NATIONAL MUSEUM
OF THE UNITED STATES AIR FORCE

AIRLIFT MISSION—BASIC SCIENCE OF FLIGHT

Students will learn about the history of airlift missions (both humanitarian and combat) as well as to learn about basic science related to these operations, such as how modern cargo aircraft actually fly. The U. S. Air Force's Global Reach is emphasized!

LESSON PLAN (B)

Learning Objectives

The students will

- Learn about basic scientific principles related to airlift operations, such as how huge cargo aircraft actually fly
- Learn about the Bernoulli Principle, through various demonstrations and discussions, with each member of the class participating
- Learn about the Coanda Effect, and how important it is with respect to Newton's Third Law of Motion
- Learn about the history of both humanitarian and combat airlift missions around the world
- Learn about the variety of cargo and refueling aircraft which have been used throughout recent history
- Learn about the U. S. Air Force's successful development of "Global Reach and Global Power"

Introduction/Background

Airlift and transport missions were not a real priority during the early years of flight, primarily because the small aircraft at the time were not conducive to large cargo loads or multi-passenger movement. As airplanes developed and their size and capacity increased, airlift operations became a reality. The very first successful airlift was accomplished by Germany in 1936, when they transported 20,000 stranded Spanish troops across the Strait of Gibraltar and on to Seville, Spain. It took the Germans 677 flights (sorties) using their modified Junkers Ju.52 trimotor aircraft. After hearing the news of this successful, initial airlift, other countries began developing their own cargo/transport Aircraft. The British utilized transport-bombers, such as Their Vickers Victoria airplane. The United States developed transports that were actually Douglas DC-3 and Douglas DC-4 commercial airliners, and with modifications, these two aircraft became C-47 "Skytrains" and C-54 "Skymasters," respectively. The conversions included removing the airliner interiors, adding heavier floors and creating large cargo doors. C-47s were affectionately called "Gooney Birds," and the Army Air Corps first ordered these cargo airplanes in 1940. By the end of World War II, over 9,300 "Skytrains" had been procured. C-54 "Skymasters" could carry much heavier loads than the C-47s (28,000 pounds of cargo versus 6,000 pounds) and the U. S. military (the Army Air Corps and Navy) began using C-54s in 1942.

Grade Level: 4—6

National Science Education Standards:
Science as Inquiry, Science and Technology, Physical Science, Science in Personal and Social Perspectives and History and Nature of Science

National Standards for History:
Chronological Thinking and Historical Comprehension

National Standards for Mathematics:
Data Analysis and Probability, Geometry, Communication and Measurement

Materials Required:

- Magic board and markers
- PowerPoint presentation
- Laptop, monitor, digital projector
- Styrofoam or balsa wood glider
- Demo items as listed within lesson plan

Resources:

- General Information:

http://www.amc.af.mil/library/factsheets/factsheet.asp?id=229 and id=239 and http://www.centennialofflight.gov/essay/Air_Power/cargo/AP19.htm and http://www.futurefirepower.com/us-air-force-airlift-global-us-military-aircraft and http://www.theaviationzone.com/factsheets/c5.asp (and c17.asp and c130.asp) and www.konnections.com/airlift/berlin.htm and www.caa.govt.nz and http://www.grc.nasa.gov/WWW/k-12/WindTunnel/Activities/balance_of_forces.html and http://avstop.com/technical/weightbal.htm and http://www.dod.mil/execsec/adr96/airforce_report.html and http://www.af.mil/information/factsheets/index.asp and http://www.Airforce.com/learn-about/history/part4/ and http://www.answers.com/topic/air-mobility-command and http://www.grc.nasa.gov/WWW/K-12/airplane/acg.html and www.nationalmuseum.af.mil/education

From 1942 through 1947, the Army Air Corps procured 1,164 C-54 “Skymasters.” Special Note: the U. S. Air Force was not a separate branch of the U. S. military until 1947. However, from its very beginnings as a distinct entity, the Air Force has NOT just used its airlift capabilities to transport combat troops and supplies into, and out of, theaters of war (as exemplified by Operation Desert Storm, one of the largest strategic airlifts since World War II). Humanitarian airlift efforts have always been a key component and top priority for the Air Force, and these missions have made an extremely positive impact on the lives of countless individuals around the world. For example, in June 1948, when the Air Force was still in its infancy, the Soviet Union decided to block all roads, railways and rivers going into the city of Berlin (which was still in ruins after World War II). They cut all power as well, so the 2.5 million inhabitants of West Berlin faced certain starvation. There were, however, three narrow air corridors left open, as the Soviets thought the Allies’ airlift capabilities would be negligible. The United States, Britain and France agreed to join forces to keep West Berliners supplied with coal and food, and above all, to keep them free from Soviet rule. The Berlin Airlift, nicknamed “Operation Vittles’” lasted for fifteen straight months, and nearly 2.3 million tons of supplies (4.6 billion pounds) were flown into Berlin during 277,000 flights (there was one flight every three minutes)! The workhorses for this incredible humanitarian airlift were C-47s and C-54s, and that is what makes this whole airlift operation so amazing—none of the gigantic cargo aircraft of today, such as the C-17 “Globemaster III,” the C-5 “Galaxy” and the C-130 “Hercules,” were in existence! More recently, the Air Force has been heavily involved in global humanitarian airlift missions, which provide relief and assistance to victims of civil war, famine, floods, earthquakes, wildfires, harsh winter weather, etc. Some of the countries that have benefitted from these humanitarian operations include Somalia, Bosnia, Kosovo, Greece, Peru, Ecuador, Venezuela, the former Soviet Republics, Rumania, Rwanda, Iraq, Turkey, Mozambique, Madagascar, Pakistan, India, Japan, Haiti, Honduras, El Salvador, Nicaragua, Afghanistan and Indonesia! Some of our states that have benefitted from the Air Force’s humanitarian efforts include Oklahoma, Kansas, South Dakota, Louisiana, Hawaii, California and Florida. In 1992, the Military Transport Service (airlift division) merged with Strategic Air Command’s refueling operations to form the Air Mobility Command (AMC). AMC is a major command which is headquartered at Scott Air Force Base in Illinois, and it provides worldwide cargo and passenger delivery, air refueling and aeromedical evacuation. It is also the command which is the focal point for all Air Force humanitarian airlift operations. With regard to air refueling operations, the two primary aircraft that allow the Air Force to have such amazing “Global Reach” are the KC-135 “Stratotanker” and the KC-10 “Extender.” They extend the range of our tactical fighters and strategic bombers during overseas operations, and they also provide refueling support to the Navy, the Marine Corps and many aircraft of our allied nations. Not only do these aircraft play a key role in the mobilization of our military assets, they are also capable of transporting litter and ambulatory patients utilizing patient support pallets during aeromedical evacuations! Regarding modern cargo aircraft, such as the C-17 and the C-5, their inherent performance and flexibility greatly improve the ability of the Air Force’s ‘total airlift system’ to fulfill its global air mobility requirements. These requirements have increased significantly, since the size and weight of U. S. mechanized firepower and equipment have grown in response to the improved capabilities of our potential adversaries. Finally, the ultimate measure of airlift efficacy is the ability to rapidly project and sustain an effective combat force in close proximity to a potential theater of war. Most assuredly, the U. S. Air Force has that ability! And, its proficiency in providing humanitarian aid is beyond repute!

Procedures:

SPECIAL NOTE: Teachers may use as much of the information contained within the “Intro/Background” section as they deem appropriate for their students; similarly, teachers may wish to pick and choose items within this “Procedures” section. Teachers may wish to cover four forces/airfoils/Bernoulli Principle/Coanda Effect/ Newton’s Third Law one day (including demos/discussions), then cover items found in Lesson Plan “C” (three axes of motion/control surfaces/predictions) another day. Background PowerPoint is at http://www.nationalmuseum.af.mil/shared/media/document/AFD-121218-021.pdf.

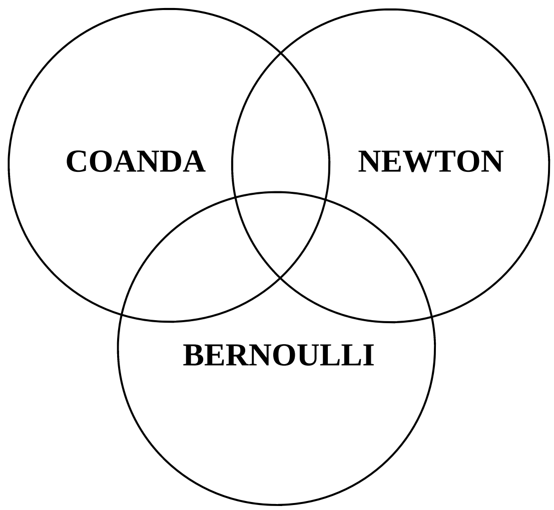
- Write (on board) the things that will be covered/discussed/reviewed in class, including: the four aerodynamic forces of flight, airfoils, the Bernoulli Principle, the Coanda Effect, Newton’s Third Law, the history of airlift operations, the types of aircraft used for airlift missions and a PowerPoint presentation.
- Hook: hold up a Styrofoam or balsa wood glider and tell the students that, as an aircraft flies, there are four aerodynamic forces of flight at work…..as you travel from Los Angeles to Tokyo (a 14-hour flight) the four forces are balanced and the airplane is stable, so you almost forget you are flying, and it is as if you were still relaxing in your family room (especially after watching a few movies and partaking of several meals)!
- Draw an airplane on the board and add arrows to correlate with the four forces. Have students draw a similar airplane with arrows on a sheet of paper. Ask them to name each of the four forces (thrust, drag, weight, lift).

Procedures (continued)

SPECIAL NOTE: A 'Teacher's Addendum' is on page 5, and it includes helpful illustrations and descriptions!

- Tell the students to write the names of the four forces on their sheets as you write them on the board; discuss!
- Ask the class which two forces need to be greater in order for a huge cargo aircraft to take off (lift and thrust); then ask them which two forces have to be greater for the airplane to land (drag and weight).
- Draw an airfoil shape on the board and ask students what they think the shape is, and what it might represent.
- Tell the class it is actually a cross-section of a aircraft's wing, showing the thick 'leading edge' and the narrowing 'trailing edge.' Tell the students that you have drawn it to represent the typical 11 degree 'angle of attack into the wind' as an airplane takes off (if you have a Styrofoam plane, take both of the wings off and allow students to pass them around to get a better look at the side view of them/side view of an airfoil). Also, have students draw an airfoil shape on their papers (tell them it looks like a tear drop turned sideways).
- Draw lines representing an air current under the airfoil shape on the board (fairly straight lines) and then draw other air flow lines over the top of the wing, showing that the path of the air over the thicker leading edge curves up and over the wing. Describe the Bernoulli Principle to the students—Daniel Bernoulli, a physicist and mathematician in the 1700's, discovered that, the faster a fluid moves (whether it is water, air, etc.) the lower the pressure is which occurs within that fluid (please refer to illustrations on page 5)!
- Ask students to look at the airfoil on the board—if the air moving over the top of the wing is moving faster, then according to Bernoulli, what type of pressure is above the wing (lower pressure) and beneath the wing would be what type of pressure—if the students answer higher, they are correct—and this helps with lift!
- You may wish to demonstrate some 'airfoil toys,' such as a Frisbee and a throwing ring—ask the class which one will fly further with the same muscle power (thrust) applied to both. The ring will go further because there is less air resistance (drag) in the center of it than over the center plastic surface of the Frisbee. Demonstrate the throwing ring and the Frisbee, and tell students that both are spinning for stability, but the ring only has a tiny surface area for air to pass over, from its leading edge to its trailing edge!
- Show the class various Bernoulli Principle demonstrations: (1) Take a hairdryer and turn it on full power, then direct the air flow straight up and place a ping pong ball in the air current. Ask students why the ball is staying above the hairdryer and not just flying away and onto the floor—tell them that, if they think about Bernoulli, the air flows around the curvature of the ball, and the pressure adjacent to the ball is what kind of pressure (low) and further out from the ball is what kind of pressure (normal, higher pressure) which keeps the ball contained within the column of air. With practice, you can show the class that the hairdryer can be tilted quite a bit, and the ball will <u>still stay suspended</u> within the column of air! (2) Give each student a strip of paper which is 1.5 inches wide and 7.5 inches long (Bernoulli Strip). Demonstrate it by holding both corners of one end with the thumb and forefinger of each hand, position it so that it is curved a bit, place it against the skin just below your lower lip and blow—ask the students why the paper strip is lifting up—then have the students try! The air being blown over the top of the strip is moving fairly fast, so the pressure above the paper is what—lower than the pressure beneath it. (3) For the next experiment, take a wide-mouthed, plastic bottle, turn it sideways, place a craft pom-pom or small ball of paper in the opening of the bottle and ask a student to come up and blow the pom-pom into the bottle—before the student tries, ask the class if it is even possible—when the student does try, and the pom-pom comes flying out of the mouth of the bottle, ask the students why that happened. The region of air that is being moved by the student's breath, <u>just outside the bottle</u>, has what kind of pressure (low) and the air inside the bottle is normal (higher) pressure—which forces the pom-pom out into the area of lower pressure! (4) Take a letter-sized piece of paper and fold each end so that there are 2.5 inch 'legs' to form a 'U' shape. You may also simply fold the paper in half without any 'legs.' Place the paper on a table in a tent-like configuration. Ask for a student volunteer to come forward, and ask the class what will happen when the student blows <u>under</u> the 'tent.' The tent will collapse because the air being blown under it is moving quickly, and the pressure under it is low, while the pressure above the paper is higher….which causes the paper to collapse! Teachers may wish to research more Bernoulli Principle demonstrations and show them to their students, including the Bernoulli balloons, the Bernoulli balls the Bernoulli pipe and the Bernoulli bag!
- Tell the class that Henri Coanda was a 20th century aerodynamicist and inventor, and he found that, when a moving fluid (water, air, etc.) hits a curved surface, it will "stick" to that surface and follow the curvature of it. A real-world demonstration of the Coanda Effect can be found in the 'gutter guard,' which employs curved metal at the base of a home's roof. The rain water runs down the roof and follows the curvature of the metal, and then it goes into a small slit in the gutter (while the leaves and debris fall to the ground)!

Procedures (continued)
Demonstrate the Coanda Effect to your students using an aquarium, a large spoon and a small pitcher of water. Hold the spoon perpendicular to the floor and over the aquarium. Ask students what the water will do as it travels over the spoon. If the class indicates that the water will "stick" to the spoon, follow its curvature and shoot off its tip at an angle, the students are absolutely correct. Reinforce the idea that a fluid "sticks" to, and follows, a curved surface by demonstrating what air does when it goes over the top of an aircraft's wing. Show this on the board with airflow traveling over the airfoil drawing, and then suddenly shooting down beneath it at an abrupt angle. Also show this with your Styrofoam glider by moving your hand over the top of a wing and then by making your hand shoot down below the wing, while making the glider lift higher. Explain to the class that this Newtonian Effect is yet another explanation for lift, and it also demonstrates Newton's Third Law of Motion (for every action, there is an equal but opposite reaction). The action is the air moving over the wing and shooting down beneath the trailing edge, and the reaction is the lift force acting upon the aircraft (this third principle can only come about because the air "sticks" to the wing/the Coanda Effect)! Draw a three-circled Venn Diagram on the board and show the class that all three explanations for lift are interrelated/linked. Write one of the three effects/principles within each of the connected circles: the Bernoulli Principle, the Coanda Effect and Newton's Third Law of Motion—see illustration below.



Assessment/Evaluation
The students should be evaluated on their class participation, listening skills and ability to follow verbal instructions, especially when they are involved with assisting in demonstrations, etc.

Extension
Have the students research other demonstrations regarding the Bernoulli Principle, the Coanda Effect and Newton's Laws of Motion. Ask them to share with the class in a few days.

References

The C-47: Flying Workhorse of WWII by Richard D Harvey; Bloomington, IN: Author House; 2005

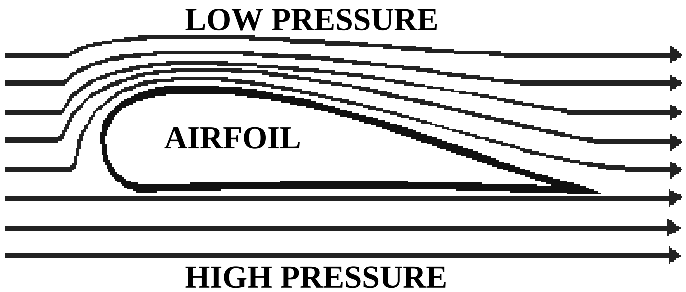
C-54-PLM Revisited by Ralph L. Stevenson, Jr; Sante Fe, NM: Sunstone Press; 2010

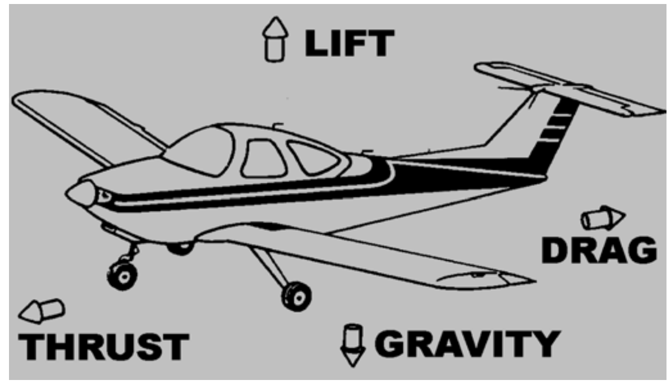
Humanitarian Airlift Operations by Daniel L. Haulman; Washington, DC: U. S. Printing Office; 1998

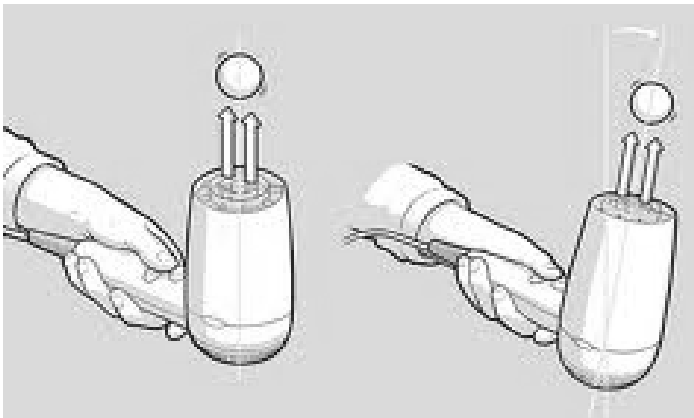
The Lockheed Martin c-130 Hercules by Peter C. Smith; Manchester, England: Crecy Publishing Ltd.; 2010

The "C" Planes: U. S. Cargo Aircraft 1925 to Present by Bill Holder & Scott Vadnais; Atglen, PA: Schiffer Publishing Ltd.; 1996

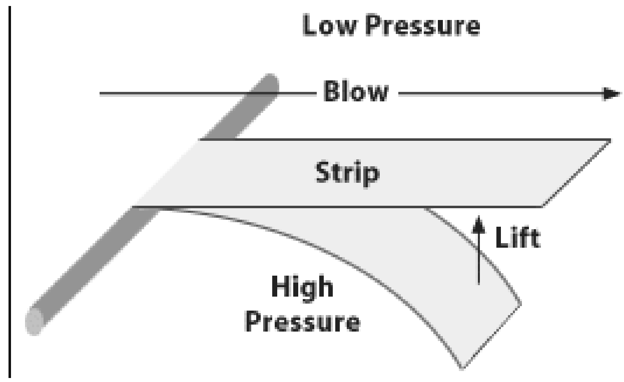
The Boeing C-135 Series: Stratotanker, Stratolifter and other Variants by Don Logan; Atglen, PA: Schiffer Publishing Ltd.; 1998



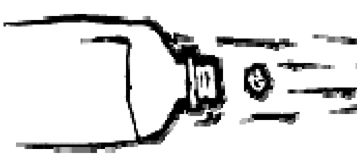


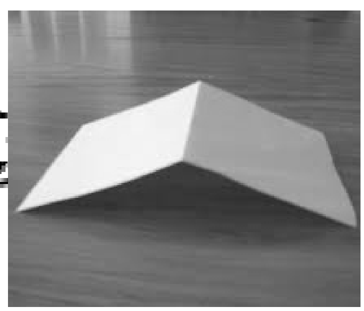


BERNOULLI HAIR DRYER / PING PONG BALLS



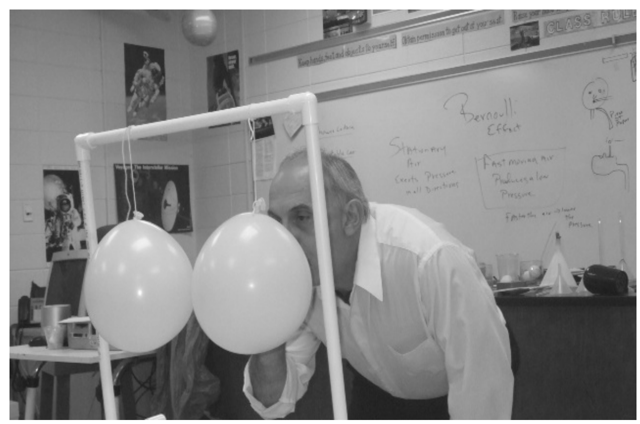
BERNOULLI (PAPER) STRIP



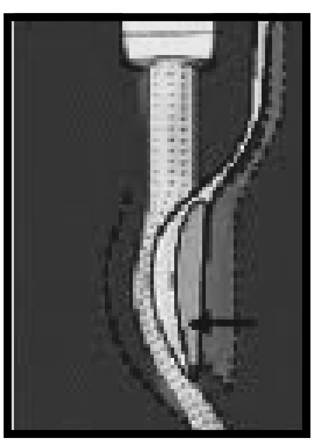


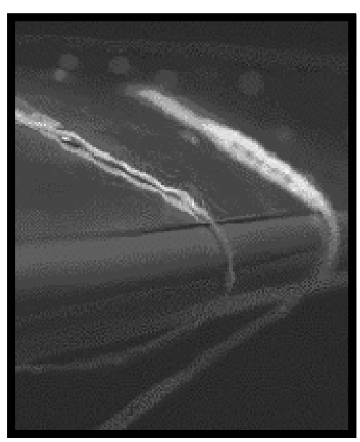
BERNOULLI BOTTLE

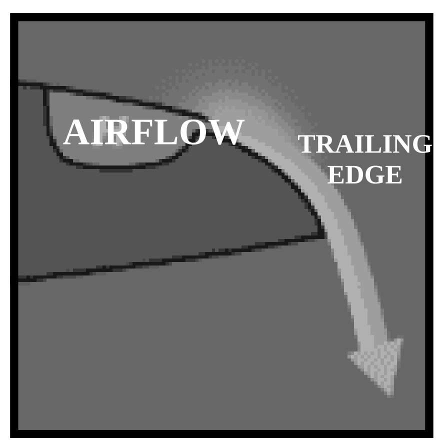
BERNOULLI TENT



BERNOULLI BALLOONS / BALLS







COANDA EFFECT WITH SPOON

WITH AIRCRAFT WING

NEWTON'S 3RD LAW