NATIONAL MUSEUM OF THE UNITED STATES AIR FORCE

AIRLIFT MISSION——CONTROLLING 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 pilots control cargo aircraft. The U. S. Air Force's Global Reach is emphasized!

LESSON PLAN (C)

Learning Objectives

The students will

- Review basic scientific principles related to airlift operations, namely the Bernoulli Principle, the Coanda Effect and Newton's Third Law, and learn how they combine to play a vital role in controlling cargo aircraft
- Learn how pilots use control surfaces to control the movement of huge cargo aircraft with great precision
- Predict the direction an airplane will fly, and build and fly a delta dart paper airplane to test their predictions
- 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 review four forces/airfoils/Bernoulli Principle/Coanda Effect/ Newton's Third Law (from Lesson Plan "B") then cover items found in this lesson plan (three axes of motion/ control surfaces/predictions/build/fly paper airplane). 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 three axes of motion of an airplane, control surfaces, predictions as to how a delta dart paper airplane will fly, the history of airlift operations, the types of aircraft used for airlift missions and a PowerPoint presentation.
- Hook: hold up a stuffed, toy bird and tell the class that birds control their flight by flapping both of their wings, which are, in fact, airfoil shapes, or they can just glide and soar. They can also make subtle changes by moving individual feathers or groups of feathers, so they can maneuver and even land in the tightest of spaces!
- Hold up a Styrofoam or balsa wood glider and ask the class how they think a pilot is able to control the movement of a gigantic cargo airplane, such as a C-17 "Globemaster III."

Procedures (continued)

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

- Take several answers and assess your students' prior knowledge on this subject.
- Ask the class the names of the two brothers who invented the first airplane (Orville and Wilbur Wright).
- Tell them that, in 1899, Wilbur was in their bicycle shop in Dayton talking to a customer. While he was talking, he was moving an old inner tube box around in his hands. Suddenly, he envisioned a way they could control an airplane in flight, specifically, the roll or turn of an airplane! When he pressed the corners together, the upper and lower surfaces of the inner tube box were given a twist, and it was quite apparent to him that the wings of a biplane could be moved in a similar fashion. They tested this "wing warping" theory out on a five-foot-long box kite with no front or rear skins (so it resembled a two-winged biplane). The idea worked!
- Teachers may wish to copy a facsimile of the famous inner tube box at: www.first-to-fly.com .
- Tell the class that a car's movements can be forward, backward, right turn, left turn; a train can move forward and backward only; but an airplane has three, distinct axes of motion while in flight!
- Hold up the Styrofoam glider, and use a dowel or pencil for demonstration purposes: tell the students that you've just discussed the roll or turn of an aircraft, including Wilbur Wright's "wing warping" idea.
- Hold the dowel so that it is aligned with, and on top of, the fuselage (body) of the glider; slowly turn the glider on the roll axis, so that the wing tips move up and down, but the fuselage and the dowel remain fairly stationary (except for the spinning of the fuselage); tell the class that this is the roll axis, and it is also known as the longitudinal axis (it is along the length of the aircraft); however, we no longer use Wilbur's "wing warping" concept to control the roll of an airplane—we use a control surface called "ailerons!" Attach post-it notes to each wing at the outer portion of the trailing edge—these represent your glider's ailerons.
- Write these headings on the board: Axis Name / Axis Motion / Control Surface .
- Ask the class what name of the axis is that you just demonstrated (longitudinal); and the axis motion (roll); and the control surface used (ailerons). Also, tell the class that, if an aircraft has delta wings (shaped like a "V") the ailerons and elevator are combined into control surfaces called "elevons!"
- Hold up the glider again; this time, place the dowel from wingtip to wingtip, as if you were measuring the wingspan; make the glider rock up and down (nose up/tail down; nose down/tail up); ask the class what they think this axis motion is (tell them that this is known as the lateral axis, and write that on the board under "Axis Name;" when someone says that the axis motion is "pitch," write that under "Axis Motion." Place post-it notes on the trailing edge of the horizontal stabilizer of the glider's tail and ask the class what this control surface is (the one controlling pitch); when someone answers "elevator," write that under "Control Surface."
- Hold up the glider to demonstrate the third axis of motion; position the dowel so that it is perpendicular to the fuselage of the airplane and going straight down through the middle of it; turn the glider on that axis so that the whole airplane spins back and forth (like a washing machine); this axis name is the vertical axis; the axis motion is yaw; post-it notes should be placed on the vertical tail of the glider; the control surface is the rudder.
- **Special Note**: National Science Academic Standards/Science As Inquiry/Evidence, Models And Explanation: models correspond to real objects and have explanatory power. They help both scientists and students understand how things work!
- Make students copies of the delta dart paper airplane found on page 6 of this lesson plan; cut slits on both sides of each "elevon" control surface prior to class.
- Pass out delta dart paper airplanes to the students, and give them step-by-step instructions on how to construct the gliders: write your first name on the "made by" line; make a horizontal, hot dog bun fold (longitudinally bisecting the paper); turn the paper upside down with the elevons closest to you; fold the upper corners over to meet the original fold (the result looks like the roof of a house we all used to draw in Kindergarten); fold each side again to meet the original fold (from the point) so that the "National Museum" logo shows; fold the airplane back together, using the original fold as a guide (you can only see elevons and your name at this point in the construction); this is the toughest part: start at the point (nose) and fold each side so that the paper meets the outside of the original fold, and the shape of the plane becomes a small wedge (dart); open the wings back up so that "National Museum" logo is showing and tape the airplane so that the wings stay flat and together.
- Familiarize students with the elevon control surfaces, and tell them that aircraft with delta wings (such as the Shuttle Orbiter) have these instead of ailerons and elevators.
- Ask the class which way the airplane will turn (clockwise or counterclockwise) when the left elevon is down and the right one is up (tell them that the left/right designation on an airplane is always from the pilot's perspective); as the plane flies away from them, it would turn clockwise in the aforementioned configuration!

Procedures (continued)

- Have the students fill out the test flight prediction sheet found on page 5 (make enough copies for every student, or allow them to work in dyads/cooperative learning pairs).
- **Special Note**: To adhere to National Science Teachers Association safety standards, all students flying any form of projectile (including paper airplanes) must don protective eyewear!
- Set up a time that your class can utilize the gym or multi-purpose room for test flying their delta darts.
- Brief them on safety measures: everyone will wear protective goggles; students will line up in two rows of fourteen, fifteen, etc. (so that there is one student behind each student in the first row); students will listen to the teacher for instructions on how to configure their elevons for each test flight; students will observe the flight of their own airplane; all airplanes will be flown/thrown using an even, smooth forward motion (no hard throws) as the teacher counts down with 5..4..3..2..1..; students will NOT run to retrieve their gliders until they get permission from the teacher/adult leader (because someone always throws their glider late, and that is a real safety concern).
- Conduct the test flights, making sure each student is observing how their airplane's flight changes with changes in elevon configuration.
- Ensure that students position all elevon settings at an approximate 45 degree angle (students typically set their elevons at an extreme 90 degree angle, and this makes them much less effective as control surfaces).
- Teachers may also wish to have students measure the three longest flights (with elevons straight). This is not to promote competition, but rather to have a bit more fun with the overall test flight scenario.
- Return to the classroom and allow students enough time to complete the "actual results" portion of their prediction sheets (cooperative learning pairs/dyads may be used in this instance as well).
- Discuss the difference between students' predictions and actual flight results: if the elevons are both up, the nose goes up and the airplane stalls (air slows down over both elevons and lowers the tail); if the elevons are both down, the airplane goes into a nose dive (air speeds up over both elevons and raises the tail); if they are both straight, the flights will be fairly straight; if the right one is down and the left one is up, the airplane will turn counterclockwise (air over the right elevon moves faster and the right wing lifts); if the right elevon is up and the left one is down, the delta dart will spin clockwise (air moving over the left elevon moves faster and the left wing lifts). A simple explanation for all of these actions is: the Bernoulli Principle!

SPECIAL MEMO: Both the prediction sheet idea and delta dart paper airplane were originally published in the 1997 edition of Project SOAR: Science in Ohio through Aerospace Resources Curriculum Guide!

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 delta dart construction, prediction and test flights.

Extension

Have the students experiment with their paper airplanes at home, but never fly them toward a sibling or a pet!

References

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

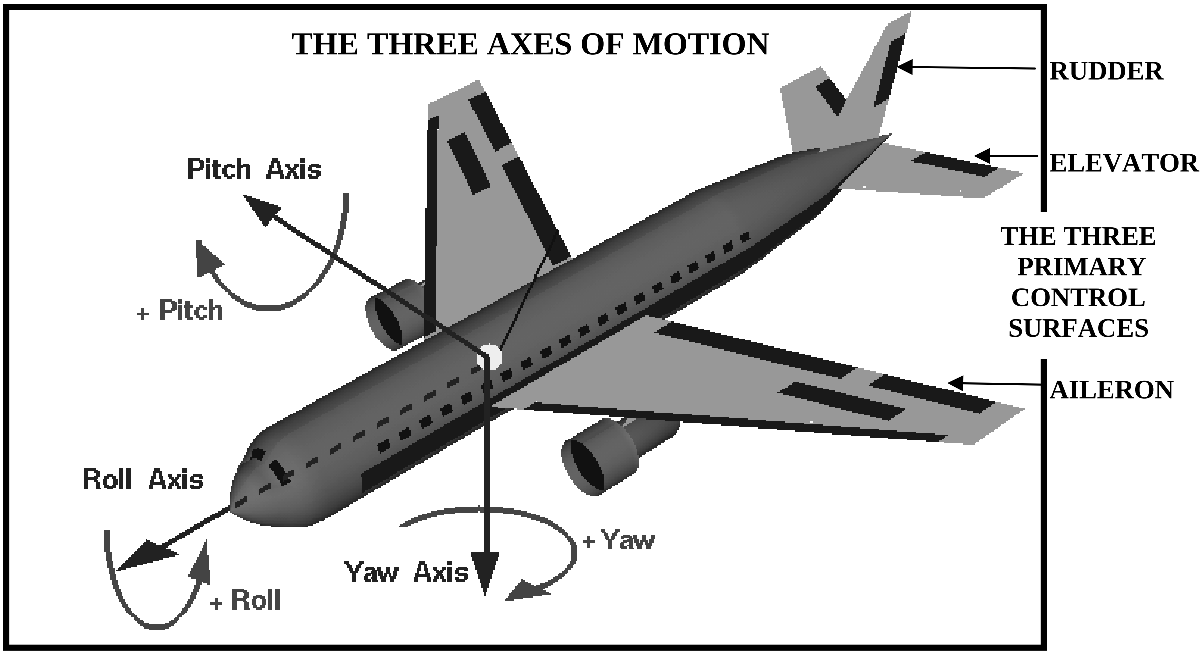
C-54-PLM Revisited by Ralph L. Stevenson, Jr; Sante Fe, NM: Sunstone Press; 2010

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

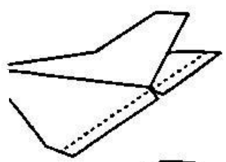
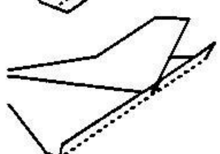
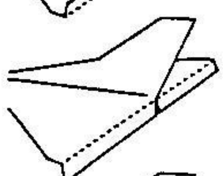
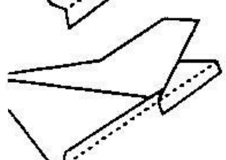
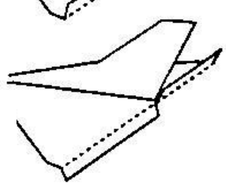
The Lockheed Martin c-130 Hercules by Peter C. Smith; Manchester, England: Crecy Publishing Ltd.; 2010

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



Student Test Pilot Record Sheet (What I Observed)

Position Of Elevons		Predicted Flight Path	Path Of Test Flight
Right and left straight		________________	________________
Right and left up		________________	________________
Right and left down		________________	________________
Right down, left up		________________	________________
Right up, left down		________________	________________

Does moving the elevons change the way the glider flies?

What happens when both elevons are in the up position?

What happens when both elevons are in the down position?

Does changing the position of elevons on a delta wing glider change its flight path?

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