21

Air Transportation Systems

Basic Concepts

- Define *aircraft*.
- Identify aviation services.

Intermediate Concepts

- Describe how airways are used to keep the air safe.

Advanced Concepts

- Compare lighter-than-air craft to heavier-than-air craft.
- Calculate lift in balloons.

Air transportation has evolved in just over 100 years from flying a few feet to flying around the world. Air transportation systems rely on people and vehicles. Many of the people in these systems are pilots, maintenance personnel, airport employees, and air vehicle designers. The vehicles used are known as aircraft. An ***aircraft*** is any vehicle that transports people or cargo through the air.

The History of Air Transportation

Air transportation is a relatively new form of transportation. Both land and water transportation have been around for thousands of years. Air transportation, however, is only a few hundred years old. Many people throughout history have looked to the sky with a desire to fly. Leonardo da Vinci, for example, created sketches of gliders and helicopters over five hundred years ago. ***Gliders*** are aircraft with stable wings, but no power source. ***Helicopters*** are aircraft with rotating wings. Many attempts at flying were made through the early years of transportation development. The first developers of air transportation were people who were imaginative, courageous, and creative. Many of these inventors looked at nature to

Aircraft: A vehicle that transports through the air.

Glider: An aircraft with stable wings, but no power source.

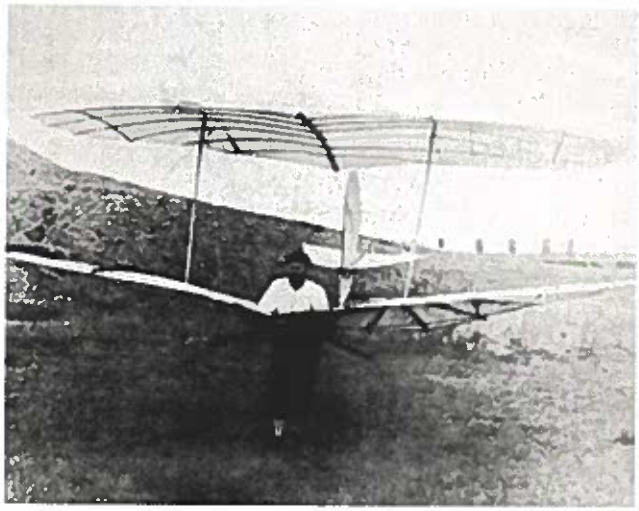
Helicopter: An aircraft with rotating wings.

gather clues as to how human flight could be possible. The Montgolfier brothers, for example, watched smoke rise through a chimney and knew, if they could trap the smoke, they could rise along with it. As a test, they filled a bag with smoke and hot air. The bag rose, as they predicted. Using this concept, they developed a balloon made out of paper and filled it with smoke and heated air. The balloon rose 6000' and traveled 7500' before it deflated and fell to the ground. In 1783, the Montgolfier brothers designed and built the first passenger hot air balloon. The balloon made a 5-mile flight over Paris, France. On its flight, the balloon was manned by two men, and it stayed up for 23 minutes. The development of the hot air balloon gave humans a glimpse of what was possible. This limited success with a form of flight attracted more research and development by creative and courageous people.

Aerodynamics: The study of the motion of air and how it reacts to objects passing through it.

In the early 1800s, George Cayley began to investigate the principles that would make flight possible. His studies became the basis of the new study of aerodynamics. ***Aerodynamics*** is the study of the motion of air and how it reacts to objects passing through it. Cayley's studies led to the building of many models of gliders, including a full-scale glider that could be piloted. This glider became the first human-piloted glider. Several men, including Otto Lilienthal, Samuel Langley, and Octave Chanute, continued the study of gliders and aviation through the 1800s. Lilienthal designed a number of both single- and double-winged gliders. See **Figure 21-1.** Langley, a Smithsonian director, was the first to add a gasoline engine to a glider. His tests of small models were successful. He was never able, however, to successfully fly a full-size, piloted, powered glider. Chanute developed moveable wings to add to the control of the gliders. All these pioneers were very adamant about sharing their work and test results with others. They published books and made their work available to others, including Orville and Wilbur Wright.

Figure 21-1. Otto Lilienthal with one of his double-winged gliders. His work most closely represents the hang gliders of today. One of the Wright brothers took this photo in 1895. (Library of Congress)

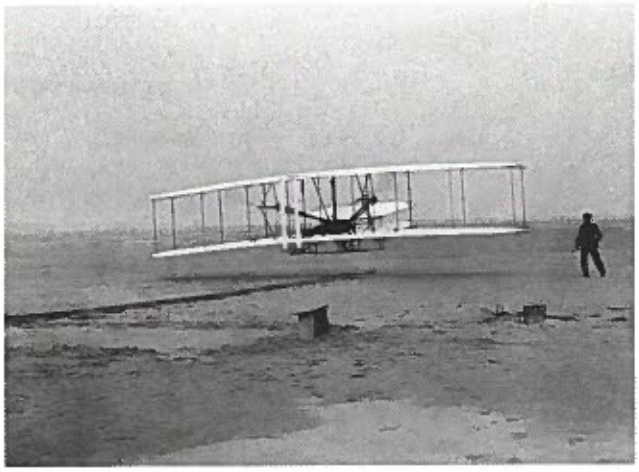


About a century after the first balloon flight, the Wright brothers chose to enter the aviation world. See **Figure 21-2.** They were both experienced mechanics. The brothers gathered as much information as they could about the work of the pioneers before them and set out to build the first manned, powered flying machine. They began by building a series of kites, small wings, and gliders to investigate the principles of flight. The Wright brothers did much of their building at their bicycle shop in Dayton, Ohio, and their testing was done at Kitty Hawk, North Carolina. By 1903, they had developed ways to control the movements of an aircraft, or a vehicle that transports through the air. The way these movements are controlled today is very similar to the way they were controlled in the Wrights' gliders and flyers. In 1903, the Wright brothers added an engine that provided power to two propellers at the rear of the wing, known as

pushers. They named the plane *Flyer*. *Flyer* was the first successful ***airplane***, or fixed-wing aircraft kept in flight by an engine or other power source. The Wrights' airplane was airborne for 12 seconds and covered 120′. By the end of that day, the Wrights had increased the time and distance of flight to 59 seconds and 859′.

By the 1920s, companies such as Boeing, Douglas, and Lockheed were developing new and innovative airplane designs. The original biplane, an airplane with two wings on top of each other, had been discarded for the monoplane, a single-wing design. Several of these companies and others began transporting mail and then moved into the business of transporting people by airplane. By the 1940s, air travel was becoming a common method of travel. Planes were carrying passengers all over the world. See **Figure 21-3.** Airplanes, both large and small, were using piston-propeller engines. These engines used pistons that turned a crankshaft attached to the propellers. This was the common type of propulsion until the jet engine was invented in the late 1940s. Today, the jet engine has made it possible to break the sound barrier and easily travel around the world.

Figure 21-2. The world's first powered, sustained, and controlled flight took place on December 17, 1903. Orville Wright is at the controls of the *Flyer* in this historic photo that recorded the first flight. He and the *Flyer* were airborne for 12 seconds and covered 120′. By the end of that day, they had increased the time and distance to 859′ in 59 seconds. Due to patent concerns, the airplane was kept out of the public eye until 1908, when the Wright brothers made frequent appearances, showing their invention. (Library of Congress)



Airplane: A fixed-wing aircraft kept in flight by an engine or other power source.

Figure 21-3. Charles Lindbergh flew this Ryan monoplane, *Spirit of St. Louis*, from the United States to France in 1927. It was the first solo (single-person) flight across the Atlantic Ocean. The flight lasted over 33 hours. (National Aeronautics and Space Administration)

GREEN TECH

It has been found that airplanes may contribute a great deal to air pollution. When burning fuel, airplanes can emit carbon dioxide, nitrogen oxide, and other harmful vapors.

Routes

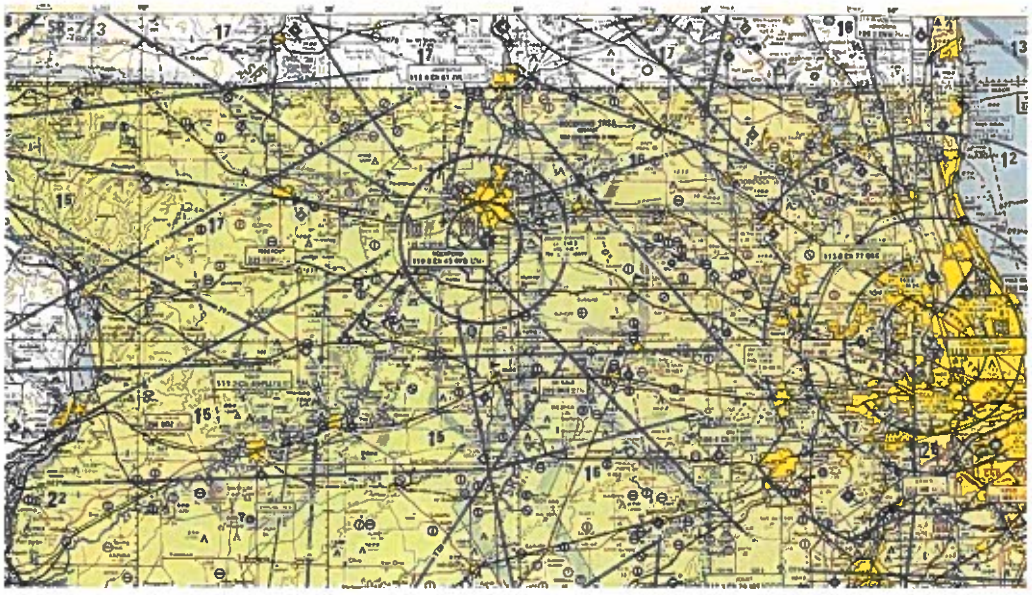
Airway: A path or route airplanes follow.

Just as water transportation has no physical highways on the water, there are no physical highways in the air. There are, however, airways. ***Airway*** is a general term for a path or route airplanes follow. The airways are designated, regulated, and controlled by the Federal Aviation Administration (FAA). They are set up in a pattern that looks very similar to a highway system. See **Figure 21-4.** The intersections of the airways are placed above very-high-frequency omnidirectional radio range (VOR) devices. VOR devices are transmitters that supply airplanes with location information.

Jet route: An air transportation path reserved for large commercial jets and airliners.

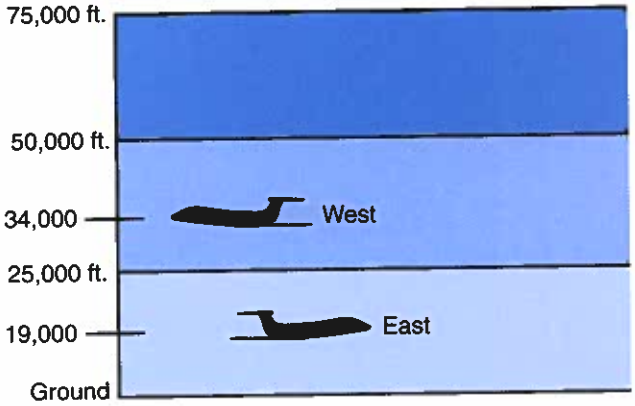
Air transportation paths can be divided into two different types: airways and jet routes. Specifically, airways cover the area from ground level to 18,000′ above sea level. Airways serve small aircraft on short routes. ***Jet routes*** are positioned from 18,000′ up to 75,000′. They are reserved for large commercial jets and airliners. Both of these types of lanes are 8 nautical miles wide. For safety, planes must be kept apart from one another. This is done through maintaining distance, or airspace, from one another. The airways and jet routes are divided into 1000′ layers, according to their distance from earth. The layers assist the pilots in maintaining the proper distance from one another. For example, in the jet route layers, three of the layers are at 22,000′, 23,000′, and 24,000′. All even-numbered layers are for planes flying west (from 180°, south, to 359°, just shy of north). All odd-numbered layers are for planes flying east (from 0°, north, to 179°, just shy of south). See **Figure 21-5.** Aircraft must maintain either 1000′ or 2000′, depending on the lane, of vertical distance between each other. They must also leave more than 10 minutes of travel time between one another. The air layers are designed to keep the skies safe from accidents.

Figure 21-4. Airways are "highways in the sky" intersecting above very-high-frequency omnidirectional radio range (VOR) transmitters that provide location information. The circled area is the Rockford, Illinois VOR transmitter.



The air is also divided into classes of airspace. The different types of airspace dictate the types of planes that can enter. For example, Class B airspace surrounds major airports. To enter Class B airspace, the pilot must gain permission from the control tower. He must also have a private pilot license. Other airspaces have different requirements. Airplane pilots need to be well versed on the regulations for flying an aircraft. There is other airspace, some of which surrounds military bases, which is restricted to only military personnel. Even the airspace above and around sporting arenas is often restricted during events.

Figure 21-5. Airways divide the sky into layers so air collisions are avoided. Craft are assigned layers according to their direction of flight and type of aircraft. In all even-numbered layers, aircraft fly west. Aircraft fly east in all odd-numbered layers.



Modes of Air Transportation

An aircraft is a vehicle designed for navigation in the air. It is supported by the air against its surfaces. Lighter-than-air craft are known as balloons and airships. They rise and float. Wind, in the case of a balloon, is the only means of propulsion. Heavier-than-air craft are airplanes, helicopters, and gliders. This type of craft requires power to maintain its speed, thus, creating lift. Lift keeps the craft in the air as long as it maintains sufficient airspeed.

Lighter-Than-Air Craft

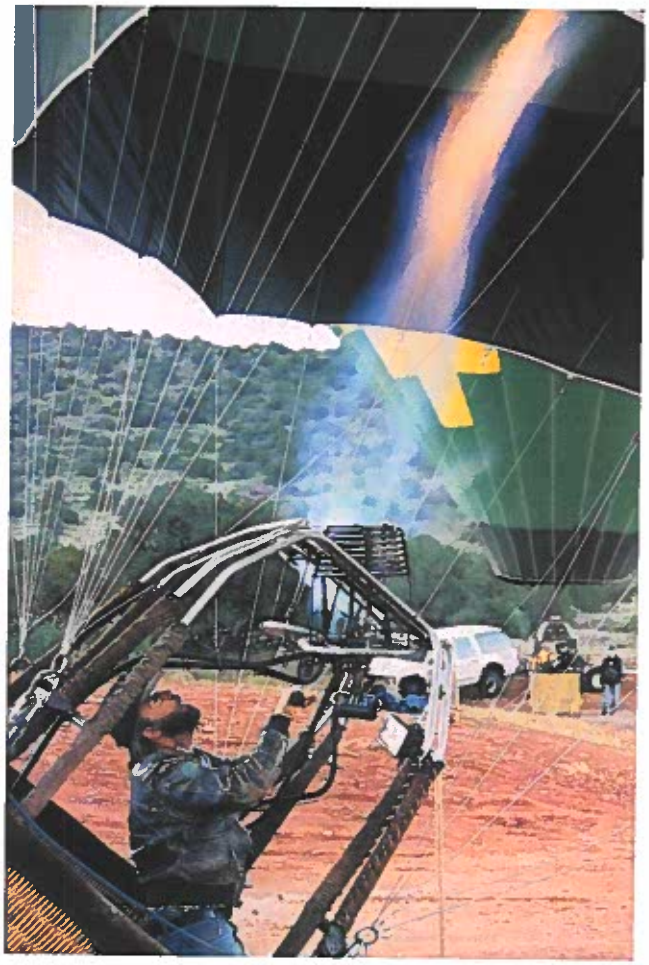
Once the subject of much experimentation, lighter-than-air craft are more energy efficient than heavier-than-air craft. Heavier-than-air craft require large quantities of energy to take off and keep them in the air. Lighter-than-air craft are held aloft by their captive gases. The gases used for lighter-than-air vehicles are selected because they are less dense than air. The density, or mass divided by volume, of air at sea level is 1.23 kg/m^3. This measurement varies according to altitude and temperature. The gases used must be less dense than 1.23 kg/m^3. The two gases typically used are helium and hot air. These gases are safe to use, are less dense than air, and can be used in several different lighter-than-air vehicles.

Balloons

The invention of balloons dates back to the 1700s, when people were curious about the upper atmosphere. The early experimental balloons were very similar to and operated on the same principles as the balloons used today. Balloons have little structure. The envelope (balloon portion) is filled with gas or hot air. Balloons used for recreation are filled with hot air. See **Figure 21-6.**

A balloon floats in the air using the same principle a boat uses to float in water. Just as objects in water have buoyancy, objects in the air have lift. Lift is the upward pressure equal to or greater than the air the object displaces. A balloon or any other object that floats in the air must weigh less than the air that has been displaced. In a hot air balloon, the load

Figure 21-6. Propane burners heat air to inflate and provide lift for a balloon. Heating the air lowers its density, making the air inside the envelope lighter than the air around it.



normally carried is the weight of the passenger basket, the burner and propane tanks, and the passengers. Hot air balloons are lowered by allowing the air to cool and become the same density as the air outside the balloon. They rely on the movement of the wind to propel them from place to place.

Balloons have been used for a number of different purposes throughout history. See **Figure 21-7.** They have periodically been called on for military duties all over the world. Balloons have also been used to measure and observe weather conditions.

Airships

In the late 1800s and early 1900s, large lighter-than-air ships were being built. They were designed to carry cargo and passengers around the world. This type of lighter-than-air ship is known as an airship. An airship is also known as a ***dirigible***, a French word meaning "steerable." See **Figure 21-8.** Airships have rudders and elevators, which are used to control the direction and altitude. They also have engines, which are used to move the airships. The balloons of airships are filled with gas, unlike hot air balloons, which are usually filled with air. Early airships were filled with hydrogen. Hydrogen is the least dense gas on earth. This meant the airships could carry a large amount of weight. These

Dirigible: An airship that has rudders and elevators, which are used to control the direction and altitude. It also has an engine.

Figure 21-7. Balloons are mainly used today for recreational purposes.

STEM Connection

Math: Lift

It is relatively easy to figure how much hot air is needed to lift the load of a balloon. Every 1 ft^3 of hot air, at 100°C (212°F), can lift approximately .015 lbs. of load. So, if a balloon is needed to carry a load of 600 lbs., it needs to hold at least 40,000 ft^3. To figure this, divide the weight of the load (600 lbs.) by the weight 1 ft^3 of hot air can lift (.015 lbs.). The formula is V = W / lift.

V = Volume of the balloon
W = Weight of the load
Lift = amount of weight lifted per cubic foot (hot air = .015 lbs.)

This formula can also be used to determine how much weight a balloon can lift. For this calculation, the formula is W = V × lift. If you have a balloon envelope that can hold 120,000 ft^3 of hot air, you would use the formula to figure the weight the balloon can lift.

W = 120,000 ft^3 × .015 lbs.
W = 1800 lbs.

airships could carry over 10 times the load a balloon of the same size filled with air could. Hydrogen, however, is very combustible and burns very rapidly when it is ignited. The two main types of airships are rigid and nonrigid.

A rigid airship has a metal frame surrounding the balloon and holding it in place. It can be built very large. The greatest of the old dirigible airships was the *Hindenburg*. The *Hindenburg* was docking in New Jersey after a trans-Atlantic flight, when the hydrogen gas caught fire. It burst into flames and was destroyed. The concerns over the outcome of the *Hindenburg* put an end to the commercial use of rigid airships for good, as it seemed, until recently. There are several companies that have constructed new rigid airships. The main uses of the new airships are to transport cargo to or from places that are hard to reach by train or truck. These airships are also useful in hauling products and machinery that are too large to haul in other modes of transportation. Helium is used, rather than hydrogen, to fill the balloons of the airships. It can carry 1 kg of load for each cubic meter of gas. This is four times more load than air can handle. So, if an airship has the same size balloon as a hot air balloon that can carry 600 kg, the airship will be able to carry 2400 kg.

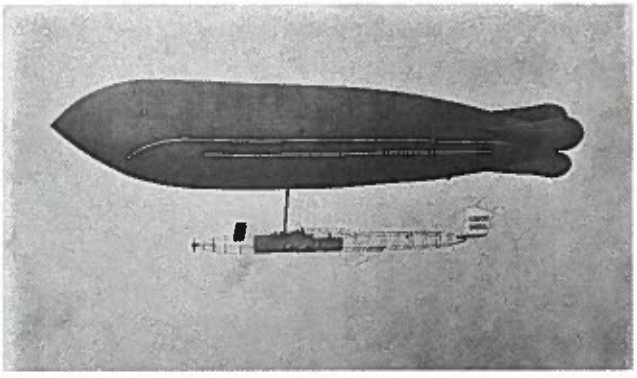


Figure 21-8. An example of an early airship, or dirigible. The French dirigible *Clement Bayard* was photographed around 1900. Note the framework, with the open cabin and steering rudder suspended below the balloon. By the 1930s, large airships with enclosed cabins that could carry 100 people on long trips were being built. (Library of Congress)

Figure 21-9. The most famous of modern blimps is this one, which advertises a brand of tires. (The Goodyear Tire & Rubber Company)

Nonrigid airships are similar to hot air balloons in that they collapse when they are not filled with a gas. These airships are more commonly called ***blimps***. They use helium instead of hydrogen or air to provide lift. Helium is a heavier gas than hydrogen, but it is much safer because it does not burn. Blimps have been used in the past for military surveillance. Today, however, they are mainly used to provide a platform for observation cameras and aerial views. They are also used for advertising and for some cargo lifting. See **Figure 21-9.**

Blimp: A nonrigid airship that collapses when not filled with a gas. It uses helium to provide lift.

Heavier-Than-Air Craft

Heavier-than-air craft are far more numerous than lighter-than-air vehicles. Although more energy must be expended to keep them in the air, they are usually much easier to control than lighter-than-air craft. The heavier-than-air craft include gliders, planes, and helicopters.

Gliders

George Cayley envisioned and developed a fixed-wing aircraft. The craft was made of light wood and stable wings, but it had no power source. It was known as a glider. Gliders can still be seen in the air today. They are used for both recreation and training. Because they are heavier-than-air craft, they have to overcome their weight before they can fly. Airplanes and helicopters use their engines to generate thrust. ***Thrust*** is the force that moves the aircraft through the air. Gliders, however, have no engines. In order for a glider to fly, it must be pulled behind another aircraft until it generates enough speed to maintain lift. See **Figure 21-10.**

Thrust: The force produced by the propulsion system that moves an aircraft through the air.

Figure 21-10. Gliders resemble small airplanes. These aircraft are built from strong, yet lightweight, materials. A glider has no engine, but it stays aloft by riding rising currents of warm air. To begin flying, the glider must be towed into the air by a powered aircraft. (DG Flugzeugbau, GmbH)

GREEN TECH

Though they are not as convenient as traditional commercial airplanes, airships have the potential to be significantly more environmentally friendly due to less emissions and better energy efficiency.

Airplanes

Since 1900, the airplane has progressed very rapidly in design and construction. See **Figure 21-11.** Planes have advanced in design from the Wright brothers' two-wing plane (biplane), which traveled roughly 7 miles per hour (mph); to airplanes that travel at Mach 1, the speed of sound; to supersonic transports (SSTs), which can travel at speeds of 1550 mph (2494 km/h). There are many supersonic aircraft in the military, but only one type was used to transport passengers. See **Figure 21-12.**

Airplanes, like all types of air vehicles, have four forces that act on the aircraft at all times. See **Figure 21-13.** Lift is the upward force that an airplane's wings produce to keep it in the air. It acts directly against ***gravity***, a natural force that tries to pull the plane to the ground. Thrust is the force produced by the plane's propulsion system. It is opposed by ***drag***, which is the force resisting forward motion of the aircraft.

There are many types of airplanes used for business, personal, sporting, agricultural, and commercial activities. Some small private planes have only two seats and one propeller. Other airplanes are used for long-distance commercial flights. These planes, known as

Figure 21-11. Aircraft design and construction have advanced rapidly in approximately a century. National Air Transport (NAT), a predecessor of United Airlines, operated the airmail plane at the top in the early 1900s. Airlines flying long routes operate large aircraft, which can carry hundreds of passengers. (United Airlines)

Figure 21-12. A supersonic transport (SST) travels over twice the speed of sound, which is known as Mach 2. The Concorde was one of the only supersonic airliners in commercial service. It was used to carry passengers from New York to Europe in 3 1/2 hours. British Airways and Air France built and operated a total of 20 Concorde aircraft. The planes flew for nearly 30 years and have all been retired from service.

Gravity: A natural force that tries to pull a plane to the ground.

Drag: The force resisting forward motion of an aircraft.

Curricular Connection

Language Arts: Research

When writing papers, you typically start with a main idea. The majority of your paper is then written to support that idea. In order to do that, you must often do research. *Research* is gathering information and finding facts associated with the topic of your paper.

Research may be done in different ways depending on the topic. For example, a scientific paper may require you to experiment, observe an experiment, and record data. That data is considered research. More common types of research include library and Internet research. Library research involves finding information in books to support your ideas. Internet research involves finding reliable Web sites, such as journal or magazine, government, or academic sites, for the information you need to support your idea.

When you transfer this information from the source to your paper, you can make notes of the facts in your own words. These notes can be used in your final paper. Do not "cut and paste" or directly copy exact sentences or phrasing in your paper. Without citing the source (such as the name of the author and journal or the name of the organization), it is like passing off someone else's work as your own, or *plagiarism*. If you do not intend to cite your source, be sure to reword or rephrase the ideas to support your main idea.

airliners, have seating for hundreds of people. Some planes, known as seaplanes or amphibians, are designed to land on water. Other aircraft are designed to take off and land on short runways. These planes are called short takeoff and vertical landing (STO/VL) planes. See **Figure 21-14.** Other planes are jumbo jets used to transport cargo and passengers. Aircraft are also used for aerial views, photography, crop dusting, and advertising businesses by flying banners.

Figure 21-13. The four forces that act on an airplane in flight. When the forces of lift and thrust are greater than gravity and drag, the plane will fly.

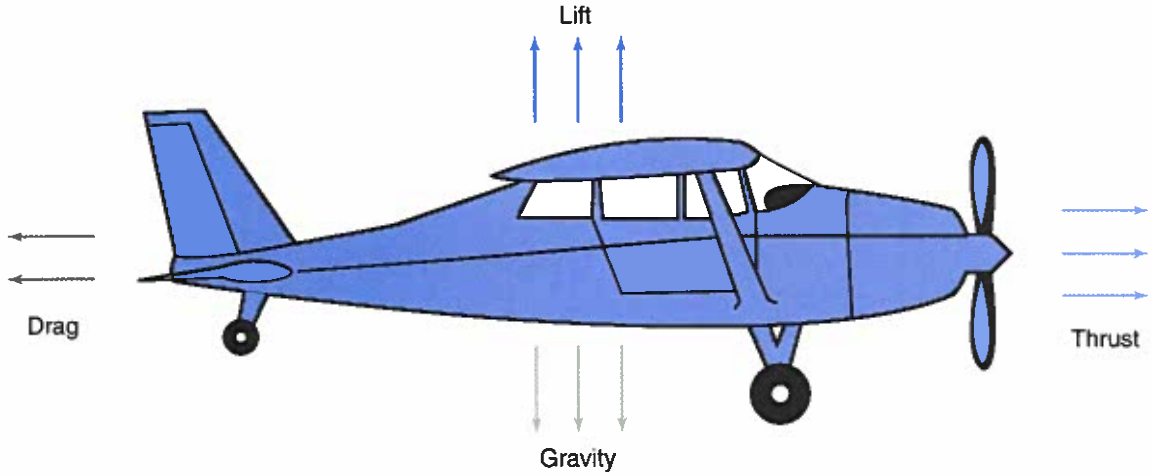


Figure 21-14. Short takeoff and vertical landing (STO/VL) aircraft. A—A Harrier jump jet uses swiveling jet nozzles to take off, land, and fly forward. B—The Osprey aircraft relies on swiveling turboprop engines, rather than jets, for takeoff, landing, and flight. (U.S. Navy)

A

B

Helicopters

Helicopters are used to transport people and cargo to places that are hard to reach by other transportation vehicles. See **Figure 21-15.** A unique quality of the helicopter is that it can take off and land in vertical flight. See **Figure 21-16.** Helicopters can hover in the air. They can also change direction of flight very quickly. Helicopters fly a little differently from the way airplanes do. A helicopter has rotating wings to make it fly, whereas a plane has stationary wings. The rotating wings, also known as ***rotor blades,*** provide lift in the same way a wing does on a plane. Most helicopters have two types of rotors: a main rotor and an auxiliary rotor, or tail rotor. The main rotor is mounted above the cockpit and generates the lift needed to fly. The auxiliary rotor is located on the tail and keeps the helicopter from spinning along with the main rotor.

Rotor blade: A rotating wing on a helicopter that provides lift.

Figure 21-15. Helicopters play roles that are difficult or impossible for conventional aircraft. A—Medical evacuation from remote locations. (U.S. Coast Guard) B—Suppressing brush and forest fires in difficult-to-reach areas. (Sikorsky Helicopter)

A

B

Figure 21-16. The helicopter's ability to take off and land from a tiny pad is vital to transporting crews to and from ocean oil platforms. (Sikorsky Helicopter)

Technology Link

Medicine: Emergency Vehicles

The use of transportation technology allows for much faster movement of people and goods than is possible without vehicles. In some cases, the speed of transportation technology may mean life or death. Most modes of transportation have at least one type of vehicle used in cases of medical emergencies. In land transportation, these vehicles are ambulances. Ambulances are basically small emergency rooms on wheels. They are staffed by emergency medical technicians (EMTs) and are equipped with emergency medical supplies. In many cases, the EMTs are able to provide medical care while in route to a hospital.

In air transportation, there are several types of emergency vehicles. Helicopters are often used to transport patients in critical condition to large or specialty hospitals. Private companies or nonprofit organizations can provide these helicopter services. Flight nurses and, often, emergency doctors staff the helicopters. Emergency airplanes are often used to transport patients awaiting major surgical procedures, such as transplants. Angel Flight America is a nonprofit organization that has a corps of volunteer private pilots who fly these types of assignments across the United States. Medical airplanes are also used to transport injured travelers back to the United States or to their local hospitals. The use of transportation for medical purposes and the equipping of vehicles with medical technology save lives daily and provide for an efficient response to medical emergencies.

Recreational vehicles

Some types of air transportation vehicles are used only for recreation or sport. Hang gliding is done mainly for recreation. Paraplaning, parachuting, and ballooning are done for either sport or recreation. See **Figure 21-17.**

Figure 21-17. Hang gliding is a type of air transport done for recreation.

Aviation Services

Aviation describes all air transportation activities. There are three categories of aviation. They are the following:

- General aviation.
- Commercial aviation.
- Military aviation.

General Aviation

General aviation consists of privately owned planes used for a wide variety of tasks. It usually includes the use of smaller aircraft, as opposed to the very large aircraft

Career Connection

Airplane Pilots

Transportation, Distribution & Logistics

Without pilots, airplanes and the airline industry would not perform any transportation functions. Pilots are the people who operate and fly aircraft. There are three main types of pilots: private, commercial, and airline. Private pilots are pilots who have a license allowing them to fly small aircraft for personal reasons. These pilots do not fly planes as an occupation. Conversely, commercial and airline pilots do make their livings from piloting aircraft. Commercial pilots are found in many different areas and perform many different functions, including crop dusting, flying sightseeing tours, fighting forest fires, and flying helicopters for news and police organizations. Airline pilots operate airplanes for regional, national, and international airlines.

Pilots are responsible for many activities, besides just flying the aircraft. They plan their flights, check the aircraft and instruments, review weather charts, and complete paperwork. Actually, many pilots spend nearly half of their working time completing nonflying duties. The Federal Aviation Administration (FAA) monitors the hours pilots work to ensure the pilots are not overworked and can remain alert.

The FAA also regulates the licensing of pilots. Commercial pilots must obtain a commercial pilot's license with an instrument rating. This ensures the pilots can fly in all types of weather and visibility. Airline pilots must have a airline transport pilot's license, which requires 1500 hours of flying experience (1250 more hours than the commercial pilot's license). These licenses can be obtained from flight training schools and some colleges and universities. Once hired, many airlines and commercial operations require the pilots to complete additional training. The average yearly salary is near $58,000 for a commercial pilot and $117,000 for an airline pilot.

General aviation: Privately owned aircraft used for recreational, business, and community-oriented tasks.

commercial aviation uses. General aviation is used to transport fewer people over short distances. Some services that general aviation offers are to farmers, the community, businesspeople, and individuals. See **Figure 21-18.** To farmers, general aviation performs such tasks as planting, spraying, and fertilizing crops. To individuals, general aviation provides a form of recreation and personal transportation. For businesses, general aviation offers fast and efficient transportation and communication. To the community, general aviation offers mail services, fire fighting, aerial mapping, and photography.

The aircraft used in general aviation have a wide range of sizes. Some are small single-engine craft, and some are small jet engine luxury craft. The most common craft flown in general aviation is the single-engine aircraft. Many individuals own their own planes. These airplanes can take off and land on small runways at small airports.

Commercial Aviation

Commercial aviation: Scheduled airline flights that provide passenger and cargo transportation, using aircraft that carry from dozens to hundreds of passengers.

All scheduled airline flights are examples of ***commercial aviation***. See **Figure 21-19.** ***Commuter airline service*** transports people from several small airports to a major airport in a major city. ***Regional airline service*** involves the transport from small airports to major airports within a specific region. ***Domestic airline service*** is the transport by way of air to and from major airports within a country. ***International airline service*** is a service that provides travel between countries.

Commuter airline service: The transport of people from several small airports to a major airport in a major city.

Regional airline service: The transport from small airports to major airports within a specific region.

Domestic airline service: The transport by way of air to and from major airports within a country.

Military Aviation

Military aviation consists of air activity performed by the armed forces. See **Figure 21-20.** The aircraft used in military aviation are designed to function in specific roles. These roles fall into six different

Figure 21-18. The term *general aviation* refers to privately owned aircraft used for recreational, business, and community-oriented tasks. Small, single-engine aircraft, such as this one, are typical of general aviation. (Cessna Aircraft Company)

Figure 21-19. Commercial aviation provides passenger and cargo transportation, using aircraft that carry from dozens to hundreds of passengers. This artist's conception shows the Airbus A380, which can carry more than 500 passengers on long-distance routes.

Figure 21-20. Military aircraft are used in many roles, from offensive operations (fighters and bombers) to in-air refueling, cargo transport, and surveillance. This Airborne Warning and Control System (AWACS) plane is used for surveillance work. It is a modified Boeing 707 aircraft. (The Boeing Company)

categories: surveillance, cargo, tanker, bomber, fighter, and attack. When looking at some aircraft, it is easy to see the function they serve. For example, surveillance planes often have large disks on the top that house electronic equipment used to monitor events on the ground. Cargo planes are usually large planes used to haul equipment, supplies, and troops. The tanker planes are used to refuel other aircraft in flight. See **Figure 21-21.** Bombers are typically large and relatively slow airplanes that carry cruise

International airline service: A service that provides travel between countries.

Military aviation: Air activity performed by the armed forces.

Figure 21-21. Large flying tanker aircraft can refuel fighter aircraft in flight. This view from the tanker shows the fuel boom connected to the aircraft being refueled. The close proximity of the two aircraft leaves little margin for error. (U.S. Navy)

GREEN TECH

The manufacture of airplanes impacts the environment. Some of the materials used are metals that contain toxins. If the waste from these materials is not recycled or disposed of properly, it can contaminate the land and water around it.

missiles and guide bombs. Fighter and attack aircraft are often similar looking. Fighters are used for air combat with other aircraft. Attack aircraft are used for the ground support of troops. The newest advance in military aviation is the design of stealth aircraft. These aircraft perform one of the functions above, but they are designed in a manner that makes it difficult for the opposition to monitor and track them.

STEM Connection

Technology: Stealth Technology

The idea of stealth technology is to avoid the enemy's detection of an aircraft. This can be done in several ways. The first method of designing a stealth aircraft is to create a plane that radio detecting and ranging (radar) cannot detect. The second method is to create a plane that cannot be detected using infrared, heat sensing, devices.

Adding features to aircraft that would decrease the radar detection has been done for over fifty years. It was not until the 1970s, however, that the details of how radar worked were completely understood. Once radar was understood, several planes have been completely designed to minimize the reflection of radar. Aircraft such as the F-117 and the B-2 are very large aircraft, but they appear to be only the size of a bird on a radar screen. See **Figure 21-A.** These aircraft are extremely flat and contain very few curved edges. The windows are covered with a nonreflecting coating. The skin of the aircraft actually absorbs the radar that hits the airplane. It has a coating that changes the radar waves to heat waves and then absorbs the heat.

Heat, as mentioned above, is the second way an aircraft can be detected. The greatest source of heat in a jet aircraft is the air forced out the back of the engine. In stealth aircraft, this air is funneled through the plane and mixed with cool air before it escapes the aircraft. Stealth technology is highly classified and continues to evolve daily. New materials and methods are continually being developed to better evade detection.

Figure 21-A. Stealth technology used for two different types of aircraft. A—An F-117 surveillance plane. B—The B-2 bomber. (U.S. Air Force)

A

B

Summary

Humans have made many attempts to fly throughout the centuries. The development of air transportation has progressed rapidly since the early 1900s. The Wright brothers have been recognized throughout history for their accomplishments in airplane design. They were the first to achieve powered flight. The pace of development for air transportation has been accelerating since 1906. Inventors all over the world contributed their ideas to new designs. By 1914, flying had moved beyond being a novelty, as the military adopted the airplane.

Air transportation users have devised a set of airways. The airways are the routes airplanes travel. They are the highways of the skies. Airways are set up in layers. These air layers are designed to keep the skies safe from accidents.

Transportation through the air occurs in two different modes. There are lighter-than-air and heavier-than-air vehicles used to transport people and cargo from one place to another. Lighter-than-air vehicles include balloons, dirigibles, and blimps. Heavier-than-air vehicles include gliders, airplanes, and helicopters.

The activities that take place in air transportation are known as aviation. Aviation occurs in three categories. Privately owned aircraft are known as general aviation. Commercial aviation consists of scheduled airline businesses that make a profit on their services. Aircraft flown and used by the armed forces are part of military aviation.

Key Words

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

aerodynamics
aircraft
airplane
airway
blimp
commercial aviation
commuter airline service
dirigible
domestic airline service
drag
general aviation
glider
gravity
helicopter
international airline service
jet route
military aviation
regional airline service
rotor blade
thrust

Test Your Knowledge

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

1. *True or False?* The Montgolfier brothers flew the first hot air balloon.
2. _____ work became the basis for aerodynamics.
3. State the definition of *aircraft*.

4. _____ was the first to add a gasoline engine to a glider, but he was never able to make a successful flight.
   A. George Cayley.
   B. Otto Lilienthal.
   C. Samuel Langley.
   D. Wilbur Wright.
5. The Wright brothers' first airplane was named _____.
6. *True or False?* The propeller made it possible to break the sound barrier.
7. An airway above 18,000' is known as a(n) _____.
8. The main reason for airways (routes) is for _____.
9. Explain how airways are used.
10. Name three heavier-than-air vehicles.
11. In order for a lighter-than-air craft to rise, the gas it contains must be less dense than _____.
12. *True or False?* A hot air balloon is a heavier-than-air vehicle.
13. If you weighed 175 lbs., how much hot air would be needed to lift you?
14. The word *dirigible* means _____ in French.
15. *True or False?* Blimps today use hydrogen as the safe alternative to helium.
16. Heavier-than-air vehicles are _____ to control than lighter-than-air vehicles.
17. Thrust is the force that moves the aircraft _____.
    A. forward
    B. backward
    C. up
    D. down
18. List four uses of an airplane.
19. _____ are used to transport people and cargo to hard to reach places.
20. Discuss the aircraft used in general aviation.
21. Fighter and attack aircraft are part of _____ aviation.

STEM Activities

1. Construct a model of a heavier-than-air aircraft.
2. Create a display showing the history and evolution of an aircraft.
3. Write a report about the functions and authority of the Federal Aviation Administration (FAA).