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The Spirit of St. Louis: The Man, The Machine-The Legacy

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On a rain soaked field, in the early light of dawn, a daring young aviator parlayed his skill, his ambition and his courage to embark on a flight that would promote the cause of aviation in the hearts and minds of people around the world. The aviator was 25 year old Charles A. Lindbergh, piloting the "Spirit of St. Louis", a custom designed single engined airplane that would be the first to cross the Atlantic Ocean non stop New York to Paris. Charles A. Lindbergh not only captured the Orteig prize but the imagination and interest of people around the globe.

The successful flight made by Lindbergh celebrated the culmination of all the advances that had occurred in aviation before this historic flight and heralded the potential of commercial air transport that was to follow. It was a flight of tremendous impact.

My curriculum unit, "The Spirit of St. Louis: The Man, The Machine, The Legacy," will capitalize on this historic real life drama and use Lindbergh's story to teach junior high school students basic concepts in aeronautics. The basic strategy of this unit will be to follow the flight of Lindbergh's epic journey from his take off in New York to his landing at Le Bourget field in Paris. To accomplish this, serial "clips" from the classic Jimmy Stewart film "The Spirit of St. Louis", along with Lindbergh's own biographical notes will be used and the principles of flight will be investigated in the order they present themselves. To be more specific, and to illustrate a case in point, historical records reveal that at 7:52 A.M. on an overcast day on the 20th of May 1927, Lindbergh's plane heavily loaded with fuel lumbered down a muddy field in New York and with agonizing slowness struggled to gain altitude at the end of the field. At this "teachable moment" the film or video tape would be stopped and the class challenged to explain what force or forces act on a plane and permit it to "lift" off the ground and to remain in the air. At this point, the instructor would guide his or her students to carefully examine the cross section of an airplanes wing. I would suggest that a plastic or wooden model of an airplane be displayed in the classroom for close examination. At this point it would be instructive to introduce through lecture and student experiment *BERNOULI'S PRINCIPLE* . Sample lesson plans that demonstrate this principle are included in this instructional unit. Since "lift" is such an important concept in the study of aeronautics, many and varied experiments should be performed so that all students have a clear understanding of this phenomenon.

I would suggest that this curriculum be taught by breaking it into three main parts. These three sections of the curriculum could be taught by one instructor in a self contained classroom or be divided up if they are taught in a inter-disciplinary setting. The first part of this trilogy would be a study of *The Man* —the forces that shaped the character of this 25 year old that had the audacity to attempt such a bold adventure. Students in language arts or humanities classes could read Charles Lindberg's book "WE". Similarly, students could read literature of the time period to get a flavor of this era.

The second part of the trilogy concentrates on *The Machine* . In this section which relates best to instruction in a science classroom, students examine aircraft in general and Lindbergh's plane in particular. The core of the curriculum is the study of aerodynamic principles as they relate to the flight of winged aircraft. Whenever possible, the instructor should relate understandings to the actual flight Lindbergh made.

The third and final section, *The Legacy* relates well to instruction in social studies or could be continued in the science classroom. In the conclusion of this curriculum unit students examine the impact this historic flight would have on the future of commercial as well as general aviation.

IMPLEMENTATION

In keeping with the format of the trilogy, the scientific study of aeronautical principles is also broken up into three natural divisions. The three primary investigations involve the forces in play as a plane i.e. "The Spirit of St. Louis" takes off, the forces involved during controlled flight, and the forces involved during landing. This instructional scheme allows a natural path that follows the story line of the film "The Spirit of St. Louis". It is very important make sure the students be given ample opportunities to investigate and understand the key concept of *LIFT* . As mentioned earlier in the text, the discussion of the concept of lift would be introduced as Lindbergh's plane leaves the runway. Students would be challenged to explain how an aircraft weighing over 5,000 pounds could rise up into the air and remain airborne for over 35 hours on the flight to Paris. Once the students understand the concept of LIFT, the instructor should introduce a discussion of the forces that act as a deterrent to flight. WEIGHT and DRAG should be discussed at this point.

A return to the film for the next serial segment shows Lindbergh controlling the "Spirit" as he crosses the Atlantic. The film is stopped again and the ways in which an aircraft is controlled during sustained flight is studied. The film dramatically highlights the problems associated with control of an aircraft in flight. The film shows Lindbergh diving, rising, fighting to prevent ice build up on his wings, and trimming to maintain level controlled flight. At this point in the curriculum, a pictorial drawing of the "Spirit" or other typical aircraft should be distributed to the students. Using a large poster or by using an overhead projector, the students should label the control surfaces of their drawings, learning the nomenclature and operation of each part of the aircraft.

This curriculum unit is well suited for an inter-disciplinary approach in implementation. Students should be immersed in the study of this topic. While students are studying scientific facts and principles in the science class they could be listening and singing songs and music from the late twenties. The sheet music for songs such as "Lucky Lindy" could be obtained at a modest cost and used in class or auditorium assembly. The entire staff might elect to have a "dress up day" where staff and students come to school in period clothing from the twenties. May 20th, the anniversary date of Lindbergh's historic flight would be a good choice. In social studies, students could review the world events of this time period and gain practice in mapping skills by following Lindbergh's flight path. Also, the depression and the rumblings of war offer fertile ground for study.

Charles Lindbergh’s actual notes about the flight would be very instructive to review and study. The details of the actual crossing provides many opportunities to conduct ancillary inventions.

These investigations could include such topics as celestial navigation which the film demonstrates, to a detailed study of air and air pressure and the study of weather. These ancillary explorations are not limited to the physical sciences, a humanities class might explore the general theme of our need as humans to conquer new frontiers. A less lofty goal might be to include a section on nutrition, a lesson even Lindbergh might have benefited from.

This unit concludes with a study of how airplanes prepare for and execute a landing. The final lesson discusses the importance of this historic flight and its impact on the future of commercial aviation.

The actual sample lesson plans developed for this unit are in keeping with the aeronautical theme called “FLIGHT Plans”. These “FLIGHT PLANS” are designed to show the teacher a direction to take and how to get there.

THE EARTH’S ATMOSPHERE

All conventional aircraft operate within the ocean of air that surrounds the earth. Aerodynamic forces created by the interaction of the aircraft with the atmosphere makes flight possible. Atmospheric conditions greatly influence aircraft performance. The density of the air, for example is so critical to performance of an aircraft that pilots use air temperature and pressure to compute a figure called the DENSITY ALTITUDE. This is necessary because the density of the air directly affects both LIFT and DRAG on an aircraft. It is recommended that students have a good working knowledge of the structure of the earth’s atmosphere. This is a prerequisite to an understanding of the basic aerodynamic principles that follow in the next pages. Students should be familiar with the different regions of the atmosphere and the characteristics of each region. It should be explained that although the earth’s atmosphere extends outwards for hundreds of miles, most of the air lies in the two regions closest to the earth’s surface. These two zones or regions are called the TROPOSPHERE and the STRATOSPHERE. The TROPOSPHERE is the region that extends from the surface of the earth out to an altitude of about 10 miles or 16 kilometers. This is the region in which weather occurs and in which we live. The study of this layer is important not only to the study of weather, but also it is the layer in which Lindbergh=s plane flew. His plane, “ The Spirit of St. Louis “ and all other standard single engine aircraft, that have neither pressurized cabin or supercharged engines have a maximum ceiling of about 17,000 feet above sea level.

A transition zone exist between the TROPOSPHERE and the STRATOSPHERE. It is called the TROPOPAUSE. The TROPOPAUSE is an area of relative calm, but because of the temperature change that occurs within this layer, rivers of swiftly moving air are formed. These fast moving rivers of air are called JET STREAMS. These JET STREAMS flow from west to east. Pilots flying commercial jet aircraft often use these JET STREAMS to get a boost from these “tail winds” when they are traveling east in the TROPOPAUSE.

THE ATMOSPHERE

(figure available in print form)

BASIC AERODYNAMIC PRINCIPLES

This curriculum unit is not intended to be an encyclopedic treatment of the broad subject of aerodynamics. It is designed to be a starting point from which the teacher can build onto or branch out from. In even a cursory study of aerodynamics, four fundamental forces must be defined and understood. The four fundamental forces involved in flight are THRUST, LIFT, DRAG, and WEIGHT. It is instructive to study each of these forces in detail. The study of these forces will undoubtedly lead to further discussions about Newtons' Laws of Motion, the differences between WEIGHT and MASS, along with a myriad of other questions. The bibliography offers suggestions for locating support materials.

THRUST

The basic element essential for the flight of a fixed-wing aircraft is THRUST. This force can be generated from a motor driven propeller, a jet engine, or from rocket propulsion. In the case of Lindbergh's plane, a 220 horsepower Wright Whirlwind radial engine drove the propeller that provided the necessary THRUST to keep the "Spirit" aloft. In effect, a propeller acts like a revolving wing. The rotary action of this airfoil changes the engine power to the force called THRUST. This force is produced due to the fact that the configuration of the propeller blade creates an area of lower air pressure at the face of the whirling blades. The pressure differential created creates a forward force called THRUST. Also, the stream of air directed rearward causes an opposite and equal reaction forward in agreement with Newton's Third Law of Motion.

WEIGHT

The WEIGHT of an aircraft is a number expressed in pounds that represents the sum of the weights for the aircraft, its fuel, the crew, and cargo. This numerical expression is the measure or force of the gravitational attraction between the earth and the aircraft. The WEIGHT of an aircraft influences almost every aspect of performance. A heavily loaded aircraft requires a higher takeoff speed, takes longer to leave the ground, has a shorter flying range, and has a longer landing roll One of the primary concerns in the design of "The Spirit of St. Louis", was the weight of the fuel Lindbergh would need to cross the Atlantic. Lindbergh's plane was essentially a flying fuel tank capable of carrying over 450 gallons of fuel. The "Spirit" has three fuel tanks in the wings that total 153 gallons. In addition to the wing tanks there are two tanks located in the fuselage. Both fuselage tanks are located in front of the pilot. The most forward tank has a capacity of 89 gallons and the larger tank behind this tank has a capacity of 209 gallons. Given the weight of a gallon of aviation fuel weighs 6 pounds, challenge the students to compute the total weight off the fuel at takeoff. A drawing of "The Spirit of St. Louis" should be distributed to the class for this exercise. (Refer to appendix)

LIFT

LIFT is a force that opposes the force of GRAVITY. LIFT allows an aircraft to leave the earth and to remain in the air. LIFT is a resultant force caused by the movement of air over the wings of the aircraft. A small amount of LIFT is also produced by the body and tail surfaces of the aircraft. The scientific explanation of LIFT rest in a large part on a theorem first proposed by a gifted Swiss mathematician Daniel Bernoulli. In 1738, Bernoulli published a paper entitled HYRODYNAMICA. The subject of his paper was a discussion of pure and applied fluid motion. One very important concept in this paper was the principle that, “The higher the speed of a flowing liquid or gas, the lower the pressure”. This theorem used in conjunction with the concept of a “boundary layer” advanced by Ludwig Prandtl in 1904 can be used to explain the phenomenon of LIFT. It is interesting to note that at the time Bernoulli lived (1700-1782) no airplanes existed.

There are several factors that determine the amount of LIFT generated by an aircraft. The primary factor is the surface area of the wing. Generally, the larger the surface area the greater the LIFT. Aware of this fact, the designer of “The Spirit of St. Louis” increased the wingspan from 42 feet to 46 feet to gain additional LIFT to help carry the heavy load of fuel necessary for the journey.

A second factor that determines the amount of LIFT is the relative speed of the airstream. In accordance with Daniel Bernoulli’s principle, the faster the airstream passes over the curved surface of the airfoil, the greater will be the pressure *differential* between the upper and lower surfaces of the wing. It is important to keep in mind that LIFT is produced by a difference in pressures on the upper and lower surfaces of the aircraft. The lower air pressure created on the upper surface of the wings results in an upward force from below-LIFT. This relative increase in pressure or LIFT on the bottom of the wing can counter the downward force of GRAVITY and support the WEIGHT of the aircraft and crew.

A third factor is “THE ANGLE OF ATTACK” or the angle formed by the chord of the airfoil and the direction of the relative wind. A high angle of attack will increase the amount of LIFT, there is a point at which increasing the angle of attack will have a negative if not disastrous result. At a certain point, a high angle of attack will cause a separation of the “boundary layer” of air that surrounds the airfoil. Normally, the boundary layer forms a thin stratum of air immediately adjacent to the surface of the airfoil. The air flow right at the surface of the airfoil actually adheres to the skin of the wing. This is due to the frictional forces involved between the two surfaces. At this interface the velocity of the airstream is actually zero. When this boundary layer is disturbed,the flow of air may separate from the wing and form a turbulent pattern. This turbulence can increase to a point where there is a loss of LIFT where it is taking place. The angle at which the airflow begins to “burple” or become turbulent is called the “CRITICAL ANGLE OF ATTACK”. When the air moving over the entire surface of the wing is turbulent, the stall is complete and there is no longer “LIFT” to support the WEIGHT of the aircraft. There are maneuvers a pilot can execute to recover from a stall. One way is to drop the nose of the aircraft to decrease the angle of attack. Another is to accelerate the speed of the aircraft. If the aircraft is already moving at full throttle, the only way to regain LIFT is to drop the nose. A stall condition during landing is very serious and pilots need to guard against it.

DRAG

DRAG can be defined as the resistance to the forward motion of an aircraft. Students can probably best understand what drag is by experiencing it. Explain that DRAG can be “felt” by putting your hand out of the window of a fast moving automobile. The hand with fingers extended is placed with the open palm facing in the direction of travel. The impact of the airstream creates a force (DRAG) that is readily sensed. In more scientific terms, DRAG is actually a combination of many separate forces that add together to retard the forward motion of the aircraft. DRAG can be divided into two main categories, *INDUCED* DRAG and PARASITIC *DRAG* . INDUCED DRAG is the DRAG created as a result of the process required to produce LIFT. PARASITIC *DRA* G is due to the frictional forces involved as the airstream pass-es over the surfaces of the aircraft.

At certain times, the pilot uses DRAG intentionally to control the aircraft. As an example, in preparation to landing a pilot lowers FLAPS to increase DRAG to slow the aircraft down to the proper approach speed.

(figure available in print form)

FLIGHT PLAN

TOPIC: The forces of flight—LIFT

Rationale All aircraft that fly within earth’s atmosphere rely on a force called LIPT that acts in a predictable and upward direction against the downward force of the earth’s gravitational field. The understanding of the concept of LIFT is key to the basic forces involved in the study of aerodynamics.

Objective After instruction the student will be able to explain how the movement of an air-stream over the curved surface of an aircrafts wing, provides the LIFT that allows an aircraft to rise up and remain in the air.

Materials Required

Strip of paper that is 3 inches (7,5 cm) wide and about 82 inches (21 cm) in length.

Pencil or pen

Procedure Glue or tape the ends of the paper strip together as shown in the diagram fig. 1. Insert a pencil or pen into the open loop of the model wing. Blow a strong, blast of air across the top surface of the “wing”. Observe what happens.
Fig. 1

(figure available in print form)

Conclusion The paper wing is shaped in such a way that the air blowing over the top surface has

to travel a longer distance than the bottom surface. The air traveling over the longer top surface has further to go so it is speeded up. Bernoulli's principle states that an area of low pressure will develop on the top surface of the "wing". The atmospheric pressure pushes up on the bottom of the wing trying to fill the place where the air pressure is not as great. This force called Lift makes the wing rise.

FLIGHT PLAN

TOPIC: Bernoulli's Principle

Rationale In 1738 Daniel Bernoulli published a paper entitled HYRODYNAMICA.
This work was on pure and applied fluid notion. One concept discussed in this work is the principle that, "the higher the speed of a flowing liquid or gas, the lower the pressure. Bernoulli's principle can explain the "LIFT of an airplane wing or in this case why a coin seems to magically fly up from a desk and land in a nearby saucer.

Objective To have students perform a simple experiment that demonstrates in a dramatic way a basic principle of aerodynamics the concept of LIFT.

Materials Required
A coin (dime)

A small saucer or plate

Procedure Place a dime about 1/2 inch (13mm) from the edge of a desk. Position a saucer or small plate a few inches (5cm) from the coin as shown in figure 1. Blow a quick, strong blast of air across the top of the coin. With practice, the dime will "jump" into the air and land in the saucer.
Fig. 1

(figure available in print form)

Conclusion This "magic trick" can be explained using a principle that was discovered by a scientist over 250 years ago. In 1738, Daniel Bernoulli stated that an increased flow of air would create an area of lower air pressure over a surface. The sudden,swift movement of an air-stream over the coin creates an area of low pressure. The atmospheric pressure in the room rushes in to fill the area of low pressure. This force provides the "LIFT" which causes the coin to rise up into the air and land in the saucer.

Appendix

(figure available in print form)

AIRCRAFT INSTRUMENTATION

Charles A. Lindbergh found his way across the Atlantic primarily by using a type of navigation known as “dead reckoning”. In this type navigation his primary navigational aids were his eyes, his compass, an accurate clock,and an ordinary ground map of the land areas he would fly over. He pilotage the pilot records the elapsed time between two landmarks and then computes his airspeed using basic arithmetic. The fact that Lindbergh was able to fly over the Atlantic for over 16 hours, and then end up almost exactly on his planned course was an incredible feat of skillful flying. While it is true that he had one of the most advanced instrument panels of its time, it is extremely crude and unreliable by today’s standards. The experience Lindbergh gained as an air mail pilot flying between Chicago and St. Louis helped prepare him for his Atlantic crossing. His night time flying through clouds and storms gave him the opportunity to perfect the skills necessary in navigating by dead reckoning. In this type of elementary navigation a pilot uses an airspeed indicator, a compass, and a clock to locate his or her position along a route. Weather conditions or light permitting Lindbergh would look for landmarks and correct his heading if necessary.

Today’s pilots have a host of electronic and mechanical instruments that help them stay on their planned course. The basic instruments used by Lindbergh are still used today. They are of course much improved and highly reliable. The vital importance of these instruments to navigation, both in historical Perspective as well as current use, makes them worthwhile of more detailed study.

LINDBERGH’S INSTRUMENT PANEL

(figure available in print form)

AN ELEMENTARY AVIATION GLOSSARY 101 Words and Definitions

AERODYNAMICS-Study of the forces of air acting on objects in motion relative to air.
AILERON—Control surfaces hinged at the back of the wings which by deflecting up or down helps to bank the airplane.
AIR—A mixture of gases making up the atmosphere which surrounds the earth.
AIRFOIL—A streamlined surface designed in such a way that air flowing around it produces useful motion.
AIRPLANE—A mechanically-driven, fixed-wing, heavier-than-air craft.
AIRPORT—A tract of land or water for the landing and takeoff of aircraft. Facilities for shelter, supply, and repair are usually found there.
AIRSPEED—Speed of the aircraft relative to the air through which it is moving.
AIRWAY—An air route marked by aids to air navigation such as beacons, radio ranges and

direction-finding equipment, and along which airports are located.
ALTIMETER—An instrument for measuring in feet the height of the airplane above sea level.
ALTITUDE—The vertical distance from a given level (sea level) to an aircraft in flight.
AMPHIBIAN PLANE—An airplane that can land on both land and water.
ANEMOMETER—Instrument to measure speed of wind.
ASCEND—Climb.
ATMOSPHERE—Blanket of air surrounding the earth.
ATTITUDE—Position of the airplane relative to the horizon, i.e., a climbing attitude, straight-and-level attitude, etc.
AVIATION—A term applied to all phases of the manufacture and operation of aircraft.
BANK—A flight maneuver in which one wing points toward the ground and the other to the sky.
BAROMETER—An instrument to measure pressure of the atmosphere.
BEACON—A light or other signal indicating direction.
CEILING—Height above ground of cloud bases.
CHART—An aeronautical map showing information of use to the pilot in going from one place to another.
CIRRUS—Type of high thin cloud.
COCKPIT—The portion of the inside of the airplane occupied by the person(s) operating the airplane, and containing the instruments and controls.
COMPASS—An instrument indicating direction.
CONTACT—Switching on the ignition of an aircraft engine. “Contact” is the word of warning that someone is about to turn on the ignition.
CONTROL TOWER—A glassed-in observation tower on the airport from which control tower operators observe and direct airport air and ground traffic.
COURSE—The direction over the earth’s surface that an airplane is intended to travel.
CROSSWIND—Wind blowing from the side, not coinciding with the path of flight.
CUMULUS—Type of cloud formed in puffs or domeshaped.
CURRENT—Stream of air; also, up-to-date.
DEAD STICK LANDING—Landing made without the engine operating.
DEGREE—1/360 of a circle, or 1/90 of a right angle.
DIVE—A steep angle of descent.
DRIFT—Deviation from a course caused by crosswise currents of air.
ELEVATION—The height above sea level of a given land prominence, such as airports, mountains, etc.
ELEVATORS—Control surfaces hinged to the horizontal stabilizer which control the the pitch of the airplane, or the position of the nose of the airplane relative to the horizon.
ENGINE—The part of the airplane which provides power, or propulsion, to pull the airplane through the air.
FIN—A vertical attachment to the tail of an aircraft which provides directional stability. Same as vertical stabilizer.
FLAPS—Hinged or pivoted airfoils forming part of the trailing edge of the wing and used to increase lift at reduced airspeeds.
FLIGHT PLAN—A formal written plan of flight showing route, time enroute, points of departure and destination, and other pertinent information.
FORCE—A push or pull exerted on an object.
FREIGHT—Cargo.

FRONT (weather)—Boundary of two overlapping sir masses. When cold air is advancing on warm air, it is said to be a cold front; warm air advancing on cooler air is a warm front.
FUSELAGE—The streamlined body of an airplane to which are fastened the wings and tail.
GEAR—The understructure of an airplane which supports the airplane on land or water; wheels, skis, extractable gear folds up into the airplane in flight. Gear that does not retract is called "fixed."
GLIDE—A motion of the airplane where the airplane descends at an angle to the earth's surface.
GLIDER—A fixed wing, heavier-than-air craft having no engine.
GRAVITY—Force toward the center of the earth. HAIL—Lumps or balls of ice falling to the earth out of thunderstorms.
HANGAR—Building on the airport in which airplanes are stored or sheltered.
HAZARD—Obstructions or objects or threats to the safety of the passenger and aircraft.
HIGH PRESSURE AREA—Mass of air characterized by high barometric pressure.
HORIZONTAL—Parallel to the horizon.
HUMIDITY—Amount of invisible moisture in a given mass of air.
INSTRUMENTS—Dials or gauges by which information about the flight, airplane, or engine is relayed to the pilot. When the pilot flies the airplane solely by reference to the gauges, he is said to be flying "on instruments."
KNOT—A measure of speed, one knot being one nautical mile per hour.
LAND—The act of making the airplane descend, lose flying speed, and make contact with the ground or water, thus ending the flight.
LANDING PATTERN—A set rectangular path around the airport which airplanes follow to land.
LIFT—An upward force caused by the rush of air over the wings, supporting the airplane in flight.
LOW PRESSURE AREA—Mass of air having low atmospheric pressure.
METEOROLOGY—The scientific study of the atmosphere.
MOISTURE—Water in some form in the atmosphere.
MONOPLANE—An airplane having one set of wings.
MULTI-ENGINE—Having more than one engine. PARACHUTE—A fabric device attached to objects or persons to reduce the speed of descent.
PEDALS—Foot controls in the cockpit by which the pilot controls the action of the rudder.
PILOT—Person who controls the airplane.
PRECIPITATION—Any falling visible moisture; rain, snow, sleet, hail.
PRESSURE—Force in terms of force per unit area.
PROPELLER—An airfoil which the engine turns to provide the thrust, pulling the airplane through the air.
RADAR—Beamed radio waves for detecting and locating objects. The objects are "seen" on the radar screen, or scope.
RAMP—Area outside of airport buildings where airplanes are parked to be serviced or to pick up and discharge passengers and cargo.
RUDDER—Control surface hinged to the back of the vertical fin.
RUNWAY—A surface or area on the airport designated for airplanes to take-off and land.
SEAT BELT—Belts attached to the seat which fasten around the pilot and passengers to hold them firmly in their seats in bouncy air and during takeoffs and landings.
SEAPLANE—An airplane that operates from water.
SLIPSTREAM—Current of air driven back by the propeller.
STABILIZER—Horizontal surface which stabilizes the airplane around its lateral axis.

STALL—The reduction of speed to the point where the wing stops producing lift.
STATIONARY—Something that does not move is said to be stationary. A front along which one air mass does not replace another-
STRATUS—Layered clouds.
STEAMLINE—An object shaped to make air flow smoothly around it.
TACHOMETER—Instrument which measures the speed at which the engine crankshaft is turning, hence the propeller speed in r.p.m.'s (rounds per minute).
TAIL—The part of the airplane to which the rudder and elevators are attached. The tail has vertical and horizontal stabilizers to keep the airplane from turning about its lateral axis.
TAKE-OFF—The part of the flight during which the airplane gains flying speed and becomes airborne.
TERMINAL—Building on the airport where people board planes, buy tickets, and have their luggage handled. Flight services are frequently located at the air terminal.
THRUST—Forward force.
TRANSMITTER—Microphone, or part of the radio that sends the message.
TRICYCLE LANDING GEAR—Airplane's landing wheels, two under the wings and one under the nose.
TURBULENCE—Irregular motion of air; uneven currents of air.
TURN—Maneuver which the airplane makes in changing its direction of flight.
UPDRAFT—Vertical currents of air.
VELOCITY—Speed.
VERTICAL—Ninety degrees from the horizon.
VISIBILITY—Distance toward the horizon that objects can be seen and recognized. Smoke, haze, fog, and precipitation can hinder visibility.
VORTEX—A circular, whirling movement of air forming a space in the center toward which anything caught in the vortex tends to move.
WEATHER—Condition of the atmosphere at a given time with respect to air motion, moisture, temperature, and air pressure.
WIND—Air in motion, important to aviation because it influences flight to a certain degree.
WIND SOCK—A cone-shaped, open-ended cylinder of cloth to catch the wind and show its direction.
WINGS—Part of the airplane shaped like an airfoil and designed in such a way to provide lift when air flows over them.
ZOOM—The climb for a short time at an angle greater than the normal climbing angle, the airplane being carried upward at the expense of airspeed.
Source: Aviation Curriculum Guide by Aimee Dye

AUDIO VISUAL MATERIALS

FILMSTRIPS

Basic Principles of Flight , Scott Educational Division Holyoke, Massachusetts.

How Airplanes Fly , Scott Educational Division, Holyoke, Massachusetts.

Air Transportation, National Air and Space Museum, Washington,

DC., 20560.

Early Flight , National Air and Space Museum, Washington, D.C.

Flight Technology , National Air and Space Museum, Washington, D.C.

The A.B.C. of the Internal Combustion Engine , General Motors Corporation. Detroit Michigan.

FILMS

A Man's Reach Should Exceed His Grasp , NASA, Lyndon B. Johnson Space Center, Education Office, Houston, Texas

How an Airplane Flies , Shell Film Library, 1433 Sadlier Circle West Drive, Indianapolis, Indiana.

Icarus and Daedalus , Sterling Productions, New York.

Learning About Air , Paramount Pictures Inc., 107 Park Place, Falls Church, Virginia

The Airplane Changes Our World , Encyclopedia Britannica Films. New York, New York.

VIDEOTAPES

The Spirit of St. Louis , Yale-New Haven Teachers Institute 53 Wall Street, New Haven, CT

BIBLIOGRAPHY SUGGESTED READINGS FOR STUDENTS

Bendick, Jeanne. 1982. Airplanes. New York: F Watts

Dalgliesh, Alice, 1956. Ride the Wind. New York

DeLeeuw, Adele. 1969. Lindbergh; Lone Eagle. Philadelphia: Westminster Press

Foster, John T. 1974. The Flight of the Lone Eagle: Watts Focus Book

Gibbons, Gail. 1986. New York: Holiday House

Hoyt, Edwin P..1983. Heroes of the Skies. New York: Doubleday

Rosenblum, Richard.1984. The Golden Age of Aviation. New York: Atheneum

Rosenblum, Richard. 1980. Wings,The Early Years of Aviation. Four Winds Press.

SUGGESTED READINGS FOR TEACHERS

Ault, Phil. 1978. By the Seat of Their Pants: The Story of Early Aviation: Dodd

Alvin, Joseph M. Jr., 1962. The American Heritage of Flight.

Davis, Kenneth S. 1959. The Hero Charles A. Lindbergh and The

American Dream. New York: Doubleday & Company.

Kershner, William K. 1978. The Instrument Flying Manual: Iowa State University Press.

Lindbergh, Charles A.. 1953. The Spirit of St. Louis. New York: Charles Scribner's Sons.

Lindbergh, Charles A. 1927. "WE" New York. London: G.P. Putnam's Sons.

Talay, Theodore A. 1976. Introduction to the Aerodynamics of Flight. NASA.

Wagner, William. 1971. Ryan, The Aviator, New York: McGraw-Hill Book Company New York.