the angle of attack increases, so does the lift the wing generates.



upward, the angle of attack increases. This means a great amount of the oncoming air hits directly on the bottom of the wing. This action tends to push up on the plane, forcing it higher in the air. There is a limit, however, to the angle of attack. If the angle becomes too great, the wing will quickly lose lift. This situation is known as ***stall***, and it can be very dangerous.

Structural Systems

The structures of aircraft are substantially different in lighter-than-air and heavier-than-air vehicles. Lighter-than-air vehicles require an envelope in which they can hold either air or another gas. Heavier-than-air vehicles, typically, require a much more rigid structure.

Lighter-Than-Air Vehicle Structural Systems

Lighter-than-air vehicles, as we have seen, are designed to displace a large amount of air. Their structures need to be large in order to contain enough air or gas to rise. Each type of lighter-than-air vehicle has a slightly different structural system.

Blimps are nonrigid airships. The pressure the gas exerts maintains the shape of the vehicle. When the gas, usually helium, is let out of the blimp, the vehicle deflates and does not retain its shape. The blimp balloon, or envelope, is constructed of a strong, but lightweight, polyester or fabric. The internal structure of the balloon contains two air bags or ballonets, which can be filled with helium. Cables running within the envelope attach the cars, or gondolas. The gondolas include an area for passengers and the pilots and also have engines mounted to each side. The stabilizers are mounted to the rear of the envelope.

Stall: A situation in which the angle of attack becomes too great and the wing quickly loses lift.

GREEN TECH
Lighter-than-air vehicles have the potential to be more environmentally friendly than other types of air vehicles. Recently, it has been shown that these ships can be powered by solar energy.

Hot air balloons are similar to blimps. The pressure of the hot air they contain holds their shape. Balloons are made of ripstop nylon, similar to the sails on sailboats. Steel cables running through the fabric are attached to the basket holding the fuel and occupants. See **Figure 22-29.**

An inflator fan fills the envelope with air. This gives the balloon its initial shape while it is still on the ground. When the pilot is ready and has done a safety check of all the vehicle's systems, he heats the air inside the envelope with large propane-fueled burners. As the air heats, the envelope begins to rise and stand straight up. After a few more safety checks and more heat, the balloon is ready to ascend.

Rigid airships are sometimes referred to as zeppelins, named after Count Ferdinand von Zeppelin, a German general and aeronautical designer. They have stiff frameworks that serve as hulls. The hulls retain the shape of these airships, unlike nonrigid airships. Inside the rigid airships, there are a number of airtight compartments filled with hydrogen or helium gas. The propulsion systems and stabilizers are attached to the hull structure using mounting brackets. Large, hotel-like gondolas are also part of the rigid superstructure. These airships are no longer in use.

Heavier-Than-Air Vehicle Structural Systems

Heavier-than-air vehicles are designed to have large lifting capabilities. The structures of heavier-than-air vehicles can be divided between airplanes and helicopters. Both types of aircraft have specific structural needs.

Airplane structural systems

When powered flight first became a reality, airplane structures were made of wood. They had wire and cables for support and bracing. The wooden structures were covered with fabric, which gave the vehicles smooth skins. These surfaces enabled airflow to generate lift. Today, airplanes are built quite differently.

Figure 22-29. Because it is lightweight and shock resistant, wicker has traditionally been used for the baskets of hot air balloons.

The fuselage

The fuselage is the large hollow section that holds the other parts of the plane together. In passenger aircraft, the fuselage contains a passenger cabin, a cargo hold, and a cockpit. See **Figure 22-30.** In cargo planes, the fuselage is divided into just two sections, the cargo hold and the cockpit.

The structure of the fuselage can be either constructed as a truss or shell. Early aircraft used the truss-type construction. This type of structure consists of pieces of wood or steel running the length of the plane. These are called ***longerons***. Cross-members called webs attach the longerons. The resulting truss structure is very strong and rigid, but it fills the interior with braces and wires, which cut down on useable space. Modern aircraft make use of monocoque or semimonocoque construction. ***Monocoque*** means "one shell." This type of construction results in a hollow structure with plenty of room for passengers, cargo, and equipment. See **Figure 22-31.** Monocoque construction relies on the outer covering, or skin, of the aircraft to carry most of the load. ***Semimonocoque*** construction makes use of both vertical and horizontal frame members that relieve some of the stress on the skin of the aircraft. Bulkheads, frames, and formers are the vertical members used to give greater strength. The horizontal members include longerons and stringers, and they help to keep the fuselage from bending.

Longeron: A piece of wood or steel running the length of the plane.

Monocoque: A type of fuselage construction that results in a hollow structure. A series of ringlike ribs attached to the strong metal outside covering of the plane form the skeleton of the structure.

Semimonocoque: A type of fuselage construction that makes use of both vertical and horizontal frame members, relieving some of the stress on the skin of the aircraft.

STEM Connection

Math: Lift Coefficients

The amount of lift an airfoil will provide can be figured mathematically. In order to figure the lift, you must know the lift coefficient for the airfoil in question. The lift coefficient is a number that takes into account the shape, the angle of attack, and other features of the airfoil. It can be figured either experimentally or by using computer software. Once the lift coefficient is known, the amount of lift can be determined mathematically using the following formula:

lift = coefficient × density × 1/2 × velocity squared × wing area

or

$$L = Cl \times r \times .5 \times v^2 \times A$$

L = the weight the aircraft can carry
Cl = number determined experimentally
r = air density at the altitude to be measured
v = speed of aircraft (in feet per second)
A = the chord × the length of the wing

Here is an example:

Cl = .59
r = .00237 slug/ft^3 (density of air at sea level)
v = 250 miles per hour (mph), or 336.75 feet per second (fps)
A = 400 ft^2

$$L = 0.59 \times 0.00237 \times .5 \times (336.75)^2 \times 400$$

Lift = 31,713 lbs.

If a pilot knows any four of the variables in the above formula, she can solve for the unknown quantity. A pilot could solve for the speed of the aircraft if she knows the amount of lift, the coefficient of the airfoil, the area of the wing, and air density. For more information about lift and lift coefficients, visit the National Aeronautics and Space Administration (NASA) Glenn Research Center's on-line Beginner's Guide to Aerodynamics.

The tail section

Empennage: The tail section of a plane.

The tail section of the plane is also called the ***empennage***. See **Figure 22-32.** This section is the part that contains many of the vital control surfaces. The empennage consists of a tapered continuation of the fuselage to maintain an aerodynamic shape.

The wings

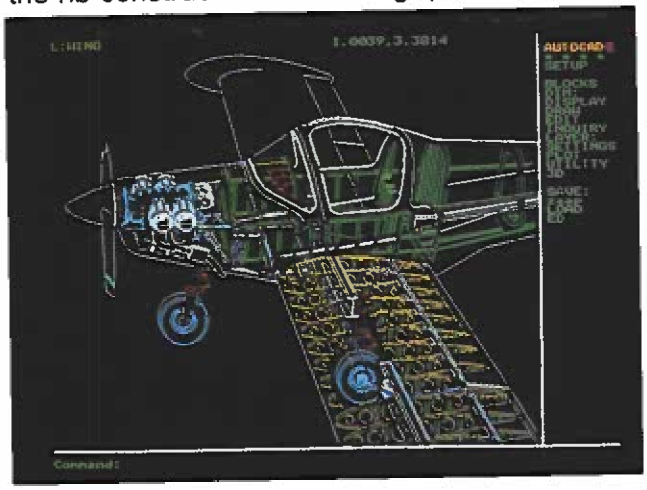
The wings are an extremely important structural part of the aircraft. The main structural members are two aluminum alloy spars. These run the length of the wing, starting at the fuselage. The airfoil shape of the wing is made by adding strong, lightweight ribs. These are spaced at regular intervals between the fuselage and the tip of the wing. The ribs are

Figure 22-30. The cockpit, passenger cabin, and cargo hold are the major sections of an airliner's fuselage. At the front of the fuselage is the cockpit. This is where the pilots and flight crew control and navigate the plane. The passenger cabin contains seats, windows, and amenities to ensure a comfortable trip. The cargo hold is typically either behind or underneath the passenger cabin. It is used to store baggage and other cargo during transport. (Airbus)

Figure 22-31. Monocoque construction results in large unobstructed cargo areas in modern aircraft. Smooth, aerodynamic shapes are also possible with monocoque construction. Instead of structural members running the length of the plane, monocoque construction relies on a series of ringlike ribs. These ribs form the skeleton of the structure. They are attached to the strong metal outside covering of the plane. (U.S. Air Force)

Figure 22-32. The empennage, or tail section, of an aircraft consists of the vertical and horizontal stabilizers. The rudder is attached to the vertical stabilizer, and the elevators are attached to the horizontal stabilizer.

Figure 22-33. This computer-aided design (CAD) drawing shows details of the wing and fuselage construction for a small plane. Note the rib construction in the wing. (Autodesk, Inc.)



braced with cross-members to give the structure strength. This framework of spars, ribs, and braces is covered with thin, lightweight sheets of aluminum alloy. These sheets form the skin and provide the smooth aerodynamic shape essential for flight. The skin is also essential to the strength of the wing structure. Wings must be securely attached to the fuselage. See **Figure 22-33.** Usually, wings are cantilevered out from the plane. Airplane wings have taken many shapes and forms. This is the result of designers trying to improve flight characteristics of aircraft. See **Figure 22-34.**

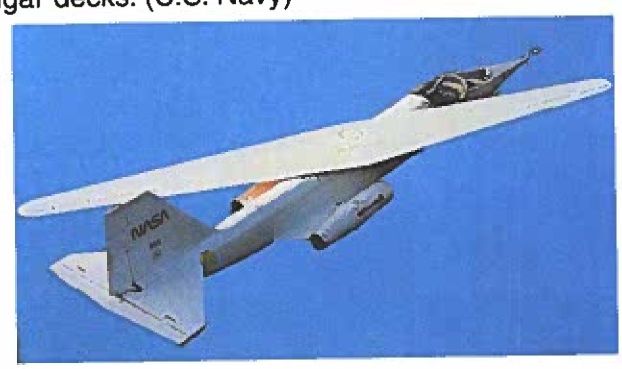
Helicopter structural systems

Helicopter structures follow designs similar to those of airplanes. Usually, a combination of truss and semimonocoque construction methods is employed. The two main sections of the helicopter are the tail section and cabin. The cabin may be compared to the fuselage of an airplane. See **Figure 22-35.** The tail section of a helicopter is usually of the truss type. It needs to be rigid. This section usually does not, however, need to support cargo or passengers.

Figure 22-34. Different wing shapes. A—This experimental aircraft, the X-29, has a forward-swept wing. (National Aeronautics and Space Administration) B—A pivot-wing aircraft. C—Folding wing aircraft are used to save space on aircraft carrier hangar decks. (U.S. Navy)

A

B



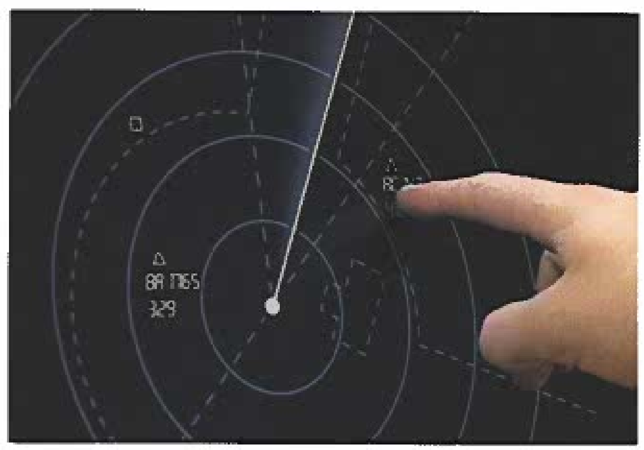
C

Support Systems

Airports are facilities that house most of the major support systems for air transportation. They are busy places. The communication centers and control towers are important parts of this system. Their main activity is to keep track of all planes within their airspace. Controllers work in the control tower and use radio detecting and ranging (radar) screens to keep track of all the planes. See **Figure 22-36.** There are several stages of air traffic control. The air traffic control tower is located at the airport. It tracks all planes within 5 miles of the airport and handles all departures and landings. The terminal radar approach control station monitors planes between 5 and 50 miles from the airport. While planes are in route and outside of 50 miles from an airport, air route traffic control centers view their locations. Another important activity is ground support. This involves the people who guide the aircraft to the gates, service the planes, and handle baggage. All types of support systems are represented at airports. Airports are where passengers and cargo make the transition from land to air transportation.

Figure 22-35. Helicopter cabins are generally similar to the cabins of comparable-sized airplanes. They are where the passengers, pilots, and cargo are located. The fuel and propulsion systems are also part of a helicopter cabin.

Figure 22-36. Controllers rely on radar to keep track of multiple aircraft. They are also in voice contact with the pilots of the aircraft.



Runways

In order to take off and land, airplanes need lengthy runways. See **Figure 22-37.** Small airports use a single runway. As air traffic increases, other runways are usually added either parallel or perpendicular to the first one. A ***taxiway*** is the name of the roadway that connects the runway to the terminal. As airplanes leave the terminal, they follow the taxiways to the runway they will use for takeoff. Runways are generally labeled based on their magnetic heading, with the last digit removed. For example, a runway positioned at 040 degrees is labeled "04," if you are heading to the northeast, and "22" (for 220 degrees), if you are heading on the same runway to the southwest.

Taxiway: A roadway that connects the runway to the terminal.

Special markings are added to runways to guide pilots of approaching and landing aircraft. Runway lighting helps guide pilots who are landing or taking off at night or in weather conditions that limit visibility. See **Figure 22-38.**

Career Connection

Air Traffic Controllers

Transportation, Distribution & Logistics

Air transportation is a fast moving and busy part of the global transportation system. It is so busy, in fact, that some of the world's busiest airports see nearly 2500 airplanes take off from their runways each day. It is the job of air traffic controllers to direct those airplanes on the ground and in the air to make sure the aircraft maintain safe distances from each other.

There are a number of different types of air traffic controllers stationed throughout the journey of an airplane. These controllers include tower controllers, ground controllers, en route controllers, radio detecting and ranging (radar) controllers, and flight service specialists. A controller is in contact with an aircraft pilot from the time the pilot is taxiing to the runway until he lands and receives a gate location at the destination. Controllers are employed by the Federal Aviation Administration (FAA), and most work typical 40-hour work weeks.

Air traffic controllers are under high amounts of stress and must maintain deep concentration throughout their shifts. Because of this, controllers must take preemployment tests that measure their abilities to work in high-stress environments and to learn the activities of an air traffic controller. All candidates for air traffic controller jobs must have a college degree or full-time work experience. They must also attend the FAA Academy, where they receive controller training. With experience and time, controllers are able to advance through different controller positions. Average earnings for air traffic controllers are slightly over $110,000 per year.

Figure 22-37. Many airports have runways in different directions because of changeable wind patterns in the area. Airplanes usually take off and land headed into the wind. With a variety of runways, airports can always provide a relatively safe landing area. This is a diagram of Chicago's Midway Airport, which occupies a one-square-mile site.

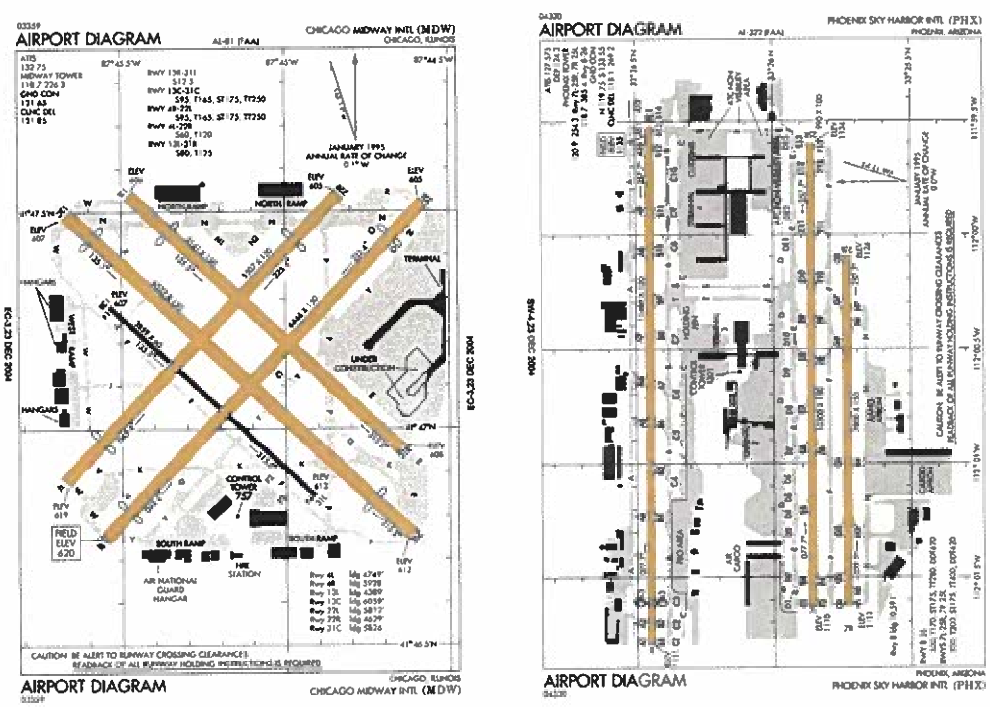


Figure 22-38. Many runways are fitted with recessed lights in the center to help at night or when weather creates poor visibility. A series of lights is also placed in rows along the sides of the runways. These lights help the pilot determine the runway width. Lights at the end of the runway blink in a sequence indicating the direction of travel.

GREEN TECH

The construction of airport terminals has a large impact on the environment. Airports require large amounts of land, which can adversely affect the surrounding ecosystem. The amount of flat land that is constructed can also cause more inclement weather, such as fog, to occur more often.

Airport Terminals

Passenger and cargo terminals are often very large at airports in major cities. See **Figure 22-39.** Passenger terminals in airports have all the services of other transportation terminals. Ticket counters, restaurants, lounges, shops, and comfortable waiting areas are available for passenger use. Separate baggage areas are in the terminal so passengers can pick up their luggage on their way to securing land transport. See **Figure 22-40.** Cargo terminals at airports are usually separate from passenger terminals. Cargo planes are directed straight to them once they land.

Aircraft Maintenance

It is extremely important that aircraft be well maintained. Proper and thorough maintenance on the ground can save lives, as well as cargo and vehicles. See **Figure 22-41.**

Inspections are a part of aircraft maintenance. The FAA requires thorough inspections on a regular basis. Because of the increasing number of accidents among aging aircraft, the FAA has increased the number of inspections. The FAA determines and enforces the inspections for all types of aircraft, commercial and private.

Various types of inspections are carried out on aircraft. See **Figure 22-42.** Because the cabins must be pressurized to fly at high altitudes, structural stress is great. Every time the vehicle takes off and gains altitude, the fuselage expands, or gets larger. When the vehicle descends to land, the fuselage contracts because of atmospheric pressure changes. This flexing is not great, by any means, but it causes metal fatigue over a long period of time. Metal fatigue results in the weakening of the material until it is

Figure 22-39. Most airport designs incorporate their facilities in the land-side–air-side layout. In this type of layout, passengers and cargo approach the airport from one side, and air traffic operates on the other. This layout permits smooth traffic flow for both land and air vehicles. Airport buildings are usually located in the center of the layout. Airport fire and rescue stations, however, are usually located away from the congested central area of the airport. In this large airport, the double roadway down the center and the semicircular parking and terminal structures are the land side. The air side consists of the runways arranged along either side of the airport; the gate areas, where planes load and unload at the terminals; and the support structures, such as cargo and maintenance facilities.

Figure 22-40. Moving baggage efficiently from check-in counters to departing aircraft and from arriving aircraft to the baggage claim areas is a major concern at large airports. This baggage handling and sorting system located in Munich, Germany uses scanners to read bar codes attached to bags and automatically route them to the correct aircraft or baggage claim area. (Siemens)

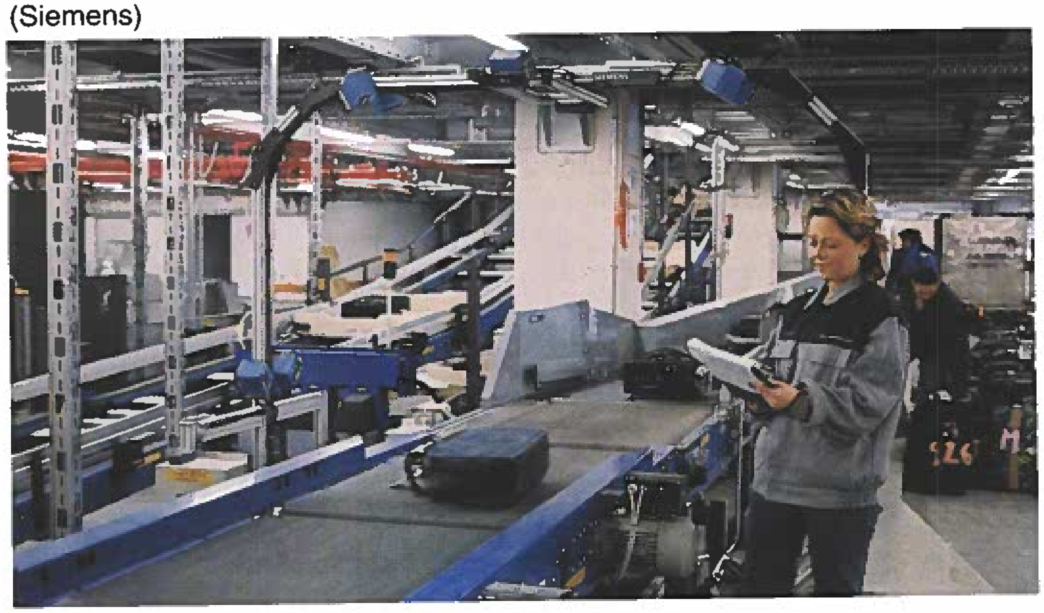


Figure 22-41. Careful maintenance of equipment is essential for safe air travel. (America West Airlines)

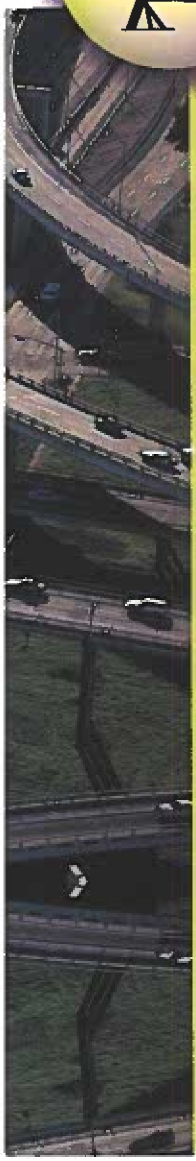
Figure 22-42. Inspections of aircraft engines and other systems and components are carried out on a regularly scheduled basis. These inspections are used to find faults that may cause engine, landing gear, electronic, or structural problems. The various inspections airplane support crews perform range from visual inspections to highly complex electronic inspections. (United Airlines)

prone to breaking. Should the metal fuselage break, air disasters can easily happen. Inspectors were once able to find cracks in the fuselage by locating small brown stains on the airplane. Tobacco smoke–filled air leaking from the fuselage caused the stains. Now that smoking is not allowed on most flights, more advanced methods are being used. Bright lights and cleaning solutions help inspectors see small cracks.

X-ray techniques have been developed to study internal components of aircraft. The X rays can produce images of very complex parts. The problem is that the pictures are hard to read and interpret. Misread X rays have led to crashes.

Another type of inspection uses eddy currents. A magnetic field produces a small electrical current in a piece of metal. Any cracks will disturb the flow of current. These can be monitored on a meter or screen. Cracks that are invisible to the naked eye can be detected in metal up to 5/8″ (16 mm) thick. This type of inspection is very slow, and expensive magnetic probes must be used. Different probes are used on different parts of an aircraft.

Besides the conscious and rigorous inspections, normal vehicle maintenance must be performed on aircraft. The same types of things you would do for any other vehicle, you do for an airplane. This makes sense because vehicles can last a lot longer with proper maintenance.



Technology Link

Communication: Airline Use of Internet Services

The flight segment of air transportation is usually very efficient and much faster than any other form of transportation. There are many other things, however, that go into air travel. Airport parking, ticketing lines, security checkpoints, concourses and gates, and baggage claims can all be points of stress. The airline companies realize this and have begun to use the Internet and other communication systems in order to help travelers deal with these issues.

Many airlines have Web sites that allow passengers to check the status of their flights. One of the first uses of the Internet in air transportation was the electronic ticket (e-ticket). It is now common to purchase reservations for an airline and not receive a paper ticket. The reservation is held in a computer system and accessible at the ticket counter. Before leaving for the airport, passengers are able to determine if the flight is on time or delayed. There are Web sites that track the location, speed, elevation, and estimated time of arrival of all airplanes in flight. This gives people picking up passengers at the airport an idea of when the airplane will actually land. Flight information can even be sent to mobile devices, such as personal digital assistants (PDAs) and cell phones.

Many airlines have self check-in kiosks. These kiosks allow passengers to check themselves in and receive their boarding passes. Those passengers who check baggage to be stored in baggage compartments also benefit from information technology. Baggage tags have scan bars placed on the luggage, and the passengers receive a receipt with the baggage code. Each time the baggage is moved, it is scanned. In an instance in which a piece of luggage is lost, the baggage tag can be tracked down by computer to find the last location where the baggage was scanned. While this does not always help the baggage get to the right location, the baggage can at least be tracked down.

Lastly, travelers often find themselves waiting in airport terminals for several hours, either before a flight or on a layover. For business travelers, this often means a loss of work time. Many airports have, however, installed wireless networks. These networks allow travelers to use their laptop computers or PDAs to communicate with others using e-mail or to simply surf the Internet in an effort to pass the time. While air transportation can be frustrating at times, the use of information technology has the ability to keep passengers better informed and to speed up the process of air travel.

Summary

Air vehicular systems allow both lighter-than-air and heavier-than-air vehicles to perform the act of transportation. Either the use of a reciprocating engine and a propeller or a type of jet engine generates propulsion. When an aircraft is in flight, the pilot monitors the onboard instruments and navigation equipment to make sure the aircraft has the right heading. Global positioning systems (GPSs) have begun to revolutionize how aircraft are guided and will continue to advance in the future. To keep an aircraft on course, the pilot uses aircraft control systems. Control systems in airplanes involve both stationary and moveable surfaces that change the attitude and heading of the plane. Helicopters are controlled by changing the amount of rotation in the tail rotor and the pitch of the main rotor blades. All aircraft require both suspension and structural systems. Suspension systems in airplanes rely on the wings to keep the plane in the air and on the landing gear to safely land the plane. The structural system involves the shell or system of trusses holding the plane together. Commercial airplanes contain different sections within the structural system, allowing for the pilot's cockpit, the passenger cabin, and a luggage compartment. Support systems aid all air transportation vehicles. These systems include maintenance facilities, terminals, control towers, and runways. They are most often found at airports.

Key Words

All the following words have been used in this chapter. Do you know their meanings?

aeronautical chart
afterburning turbojet engine
aileron
airfoil
airspeed indicator
altimeter
angle of attack
angle of incidence
artificial horizon
aspect ratio
attitude
camber
chord line
collective pitch control lever
control stick
control surface
coordinated turn
cyclic control stick
directional stability
elevator
empennage
envelope
fuselage
heading indicator
horizontal tailplane
instrument flight rules (IFR)
instrument landing system (ILS)
Isaac Newton's third law of motion
lateral stability
leading edge
longeron
longitudinal stability
Mach 1
monocoque
pitch
radial
radial engine
ramjet engine
roll
runway
semimonocoque
span
spoiler
stabilizer
stall
stationary surface
swash plate
taxiway
trailing edge
turbofan engine
turbojet engine
turboprop engine
vertical speed indicator
very-high-frequency omnidirectional radio range (VOR) navigation
visual flight rules (VFR)
way point
yaw

Test Your Knowledge

Write your answers on a separate sheet of paper. Do not write in this book.

1. _____ engines are configured with the pistons arranged in a circle.
2. Name the two variables that determine the amount of thrust a propeller generates.
3. What gearbox ratio is needed if the output shaft needs to turn at 1750 revolutions per minute (rpm), and the input shaft turns at 7000 rpm?
4. Jet engines operate on the principle of the _____ law of motion.
5. The simplest jet engine is the _____.
   A. turboprop
   B. ramjet
   C. afterburner
   D. turbojet
6. Explain how the turbojet engine operates.
7. *True or False?* The thrust from the rear of the turboprop engine is not the main source of propulsion for turboprop engines.
8. *True or False?* Afterburners are inefficient to operate.
9. *True or False?* The air leaving the rear of a turboprop is used to provide thrust.
10. Maps pilots use are known as _____.
11. Aeronautical charts are similar to _____ maps.
    A. political
    B. topographic
    C. road
    D. city
12. Artificial horizon instruments are used to determine _____.
    A. speed
    B. altitude
    C. pitch and roll
    D. heading
13. Summarize how the instrument landing system (ILS) operates.
14. Define the three types of stability of an aircraft.

Matching questions: For Questions 15 through 17, match the terms on the left with the correct term on the right.

15. Yaw.
16. Roll.
17. Pitch.

A. Elevator.
B. Rudder.
C. Aileron.

18. *True or False?* Propulsion systems are used to generate drag.
19. Discuss the use of the cyclic control stick in helicopter control.
20. Commercial passenger planes use _____-style landing gear.
21. Write two or three sentences explaining how an airplane flies.
22. The length from the leading edge to the trailing edge of an airfoil is the _____.
    A. chord line
    B. aspect ratio
    C. camber
    D. angle of incidence
23. Paraphrase the two explanations of the creation of lift.
24. The position of the wing as it hits the air is known as the _____.
    A. deflection angle
    B. camber
    C. chord line
    D. angle of attack
25. Determine the lift of an airfoil with the following statistics: Cl = .64, r = 0.00237 slug/ft^3, v = 300 fps, and A = 425 ft^2.
26. *True or False?* Nonrigid airships retain their shape when the air is let out.
27. The tail section is also known as the _____.
28. Identify the parts of the structural system of an airplane.

Matching questions: For Questions 29 through 31, match the phrases on the right with the correct term on the left.

29. Air traffic control tower.
30. Terminal radio detecting and ranging (radar) approach control station.
31. Route traffic control center.

A. 50 miles and farther from an airport.
B. Between 5 and 50 miles from the airport.
C. Within 5 miles of the airport.

32. List three types of services available at most airports.

STEM Activities

1. Use the FoilSim software available at the National Aeronautics and Space Administration (NASA) Web site to design and test various types of airfoils.
2. If a wind tunnel is available, test a model aircraft in the wind tunnel.
3. Construct a model of a hot air balloon and test it.
4. Build a model or display of one of the types of jet engines.
5. Create a flight plan using aeronautical charts.