NATIONAL MUSEUM
OF THE UNITED STATES AIR FORCE®

FLIGHT SUITS AND PHYSIOLOGY

Students will have an understanding of the development of flight suits through the first century of flight and will understand how components of those suits help protect the crew while in flight.

LESSON PLAN

Learning Objective

The students will:

- gain a basic understanding about protective flight equipment.
- learn pertinent vocabulary related to this topic.
- be able to identify flight gear from several eras of flight and describe how the human body would be impacted without the benefit of these items.
- work in teams to gain an understanding of these concepts and make predictions about how these systems work using provided materials.

Goal

For as long as manned flight has existed, pilots have sought protection from the elements they encounter in the air. In this lesson, students will learn about protective equipment including; helmets, flight suits, fire protective clothing and oxygen masks used by pilots and crews while in flight. They will also learn about the physiological perils of flying without these protections.

Once students have an understanding of the protective equipment, and their importance, they will work in teams to design and create a "flight suit" for their "pilot" and test it for safety.

INTRODUCTION

It was believed, at the time of the first manned hot air balloon flight, in 1783, that if one merely ascended to an insignificant height from the Earth they would die due to a lack of oxygen. We now know that typically, an assent must be above 1 to 2 miles before any great physical affect is experienced by humans.

Grade Level: 4-6

Next Generation Science Standards
Science and Engineering Practices:
Asking Questions and Defining Problems, Developing and Using Models, Planning and Carrying Out Investigations, Constructing Explanations and Designing Solutions, Obtaining, Evaluation and Communicating Information
Engineering Design:
Defining and Delimiting Engineering Problems; Developing Possible Solutions; Optimizing the Design Solution

National History Education Content Standards:
Chronological Thinking, Historical Comprehension, Historical Analysis and Interpretation, Put Historical Thinking Skills to use.

Materials Required:

- Eggs
- Packing peanuts
- Packing bubble-wrap
- Empty cardboard tubes of various sizes
- Variety of small cardboard boxes
- Wood glue and/or hot glue guns
- Various types of tape
- Scissors
- 5x5 fabric scraps
- Medium to thick string (24 in.)
- PowerPoint

At altitudes greater than 2 miles, there are significant threats to ones well-being however, to off-set these hazards, there are protections in both the aircraft and in flight suits that provide safety while in flight

FLIGHT SUITS

In the years of early manned flight, aircraft reached relatively low altitudes so the need for oxygen was not a great concern. Conversely, the decreased air temperatures at even lower altitudes were of concern. In an effort to find protection from the elements aloft, pilots sought warmer clothing. Many flight suits were developed during War World I.

Most were simply made of leather, often worn over layers of clothing. However, an aviator from Australia provided the idea for the most popular flight suit of that time period. Sidney Cotton developed the "Sidcot" suit in 1917. Cotton found that his oil drenched overalls provided an extra layer of protection when worn under his leather flight suit. He used that idea to have a special flight suit created with the same concept in mind. The "Sidcot" flight suit became a favorite of pilots until aircraft improvements during World War II provided a more protected fuselage.

Temperature continued to be an issue even with the introduction of closed cockpit aircraft. As an aircraft and its crew ascend, temperatures drop dramatically. Prior to advancements in aircraft during World War II, a waist gunner, sitting near an opening in the fuselage, would still need to wear an electrically heated suit as he was exposed to the elements. His conundrum was that without this protective gear, his hands would immediately freeze to metal at 30,000 feet.

By World War II, aircraft design helped to better protect crews from the elements. These same improvements created additional concerns. Aircraft were now moving through the air at speeds up to 120 miles per hour and also at much higher altitudes. The speed coupled with the diminished temperatures in the upper elevations, created a very cold environment for pilots. Protective clothing and aircraft enclosures provided a satisfactory, although temporary, answer for the issue of temperature however, the issues related to altitude created much greater dangers.

Pilots not wearing protective equipment at altitudes above 10,500 feet (approximately 1– 2 miles) experience a number of physiological problems. Some can be minor, others life threatening. At higher altitudes there are many environmental changes that one will experience; temperature, of which we've already addressed, oxygen and air pressure are two others and too much or too little of either can be fatal.

At sea level, oxygen is around 21% of the atmosphere. As one ascends, the level of oxygen decreases. At 29,000 feet or the height of Mt. Everest, oxygen levels decrease to 9 %. At these altitudes, it is very likely that without supplemental oxygen, altitude sickness or hypoxia will occur. Hypoxia makes it harder to breath at altitudes reached by some aircraft. It is simply too difficult for a pilot or crew to inhale sufficient amounts of air to inflate their lungs.

Hypoxia begins with fatigue, loss of appetite, headache and inability to think clearly. If the pilot and crew continue to climb into thinner atmosphere or experience a sudden change in altitude, the symptoms will drastically change. Fluid will build in the lungs and brain and the heart will beat more slowly.
The crew will lose consciousness and within a short period of time they will die. If a pilot and crew are not provided an oxygen mask in these circumstances, the consequences will be dire.

Persons who consistently live in higher altitudes, for instance Peruvians, are better adapted at surviving and actually thriving in higher altitudes as they are constantly in an atmosphere of oxygen level of around 13,000 feet. Runners and other athletes who are unaccustomed to higher altitudes must go and train at an increased altitude if they wish to compete in sports at these locations. They must *acclimatize* (or become used to breathing) in higher altitude environment.

As the Air Force's aircraft, such as the SR-71, have reached altitudes of 80,000 feet and speeds of over 2,000 mile per hour, we have needed to revolutionize the flight suits worn by the pilots. At these heights and speeds, the flights more closely resembled those of astronauts and multiple layers of protection are needed. One of these layers consists of a water-cooled interior flight suit. Early test flights of the SR-71 reported that at 68,000 feet a flask of water placed in the test chamber began to boil, at 70,000 feet, it reached a rapid boil and at 80,000 feet it evaporated. As the human body is comprised of up to 60% water, imagine the impact of these temperature changes on the pilot.

It was not until World War II, with the B-29, that aircraft fuselages were pressurized. Although this provided a greater degree of safety for pilots and crews in that period it did little to assist aircrews in subsequent years. As the altitude and speed capabilities of aircraft increased once again there was concern that the pressurized cabins were not sufficient for the protection of the crews.

In an effort to acclimate a pilot and crew to decreased oxygen and air pressure in an aircraft, the fuselage is pressurized. Sometimes pilots and crews flying at increased altitudes are also provided pressurized flight suits to balance the amount of oxygen and air pressure experienced. Just as too little oxygen can cause problems, a rapid decompression or decrease in air pressure can be detrimental and serious. When a pilot and crew come from a significantly different (either higher or lower) altitude they will have experienced *ambient pressure*, or pressure created from a surrounding medium. If the airplane ascends rapidly, the crew can experience *aeroembolisms.* This can be equated to what a deep-sea diver would experience with water pressure, the bends. Rapid descent or assent can cause myriad of physiological concerns. These concerns, if caught in time, can be counteracted through the use of a pressurized chamber and other tools.

It is commonly thought that a rapid decompression will result in a person's blood "boiling". This is not necessarily a true statement. In 1965, at the then NASA Manned Spacecraft Center, a test subject was accidently exposed to a near vacuum or extremely low air pressure (less than 1psi) due to rapid decompression. The subject remained conscious for about 14 seconds, which is the amount of times it take for oxygen deprived blood to go from the lungs to the brain. The subject's suit did not reach hard vacuum (defined as b/t 1-5 psi) and the chamber was depressurized within 15 seconds. The subject regained consciousness at around 15,000 feet equivalent altitude. He later reported that he could feel and hear the air leaking out, and his last memory was of the water on his tongue beginning to boil. While there will be significant effects, typically the results of depressurization are that the pilot and crew may begin to look like very buff bodybuilders, as the present fluids in their bodies expand. If untreated or unresolved however, this condition can result in death.

On August 16, 1960, Captain Joe Kittinger, during his ascent to 103,000 feet (19.5 miles) in an open gondola, lost pressurization in the right hand of his flight suit. He continued with his jump, as his hand became pain filled and useless. However, once back on the ground, he acclimated to the lower altitudes and his hand returned to normal.

Protection is also very necessary for pilots due to the speeds they are now able to achieve. G-suits (anti-gravity suits) are used by pilots and crews to overcome the effects of gravity on their bodies. As the amount of gravity (pull from the Earth) increases, there is a decrease in the amount of blood being pumped to the brain. Pressure pants and breathing techniques are used to push the blood to the brain in order to prevent blackouts. Those who achieve higher altitudes, such as astronauts have, full-body pressure suits as needed at significantly higher "g-forces". Through the use of pressure or G-suits, Air Force pilots can successfully overcome the force of up to 9 "G"s.

HELMETS

Flight helmets have been used since the very early days of manned flight. The first military flight fatality was Lt. Selfridge during a test flight with Orville Wright in 1908. Lt. Selfridge was not wearing a helmet at that time.

During World War I, there were both rigid and soft leather helmets. Unfortunately, most pilots chose the soft leather as it provided better and much easier head movement and protection against the wind and cold. Soft helmets did not, however, provide much protection form injury. Pilots including Henry "Hap" Arnold wore soft football helmets while flying.

Only toward the end of World War I, did helmets begin to evolve as pilots sought protection from "flack" or shrapnel, and a two pound steel helmet was designed.

During World War II, both the science of aircraft ejection and speed were progressing through technology. The combination of both led to an increase in the number of head injuries. Sudden ejection from aircrafts caused a sort of cranial whiplash that resulted in concussions and brain hemorrhage for pilots. There were however still "antiquated" aircraft in use by the Air Force and for these pilots there was no ejection, but they were forced to "ride-out" a crash. Often times, these "controlled" crashes were the source of head injuries.

It was with the advances of aircraft technology that helmet design began to change. It was determined, in the years following World War II, that helmet design should include a center of gravity on the top and should weigh no more than 4.5 pounds. This combination would provide significant crash protection for the aircraft in those years and provide a balance to the helmet, assisting in minimizing the "whiplash" affect encountered by pilots during ejection.

Since the early 1970s, there have been significant improvements in the materials used for helmets and their designs have continued to evolve. Materials have include fiberglass to assist with weight and balance and Kevlar graphite, for both weight and "flack" protection. Currently, Air Force pilot and crew helmets are created using a poly carbonite material for protection from "whiplash" on ejection, "flack" and fire. They also have a cushioned liners to protect from the percussion of a strike.

In addition to the flight suit items discussed, there are a number of other protective clothing items that are useful, and in some instances essential to todays' pilots and their crews.

As we know, early pilots had to endure open cockpits, as aircraft became capable of flying at higher altitudes, however the need for goggles became apparent. One test pilot at McCook Field, Major R.W. Schroeder, found the necessity for goggles while flying at 33,000 feet. Schroeder removed his goggles to change oxygen tanks, and with temperatures at –65 degrees, his eyes froze open. He continued flying however, and made a successful landing.

Although not widely popular due to peripheral visibility concerns, pilots sometimes also chose to wear goggles to keep the engine's oil from obscuring their vision.

As aircraft design progressed to include a more enclosed environment, the need for goggles diminished. Today however, there is a renewed need for specialized goggles. For the purpose of night flight in a combat location, it is very common for a pilot to use night vision goggles (NVG).

The need for multiple layers of clothing has also diminished with better aircraft design. Early flight saw layers of clothing being worn for the purpose of warmth. Today, protective liner suits are also used by pilots and crews. Nomex® suits are light-weight suits created to protect against fire, heat and moisture in the event of a water egress. These are standard wear for all crew members today.

See accompanying PowerPoint.

BUILDING A PROTECTIVE FLIGHT SUIT
STUDENT ACTIVITY

PROCEDURES

- The students will work in teams of 4 to 5 students
- Begin by explaining the evolution of flight suits and their protective functions.
- Explain to the students that each team will be building their own protective suit with the given supplies:
  - One egg per team
  - Packing peanuts
  - Packing bubble-wrap
  - Empty cardboard tubes of various sizes
  - Variety of small cardboard boxes
  - Wood glue and/or hot glue guns
  - Various types of tape
  - Scissors
  - 5x5 fabric scraps
  - Medium to thick string

PROBLEM

- How can student create and test an effective flight suit for their pilot (the egg)?
- Students will decide what type of flight suit they are building and what materials are needed to protect their pilot. Then they will choose the type and amount of materials necessary to accomplish their task.
- Students will then test their success by “flying” their pilot, while contained in the protective suit to determine if the suit is flight worthy. If their pilot doesn't “crack” the suit is acceptable.
- Students should drop their “eggs” / flight suits from a maximum height equal to the top rung of a step ladder.

EXTENSION

- Team presentations—each team of students should prepare a presentation on the design and efficacy of their flight suits. All parts should be described and explained. The presentations could involve drawings, dioramas, PowerPoint slides, etc.

- If possible—visit the National Museum of the USAF to see actual flight suits on exhibit! Or visit the National Museum’s Virtual Tour and look for Kettering Hall. (http://www.nmusafvirtualtour.com/full/tour-std.html)

Resources:

- http://www.nationalmuseum.af.mil/photos/mediagallery.asp?galleryID=3079&?id=-1&page=5&count=48 (accessed 7 Aug 2014).
- http://www.nationalmuseum.af.mil/photos/mediagallery.asp?galleryID=4871&page=2 (accessed 7 Aug. 2014).
- http://www.nationalmuseum.af.mil/factsheets/factsheet.asp?id=562 (accessed 6 Aug).
- http://anthro.palomar.edu/adapt/adapt_3.htm (accessed 24 June 2014).
- http://rotornation.com/when-it-comes-to-flight-suits/ (accessed 30 May 2014).
- http://www.wisegeek.com/what-is-a-flight-suit.htm (accessed 30 July 2014)/
- http://www.usaarl.army.mil/TechReports/93-2.PDF (accessed 20 May 2014).
- https://www.faa.gov/air_traffic/publications/atpubs/aim/aim0801.html (accessed 6 June 2014).
- http://en.wikipedia.org/wiki/Decompression_sickness#Leaving_a_high-pressure_environment (accessed 30 July 2014).
- http://www.hill.af.mil/library/factsheets/factsheet.asp?id=5759(accessed 30 July 2014).
- http://gizmodo.com/5994110/the-most-badass-plane-ever-had-an-equally-awesome-flight-suit (accessed 30 July).
- http://en.wikipedia.org/wiki/Flight_suits (accessed 24 July 2014).
- http://imagine.gsfc.nasa.gov/docs/ask_astro/answers/970603.html (accessed 7 Aug 2014).

- Billings, C.E. Survival Under New-Vacuum Conditions in an article "*Barometric Pressure,"* Chapter 1 of Bioastronautics Data Book, Second edition, NASA SP-3006, edited by James F. Parker Jr. and Vita R. West, 1973

- Gordon, Leonard. "*Aviation and Space Technology"*, February 1995.

- Robinson, DH. *The Dangerous Sky: A History of Aviation Medicine.* (Seattle, WA: University of Washington Press) 1973.

- Sweeting, C. *Combat Flying Clothes.* (Washington, DC: Smithsonian Institution Press) 1984 pp. 71-79.