NATIONAL MUSEUM OF THE UNITED STATES AIR FORCE®

AIRLIFT MISSION—ENGINEERING DESIGN TEAMS

Students will learn about the history of airlift missions (both humanitarian and combat) as well as to learn about aircraft structures, and the engineering mindset that is needed to properly design them. The U. S. Air Force's Global Reach is emphasized!

LESSON PLAN (G)

Learning Objectives

The students will

- Learn about cargo aircraft structures, and about the importance of creative engineering to ensure safe and functional design of those structures
- Learn about the dynamics of working within a cooperative learning team, while assisting their team with specific engineering design concepts/processes
- Learn to solve problems while working within a group
- 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: 5—6
National Science Education Standards:
Science as Inquiry, Science and Technology and History and Nature of Science

National Standards for History:
Chronological Thinking and Historical Comprehension

National Standards for Mathematics:
Problem Solving and Communication

Technology Education Standards (ITEA):
Understanding/appreciating engineering design

Materials Required:

- Magic board and markers
- PowerPoint presentation
- Laptop, monitor, digital projector
- 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:

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 divide the class into four, five or six teams of five students each prior to commencing this lesson plan. 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: comparing and contrasting older aircraft structures with newer designs, engineering design challenge teams/solutions, the history of airlift operations, the types of aircraft used for airlift missions and a PowerPoint presentation.
- Hook: Hold up a Styrofoam airplane (or any type of small glider) and tell the students that what you are holding is a representation/model of a C-17 "Globemaster III" cargo airplane (also shown in the PowerPoint slide presentation). Write '170,000 pounds' on the board, and tell the class that this huge cargo aircraft's maximum payload (cargo that it can hold) is that huge amount of weight, and ask them how they think such huge airplanes can hold so much cargo and still take off, fly and land successfully (without breaking apart).
- Take a few answers, then tell the students that they will be breaking out into their engineering design teams

Procedures (continued)

- Tell the class that, during the early years of aviation, airplanes were constructed of wood and cloth. Point to the basic aircraft structures on your model as you tell them that, 100+ years ago, the wings, fuselage (body) and tail were given structure by using wooden spars and framework, and then by stretching and stitching cloth over those spars and wooden frame elements to make a lightweight skin. Draw a simple wing on the board and show them how the wooden spars/ribs were assembled (see page 4). Tell the students that more modern technology for an aircraft's 'airframe' includes the use of metal spars, frames and ribs, as well as lightweight sheet metal for the skin—and that is quite a contrast from the cloth and wood construction of 100+ years ago! Show that on the board as well, drawing the modern wing design you can also find on page 4.
- Tell them that the fuselage is the main body of the aircraft to which all parts are connected, and it is the primary carrier of the airplane's payload/cargo. The wings provide lift and control for the aircraft, and many times there are fuel tanks inside them (which saves a lot of space for other systems and cargo). The primary function of the tail of the airplane is to provide stability and control during take-off, flight and landing.

Teachers Please Note: Review this description of the **main student activity** for this lesson plan well in advance of the day you teach it. The purpose of this cooperative learning team effort is to show students how changing the shape of something can dramatically increase its overall strength, so that it can be used for safer and stronger aircraft structures. Find two objects that can be set up nine inches apart, also ensuring that the distance from the table to the top of each object is at least 3.5 inches (perhaps two bricks on their side, two small boxes of equal height, etc.). If your spouse is a good carpenter, they may be able to follow the drawings/descriptions on page 5 of this lesson plan to make one "U" shaped apparatus for each student team! If your spouse is really ambitious, perhaps they can even make dowel sections to represent aircraft payload/cargo for each team—again, please see page 5—and, paperclips can be substituted for the small dowel sections! Each team will have several sheets of normal, 8.5 x 11-inch paper, a "U" shaped apparatus and dowels or paperclips for 'cargo.' After you demonstrate to the entire class that the paper, when placed between the objects, will not even support its own weight, ask them what can be done to the sheet (without adding paper) so that it will not fall down (and so that it will even support extra weight). Allow the teams 30 to 45 minutes to (cooperatively) come up with one or two solutions! **One solution** is to fold the paper length-wise twice so as to form a "W" (the distance between each fold will be slightly over two inches—see page 5). Place the folded sheet so that the "W" is upside down on the apparatus/stand—teams will be able to add extra weight (dowels/paperclips) until the paper eventually collapses. **Another solution** is to roll the sheet of paper into a tube and use tape so it will hold its shape—then place the tube across the apparatus. Students will find that they can add quite a few pieces of cargo/extra weight before this configuration collapses! The "W" represents corrugated sheets of metal which are found inside some aircraft wings, and the tube represents the fuselage of an airplane! Back to the regular lesson plan procedure:

- Remind the students that your model C-17 can hold up to 170,000 pounds of cargo, and break them up into their respective engineering design challenge teams (of four, five or six students each).
- Present the problem that the teams will be working to solve: demonstrate to them that a normal sheet of paper, stretched from one side of the "U" shaped apparatus to the other, cannot even support its own weight, and it will droop down until it touches the table/desk/bottom of the apparatus.
- Their engineering design challenge is to devise a way to make a sheet of paper strong enough to hold its own weight, as well as several of the dowel pieces (or several paperclips).
- Tell the class that this correlates with lightweight material strength/rigidity that needs to be engineered into modern aircraft structures and components.
- Show the class the items that each engineering design team will have to work with: the wooden or cardboard "U" shaped apparatus, several sheets of regular 8.5 x 11-inch paper, two 3.5-inch dowels and a dozen 2-inch dowels (both cut from 3/8-inch diameter dowels—use page 5 information as a reference point). Regular and/or jumbo paperclips may be used as substitutes for the dowels pieces.
- Have a designated member of each team take the required materials to their team's table.
- Give the engineering design challenge teams 30 to 45 minutes to cooperatively come up with one or more solutions to the problem (walk around and ensure that all members of each team are interacting/sharing ideas).
- When all teams have devised a solution/solutions, have each team designate a spokesperson who is willing to come to the front of the classroom and explain one of their team's solutions (no ideas are too wild)!
- One final team challenge: If there is a heavy weight (such as seven or eight large, 1.5-inch washers taped together) how can we configure a piece of ordinary paper so that it will hold up the weight without collapsing? Answer: roll the paper as before, place it up on its end (like a column) and then place the weight on top!

Procedures (continued)

- After all the teams have presented their explanations, congratulate all your students for how well they have worked together as 'aerospace engineers'—tell them that cooperative learning and working within the framework of a team are important skills that will be very helpful to them as future students and in their adult lives as well!

Assessment/Evaluation

The students should be evaluated on their class participation, listening skills and ability to follow verbal instructions, especially when they are involved as cooperative learning members of an engineering design challenge team!

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

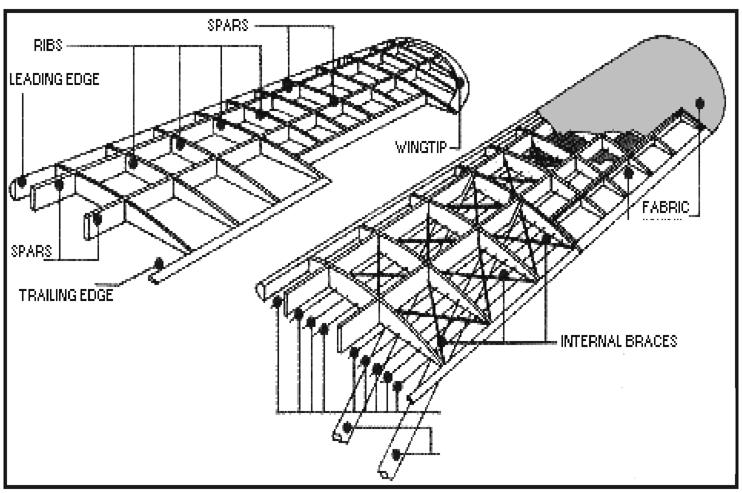
Humanitarian Airlift Operations by Daniel L. Haulman; Washington, DC: U. S. Printing Office; 1998

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

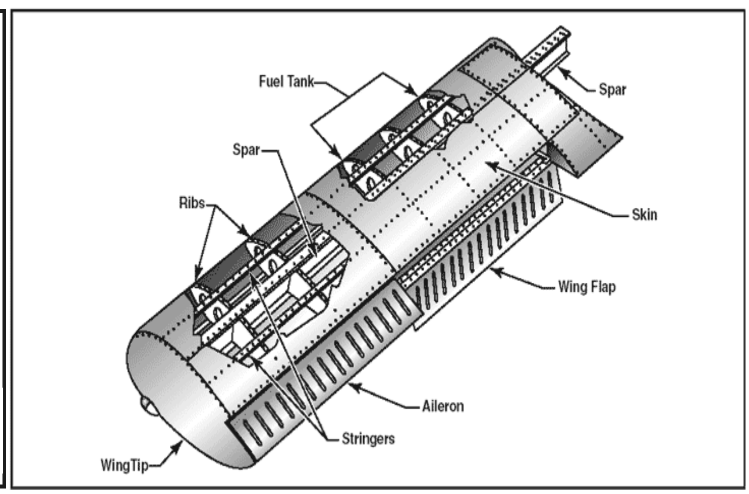
The "C" Planes: U. S. Cargo Aircraft 1925 to Present by Bill Holder & Scott Vadnais; Atglen, PA: Schiffer Publishing Ltd.; 1996

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

TEACHER ADDENDUM / PAGE 4



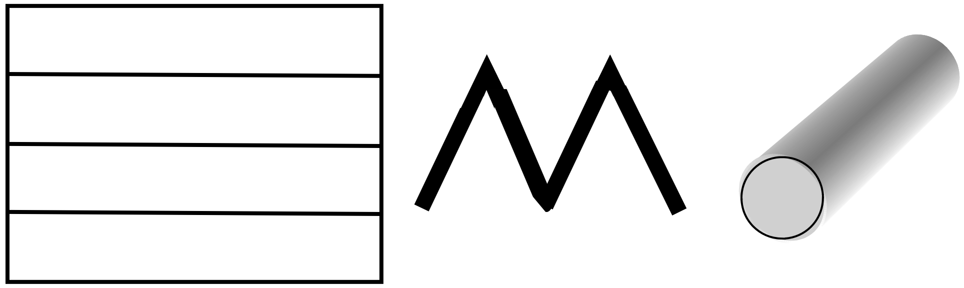
* Wood-and-fabric-type wing structure



* **Modern wing structure**

It is not the intent of this lesson plan to delve into a detailed analysis of aircraft wing structure, control surfaces, etc. When you draw the wood-and-fabric wing structure and the modern wing structure on the board for your class, there is no need to create a 'masterpiece!' This portion of the lesson plan classroom procedure is simply to give your students a little background information, and a way to compare and contrast aircraft structures of 100 years ago with those of today. You may wish to tell your students that computers are currently used to determine the necessary skin thicknesses for aircraft structures such as wings, so as to avoid excessive stress levels and strains (versus stretching and sewing fabric over wood)!

Each student engineering design team should have an "apparatus" similar to the one pictured above. Whatever is used for the two support pieces (small boxes of equal size, 1.5-inch thick boards, bricks, etc.) should be exactly 9 inches apart and at least 3.5 inches in height. The boards/bricks/boxes should also be at least 6 inches deep, so that the 8.5 x 11-inch paper will be adequately supported. Note: if you decide to make the "U"-shaped apparatus with wood, the two side pieces of 1.5-inch wood may be connected with a thinner, solid board underneath (plywood nailed or screwed to the bottom of both pieces makes an excellent base, and the 9-inch distance will always be maintained)! (Activity was designed by Mr. Don Perander, former Civil Engineer and current Museum Volunteer).



2.0 x 3/8-inch dowel sections;

3.5 x 3/8-inch dowel sections;

small and jumbo paperclips

Each student engineering design team will receive several sheets of 8.5 x 11-inch paper, and several small and large paperclips for weight/cargo (OR if you decide to make 3/8-inch diameter dowel sections for this activity, they will receive a dozen of the 2-inch long pieces and two of the 3.5-inch ones). After you demonstrate that the normal sheet of paper falls between the two support boards, bricks or boxes, it is up to the members of each student team to discover how they can make the sheet of paper stronger and more able to support weight, without adding any paper. One solution is to fold the sheet of paper longitudinally, as shown above, so that each fold is slightly wider than 2 inches. This creates a "W" shape, and that should be inverted and placed between the supports, and the paper will then be strong enough to hold a lot more weight than its own! Students should experiment by adding more and more paperclips or dowel pieces. Another solution is to roll the sheet lengthwise into a tube (also shown above) and tape it so it will hold its shape (the tube diameter should be about 1.5 inches). When the tube is placed across the supports, it will also hold much more weight than its own, and again, students should add paperclips or dowel sections until the paper eventually collapses!