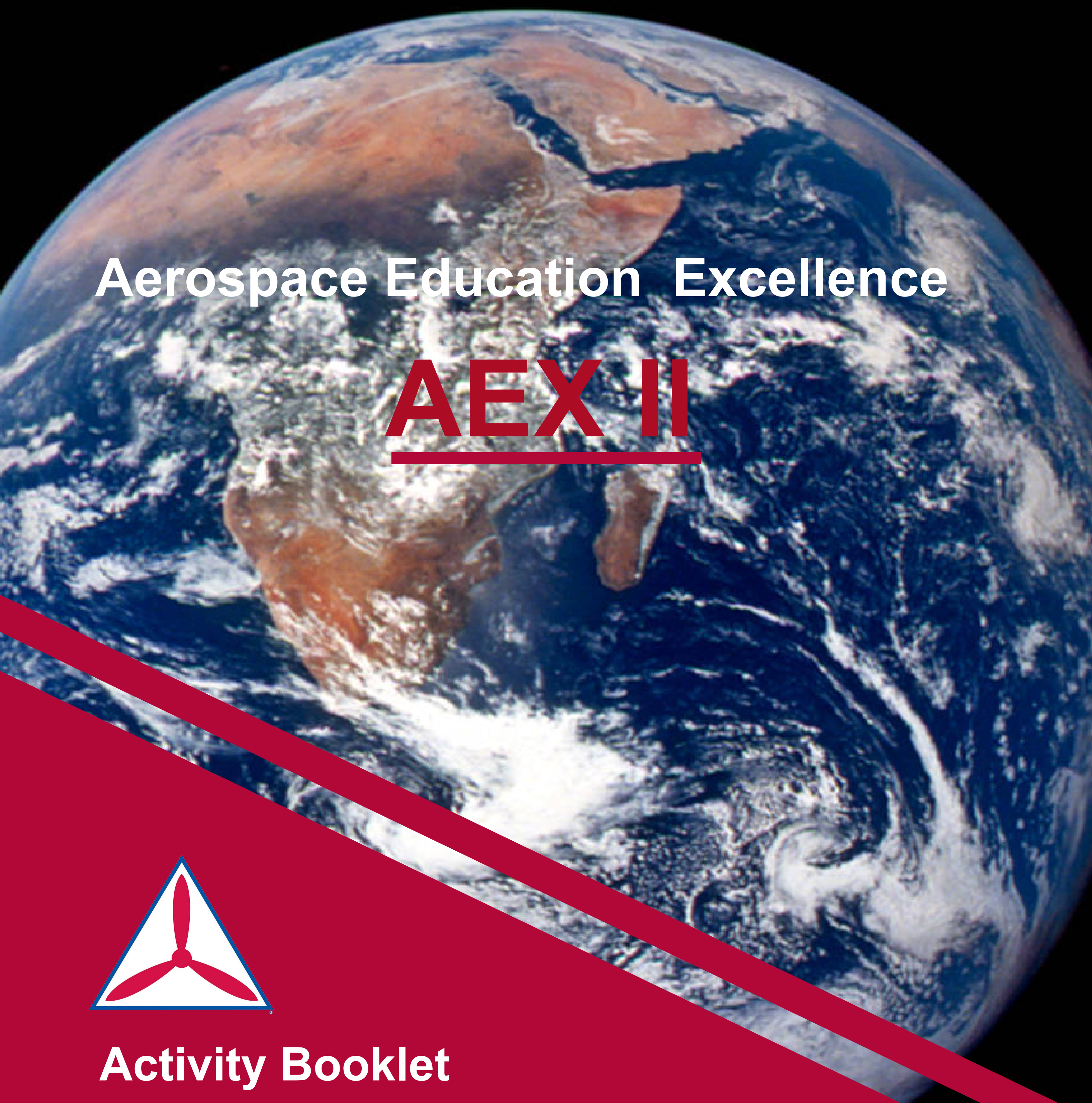
Aerospace Education Excellence

AEX II



Activity Booklet

for

6-12th grades

PRODUCED BY

CIVIL AIR PATROL

AEROSPACE EDUCATION DIRECTORATE

THE AEROSPACE EDUCATION EXCELLENCE AWARD PROGRAM

AEX II

Activity Booklet

for

Grades 6-12

and

CIVIL AIR PATROL AEROSPACE EDUCATION OFFICERS

Revised Version by
Mrs. Megan Tucker, NBCT, M.Ed.

Original Version by
Dr. Ben P. Millspaugh

Graphics
Mr. John Westcott

Standards Correlation
Mrs. Megan Tucker, NBCT, M.Ed.

Editing
Ms. Shayla Broadway
Mr. Blake Atkins

Illustrations
Mr. Seth Stewart
Ms. Saundra Carmical

PUBLISHED BY THE AEROSPACE EDUCATION DIRECTORATE NATIONAL HEADQUARTERS CIVIL AIR PATROL
Maxwell AFB, Alabama

CIVIL AIR PATROL

Table of Contents

4 Milestones in Aerospace Education

5 Aerospace Education – Exactly What Is It? -And Civil Air Patrol Acronyms/Definitions

6 Rocket Science 101

7 Wing Tips - Recommended Reading

13 Bernoulli Basics Demonstrations

20 NASA Interactive Software Resources

22 Activity One: Soaring Sailplanes – Building the Air Force Academy’s Historic TG-4A Glider

28 Activity Two: Wind Tunnel Wonders – Building & Testing the NASA Wind Tunnel

45 Activity Three: Quimby’s Quest – Harriet W. Quimby and Her Airplane, the Bleriot XI

54 Activity Four: Spinning “Sight” Sensations – Gyroscopic Technology and NASA GP-B

59 Activity Five: Parabolic Propulsion – Propulsion with a Ball Launcher

68 Activity Six: Teamwork in Aerospace

75 Activity Seven: Building the International Space Station

84 Activity Eight: Under Pressure – Experimenting with Vacuum Environments

92 Activity Nine: Warp It! Space Travel near the Speed of Light

96 Activity Ten: The SR-71 as a Simple, Fun, Foam Flying Machine

100 Activity Eleven: Build a Real Low-Flying Hovercraft

104 Activity Twelve: Become a Squadron Weather Officer

112 Activity Thirteen: Build A Radio Controlled Mars Spirit Rover

Milestones in Aerospace Education

A Complete Unit in Aerospace Education

Students Should Know:

- ...about mans' first flight in kites. Some historians believe that the Chinese invented kites around 400 B.C. There is new evidence that kites were used by South Seas island natives to catch fish before the Chinese.
- The Chinese are credited with the development of solid fuel rockets, 1220 A.D. This type of rocket launches the Space Shuttle today.
- The great works of Leonardo da Vinci, 1485, should be included. Although the technology of his lifetime would not allow their construction, he designed a parachute, a helicopter, and a flapping wing ornithopter.
- Daniel Bernoulli (1700-1782) and Sir Isaac Newton (1642-1727) developed scientific theories that were eventually used as the basis of flight within the atmosphere.
- Man's first true powered flight was in a hot air balloon. This occurred in 1783 and the inventors were two brothers, Joseph and Etienne Montgolfier, in Paris, France.
- The first successful manned free-flight in a heavier-than air-machine, 1853, is credited to Englishman, Sir George Cayley.
- Otto Lilienthal was the first to build and fly a glider with true control (1891). It was a primitive hang glider and steering was by shifting body weight. He died in an accident when his glider stalled and plummeted to the ground in 1896.
- By extensive testing, the Wright brothers developed a full, three-axis control of their glider in the windy conditions on a beach near Kittyhawk, N.C. (1900).
- After thorough flight tests, the Wright brothers built their own engine and achieved the first controlled, sustained, and powered flight. This occurred on the 17th of December, 1903. The aircraft rose 12 feet in altitude, went 120 feet in distance, and the flight took 12 minutes.
- Ms. Harriet Quimby was a very brave young woman who became the first American female (2nd in the world by just a few days) to attain an internationally recognized pilot's license. She also became the first woman to fly the English Channel (unfortunately, not very well recognized because her epic flight was two days after the sinking of the Titanic in 1912).
- Ms. Bessie Coleman was the first African American, of either gender, to obtain an internationally recognized pilot's license. She was a role model heroine in her own time and was tragically killed in an air show accident in 1926.
- Dr. Robert H. Goddard is considered to be the Father of Space Flight. He learned how to control a rocket engine through the use of liquid fuels (1926).
- Charles A. Lindbergh made aviation credible. Lindbergh is the Father of Commercial Aviation and his epic trans-Atlantic flight was the beginning of modern air travel (1927).
- Amelia Earhart helped establish a place for women in the world of aviation. She did this by her pioneering achievements and world records. (1932-1937)
- The propeller era, which began with the flight of the Wright brothers, ended in World War II when the first jets arrived. A jet engine was invented and developed by Englishman Frank Whittle (patented 1930; first flight 1941).
- By breaking the sound "barrier" on October 14, 1947, Charles E. "Chuck" Yeager opened the Space Age. He did this in a rocket-powered aircraft called the Bell XS-1. The speed of sound is approximately 761 miles per hour, at sea level, and the speed to go into orbit is 18,000 miles per hour. To go into orbit around the Earth, an air/space craft has to go through the speed of sound first. That is why Yeager's flight was so important.
- The next step was our first aerospace plane. It was known as the X-15 and was test flown by aerospace pioneer A. Scott Crossfield. He is considered by many aviation/space authorities to be America's first true astronaut. The X-15 routinely flew up and back from the edge of space. (1959)
- The great Space Race was initiated by the Soviet Union when they put a satellite into orbit on October 4, 1957. The satellite was known as Sputnik and it changed the course of history.
- America temporarily lagged behind in the technology of space; however, a concentrated effort was initiated by President John F. Kennedy to land a man on the moon and this task was accomplished on July 20, 1969. Astronaut Neil Armstrong was the first human to walk on the moon.
- First flown in 1981, the American Space Shuttle was developed to cut the cost of taking cargo into orbit and returning to Earth. The Shuttle is essentially a space "truck."
- America's satellites are directly responsible for the "giant leap" in telecommunications and weather technology. The space program has brought us closer to being a human race of "one people." (The last three decades of the Twentieth Century)
- The International Space Station will be our "stepping stone" to the stars. Incredible new technology will be developed as a result of the scientific work planned under the microgravity conditions of space (1999- and beyond).

Aerospace Education – Exactly What Is It?

- It has been found that flight, whether it's in the sky above, or the space beyond Earth, excites the imagination of children.
- The pure science and technology of atmospheric and space flight is known as AEROSPACE. This combines the terms "aeronautics" and "space."
- AEROSPACE, either in isolated examples or full curriculum units, has been found to make children actually WANT to learn more about science and technology. AEROSPACE, as a learning incentive, WORKS!

SO, WHAT IS AEX?

AEX is a popular program, free to CAP members, that brings hands-on aviation and space-related activities to cadets, students, and senior members. AEX stands for "Aerospace Education Excellence."

The requirements are simple: Register for AEX, complete six aerospace hands-on activities and one two-hour or longer field experience, then complete the AEX Award Report to earn an instructor certificate plus color certificates for your students.

- An AEO, Commander, or AEM, should register for the AEX Program in eServices. AEX program activities must take place from Oct. 1 - Sept. 30 each year.
- Select six activities out of any CAP AE curriculum, or other STEM curriculum, and use them in a classroom or squadron setting. CAP curriculum is available in eServices, AE Downloads and Resources.
- Complete a two-hour, or longer, field experience (space day, rocket launch, trip to the airport or museum, etc.).
- Activities may be entered in the AEX Award Report as they are finished, or all at one time.
- When all requirements have been completed, submit the AEX Award Report.
- The AEX Award Report will be reviewed. Once approved, an instructor certificate plus color certificates for students will be sent. The AEX certificate template is available on the AEX website.
- The AEX Award Report must be submitted at least 3 weeks prior to needing certificates.

Civil Air Patrol
ACRONYMS AND DEFINITIONS

Throughout many Civil Air Patrol publications, you will find words and acronyms that are often confusing. These are a few that are used in the AEX Activity Booklets.

AE - This stands for "Aerospace Education" and generally relates to all components of the Civil Air Patrols' third mission, aerospace education.

AEM - An AEM, which stands for Aerospace Education Member, is a unique membership category designed for formal or informal educators involved in promoting aerospace/STEM education in classrooms, home schools, museums, libraries, or other youth organizations. An AEM does not wear a uniform or attend regular CAP meetings.

AEO - An AEO, Aerospace Education Officer, is essentially a CAP squadron "teacher" and serves as one of its staff leaders. The AEO is responsible for making the aerospace education program work within a cadet, senior, or composite squadron.

AEROSPACE - A combination of the two words, "aeronautics" and "space."

AEROSPACE EDUCATION - "The branch of general education concerned with communicating knowledge, skills, and attitudes about aerospace activities and the total impact of air and space vehicles upon society."

AEX - This is an acronym for the Aerospace Education EXcellence Award Program of the Civil Air Patrol.

CAP - Acronym for Civil Air Patrol. CAP is the official auxiliary of the United States Air Force and has three missions: Aerospace Education, Emergency Services and an outreach for young Americans called Cadet Programs.

CADET - A cadet is the youngest member of Civil Air Patrol. Any person who is entering sixth grade or above, can join the cadet program. The cadet automatically becomes a senior member at age 18.

COMPOSITE SQUADRON - A CAP unit that has active cadet and senior membership.

SENIOR MEMBER - An adult member of Civil Air Patrol. Citizens who wish to join the Civil Air Patrol may become a senior member at age 18.

ROCKET SCIENCE 101 - How To Teach It!

There are several rockets featured in AEX and this page serves as a basic guide for all. For further investigation, it is recommended that teachers use the Internet or library.

Historically Speaking

1. Nearly two thousand years ago, a Greek by the name of Hero, developed a primitive "rocket" engine. He placed a hinged sphere on top of a container of water. The water was then heated and turned into steam. As the water traveled through the pipe into the sphere, two L-shaped tubes on opposite sides allowed the gas to escape. The sphere would then spin as the steam escaped through the L-tubes.
2. The Chinese are given credit for the invention of solid fuel rockets. In the Chinese-Mongolian war of 1232, the Mongolian cavalry was continually repelled by Chinese rocket attacks. They were called "fire arrows" and consisted of gunpowder packed in a hollow bamboo tube.
3. The first major breakthrough in rockets came in the early 19th Century when William Congreve (1772-1828) improved the range and accuracy of solid-fuel rockets. It was the Congreve rocket that Francis Scott Key referred to during the attack on Ft. McHenry in the War of 1812. The "…rockets' red glare" passage eventually became part of our National Anthem.
4. Robert H. Goddard, a quiet professor from Clark University, is considered to be the Father of Modern Rocketry. He developed the liquid fueled rocket and this gave control to the power that was developed by rocket engines. On March 16, 1926, he successfully launched the first liquid-fueled rocket. The flight lasted 2.5 seconds and reached a down range distance of 184 feet. It could be said that this was the beginning of the "space age" since his work opened the door to controlled flight in space.

Energy and Fuels

- First, it is recommended that you explain what "fuel" is.
- Point out that rockets require energy to move forward and fuel has stored energy.
- A rocket engine is essentially an explosion that occurs over an extended time. Point out to the students that when they watch the Shuttle take off, what they are seeing is a "long term" explosion taking place.
- A solid fuel rocket is a mixture of chemicals that require some form of ignition. A classic example would be a firecracker. When the fuse is lit, a chemical reaction occurs and it explodes. Make sure students understand that once ignition occurs, a solid fuel rocket engine cannot be stopped.
- Liquid fuels can be controlled.

Scientific Theory – Newton's Laws

- Newton's first law states, "Objects at rest, or objects in motion, will remain at rest, or in motion, unless acted upon by an unbalanced (outside) force."
- Newton's second law states, "Force equals mass times acceleration."
- And his famous third law states, "For every action, there is an equal and opposite reaction."

Putting Theory Into Motion – Why They Go So Fast!

- A simple classroom demonstration (use caution) is to have a child sit on a skateboard and then throw a basketball to someone. The basketball will go in one direction and the skateboard will go in the other. This is an example of Newton's third law. The action is throwing the basketball and the reaction is the skateboard moving. A rocket works the same way, a force in one direction produces motion in the opposite direction.
- For rockets powered by rubber bands, Newton's third law is the best explanation.
- The rubber band, when stretched, has stored (potential) energy. When it is released, the energy becomes kinetic.
- For compressed air rockets, the built-up pressure is a form of potential energy. When a valve is pressed, it releases the pressure and the rocket is thrust upward. This release of pressure is kinetic energy.
- An application of Newton's first law would be a rocket sitting on a launch pad…at rest. An outside force, (ignition) occurs and the rocket responds by moving.

WING TIPS

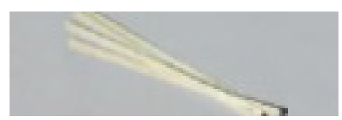
This is a special section that contains materials and techniques that you will be using in activities throughout this booklet. There is an explanation near each Wing Tip image which should help in the construction of some projects. Use this as a reference guide when purchasing supplies.

1. Hot Glue Guns-A large number of AEX Projects require safe, fast setting glue. For foam and many other applications, you can't beat hot glue. It sets-up in about a minute and it is safe.

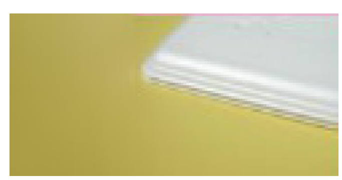
2. Cold Glue Guns-These are glue guns that have a lower melting point

3. Utility Knives or Box Cutters-It has been found that these knives are safe for cutting foam. The blade can be retracted back into the handle and when the blade gets dull. you can "snap" off a small section, revealing a new, sharp tip.

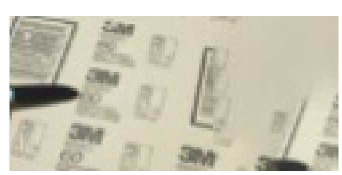
4. Cable Ties-These little gadgets have been around for a long time in the automotive and electrical business. They are made of nylon. Your best pries can be found at large home improvement stores.



5. Wooden Coffee Stirring Sticks-With coffee drinks being popular, it is easy to find these. They make great wing struts and add a look of "old technology" to models.



6. Foam Packaging Trays- Commonly known as "meat trays," these are used extensively throughout the AEX activity program. They are safe, easy to cut, easy to hot glue, very strong, and lightweight. Thicker foam trays can be sanded to make wing shapes.

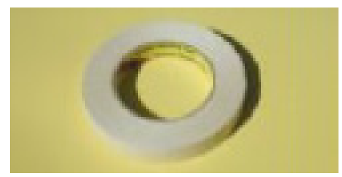


7. Sandpaper-In general science, it is graded as "course, medium, and fine." However, if you look closely, you'll find that sand paper is graded by numbers, too. The "course," or very rough grades, start around the number 16. As the numbers go up, the papers get "less course." For most hobby use, it is recommended to stick to "medium range", ie #100 to 320.

8. Pipe Foam Tubing-This lightweight foam tubing is perfect for small rocket fuselage pieces. It can be purchased at most major home improvement stores. It has been found that models like the Goddard Rocket, SR-71, and X-15 all seem to fly best when the fuselage tubing is 14 inches long. This mean you can get 4 rocket "bodies" per length. The only drawback with this tubing is you can not put hot glue directly on it. Hot glue will damage the foam.

9. Wooden Paint Stirring Sticks-You can find these, usually for free, at paint stores. When a piece of sandpaper is glued to one end, they make excellent sanding sticks for shaping foam.

10. Masking Tape-There is a difference in masking tape. By far, the best quality masking tape can be found at automotive paint supply stores. School-grade masking tape is usually acceptable, but if you are looking for strength and good adhesive qualities, automotive grade is best. For heavy duty applications, duct tape is recommended.



11. Vinyl Tape-Sometime called electrical tape, these, too, come in several grades. The best tapes are usually found in the electrical section of many hardware and building supply stores. Rather than tear the tape, it is recommended that you cut, or use a utility knife for best results.

12. Paint-It is recommended that you only use water-based paints for projects. For large groups, you can even save money by using common house paints. One quart will go a long way when an entire class is painting gliders, balloons, airplanes, and space ships. One nice feature is the ease and safety of water cleanup.

13. Acrylic Paints-These are found at hobby and craft stores and are recommended for classroom use. Use caution when buying any paint material.

14. Index Cards-The paper used to make most index cards is usually very strong and about the same thickness as a file folder. These cards are used to make movable control surfaces for gliders and other flying models. They can be taped or hot glued to foam surfaces.

15. Nylon Fishing Line-This strong line is used in several applications. It can also be used to suspend models from the ceiling or in flight tests with the force of gravity. It is strong enough to hold some large models and it is almost invisible. This makes models look like they are flying when hung in your classroom.

16. Cone Drinking Cups-These make perfect nose cones for small paper rockets.

17. Fender Washers-These can be used to make little wheels for airplanes. They are also used in simulations where the fender washers act as weight to an airplane that "flies" down a fishing line.

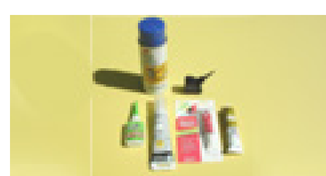
18. Templates-A template is the outline of parts that make up a model. There are several templates used in the AEX lessons. For classroom use, templates are copied and distributed to each student.

19. Rubber Bands-For most foam and glider launches, it is recommended that builders use #64 size rubber bands. These can be purchased in packages of 100 or more at office supply stores.

20. Power Strips-These work well as an attachment point for hot glue guns and other low-load plug-in applications. It is a good policy to consult the building maintenance technician, or someone who knows the electrical system, before starting a project that requires the use of many hot glue guns.

21. Straws-If you look closely, you will notice there are several different diameters of straws. In fact, some straws will fit nicely inside others. In other applications, they are used for sleeves to carry a plane down a fishing line.

22. Adhesives-Most everyone is familiar with white glue like Elmer's™ . These have very limited applications in aerospace projects because of the drying time. Whenever possible, hot glue is recommended because of its quick drying time. For plastic models, look for the words "plastic model cement" on the side of a tube. These glues have a substance that melts the plastic and bonds the parts when they are slightly gooey. Although a little tricky to work with, super glues are excellent. There are also spray glues. In all cases, it is recommended to research online or consult a hobby shop about adhesives for your specific project.



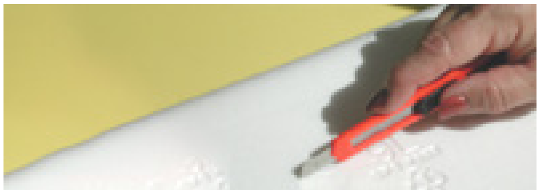
23. Pre-Val™ Paint Sprayers-These sprayers allow you to use your own choice of paint and color. The bottom of the unit has a bottle that can be taken off and filled with paint. Once properly diluted, the paint can be sprayed on any surface. These sprayers are especially nice for spray acrylics on foam projects. It is recommended to experiment first with scrap material to get a feel for technique and drying times.

Wing Tip Techniques

The Following are hints and tips on how to perform various tasks when building models.
The techniques are listed using the International Civil Aviation Organization (ICAO) phonetic alphabet.

- **Alpha**-When using a utility knife, it is recommended that you use the push button to run the blade out about 1 inch. The push button on most utility knives is made in two parts. If you pull back on the bottom of the push button, it will lock the blade in position. this makes it much safer to use when cutting.

- **Bravo**-When cutting with a utility knife or box cutter, hold it in your hand, pointed away from you, and cut with you index finger as shown. This method gives the greatest control. For best results, use the punch and pull technique. This is done by punching the knife into the foam and then pulling the blade toward you.



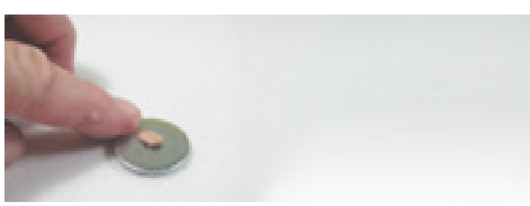
- **Charlie**-When cutting foam trays, it is best to cut it on the bottom side. This keeps students from cutting the table. To take an extra precaution so that students don't cut the table top, try using two meat trays together. The tray on the underside virtually eliminates the problem with damaged tops Sometimes, cardboard squares can also be used for extra protection.

- **Delta**-When building foam projects, always remember to apply hot glue only to the meat tray parts, not to the pipe foam tubing.

- **Echo**-To keep hot glue guns from damaging a table top, it is recommended that they be placed on a piece of card stock or cardboard during use. Do not lay the glue gun on its side when not in use. Glue guns will often leak glue and setting them on a piece of card stock or cardboard will keep the hot glue from damaging the table top.

- **Golf-**Cable ties are recommended on several activities where pipe insulation foam tubing is used. These are made of strong nylon and caution must be taken so that no sharp edges exist after cutting the excess "tails." It is recommended that nail clippers be used to cut the excess nylon down to the headpiece. One extra measure of safety is to put a dab of hot glue on the point where the tail was cut.

- **Hotel-**Fender washers are bonded to wooden stirring sticks for some models. These become "wheels" for aircraft that will be built to slide down a nylon fishing line. These "wheels" don't actually turn, they provide weight and they skid along the surface of the floor. To mount a fender washer using hot glue is simple. First, cut the wooden landing gear pieces to the correct length. Next, break off two small pieces of wood and set aside. Put a dab of hot glue on the bottom of the landing gear piece and press the fender washer into it so that some of the hot glue spreads into the hole. Now press the small piece of wood into the hot glue that has spread through the hole of the washer. This holds the fender washer in place. Repeat for the other wheel and you're set!



- **India-**Straws can be hot glued. In several activities. it is recommended that you glue small sections (about 1/2 inch long) of straws to the top of the wings and tail. Hot glue is applied to the top of the tail and the straw is pressed into the glue.

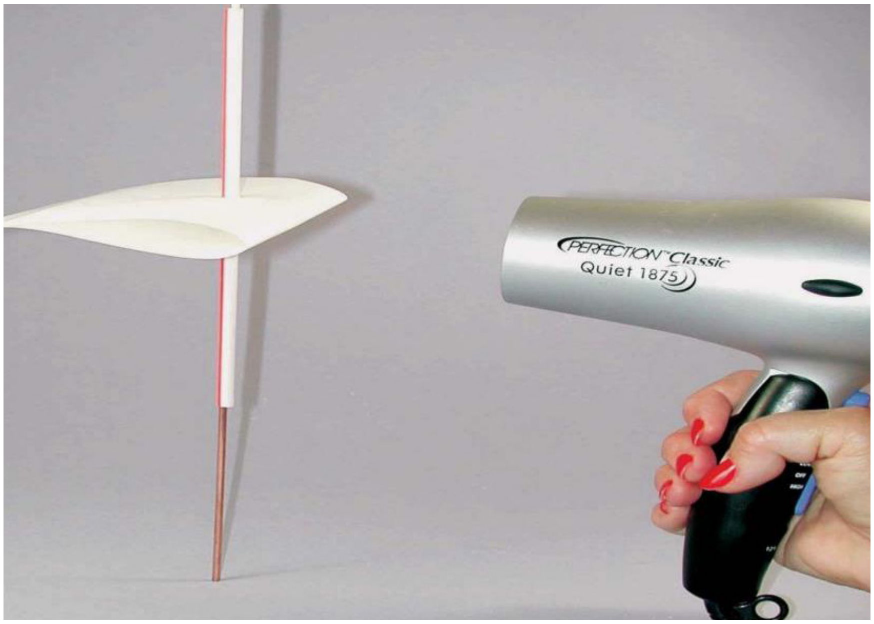
- **Juliet-**To avoid a mess when sanding foam or plastic, water can be used to carry away sanding particles. Make sure before you or the students do this, that you use a sanding block or sandpaper that is made for water sanding. If there is doubt, try it first. This is an excellent way to sand foam so that it has an airfoil shape.

- **Kilo**-To make sanding sticks for a class, pick up a handful of paint sticks from a local auto or household paint store. Use sheets of #100 sandpaper and a can of spray adhesive, such as 3M's #77. Sandpaper sheets are usually 9" x 11". Using a pair of scissors, or a utility knife, cut the sandpaper in half so you have two 4-1/2" x 9" sheets. Spray the backside the sandpaper with a coating of glue. Lay the top of each stirring stick down on sections of sandpaper. Cut off the excess sandpaper from the stirring stick.

- **Lima-**Accountability for tools. Unfortunately, we live in a time where weapons are a serious problems in schools. Hobby tools, such as box cutters and utility knives, can be considered weapons and safety needs to be encouraged as well as accountability for supplies. Box cutters and utility knives have handles and it is recommended that they be numbered with a permanent marker. At the beginning of a period, the knives can be checked out and before students can leave, each knife needs to be returned and secured.

BERNOULLI BASICS
WING ON A STICK

OBJECTIVE – Students will demonstrate Bernoulli's Principle by observing/creating an airfoil (wing) that flies with the power of a hair dryer.



NATIONAL STANDARDS –
Next Generation Science Standards (www.nextgenscience.org):
Disciplinary Core Idea Progressions
Physical Science Progression
- HS PS2.A: Forces and Motion
- HS PS3.C Relationship between energy and forces

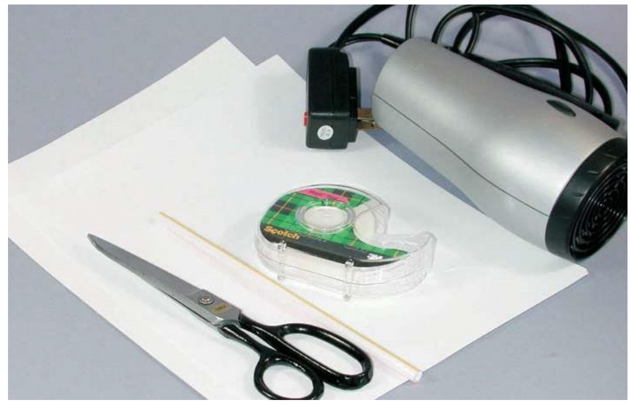
Crosscutting Concepts
- Systems and system models
- Energy and matter
- Structure and function

Science and Engineering Practices
1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
6. Constructing explanations (for science) and designing solutions (for engineering)

BACKGROUND - Daniel Bernoulli gave us a principle that is used to explain how a wing flies. However, it was the Wright Brothers' wind tunnel that proved invaluable for gathering important, accurate lift data. The brothers built a device that would provide a steady air flow to test small wing shapes. A number of designs were tested and the best tunnel developed airfoil shape was used in actual flight tests at Kitty Hawk, North Carolina. From that time on, aerodynamicists have been testing various airfoil shapes to determine lifting capabilities and drag coefficients.

MATERIALS

a. piece of paper such as card stock
b. sturdy straw
c. Scotch™ tape
d. Super Glue or hot glue
e. "Vertical Axis" such as string, fishing line, welding rod, piano wire, etc. This is the piece the airfoil will slide up and down upon.
f. Hair dryer (cool setting) or fan



PROCEDURE

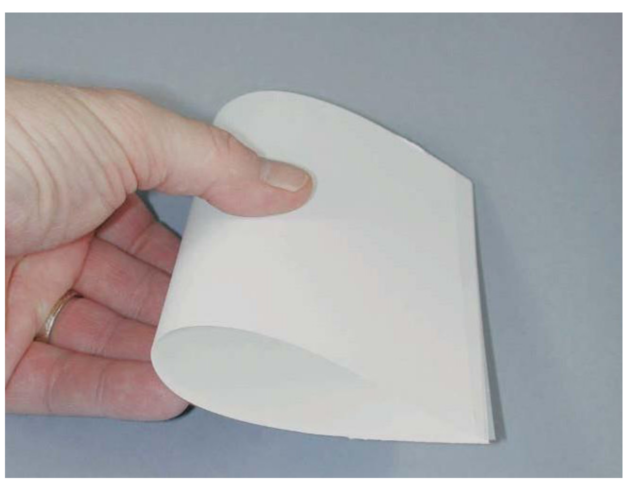
1. To make the airfoil, use about ½ of a sheet of card stock.

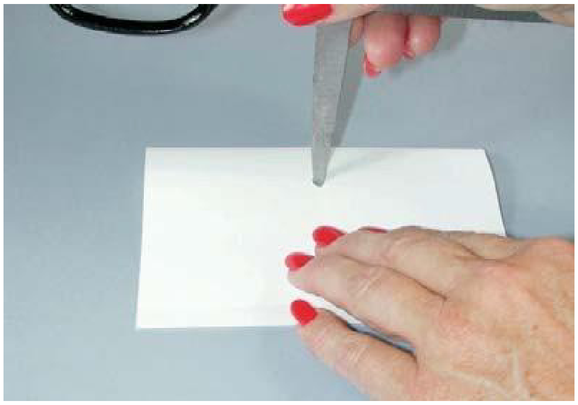
2. Fold the paper so that the chord (a line from the front to the rear of a wing) is about 4 inches long. Tape the trailing edge together with Scotch tape.

3. Do not crease the leading edge. Create a gentle curve for both the top and bottom. A view from the side is seen below.

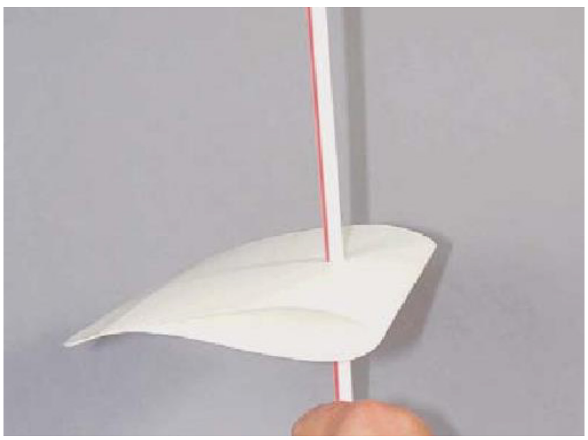
4. At the point of maximum curvature in the airfoil shape, mount a straw by punching a hole with a sharp pencil or pen. Spend some time shaping the airfoil so that the leading edge (closest to the hand in this photo) is gently rounded.

Fold Card stock as shown here





Scissors or a hobby knife can be used to cut a hole in the upper and lower curved surface (called the camber).



5. Repeat step 4 on the bottom side. This will allow the straw to slide through the wing at exactly 90 degrees to its chord.

6. A little hot glue will hold the straw in place. "Super Glue" can also be used to bond the straw to the wing. Be aware that super glue can bond fingers together. If you plan to use this activity with students, and you are using super glue, use extra caution.

7. Next, cut the straw so that only about 4 inches stick out on the top and bottom. This may even be trimmed down to about 2 inches on each side.

8. Set up a rod so that the airfoil can be mounted. It's ready to fly!

9. When you get everything together, and the wing is ready, provide a source of wind and watch it climb the rod.

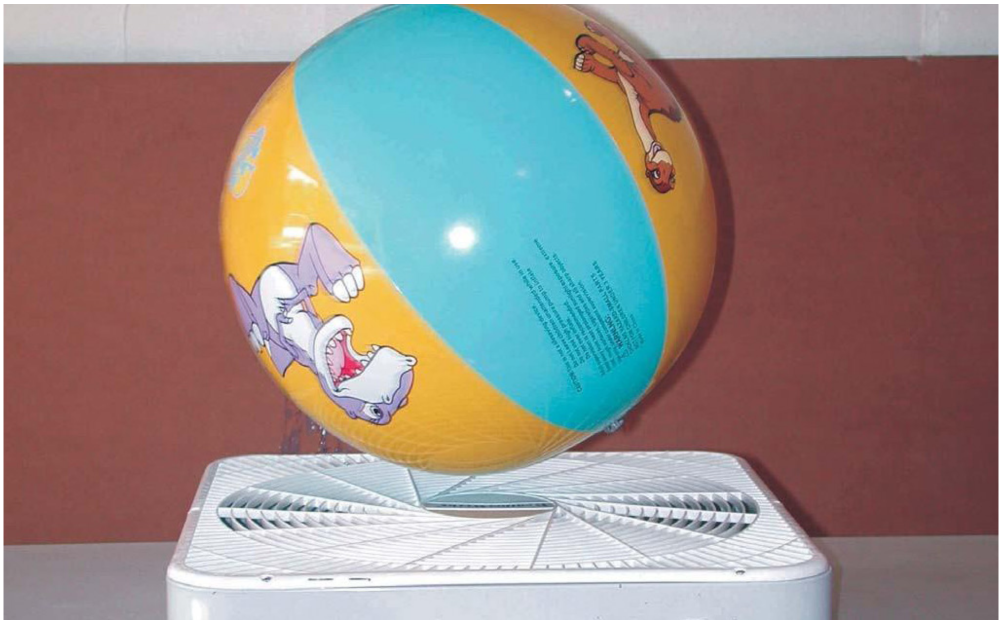
10. If the wing wants to go round and round, you might add a"rudder" by taping a piece of card stock to the back, or trailing edge.

11. Experiment with it until you make the wing rise right up the line. This will fascinate students and then, of course, everyone will want to make a wing of their own design!

This is a picture of a Civil Air Patrol Cessna. It clearly shows the shape of a wing. Notice how it is curved on the top. This is what gives the wing most of its lifting capability.

BERNOULLI BASICS
BERNOULLI BEACH BALL

OBJECTIVE – Students will learn how the air coming from a fan can be used to demonstrate Daniel Bernoulli's principle.



NATIONAL STANDARDS –
Next Generation Science Standards (www.nextgenscience.org):
Disciplinary Core Idea Progressions
Physical Science Progression
- HS PS2.A: Forces and Motion
- HS PS3.C Relationship between energy and forces

Crosscutting Concepts
- Systems and system models
- Energy and matter
- Structure and function

Science and Engineering Practices
1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
6. Constructing explanations (for science) and designing solutions (for engineering)

BACKGROUND - Daniel Bernoulli's Principle deals with pressure differentials. As a fluid in motion (in this case, air) accelerates, the pressure within it drops. In our example, there is a low pressure surrounding the ball because the air flow from the fan is accelerating. This is because of change of direction. As gravity tries to pull the ball to the ground (or toward the fan), a pressure differential is exerted across the surface of the ball and this keeps it in midair. The low pressure above the ball plays a major role in suspending the ball in the atmosphere.

Bernoulli Basics Demonstration #2

MATERIALS

a. beach ball

b. fan

PROCEDURE

To make this a meaningful learning experience, use the following explanations to the variations on the experiment:

Steps 1-5

1. First, you should have your fan in a position where the airflow will be moving upward.

2. Your fan should have some power--wimpy fans just don't work well.

3. Turn the fan on and place the beach ball in the air stream. Note how the ball remains suspended. At this point, explain to the students Bernoulli's Principle. You might try using these words: "Class, there is a flow of air moving around the ball. It is going faster because it has to change direction and this creates acceleration. As a result of this acceleration, there is a pressure drop (suction) in the stream and this is acting upon the ball."

Step 6

4. Now, gently grab the beach ball with both hands and slowly pull it toward you. As the ball is pulled from the air stream, you will feel a force trying to pull it back into the airflow. This reaction is due to the pressure differential generated between the surface of the beach ball exposed to the accelerated airflow and the relatively stationary air outside the perimeter of the fan's blast.

5. As revealed by Bernoulli, the moving air mass on one side of the ball has less pressure than the stationary air on the other side. The action produces a pressure differential. Gently release the beach ball and note how it darts back into the airflow!

Steps 7-8

6. Now, try tilting the angle of the air blast from vertical to another angle. If the flow generated by your fan is strong enough, the ball will float in midair. The low pressure above the ball plays a major role in suspending the ball. Move the fan around and note that the ball follows the airflow.

7. If your fan has enough power, place two beach balls in the air stream. Note how they battle for the center of the air stream. As they bounce off each other, observe how they move toward the center of the air blast only to bounce off each other in a repeated fashion.

8. Remember from the previous demonstration using a single beach ball, when you gently and slowly pulled the ball from the air stream, a portion of the beach ball exited the air stream and produced a pressure differential that pulled the ball back to the center of the following air mass. In this demonstration, the two beach balls are trying to occupy the same location as they see the area of low pressure!

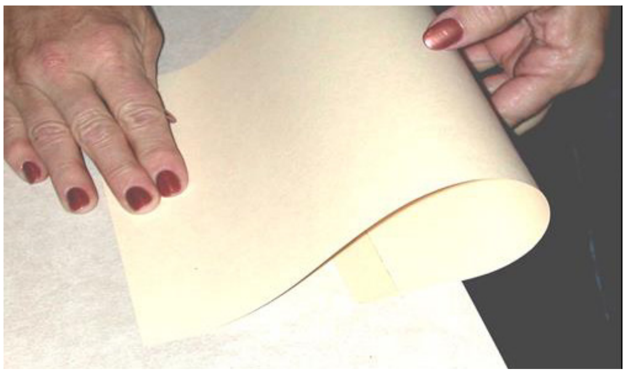
EXTENSION

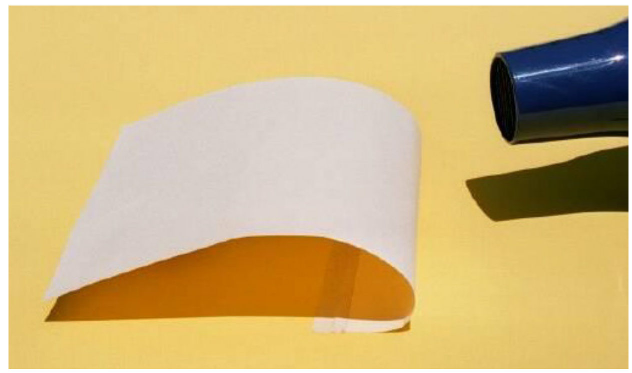
What to do: Hold a ping-pong ball over a flexible straw. As you blow into the straw, let go of the ball. What happens? Experiment with holding the straw in different ways. For example, can you tilt the straw and still keep the ball in the air? Hint: You can use any lightweight ball or a small balloon, but you may need to blow harder.

Explanation: Air is pretty pushy stuff. It never pulls or sucks, it pushes. Air is pushing on you right now from every direction. We are so used to air being around us that we often do not notice it. The constant push of air is called air pressure. As you blew through the straw, the air had to go around the ball. The air above the ball was pushing the same as before, but the air under the ball was moving faster, reducing air pressure.

BERNOULLI BASICS
IS BERNOULLI'S PRINCIPLE WORTH 2 CENTS?

OBJECTIVE – Students will learn how the air coming from a fan can be used to demonstrate Daniel Bernoulli's principle.





BACKGROUND - This is a fun way to teach Bernoulli's Principle. Using a piece of file folder, cut to the size of regular sheet of printer paper, and a hair dryer, you can make a wing that will lift not only its own weight, but the weight of coins taped to the underside. The high velocity wind blowing over the air-foil-shaped folder, will accelerate. This causes the pressure on top of the curved surface to drop, and this creates lift.

In simplified terms, Bernoulli (an 18th century scientist and mathematician) stated that a fluid in motion will have a pressure change when its velocity increases. In the example of our wing, air flows faster over the upper curved surface. As the air going over the upper surface accelerates, the pressure drops. The air on the underside, relative to the upper surface, has a higher pressure. This difference in pressure causes the wing to react by rising toward the area of lower pressure. If the air is flowing fast enough and the surface of the wing is curved enough, it will fly!

MATERIALS

a. One or more file folders cut to about the size of a sheet of paper

b. One hair dryer

c. Masking or Scotch-type tape

d. Two pennies

PROCEDURE

a. Tape the file folder piece to the edge of a smooth table.

b. Roll so that it eventually has the shape of an elongated tear drop.

c. Point the hair dryer toward the leading edge and experiment with wind flow.

d. After a few tries, the "wing" will lift right off the table.

e. Next, tape a penny to the underside of the wing.

f. Try the airflow again…and if you've done it correctly, it will lift 2, sometimes 3, pennies.

EXTENSION

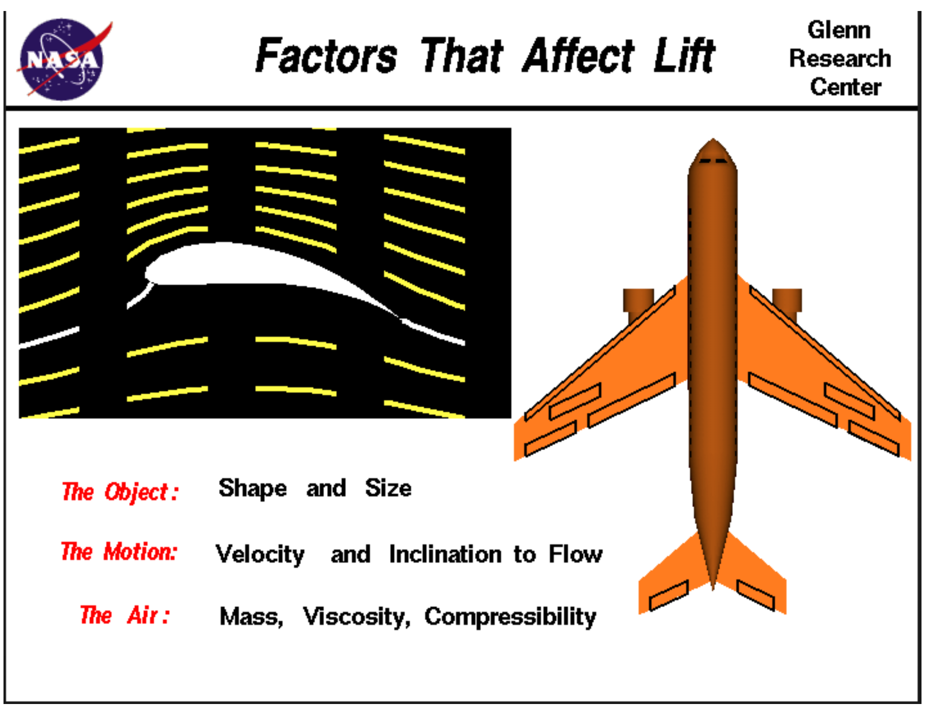
- Blow through a straw between two ping-pong balls suspended from the ceiling on strings. Account for what happens. Before blowing, ask students about Bernoulli's Principle and what they hypothesize should happen.

- Using a hair dryer (cool setting), suspend a ping-pong ball in the airflow. Tilt the blower until the ball falls. Measure the angle. Increase the speed of the hair dryer from a low to a high setting and repeat. Does the angle at which the ball drops differ? *For a larger version, use a lawn leaf blower and beach ball.

- Have each student hold two sheets of notebook paper parallel to each other and about 2 inches apart. Each student should then blow between the two sheets of paper. Like magnets attracting each other, the two pieces of paper will come together. Bernoulli's Principle is at work causing the two sheets of paper to come together because the increase in air speed between the two sheets of paper causes a decrease in the pressure.

- Design your own example of Bernoulli's Principle and demonstrate to the class, explaining what is happening.

- Can you think of other examples of Bernoulli's Principle at work besides airplanes?
  - **i.** Race cars use airfoils, which create downward lift to increase traction (help the car stay on the road.)
  - **ii.** Boating – a hydrofoil is a submerged wing attached beneath a boat. As the boat picks up speed,the hydrofoil generates lift in the water in the same way a wing generates lift in the air. The lifting force raises the boat's hull out of the water, reducing drag and allowing the boat to move faster.
  - **iii.** A sailboat has a sail that acts like a wing, creating lift in a forward direction like an airplane wing creates lift in an upward direction.
  - **iv.** Pitching in baseball – curve ball – when the baseball is given a spin as it is pitched, the rough surface of the ball causes the layer of air near the rawhide to spin the ball. This causes the relative velocity to be higher at the bottom and lower on the top, which results in a higher pressure on the top and a lower pressure on the bottom. This pressure deflects the ball and makes it curve downward.



NASA GLENN RESEARCH CENTER:
FREE ONLINE INTERACTIVE AEROSPACE EDUCATION SOFTWARE

OBJECTIVE — Students will be able to download free interactive NASA aerospace education software from the Internet to foster hands-on, inquiry-based learning in STEM.

NATIONAL STANDARDS –
Next Generation Science Standards (www.nextgenscience.org):
Disciplinary Core Idea Progressions
Life Science Progression
- HS LS1.D: Information processing

Physical Science Progression
- HS PS4.C: Information technologies and instrumentation

Crosscutting Concepts
- Systems and system models

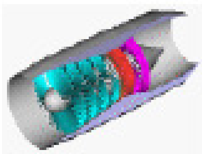
Science and Engineering Practices
1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
6. Constructing explanations (for science) and designing solutions (for engineering)
8. Obtaining, evaluating and communicating information

BACKGROUND – (Information from https://www.grc.nasa.gov/WWW/K-12/freesoftware_page.htm)
In an effort to foster hands-on, inquiry-based learning in science and math, the NASA Glenn Research Center has developed a series of interactive computer programs for students. All of the programs are Java applets which run in your browser, online. The programs can also be downloaded to your computer so that you can use them without being online. The programs are in the public domain and are constantly being modified and upgraded based on your input.

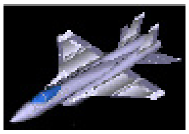
NASA Glenn Research Center has also developed a series of Beginner's Guides that accompany each of the software packages to explain the science and math. You can access the Beginner's Guides at the bottom of this page. For teachers, we have developed almost 200 activities to test the student's knowledge of the material. These grade-specific activities have been developed by teachers during summer workshops and are aligned with science and math standards.

NASA FREE INTERACTIVE SOFTWARE DOWNLOADS –

FoilSim III: (80KB) FoilSim III computes the theoretical lift and drag of a variety of airfoil shapes. The user can control the shape, size, and inclination of the airfoil and the atmospheric conditions in which the airfoil is flying. The program includes a stall model for the airfoil, a model of the Martian atmosphere, and the ability to specify a variety of fluids for lift comparisons. The program has graphical and numerical output, including an interactive probe which you can use to investigate the details of flow around an airfoil.



EngineSim: (455KB) EngineSim is a simulator that models the design and testing of jet engines. The program works in two modes: Design Mode or Tunnel Test Mode. In the Design Mode, you can change design variables including the flight conditions, the engine size, the inlet performance, the turbo machinery compressor and turbine performance, the combustors or burner performance, or the nozzle performance. For a turbofan engine design you can also vary the fan performance and the bypass ratio. When you have a design that you like, you can switch to the Tunnel Test Mode which simulates the testing of a jet engine on a test stand. You can then vary the test altitude, flight speed and throttle setting. Several existing engines are also modeled in EngineSim.

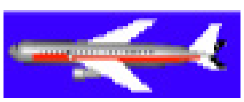


RangeGames: (487KB) This program presents a variety of multiple choice math and physics problems involving aircraft performance. The student can choose from several different types of aircraft and must answer questions about the range, fuel usage, acceleration, velocity and location of the aircraft during take-off. RangeGames can record your answers for teacher evaluation, or you can just play for fun.

TunnelSim: (111KB) Using the TunnelSim applet, students learn more about the aerodynamics of wind tunnels by changing the shape and flow conditions through the tunnel. This program can be used for the preliminary design of an open return wind tunnel. Speeds are limited to low subsonic operation and the program warns the student of high speed flow and possible separation in the diffuser. The link also includes TunnelSys which is a simulator to design an aircraft wing model and Wright-1901 Wind Tunnel which is a simulation of the wind tunnel used by the Wright Brothers in 1901 to obtain design data for their aircraft.

RocketModeler: This program lets you design and study the flight of a model rocket. You can vary the size of the rocket, the number of fins, and the materials used to construct the rocket. You can choose from a variety of available model rocket engines and test fly your rocket on the computer. The program computes the stability of your design and the flight trajectory. Output includes the maximum altitude which the rocket achieves. You can then compare the computed and actual performance of your model rocket.

KiteModeler: This program lets you design and study the flight of a kite. You can select from five different types of kites and then vary the length, width and types of materials used to construct the kite. You then trim the kite by setting the length of the bridle and tail and the position of the knot attaching the control line to the bridle. Finally, you test fly your kite on the computer by setting the wind speed and the length of control line. The program computes the aerodynamic forces, weight, and stability of your design and the shape of the control line as it sags under its own weight. Output includes the maximum altitude which the kite achieves. You can then compare the computed and actual performance of your kite design.



AtmosphereApplet: This program lets you study how pressure, temperature, and density change through the atmosphere. You can study the atmosphere of the Earth or of Mars. Since speed of sound depends on the atmospheric gas and the temperature, you can also output the local speed of sound and the Mach number for a selected aircraft velocity. You can either input a selected altitude, or change altitude using an aircraft slider.

SOARING SAILPLANES

BUILDING THE AIR FORCE ACADEMY'S HISTORIC TG-4A GLIDER / SAILPLANE

OBJECTIVE – Students will be able to build a flying foam replica of the Air Force Academy's TG-4A glider and gain more information on the glider training and the U.S. Air Force Academy.

U.S. Air Force Academy TG-4A Glider – USAF Academy Glider Training Operation

NATIONAL STANDARDS –

Next Generation Science Standards (www.nextgenscience.org):

Disciplinary Core Idea Progressions

Physical Science Progression

- HS PS2.A: Forces and Motion

Crosscutting Concepts

- Systems and system models
- Energy and matter
- Structure and function

Science and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
6. Constructing explanations (for science) and designing solutions (for engineering)

VOCABULARY – Often, the words "glider" and "sailplane" are used in the same context. A glider is an aircraft that is usually towed aloft and then released to glide back to Earth. During World War II, gliders, filled with soldiers and equipment, were towed to a combat zone and released. The gliders descended to a landing where the soldiers then entered the battle. A sailplane is also towed aloft; however, when it is released, it uses the energy of the environment to continue flying. Sailplane pilots will seek rising columns of air, called thermals, to provide lift and subsequently gain altitude. A skillful sailplane pilot can use the lifting forces within the environment to stay aloft for one or more hours.

BACKGROUND –
(https://www.usafa.af.mil/AboutUs/FlightOperations/USAFAcademyAircraftIdentification.aspx)

About the historic TG-4A: The TG-4A is a conventional two-place tandem, basic training glider/sailplane, manufactured by the Schweizer Aircraft Corporation, Elmira, New York. Its construction is all metal with fabric covering the fuselage and tail surfaces. It has a one-piece canopy for increased visibility. The wings are tapered in the outboard section and air brakes are incorporated. The model TG-4A is the same as the civilian SGS 2-33 version, except for the rudder. The TG-4A's rudder is taller and incorporates a balance weight in the upper forward end, which overhangs the top of the vertical stabilizer, or fin. The dimensions are: length—25'9"; Span—51'; Height—9' 3-1/2"; Wing area—219.48 square feet; Aspect ratio—11.85:1. The maximum gross weight is 1,040 pounds and the glide ratio is 23:1 (glide ratio of 23:1 means the glider will glide 23 times as far forward as it will fall downward. Glide ratio is forward motion to downward motion or ground distance covered to altitude lost).

The glider has dual flight controls. The flight control surfaces are actuated by control sticks and rudder pedals through a push rod and cable system. Aileron and elevator control is accomplished through push rods connected to both control sticks. Rudder control is accomplished through cables attached to both sets of rudder pedals.

Spoilers, or "air brakes," are installed primarily for glide-path control. They can also be used for rapid descents, maintaining airspeed within limits, and to recover from large slack-line situations while in tow. The air brakes are actuated through push rods, by handles located on the left side of both cockpits.

There is a red tow release knob located in the center at the bottom of the front instrument panel. There is another release knob located in the rear cockpit on the left side of the top front seat bracket.

All TG-4A aircraft are equipped with an airspeed indicator, altimeter, vertical velocity indicator, variometer (to measure ft. per minute changes) and a magnetic compass mounted on the front instrument panel.

About the current sailplanes: The Academy sailplane fleet consists of TG-15s, and TG-16s. The soaring mission also uses Piper Super Cub tow planes. These tow planes fly standardized departure and arrival routings, altered only as required to maintain safe deconfliction with other aircraft operating in the area or when weather conditions warrant deviations in the interest of safety. Soaring operations take place almost exclusively over USAF Academy property, remaining west of I-25 and periodically extending over the neighborhoods immediately to the south of the Academy.

TG-16A
Flugzeugbau DG-1000

(USAFA Soaring Program video: https://youtu.be/XF2lZeOP_Fk)

About the US Air Force Academy: The USAFA is located in Colorado Springs, Colorado. The mission statement is: "inspire and develop outstanding young men and women to become Air Force officers with knowledge, character, and discipline; motivated to lead the world's greatest aerospace force in service to the nation." The USAFA is recognized as one of the nation's finest four-year institutions of higher learning.

The Air Force Academy is both a military organization and a university. Much of the Academy is set up like most other Air Force bases, particularly the 10th Air Base Wing, but the Superintendent, Commandant, Dean of Faculty, and Cadet Wing are set up in a manner resembling a civilian university.

The Superintendent is the Academy's commanding officer and is responsible for the Academy's regimen of military training, academics, athletic, and character development programs. The Commandant oversees the 4,400-member cadet wing and more than 300 Air Force and civilian support personnel. The Commandant is also responsible for cadet military training and Airmanship education, supervising cadet life activities, and providing support to facilities and logistics. The Dean of Faculty commands a 700-person mission element and oversees annual course design and instruction of more than 500 courses, crossing 32 academic disciplines, and directs the operation of five support staff agencies and faculty resources involving more than $250 million.

The 10th Air Base Wing comprises more than 3,000 military, civilian, and contract personnel who conduct all base-level support activities, including law enforcement and force protection, civil engineering, communications, logistics, military and civilian personnel, financial management services, and the clinic, for a military community of about 25,000 people.

MATERIALS

1. Two foam meat trays per student (Preferably yellow as the real historic plane is yellow)
2. Hot glue gun/glue sticks
3. Utility knife or box cutter
4. Wooden coffee stirrers
5. One penny per student (for nose weight)
6. Wax paper
7. Optional: #80-100 sandpaper

MANAGEMENT TIP:– It is a good idea to use a piece of flat cardboard under the foam cutting procedure. This keeps the table from being cut and it allows the builder to make a clean cut all the way through the foam. You can buy utility knives or box cutters at a hardware store. These are very sharp and strong but make the job of cutting the foam much easier than with scissors. Please use caution and make sure that if students are doing the cutting, there is ample adult supervision. Also, be careful with the hot glue gun as the tips and even the glue can cause burns.

PROCEDURE -

1. Make a copy of the template. It can be enlarged or diminished in size depending upon your meat tray.

2. Put the template down on the outside surface of the foam tray.

3. Use a utility knife to cut out the glider's parts.

4. Optional- Using #80-100 sandpaper, sand the edges of the glider's wing and tail pieces so that they look like elongated tear drops. (Refer to the "Bernoulli's Basics" for correct wing shape.)

5. Position the horizontal stabilizer to the rear of the fuselage. Make sure that it is perpendicular to the fuselage. Run a bead of hot glue along the back end of the fuselage and mount the horizontal stabilizer onto the glue, centering it.

6. Mount the vertical stabilizer onto the horizontal stabilizer using hot glue. Make sure that the vertical stabilizer is perpendicular to the horizontal stabilizer.

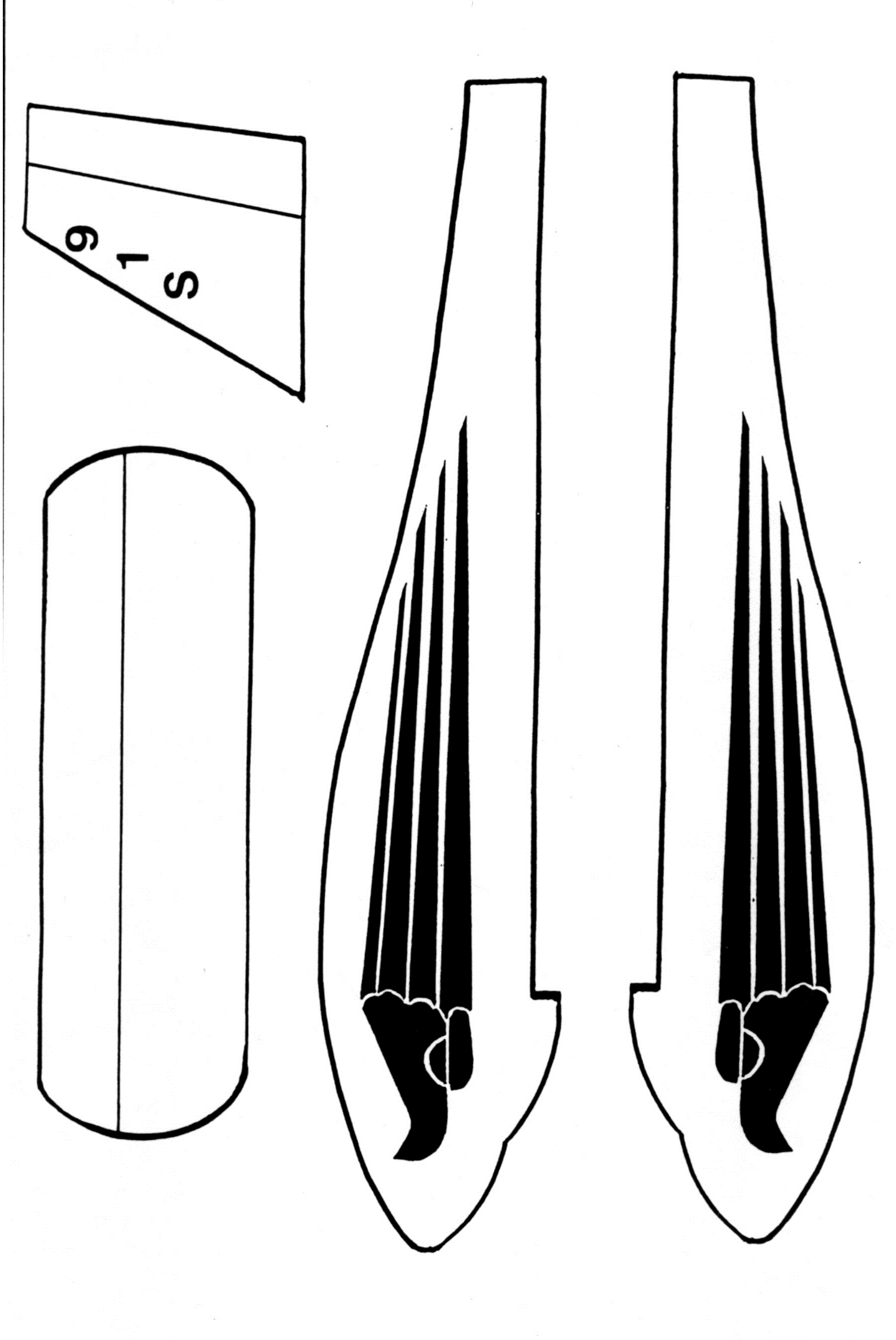
7. The wing "halves" are glued together at their roots. It is a good idea to put a piece of wax paper under the wings so the wings won't be glued to the table. When set, glue the wing to the fuselage so that the leading edge of the wing will fit into the notch just behind the cockpit.

8. The wings are placed in position and held there until the glue sets.

9. Once the wings set, you may install the small wing struts. Coffee stirring sticks work well for these.

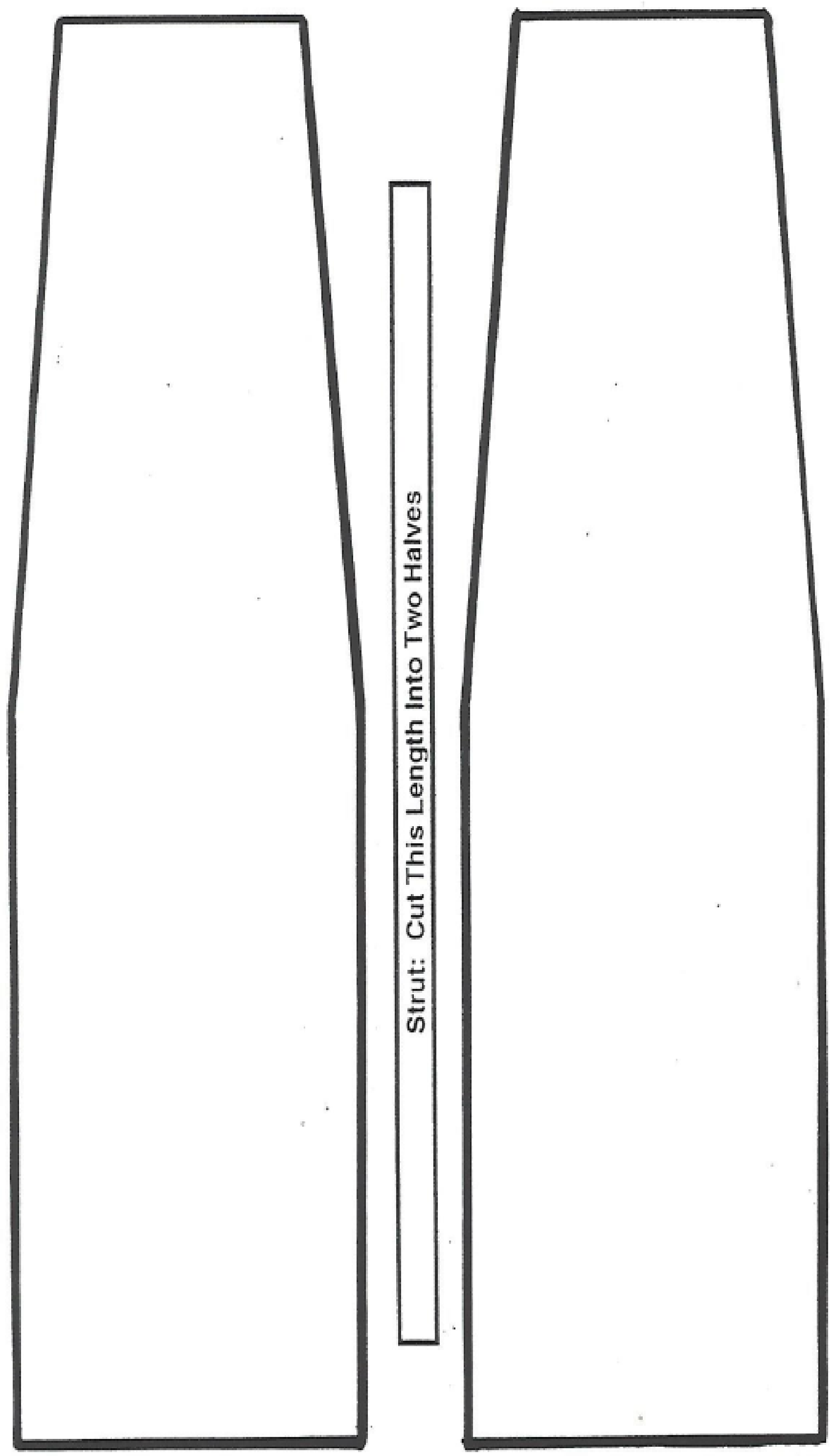
10. Find an old penny and hot glue it to the front of the fuselage. This will give you the right amount of weight to make the model glider fly.

The Fuselage Template For The TG-4A



This is one of two templates. The second template is on the next page. It is recommended that the builder enlarge these templates by 110% on a copy machine. Only one fuselage is necessary; however, the builder can make two sides and bond them together with white glue. Marking pens can be used to add the graphics.

THE WINGS TEMPLATE FOR THE TG-4A



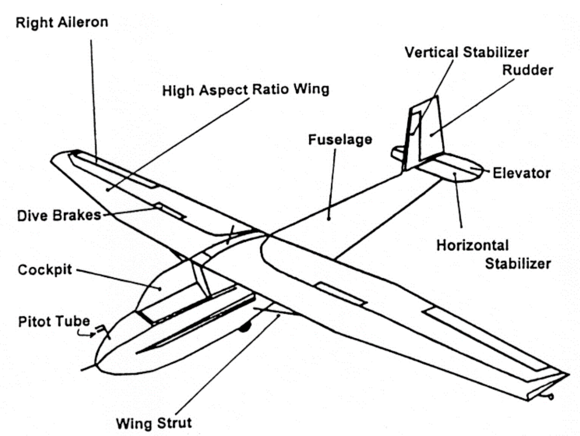
EXTENSIONS –

NASA Glenn Research Center: Let It Glide Challenge (https://www.nasa.gov/glenn-edcs-let-it-glide)

- Using the Engineering Design Process, students will develop and build a shoe box glider, and then improve it in terms of aircraft and wing materials, shapes, and structure, to produce the greatest glide slope (the ratio of the distance traveled to decrease in altitude) possible.

- Introduce the activity using the NASA Let It Glide Challenge Video (https://www.youtube.com/watch?v=ium3IS41Xqc)

LEARNING THE LANGUAGE OF GLIDERS:



TG-4A Glider Vocabulary

A glider has similar components to that of a conventional airplane. Students should know the parts of their glider after completion of the activity. Instruct the students to label the parts on their model.

1. Have students find the left aileron, the right elevator, etc.

2. Fuselage – Have the students put a 5-digit number on the side starting with the letter "N" (because "N" is the international prefix for the USA.) This will be their registration. An example would be "N55361." They could also use a letter of the alphabet to substitute for the last number. An example would be "N5536A."

3. Facilitate a discussion with the following questions: (Answers are in italics.)

- What is another name for the dive brakes? *spoilers*
- Where does the pilot sit? *cockpit*
- What is a pitot tube for? (requires outside investigation) *Static tube system, which is used to measure forward speed. (A differential pressure gauge.)*
- What is the rudder used for, and what is it attached to? *The rudder is hinged to the trailing edge of the fin (a small vertical wing fixed to the fuselage). It is used to overcome and balance yaw (sideways swing of glider).*
- What is an elevator used for? *The elevator pitches the nose of the glider up or down. It is the primary means of controlling the speed of the glider.*
- Have students investigate what "high aspect ratio" means and how it applies to gliders. *Aspect ratio of a wing is the wingspan squared divided by the area of the wing. Gliders have a high aspect ratio because they have long and skinny wings since they aren't concerned with speed and maneuverability as much as efficiency.*
- Look at the picture of the actual TG-4A at the beginning of this activity. Why is there a wheel on the wing? *To keep the wing from scraping along the ground.*
- Why do wings have struts? *A strut is a brace to support wings, usually attached from the fuselage to the wing.*
- What does it mean to "use the energy of the environment to maintain lift?" *The key to keeping the glider in the air longer is to get help from the air. There are three types of rising air used by glider pilots. The three types are thermals, ridge lift, and wave lift.*

4. Learn more about gliders and the types of rising air at http://www.howstuffworks.com/glider.htm

Wind Tunnel Wonders:
Building the NASA Wind Tunnel and Aerodynamic Testing

OBJECTIVE – Students will be able to construct an inexpensive wind tunnel for use in aerodynamic testing. Students will be able to test the drag of objects using the constructed wind tunnel.

NATIONAL STANDARDS –

Next Generation Science Standards (www.nextgenscience.org):

Disciplinary Core Idea Progressions

Physical Science Progression

- HS PS2.A: Forces and Motion
- HS PS3.C: Relationship between energy and forces

Crosscutting Concepts

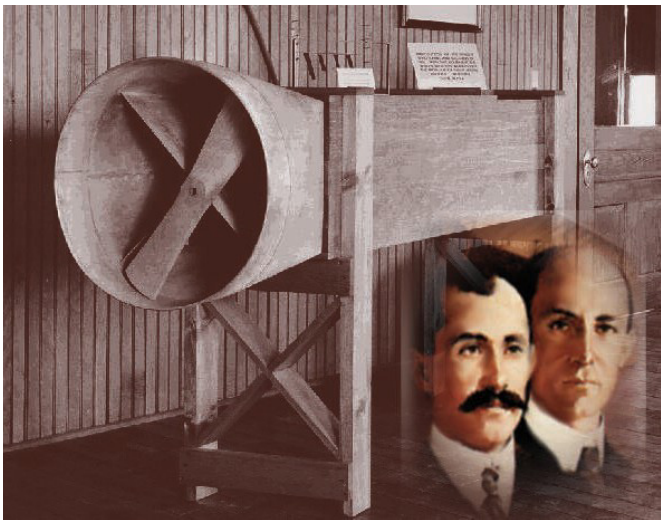
- Cause and effect
- Systems and system models
- Energy and matter
- Structure and function
- Stability and change

Science and Engineering Practices

1.Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

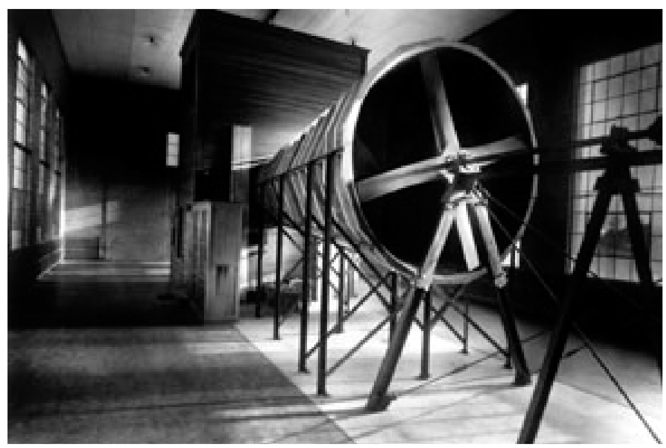
BACKGROUND – (Information from https://www.grc.nasa.gov/WWW/K-12/airplane/bgt.html and https://www.nasa.gov/centers/langley/news/factsheets/windtunnels.html)

What is a wind tunnel? How do aerospace engineers use wind tunnels? A wind tunnel is a machine which can simulate the movement of air around an aircraft in flight. In the wind tunnel, the aeronautical engineer can control the conditions that effect the forces and motion of the aircraft. By making careful measurements of the forces on a model of the aircraft, the engineer can determine the magnitude of the forces on the real, full-sized aircraft. The wind tunnel model can also be used for diagnostics to make a detailed determination of how the air moves around or through the aircraft.



The Wright Brothers, Orville and Wilbur, built a wind tunnel to test various wing shapes (airfoils) and to gather important mathematical data for the construction of their full-scale glider wings. This data proved to be one of the most important elements in the success of their project test. Wind tunnels have since been used to test not only aircraft, but automobiles, high speed trains, and boats. With a few restrictions, wind tunnels can provide scientists with important information that is directly applicable to the actual performance of the vehicle as it encounters the relative wind on the road, on the water, or in the air.

The first major U.S. Government wind tunnel became operational in 1921 and was located at the Langley Memorial Aeronautical Laboratory of the National Advisory Committee for Aeronautics (NACA), which became NASA Langley Research Center in 1958. This wind tunnel was crude when compared to the tunnels used at NASA Langley today. Like the aircraft that is tested in them, wind tunnels evolve as researchers discover ways to more accurately duplicate flight conditions.



Wind tunnels help researchers understand the forces acting on an object as it moves through the atmosphere. They are also used to measure and minimize the noise produced by aircraft and to optimize engine efficiency. Although primarily used for aircraft, other objects such as spacecraft, automobiles, ships, trucks, and wheelchairs have been tested in wind tunnels.

Why Wind Tunnels Are Used

Models in wind tunnels are used in conjunction with computers and flight simulators to learn about the flight characteristics of new aircraft designs and modifications. Components such as structural materials, wings, ailerons, horizontal stabilizers, fuselages, power systems, engine cowlings, and landing gear all affect the flight characteristics of aircraft. Small changes to one component can result in the modification of another component of the aircraft. All effects of the changes may not be clear until the aircraft experiences flight conditions. Tests with models in wind tunnels allow the study of aircraft designs without risk to a pilot or the expense of building a new full-sized test aircraft for every design improvement. Measurements, or data, from wind tunnel tests are also used to refine computer programs that predict the forces that act on a new aircraft or aircraft components.

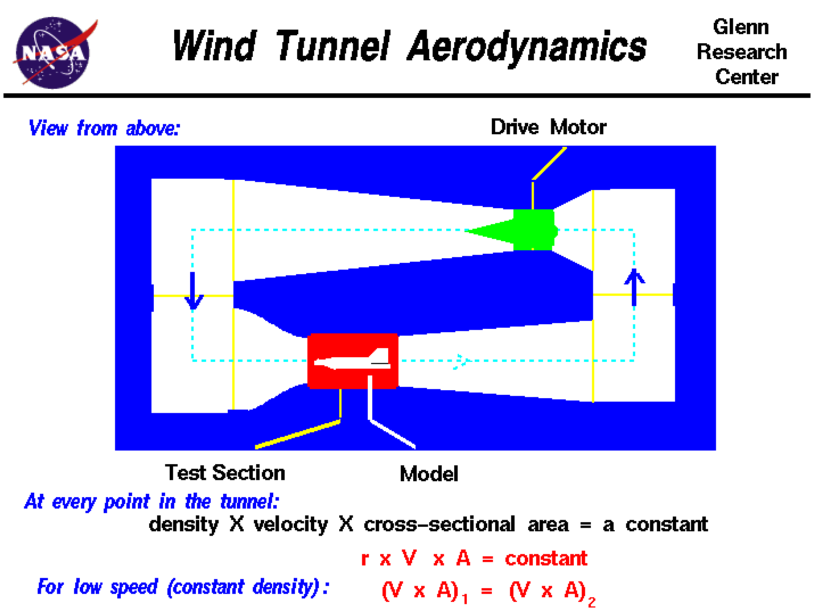
How Wind Tunnels Simulate Flight
(NASA Now: Wind Tunnel Testing- https://youtu.be/P6sCjXISmEU)

The forces that act on an aircraft are the same whether the aircraft is moving through the air or the air is moving past a stationary aircraft. Typically for wind tunnel tests, aircraft models are stationary and the air flows past. Basically, a wind tunnel is a tube through which air, or some other gas, flows so that the effects of an object moving through an air stream can be determined. A wind tunnel may be open and draw air from the room into the test section, or the wind tunnel may be closed with the air continuously circulating through the test section. To obtain meaningful data, the researcher must ensure that the airflow in the wind tunnel is very similar to that found in flight. In the tunnel, the researcher can control airflow conditions, such as speed, temperature, humidity, density, and viscosity. In continuous flow wind tunnels, the airflow is most often produced by a large fan. For very high speed “blowdown” tunnels, the air is collected in pressure vessels and released into the tunnel.

Because wind tunnels are in buildings (and the actual aircraft flight environment is not), care must be taken to avoid introducing airflow abnormalities from the tunnel itself. To accurately simulate flight, the airflow in a wind tunnel must be smooth. Wind tunnels must also be free of the effects of turbulent or unsmooth airflow, which can be caused by forcing the air around the tunnel circuit. Devices such as turning vanes, screens, and slots in tunnel walls help to maintain smooth airflow.

Simulating airflow at flight conditions in a wind tunnel is complex. Wind tunnels usually specialize in simulating a particular aspect of flight. Subsonic speed wind tunnels study flight that is slower than the speed of sound. Transonic speed tunnels study flight that is slightly below, at, and slightly above the speed of sound. Supersonic speed tunnels examine flight faster than the speed of sound and hypersonic speed tunnels look at flight more than five times the speed of sound. There are special tunnels for propulsion research, aircraft icing research, aircraft spin control research, and even full-scale model tests. The speed of airflow in a wind tunnel is usually expressed as a Mach number. For example, moving at twice the speed of sound is Mach 2, moving at half the speed of sound is Mach 0.5.

Early work in fluid mechanics, or the study of how fluids and gases behave and their effect on objects in a flow, indicated that the airflow around a scale model would not correspond exactly to the flow around a full-scale aircraft. To ensure the correlation of model data to full-scale aircraft data, researchers also determine the Reynolds number of flow in a wind tunnel.



MATERIALS – This is a two-part lesson; however, it is recommended that all the supplies are gathered for both parts – Part 1: Building the Wind Tunnel and Part 2: Aerodynamic Testing in the Wind Tunnel.

Part 1: Building the Wind Tunnel

a. Sheets of clean cardboard
b. Clear packaging tape
c. Clear sheet protectors (cut along the connecting creases so that it creates two pieces of 8.5” by 11” clear plastic sheets) or transparency film (from the old overhead projectors)
d. Yard or meter stick
e. Box Fan (preferably with 3 speeds)
f. String
g. Two chairs of equal size

Materials Used in Parts 1 and 2

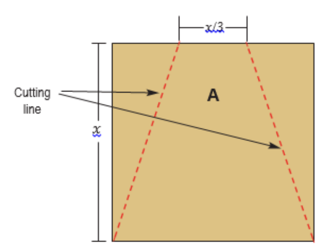
h. Sharpie® or permanent black marker
i. Scissors capable of cutting cardboard (a utility knife or box cutter will work with supervision)
j. Masking tape
k. Safety glasses

Part 2: Aerodynamic Testing in the Wind Tunnel

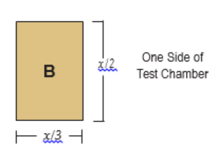
a. Wind Tunnel (assembled in Part 1)
b. Metric Ruler
c. Cardboard
d. Elastic cord (like those found on party hats or rubber band cut to make a rubber “string”)
e. Fishing line
f. Hot glue gun/glue sticks
g. Paperclips

MANAGEMENT TIPS – One of the most difficult tasks in construction of this project is the cutting of the cardboard pieces. These pieces should be cut out on a table top that has a large piece of cardboard protecting the surface. Check with department stores, hardware stores, or bicycle shops as they usually have large cardboard boxes. You can buy utility knives or box cutters at a hardware store. These are very sharp and strong but make the job of cutting the panels much easier than with scissors. Please use caution and make sure that if students are doing the cutting, there is ample adult supervision. Also, be careful of paper cuts from the cardboard. It can be tougher than it looks.

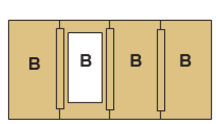
Here are the dimensions of the cardboard pieces based on “x” being one of the sides of a box window fan. Follow the photo sequence to build it and when complete you will have an impressive, strong test chamber.



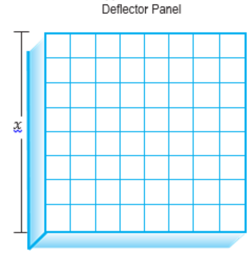
Upper and Lower Deflector Panel



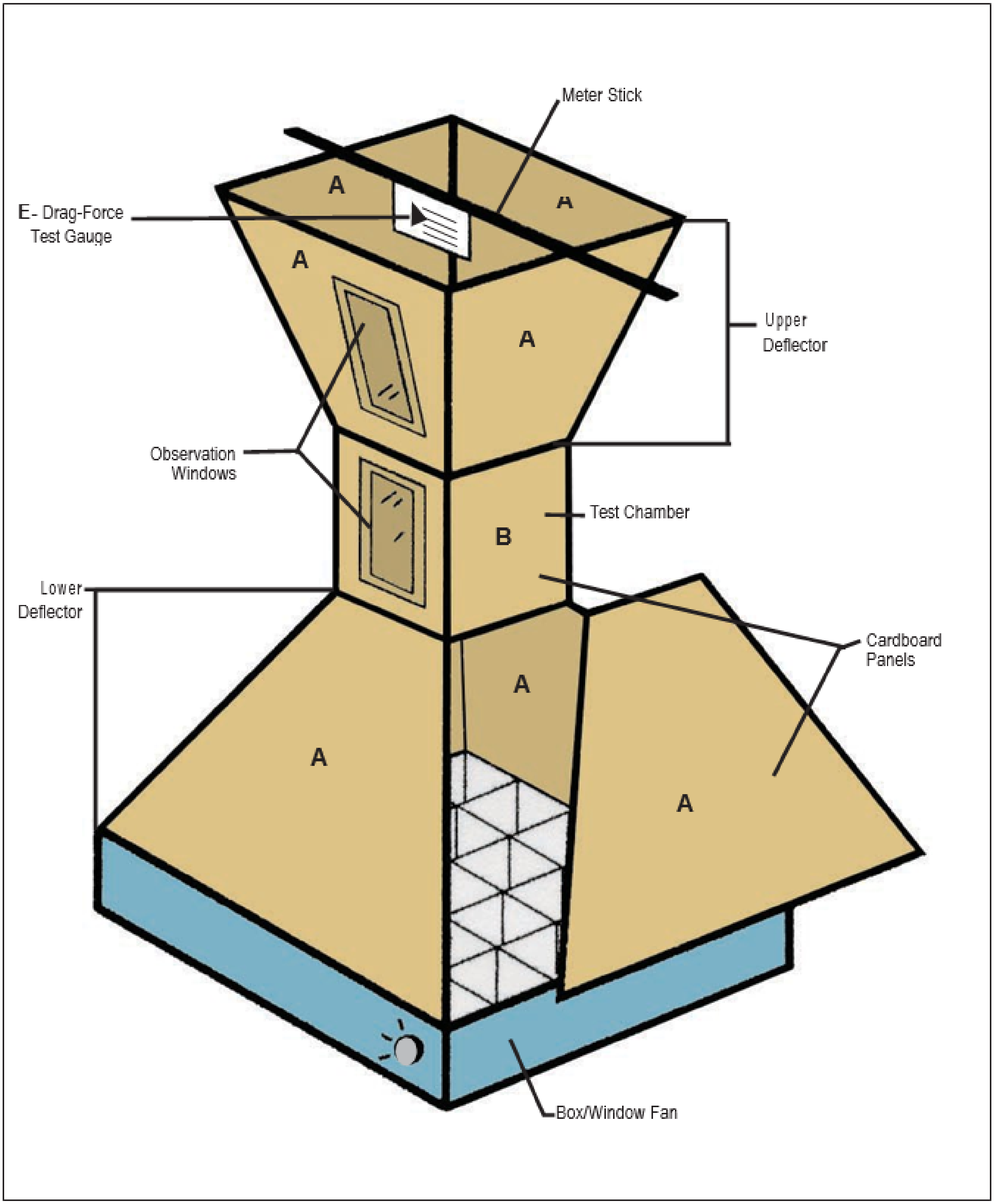
One Side of Test Chamber



Test Chamber Open With All Four Sides Showing



Box/Window Fan


Meter Stick
E- Drag-Force Test Gauge
A
A
A
A
Upper Deflector
Observation Windows
Test Chamber
B
Lower Deflector
Cardboard Panels
A
A
A
Box/Window Fan

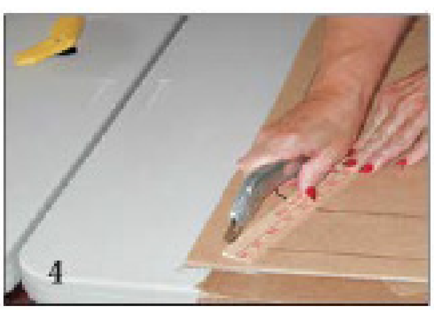
PROCEDURE –
Part 1: Building the Wind Tunnel

1. Using a Sharpie® or permanent black marker, outline the box fan on one of your cardboard sheets.

2. A yard or meter stick should be used to get the exact width of your box fan. If the box fan is 21" on each side, a template must be made so that two lines taper to a 7" line at the center of the bottom. Use similar calculations depending on the width of your box fan.

3. Be careful that you don't end up with a piece of cardboard that has a "grab handle" hole. These are common in bicycle boxes. If this happens, cover the hole with clear packaging tape.

4. Cut out the first panel with the utility knife or box cutter. This is the first of eight panels.



5. Once the template is perfected, other panels can be replicated.

6. When the panels are cut carefully, they should be evenly matched.

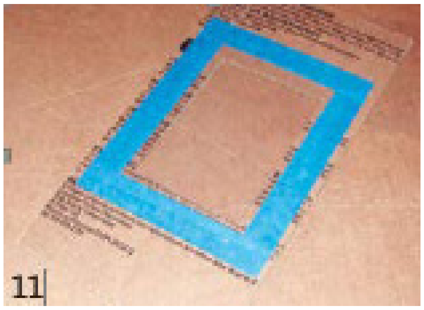
7. Bond the panels together with packaging tape from the inside.

8. Measure and cut a window out of one of the upper panels. The window should not be larger than the clear sheet protector piece that you have prepared by cutting along the crease. A transparency film could be used in place of the sheet protector. Also, make sure that the window is large enough to view objects being tested inside of the wind tunnel.

9. Cut a window out of a middle section panel.

10. Refer to the picture on the next page to see what the windows look like in the finished wind tunnel as well as the general placement of the windows.

11. Once the window is cut, take a clear sheet protector piece and place it over the hole. Use masking tape to hold it in place.



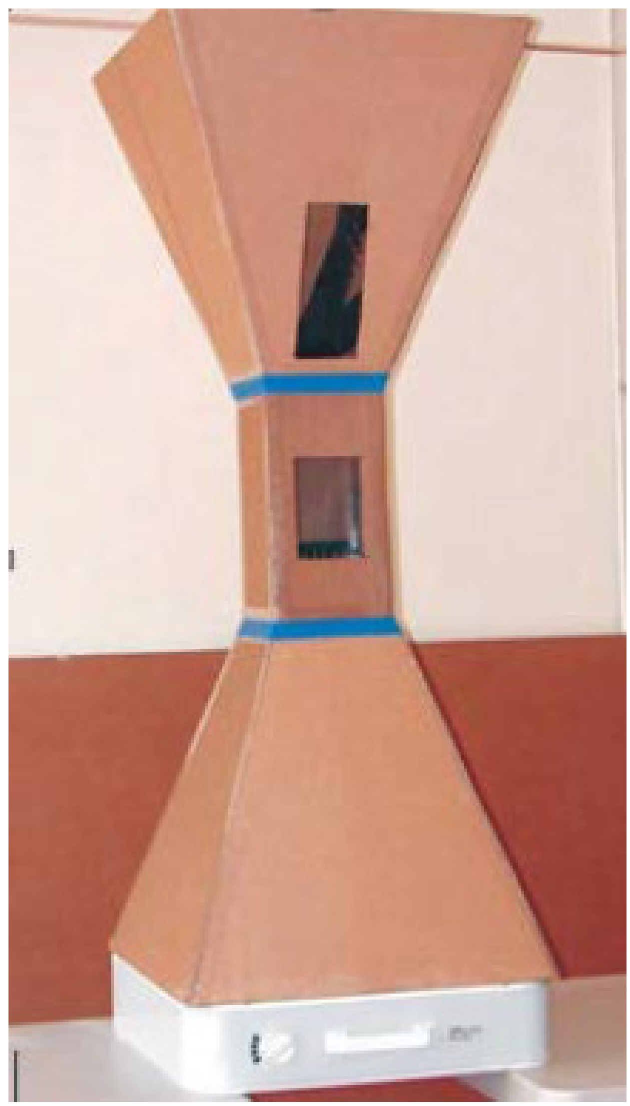
12. Repeat the same procedure for the larger upper panel.

13. The test chamber should be taped from the inside as shown. The pieces are then folded into a box and the remaining seam gets taped from the outside.

14. Repeat this procedure on the upper and lower deflector panels. Clear packaging tape should be used all around.

15. Go back over the edges with masking tape to cover where it all comes together.

Finished Wind Tunnel

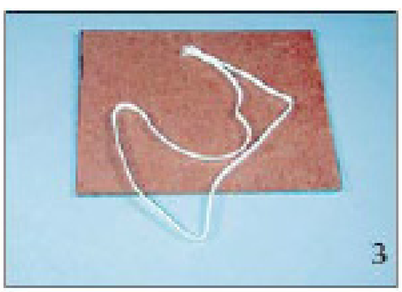


Part 2:
Aerodynamic Testing in the Wind Tunnel

1. Cut out a 10 cm x 10 cm square from a piece of light cardboard.

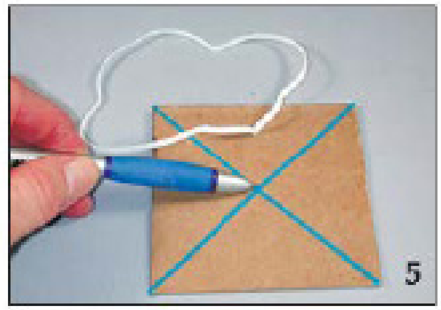
2. Punch a 1-mm hole in the cardboard, centered 3 cm from the top.

3.Get a piece of elastic (like from a party hat) that is approximately 15 cm long. Double it over to form a loop.



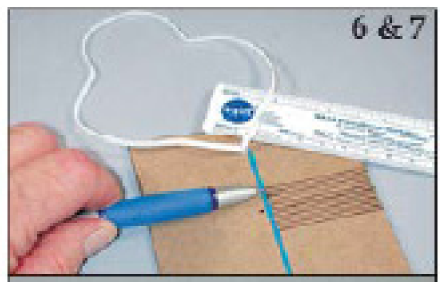
4.Thread the two loose ends of the elastic through the hole in the cardboard and hold them in place with a piece of tape.

5. Mark the center of the cardboard square.

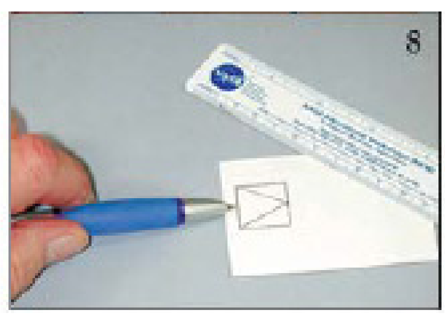


6. Beginning at the center point, draw a solid line to the right edge.

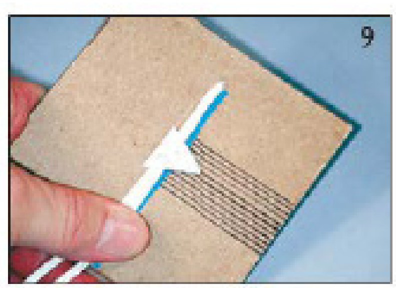
7. At 2 mm intervals, draw 5 lines above and 5 below the center line that was just drawn.



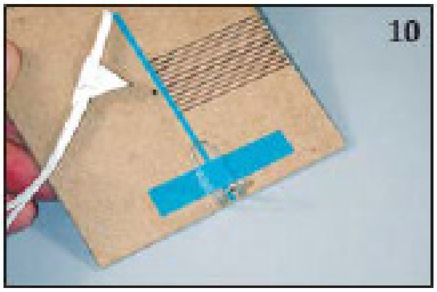
8. Using a small piece of lighter cardboard, cut an equilateral triangle with each side equal to 2 cm. Cut two slits in the triangle and pull the elastic through the slits. Center the point of the triangle on the centerline.



9. Bend a paper clip 90 degrees to form a guide for the elastic.



10. Attach the paper clip to the center of the bottom edge with tape. Slip the elastic through the loop of the paper clip.



11. Tape the top edge of the cardboard square to the center of the meter/yard stick. (The picture below shows how to attach the gauge and the piece being tested to the yard/meter stick. However, it will be inside the tunnel when the fan is turned on.)

12. Using the patterns, cut out each shape and tape together.

13. Using a hot glue gun, attach fishing line to each polyhedron shape to be tested.

EXTENSIONS:

- Create an airfoil shape to test in the wind tunnel.
- Use foam to create an aircraft model and test it in the wind tunnel recording the drag.
- Show the NASA video of testing a Boeing Aircraft Tail in the World's Largest Wind Tunnel. (https://youtu.be/4PabZAx-4Yw). Facilitate a class discussion based on the video. Be sure to ask questions about the technology used as well as what conclusions that can be drawn from watching the test.
- For more information, please visit these websites on Wind Tunnels:
  - o NASA Wind Tunnel Index
    https://www.grc.nasa.gov/www/k-12/airplane/shortt.html
  - o NASA Beginner's Guide to Wind Tunnels
    https://www.grc.nasa.gov/WWW/K-12/airplane/bgt.html
  - o Wind Tunnels at NASA Langley Research Center
    https://www.nasa.gov/centers/langley/news/factsheets/windtunnels.html
  - o NASA Wind Tunnel Interactive Software Downloads
    https://www.grc.nasa.gov/WWW/K-12/TunnelSim/index.htm

Name ______________________________ Date ____________________

Testing the Polyhedron Patterns for Aerodynamic Drag

Follow the directions to construct each of the four shapes (Cone, Cube, Pyramid, and Tetrahedron) for testing. You will test each shape three times at each of the fan speeds.

Procedure for the testing of each shape in the wind tunnel:

1. Attach one shape to a string at the end of the elastic loop so it can be seen through the window of the chamber.
2. Note the position of the gauge.
3. Start the fan on low speed and read the amount of elastic stretch by using the gauge.
4. The stretch measurement is the drag force exerted by the wind.
5. Record the drag on your Student Data Sheet in the appropriate box.
6. Turn off the fan and make sure the gauge registers at the centerline.
7. Turn the fan back on at the next higher speed.
8. Repeat the procedure above so that the initial shape is tested three times at each of the three speeds.
9. Continue to test each shape three times; one at low, one at medium, one at high.
10. Calculate the mean, median, and mode for each of the polyhedrons.
11. Record the data on your Student Data Worksheet.
12. Using the data recorded, graph the mean of each polyhedron at low, medium, and high speeds using the Graph of the Drag worksheet.

Analyzing the Data

Please answer these questions on a separate piece of paper at the conclusion of the testing of the polyhedron patterns for aerodynamic drag.

1. Do the shape, mass, and position of the objects in the wind tunnel affect drag?
2. Which factor (shape, mass, wind speed, or drag) is the constant?
3. Which object experienced the least and most drag? Why?
4. Do the direction and speed of the wind flow affect the drag on the objects?
5. In which part of the wind tunnel is the wind speed fastest? Why?
6. What is the importance of using a wind tunnel for the design of aircraft?
7. What other objects can be tested in a wind tunnel?
8. Describe the relationship between the shape of the object and the drag created.

Teacher Notes: Analyzing the Data (*Answers in Italics*):

1. Do the shape, mass, and position of the objects in the wind tunnel affect drag?
Yes, because each will affect how much force is exerted on the object.

2. Which factor (shape, mass, wind speed, or drag) is the constant?
Mass is the constant throughout the activity. Constants are needed to eliminate external factors and maintain the only two variables: The independent factor, the one that is changed, and the dependent factor, the one that is observed.

3. Which object experienced the least and most drag? Why?
See the results on the Student Data Sheet

4. Do the direction and speed of the wind flow affect the drag on the objects?
Yes, because the direction of the wind will hit different surface areas of the various shapes.

5. In which part of the wind tunnel is the wind speed fastest? Why?
The wind speed is fastest in the test chamber because the wind is passing from a larger chamber to a smaller one.

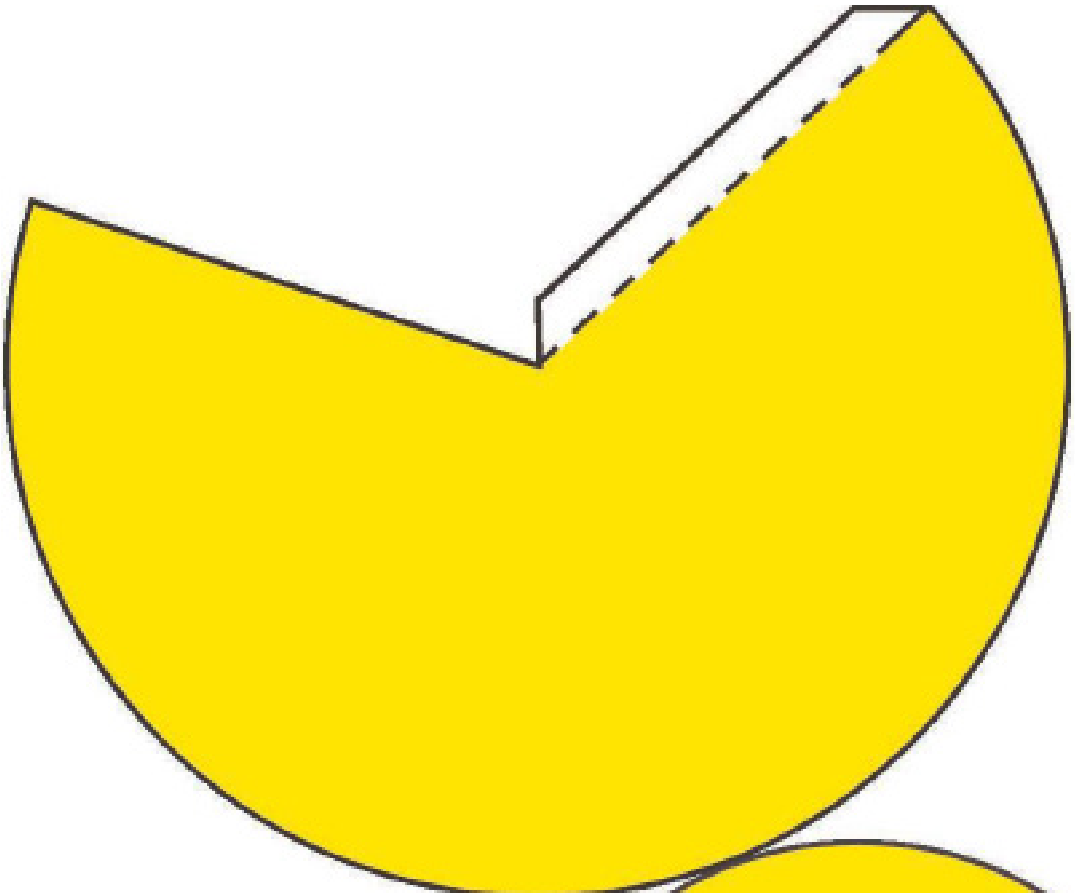
6. What is the importance of using a wind tunnel for the design of aircraft?
Wind tunnels are used to test the design and viability of aircraft and other objects before a full-scale version is built

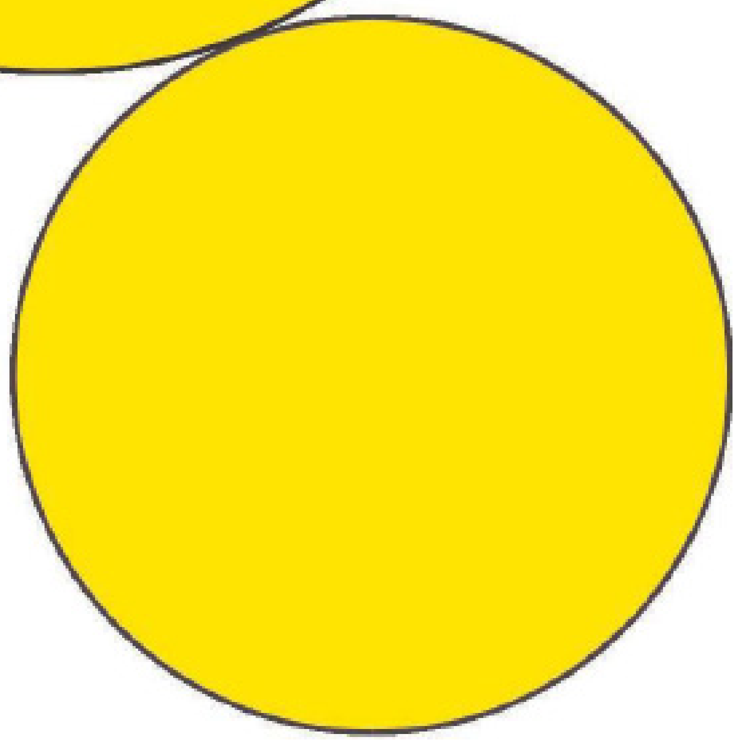
7. What other objects can be tested in a wind tunnel?
Cars, wheelchairs, hurricane-proof homes, buildings, and parafoils can be tested in a wind tunnel.

8. Describe the relationship between the shape of the object and the drag created.
Reducing the object's surface area in the wind flow lowers the drag value.

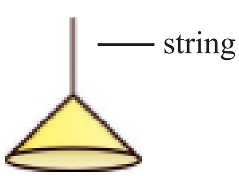
Cone

Cut out the shape, bend on the dotted lines, and tape the edges together.



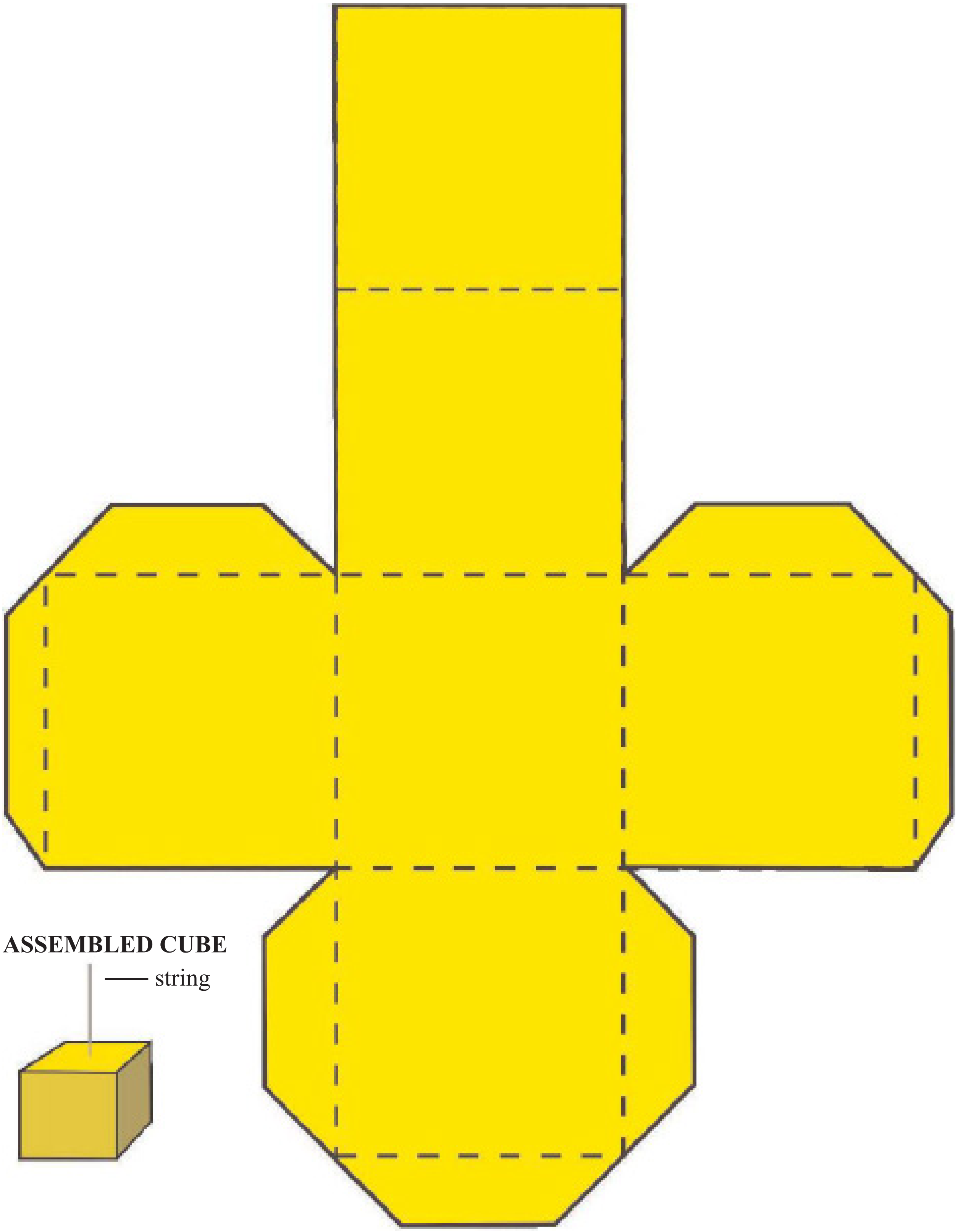


ASSEMBLED CONE

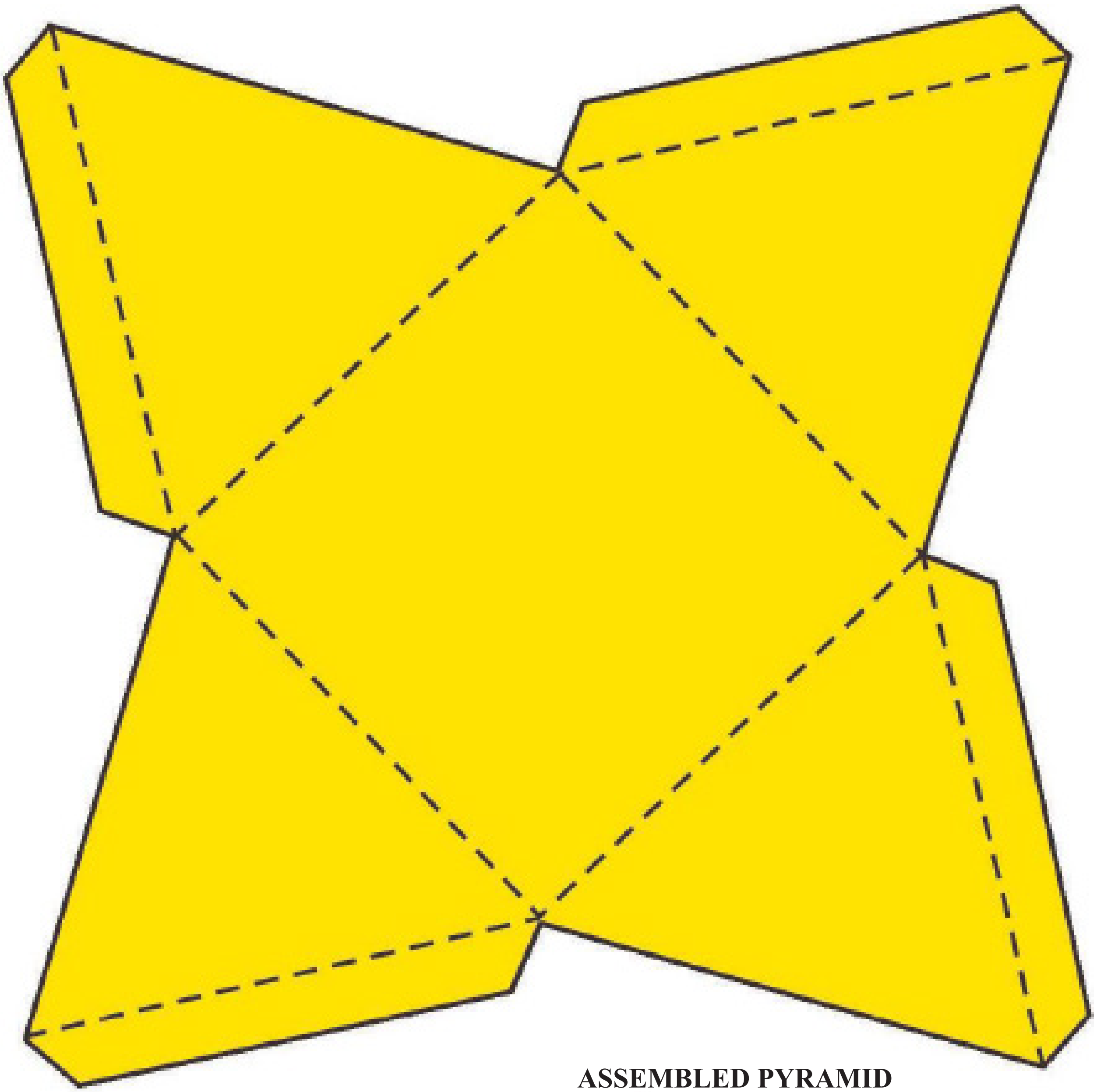


Cube

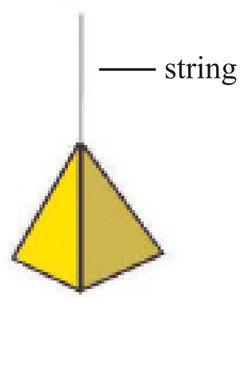
Cut out the shape, bend it on the dotted lines, and tape the edges together.



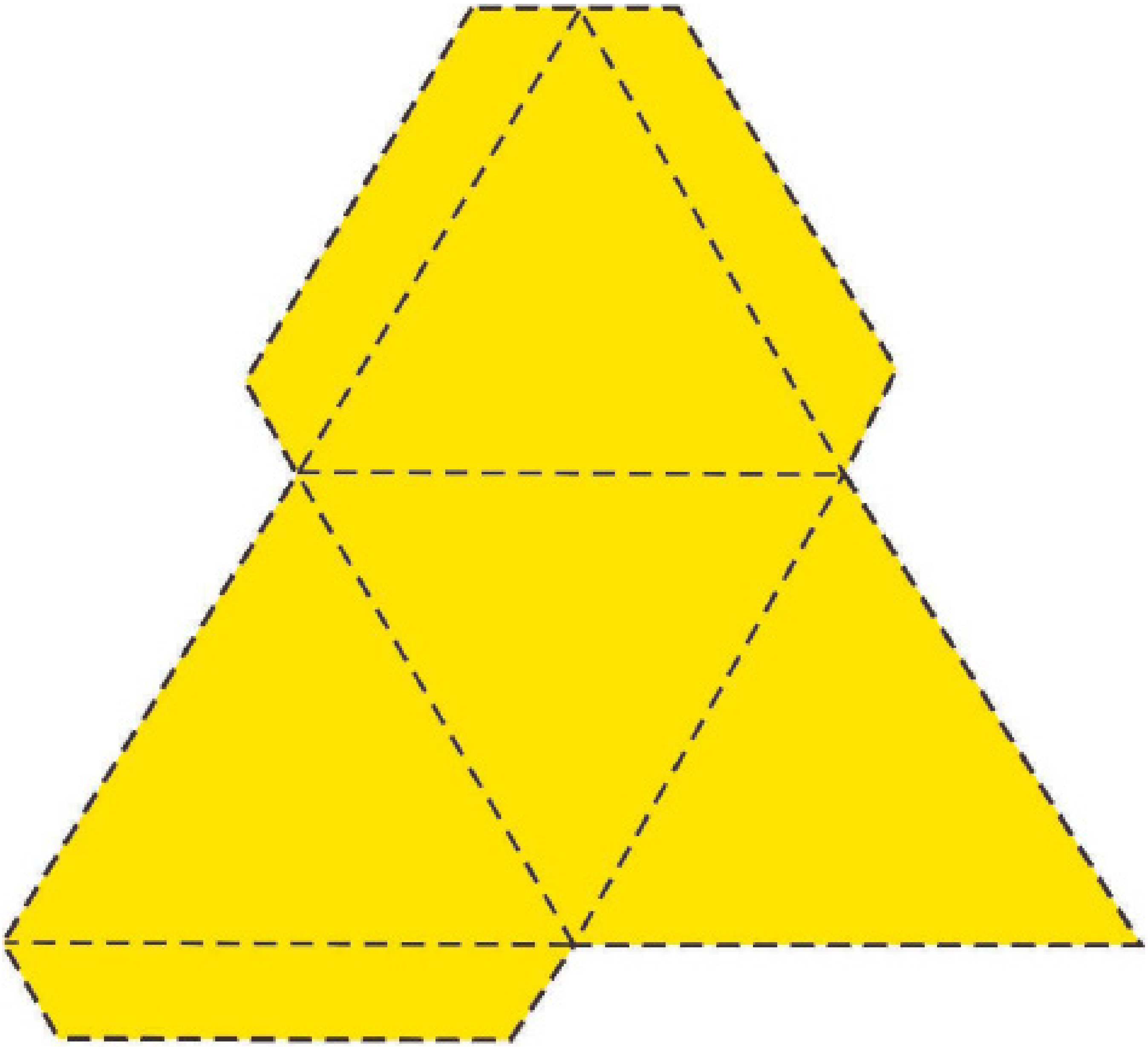
Pyramid
Cut out the shape, bend it on the dotted lines, and tape the edges together.



ASSEMBLED PYRAMID



Tetrahedron
Cut out the shape, bend it on the dotted lines, and tape the edges together.



ASSEMBLED TETRAHEDRON

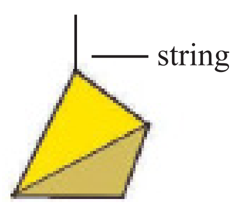


Table 1. Drag Force Value

FAN SPEEDS									
	Low Speed			**Medium Speed**			**High Speed**		
	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3	Test 1	Test 2	Test 3
Tetrahedron									
Pyramid									
Cube									
Cone									

Observations: ______________________________

____

____

____

____

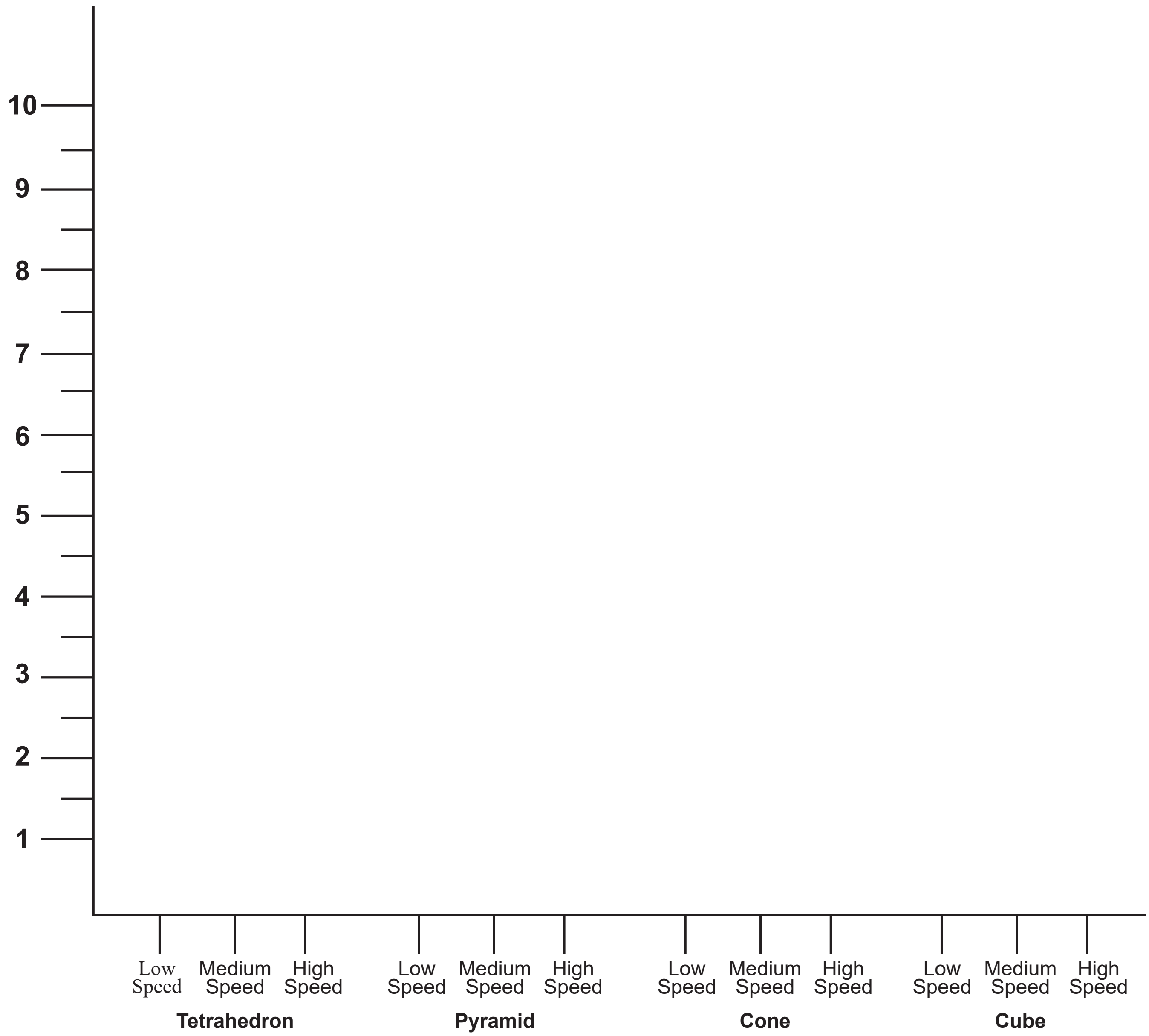
Table 2. Drag Force Value Calculations

FAN SPEEDS									
	Low Speed			**Medium Speed**			**High Speed**		
	Mean	Median	Mode	Mean	Median	Mode	Mean	Median	Mode
Tetrahedron									
Pyramid									
Cube									
Cone									

Graph of the Drag (Mean)

Directions: Use bars to graph the mean of each shape at low, medium, and high speeds. Use different colors for each speed.

Key:
Low Speed = Green
Medium Speed = Blue
High Speed = Red



QUIMBY'S QUEST

HARRIET QUIMBY, FIRST LADY OF AEROSPACE and HER AIRPLANE, THE BLERIOT XI

OBJECTIVE – Students will be introduced to America's first licensed woman pilot and be able to build a working model of her Bleriot XI airplane and fly it to simulate her 1912 flight across the English Channel.

NATIONAL STANDARDS –

Next Generation Science Standards (www.nextgenscience.org):

Disciplinary Core Idea Progressions

Physical Science Progression

- HS PS2.A: Forces and Motion

Crosscutting Concepts

- Systems and system models
- Energy and matter
- Structure and function

Science and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
6. Constructing explanations (for science) and designing solutions (for engineering)

BACKGROUND — (Based on information from Harriet Quimby, America's First Lady of the Air, by Ed Y. Hall, 1993, https://www.nationalaviation.org/our-enshrinees/quimby-harriet/, and photos from https://airandspace.si.edu/)

There is still some debate about the time and place of Harriet Quimby's birth; the evidence points to May 1, 1875, in the State of Michigan. Her father, William, and mother, Ursula, also had another child and her name was Kittie. After a failed attempt at farming, the Quimby's headed to California and settled in the San Francisco area. In her younger years, Harriet aspired to be an actress, however, she ended up as a journalist working for the San Francisco Bulletin. She wrote articles about art colonies in Monterey and San Francisco's Chinatown. By 1905, Harriet set out for New York where she eventually got a job with the prestigious publication, Leslie's Illustrated Weekly. Her writing style indicated that she had an excellent formal education. Her articles were aimed mostly at women and ranged from household tips to financial guidance. Her work also included interviews of many unusual people and, on one assignment, she was invited to visit the Vanderbilt automobile race track. She was given a ride in a race car and, after several 100 mile per hour laps, she was literally hooked on high speed. She even purchased her own car and advised readers on how to maintain automobiles "properly." In 1910, Ms. Quimby attended the Belmont Park International Aviation Tournament. This visit eventually changed her life. She met John and Matilde Moisant. John's brother, Alfred, operated a flight training school in the town of Mineola, New York. John was somewhat of a national hero for his skill and accomplishments in aviation. He promised Harriet and Matilde that he would teach them how to fly; however, prior to doing this, a tragic accident took his life during an exhibition in New Orleans.

Harriet was still determined to learn to fly so, in the summer of 1911, she started training. She tried to keep it a secret by showing up for her early morning flights wearing a long duster coat and a helmet. Eventually, the word got out and she became "headline news" in her own newspaper. This was during a time when women were supposed to be "at home" and certainly not out driving fast motorcars or flying.

On July 31, 1911, Harriet passed her ground and flight tests and became the first American woman to receive an internationally recognized pilot's license. She was second in the world by only a few days. During her qualification trials, she set a record for precision landing by being only 7' 9" from an official mark... a feat that many men had failed to achieve!

Harriet Quimby was an outstanding beauty. Had she pursued her earlier desire to be an actress, there is little doubt she would have been a star. She became known as the "Dresden China Aviatrix," which at the time was the equivalent of what we now call "gorgeous!" In her newspaper, she wrote about her training, and she even speculated on the future of aviation. This included airline travel, aerial photography, safety and airmail.

On July 25, 1909, Louis Bleriot, a well-known French aviator, became the first human in history to fly across the English Channel. He did this feat in an airplane of his own design. Bleriot became an international celebrity, and this inspired Harriet to become the first woman to make the flight.

She sailed to England in March of 1912 and eventually met and became friends with Louis Bleriot. Harriet had plans to purchase a new 70 horsepower Bleriot airplane, but one wasn't available at the time. She convinced the builder to let her use one of his 50 h.p. model XIs for her attempt to fly the Channel. Some of the glory of her flight was taken away when, just days earlier, a woman had flown across the English Channel as a passenger. The pilot on that trip was Gustov Hamel. Quimby and Hamel became friends and days before Harriet was set to depart, he offered to fly her trip in a disguise. He said he would land somewhere secret so that Harriet could come out and be in the plane when the French people found her. She declined and decided to make the trip as planned in her Bleriot XI!

The Bleriot airplane had a 25' 7" wingspan. It was 29'3" long and weighed 661 pounds. The height was 8'7" and had a wing loading of 4.38 pounds per square foot. The original engine was made by Anzani and it was a 3 cylinder, 25 h.p. air-cooled radial that turned a Chauviere 2-bladed propeller. The Bleriot was constructed of ash, bamboo, steel tube and covered with a rubberized fabric. In the early morning hours of April 16th, 1912, Harriet took off flying this airplane near the English city of Dover. Cruising speed was around 36 miles per hour. It was a gray, cloudy day and many times she flew in clouds and conditions that were extremely dangerous. She had intended to land in Calais but ended up south of there on a beach near Hardelot. The flight took 59 minutes. When she landed, local fishermen gave her a champagne welcome and carried her on their shoulders to an awaiting crowd. Unfortunately, Harriet did not receive the recognition she deserved because just two days earlier, the great ocean liner, Titanic, had sunk and this still dominated much of the world news.

After returning to the United States, Harriet hired a publicity manager and one of the events on her "calendar" included the Third Annual Boston Aviation Meet near Quincy, Massachusetts. She was scheduled to fly a new two-seat Bleriot that had been shipped from France. The event organizer, William Williard, was given the privilege of making a promotional flight with Harriet. History describes him as being overweight and excitable. These were two characteristics that eventually brought disaster to the flight. Harriet and her passenger took off and flew out over Dorchester Bay in front of thousands of spectators. At an altitude of approximately 1500 feet, it was observed that Williard apparently unbuckled his seat belt and leaned forward to attempt communication with Harriet. Apparently, Harriet had unbuckled her seat belt to answer him and it was at that time, the Bleriot pitched downward throwing Williard out of the aircraft. It was observed that Harriet tried to regain control, but she too was thrown from the plane. Both died in the fall.

Harriet Quimby was a very skilled pilot and there is speculation that, had she lived, her career would have totally overshadowed that of Amelia Earhart. Some historians even say that she could have been the first human to fly the Atlantic solo. She was flying before World War I, and years ahead of Lindbergh and Earhart.

Initially, she was buried at Woodlawn Cemetery in New York. A year later, she was moved to the Kenisco Cemetery where she remains today.

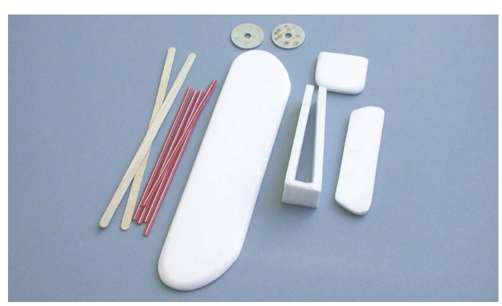
The story of Harriet Quimby demonstrates how a very brave, young American woman not only achieved the first pilot's license, but also made a historic flight under some very dangerous circumstances. This literally opened the door for women to enter the world of flight.

EXTENSION QUESTIONS FOR BACKGROUND DISCUSSION –

1. Discuss what the life and times were like, especially for women, in the period from 1900 to 1912.
2. Investigate the performance of airplanes during the time period from 1900 to 1912.
3. Investigate the weather/climate of the English Channel during April. (Harriet flew in fog and rain before landing on a sunny beach)
4. Discuss what Harriet Quimby's role might have been had she been alive during World War I.
5. Speculate what her career might have been like had she lived through the era of "barnstorming."
6. Show the video "Harriet Quimby: Women Who Dare" (https://youtu.be/NTyI_nqnUro) and lead a discussion on other women who have pushed the envelope.

HANDS-ON ACTIVITY – Create a foam model of the airplane that Harriet Quimby used to fly the English Channel in 1912 and use the model to simulate flying over the English Channel (a large blue tarp) and land on the coast of France.

MATERIALS –
a. A foam meat tray or foam plates
b. Four plastic coffee stirring sticks
c. Two wooden coffee stirrers
d. Two fender washers
e. Hot glue gun/glue sticks
f. Utility knife or box cutter
g. Template
h. Thirty feet of nylon fishing line
i. Straw
j. Blue tarp (The English Channel)
k. Stick or thick dowel (2 ft in length)

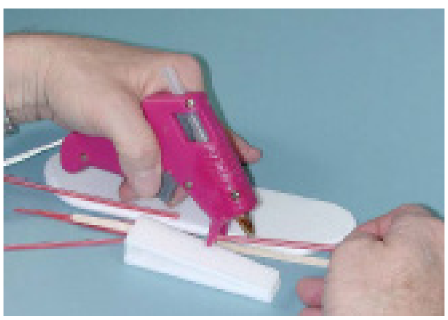


PROCEDURE –

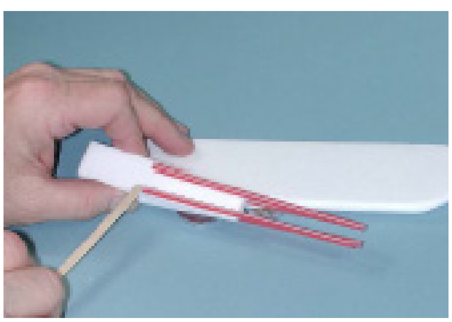
Part 1: The Building of the Bleriot XI

Step 1 – Using the "punch and pull" method, cut out the pieces from the template provided. The template can be taped, or spray glued, to the bottom side of the foam meat tray.

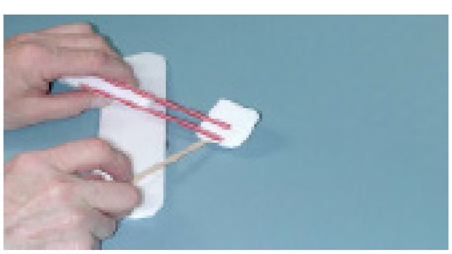
Step 2 – Run a bead of hot glue along the edge of a plastic coffee stirring stick as shown.



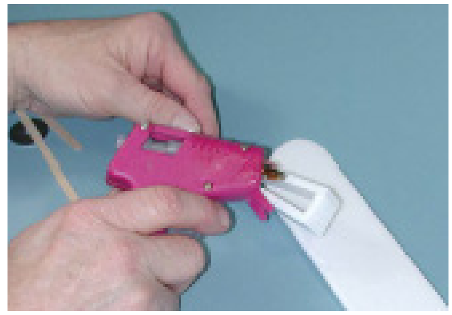
Step 3 – Using the template as a guide, glue the four plastic coffee sticks into place along the fuselage.



Step 4 – Glue the rudder to the ends of the four fuselage stirring sticks.

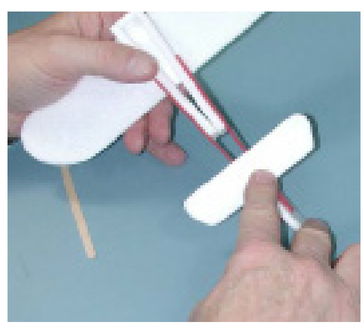


Step 5 – To install the wing, run a bead of hot glue around the upper portion of the fuselage as shown.



Step 6 – The wing is mounted to the front of the fuselage. Study the illustration to see where it is mounted.

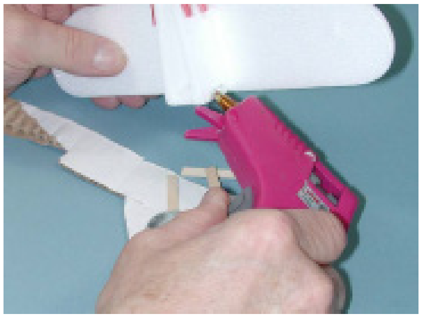
Step 7 – The horizontal stabilizer is mounted at the back near the rudder. Note that it is on the bottom of the fuselage coffee sticks. Check the illustration on how this is positioned.



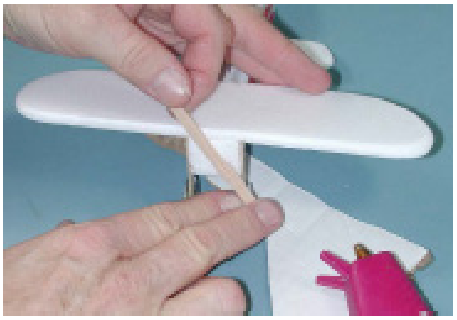
Step 8 – To make the landing gear, you must first mount the fender washers onto the wooden coffee stirring sticks. Cut the stick down to size by using the template as your guide. Then put a glob of hot glue on one tip and press a washer down into the glue. Cut a piece of wood and press this into the glue that oozes through the center of the fender washer. This will hold the "wheel" in place. Make two!

Step 8 – (cont'd.)

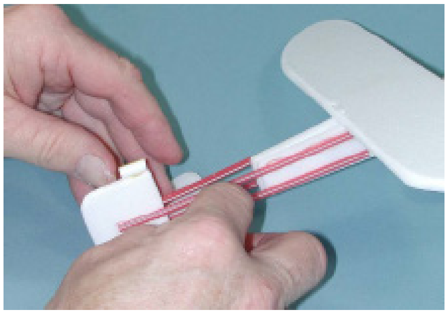
Step 9 – A bead of hot glue is run down the front of the fuselage as shown. Using the lead photograph on this activity, and the illustration, mount the landing gear strut into the correct position.



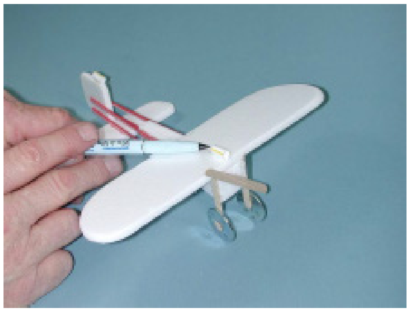
Step 10 – (Optional) Using your imagination, and a coffee stirring stick, make and mount a propeller to the front of the fuselage. This isn't required, but it does add charm!



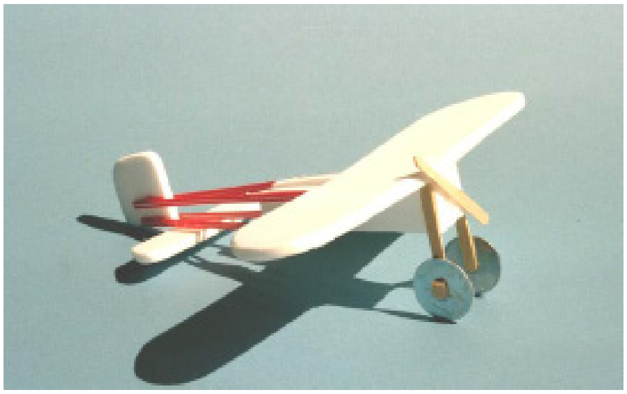
Step 11 – In order for this little airplane to slide down a fishing line we must mount a "carrier" at two points along the top of it. A simple solution is a short piece of straw hot glued to the rudder as shown.



Step 12 – Finally, another short straw is mounted to the upper portion of the wing.



Finished Model of the Bleriot XI



PROCEDURE –

Part 2: Simulating Flying over "The English Channel"

1. Show the video of an RC Bleriot XI Scale Model Flight Demonstration to engage students. (https://youtu.be/9hJDinyEzgc)

2. Flying over the English Channel is a simulation activity where students will "fly" the Bleriot XI model that was created in Part I.

3. The simulation will be set up so that the Bleriot crosses the English Channel and lands in France. The model is piloted by a student sitting in a chair.

4. Place a large blue tarp, or a large sheet of blue bulletin board paper, on the ground to act as the English Channel. Use the floor of a large area like a stage or gymnasium.

5. The "pilot" will be seated about 10 feet away from the "English Channel."

6. A helper, the person who is going to launch the Bleriot, stands on a ladder or footstool, approximately 30 feet away from the seated pilot (see illustration below).

7. A nylon fishing line is attached to a control stick on one end (usually a dowel rod or piece of broomstick about 2 feet long) and a high place in the room where the helper is stationed at the other end.

8. The tarp should be in front of the pilot and the space between the broomstick/fishing line attachment and the tarp is the "coast of France."

9. The helper is located at "Dover, England."

10. The helper carefully strings the fishing line through the straw attachments on top of the Bleriot model.

11. The model is held in position by the helper until the pilot calls for a release.

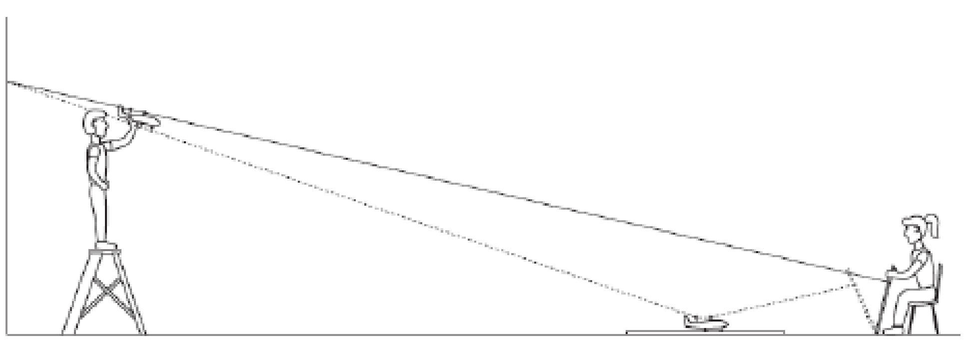
12. Once released, the Bleriot, because of the weight of the fender washers, will slide down the fishing line.

13. The pilot must control the little model so that it flies over the "English Channel" and lands to a full stop at "Hardelot on the coast of France."

14. If the pilot pushes forward on the stick too much, the little airplane will crash into the English Channel.

15. If the pilot pulls back too much, the little Bleriot will over shoot the Coast of France and another attempt will have to be made.

16. Ask the students to think about how each of the variables (angle of string, mass of plane, length of string, position of control stick) affects your ability to get your model from Dover, England across the English Channel to land on the coast of France. Adjust one variable at a time to test its importance to the outcome.



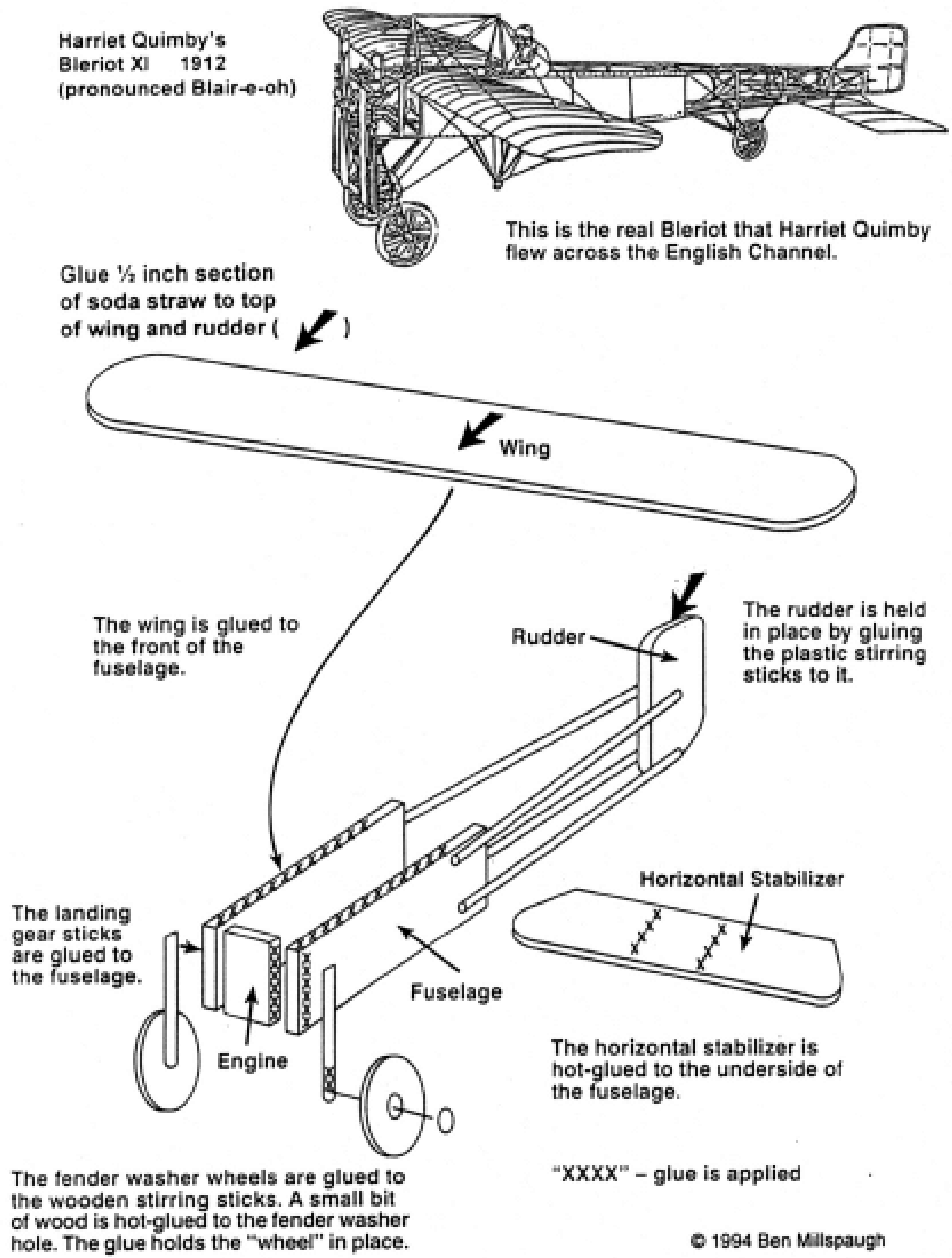
17. Have the students create a table, like the one below, to record the results of their experiment. Encourage them to try each variable at least three times and record the results. Compare findings with other students or discuss results as a class.

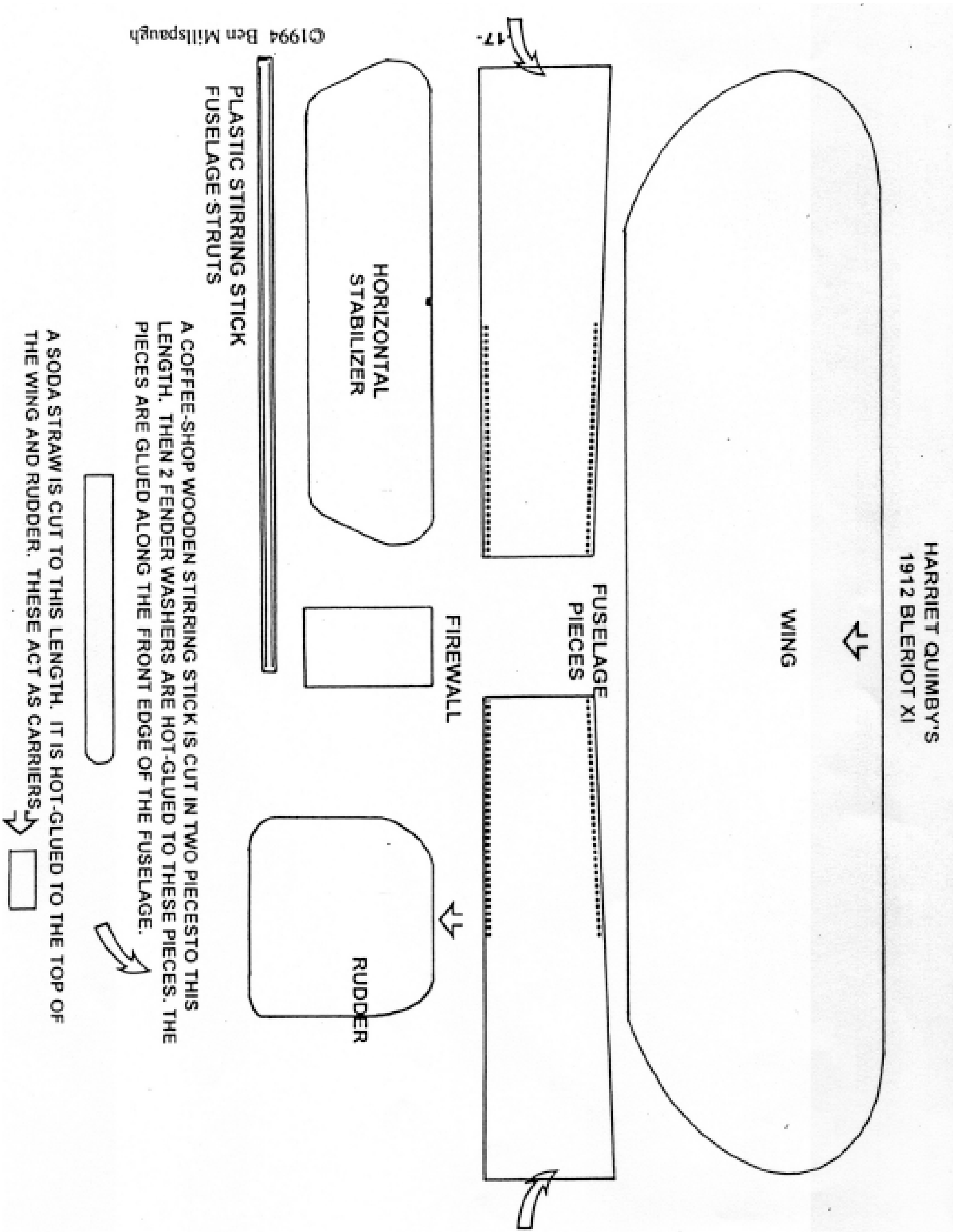
Flight #	Angle of fishing line	Mass of plane	Length of fishing line	Position of control stick (tautness of fishing line)	Results (hit, overshoot, crash into channel)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					

EXTENSIONS:

- Show the video from space of a nighttime time-lapse of flying over the English Channel from the European Space Agency. (https://youtu.be/RYDCSGPAbrg)
- Create another plane to use for this activity. Suggestions include getting a toy plastic plane with strong wheels and mounting two eye screws into the top of the plane or using another foam plane model that you have built and attach the straws as a guide. Make sure that the plane has weight, like the fender washers, to pull it down the line.
- Find the weight ratio between the Bleriot XI and the airplane you created in the extension above. What are the differences in maneuvering to go the same distance?

ILLUSTRATION - BASIC BLERIOT CONSTRUCTION



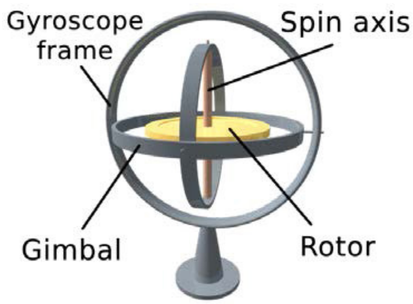

HARRIET QUIMBY'S
1912 BLERIOT XI
WING
FUSELAGE PIECES
FIREWALL
RUDDER
HORIZONTAL STABILIZER
PLASTIC STIRRING STICK
FUSELAGE STRUTS
A COFFEE-SHOP WOODEN STIRRING STICK IS CUT IN TWO PIECESTO THIS LENGTH. THEN 2 FENDER WASHERS ARE HOT-GLUED TO THESE PIECES. THE PIECES ARE GLUED ALONG THE FRONT EDGE OF THE FUSELAGE.
A SODA STRAW IS CUT TO THIS LENGTH. IT IS HOT-GLUED TO THE TOP OF THE WING AND RUDDER. THESE ACT AS CARRIERS.
-17-
©1994 Ben Millspaugh

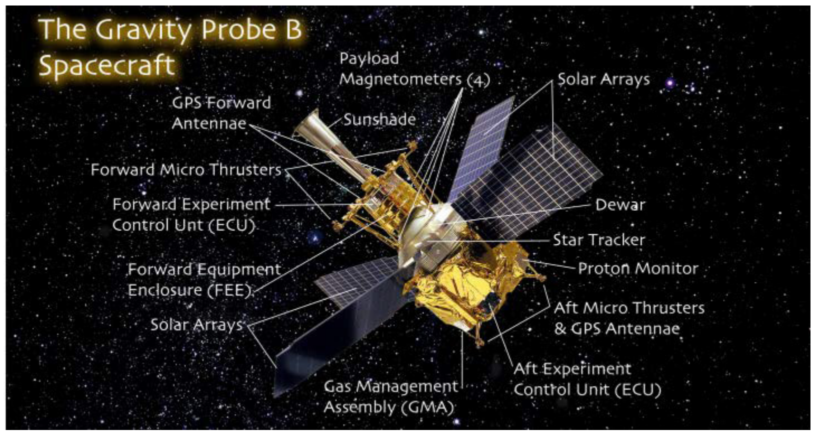
SPINNING "SIGHT" SENSATIONS

Gyroscopic Technology and the NASA Gravity Probe B

(Lesson courtesy of NASA Educator's Guide to Gravity Probe B)

OBJECTIVE – Students will be able to demonstrate how a gyroscope works through hands-on investigations. Students will also be able to explain the mission and technology of NASA's Gravity Probe B.





NATIONAL STANDARDS –

Next Generation Science Standards (www.nextgenscience.org):
Disciplinary Core Idea Progressions
- Earth Science Progression
  - HS ESS1.A: The universe and its stars
- Physical Science Progression
  - HS PS2.A: Forces and Motion
  - HS PS2.B: Types of interactions
  - HS PS3.B: Conservation of energy and energy transfer

Crosscutting Concepts
- Systems and system models
- Energy and matter

Science and Engineering Practices
1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
6. Constructing explanations (for science) and designing solutions (for engineering)
8. Obtaining, evaluating, and communicating information

BACKGROUND —
(Based on information from http://einstein.stanford.edu/content/education/GP-B_T-Guide4-2008-HQ.pdf)

Gyroscopes, or any spinning object, remain oriented in the same direction as long as they are spinning, a property called rotational inertia. A common example of this inertia is a spinning top. It balances on its end while spinning yet topples over when friction slows it down. While it spins, its rotational inertia keeps it pointed straight up, oriented in its original direction. Rotational inertia is the resistance that a mass exhibits to having its speed of rotation altered by the application of a torque (turning force); any spinning mass will continue to spin as long as no outside force acts upon it (Newton's first law of motion). Accordingly, if a top was spinning in the near-vacuum of space, it would remain constantly oriented in its original direction, since there would be no forces to slow it down. Our Earth is a prime example of this. The Earth's axis is oriented 23.5 degrees from the plane of the ecliptic, relative to the Sun. It has remained in this orientation due in part to its rotational inertia. Because of this property, gyroscopes are used to navigate ships, planes, missiles, and satellites.

According to Einstein’s General Theory of Relativity (1916), all planets and stars reside in an invisible, intangible structure of space-time. The Earth, like all masses and energy, affects local space-time in two ways. Earth’s presence warps or curves space-time around it, and Earth’s rotation drags or twists the local space-time frame with it (called “frame-dragging”). How could one test Einstein’s theory? How could one “see” this invisible structure and measure the shape and motion of this intangible space-time?

In 1960, Stanford University physicist Leonard Schiff and his colleagues were discussing the possible scientific benefits of creating a perfectly spherical gyroscope. Certainly, this perfect gyroscope could improve navigation of planes, rockets, and satellites. But Schiff proposed something else - a way to “see” local space-time.

Schiff suggested that if they placed a near-perfect spinning gyroscope in space-time above the Earth and monitored the direction its spin axis pointed, the floating gyroscope could show them the shape and behavior of our invisible space-time frame. The experiment would only work with a near-perfect gyroscope, as the effects of space-time’s curvature and motion were predicted to be microscopically small.

If a perfectly-spherical, spinning gyroscope floated above the Earth in space-time, and it was protected from any external forces that could re-orient it (e.g., gravity, solar radiation, atmospheric friction, magnetic fields, electrical charges), and any internal imbalances were removed (e.g., imperfect shape, unbalanced density, surface imperfections) it would remain pointing in its original direction. The only thing that could alter its spin orientation would be the structure of space-time itself.

If the local space-time in which the gyroscope was floating was curved or was twisting, the gyroscope’s orientation would change to follow this curve or twist. If we could monitor this change in orientation, we could “see” the shape and behavior of space-time itself! This is the mission of Gravity Probe B: to “see” our local space-time and measure it more precisely than any experiment in history.

Gravity Probe B (GP-B) was a satellite-based mission which launched on April 20, 2004 on a Delta II rocket. The spaceflight phase lasted until 2005. Gravity Probe B was a relativity gyroscope experiment funded by NASA. It was decommissioned in December 2010.

GRAVITY PROBE B FAST FACTS

A near-perfect, spherical gyroscope orbits in spacetime 400 miles above the Earth. At the beginning of the mission, the gyroscope’s spin axis points at IM Pegasi, a distant guide star. After one year, theoretical calculations predict that the gyroscope’s spin axis orientation will deflect in two directions: 6,606 milliarcseconds vertically, in the plane of the spacecraft’s orbit, due to the curvature of local spacetime—called the geodetic effect;” and 39 milliarcseconds horizontally, in Earth’s equatorial plane, due to frame-dragging—the twisting of local spacetime by a rotating mass such as the Earth.

14 MONTHS	Duration of the mission
39 MILLI-ARCSECONDS	Predicted drift of gyroscopes due to frame-dragging
0.5 MILLI-ARCSECONDS	Margin of error for GP-B
1.4×10^{-7} DEGREES	Margin of error in degrees
400 MILES HIGH	Orbital altitude of satellite
-271.2° CELSIUS	Temperature of liquid helium (1.8 K)

1.5 INCHES	Diameter of each gyroscope
3×10^{-7} INCHES	Asphericity of gyroscopes
0.001 INCHES	Space between spinning gyroscope and housing
9 FEET	Height of dewar containing gyroscopes
645 GALLONS	Capacity of dewar
44 YEARS	Years that GP-B was in development

Activity Four: Spinning "Sight" Sensations

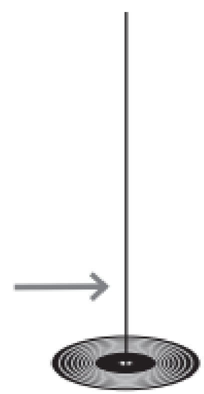
HANDS-ON ACTIVITY –Explore gyroscopes by engaging in four investigations to understand what a gyroscope is, how it works, and why it is so useful in both science and technology.

MATERIALS – (per class to run all 4 stations simultaneously)

a. Five feet of string
b. Record (vinyl recording type)
c. Crayon/pencil
d. Three bicycle wheels (large and light are the best) with stunt pegs/handles attached to axle (bike shop can do this)
e. Rope with handle and hook
f. Chair
g. Office chair that turns or a barstool that has a swiveling seat with no back

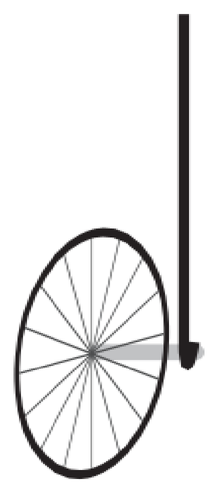
PROCEDURE –

- Discuss gyroscopes and rotational inertia. Have students discuss Newton's first law of motion and give some examples. A short explanation of Newton's first law of motion and rotational inertia, and how they are the same and different, can be found at https://www.sophia.org/tutorials/rotational-inertia-newtons-first-law-of-motion.
- Divide the students into four groups and explain to them that they will be recording observations as they rotate through four stations.
- Have students perform the following four explorations in small groups and answer the questions as they explore.



Exploration 1: Swinging Record (Materials needed: 5 ft string, record, crayon/pencil)

1. Instruct students to tie a string to a crayon.
2. Slip a vinyl record over the loose end of the string and hang the record down over the crayon. The record should be hanging horizontally (parallel to the ground).
   a. Test A: Set the record swinging gently by pushing the string near the record. Does the record stay horizontal? How far does it vary from horizontal? Does it matter how hard it is swinging?
   b. Test B: Repeat the first test, but first give the record a sharp spin. Make sure when you spin it that you thrust it along the horizontal axis, so that the record starts out in a horizontal position before you start swinging the string. Does the record stay horizontal? How far does it vary from horizontal? Does it matter how hard it is swinging?



Exploration 2: Tilting Wheel (Materials needed: modified bike wheel as mentioned above)

1. Have students hold the modified bicycle vertically in front of them with one hand on each side of the axle. Make sure the wheel is not touching your body or arms.
2. While one student holds the pegs on the sides, have another student spin the wheel towards the ground. Allow the student holding the pegs to tilt the wheel to the right, then to the left (toward horizontal).
   a. Did you notice any pulling on the wheel when you tilt it? In which direction do you feel the pull?

Exploration 3: Hanging Wheel (Materials needed: rope with handle and hook, bike wheel, partner, chair to stand on)

1. Attach a rope hook to the wheel axle.
2. Have a partner stand on a chair and hold the rope high.
3. Turn the wheel to a vertical position (axle is horizontal, held by rope and your hand)
4. Release the wheel and observe.

5. Return the wheel to the vertical position and spin it rapidly.

6. Release it again and observe.

  a. What happened to the spinning wheel when you released it? Which direction did it turn? What happens if you spin the wheel in the other direction?

Exploration 4: Send Yourself Spinning (Materials needed: bike wheel, office chair)

1. Sit on the office chair. Make sure you are well-balanced. Pull feet up so if the chair turns, your feet will not hit anything.

2. Hold the wheel vertically out in front of you with one hand on each side of the axle. Make sure the wheel is not touching your body or your arms.

3. Have a partner spin the wheel toward the ground. Tilt it (toward horizontal) to the right and then to the left.

  a. What happens when you tilt the wheel?

  b. Why does the chair move?

4. After the class finishes rotating through all four exploration stations, bring the class back together and facilitate a discussion based on the observations. Use the questions listed above as a guide and the additional information below to help explain the concepts to the students.

5. Finally, use the background information to go into more depth regarding NASA's Space Probe B and conclude the lesson with this information to tie the two concepts together. The GP-B gyroscope is designed to measure a very minuscule change in the orientation of space-time around Earth during the course of one year in orbit. Since gyroscopes maintain their orientation in space while they are spinning, the only reason that the GP-B gyroscope will shift its orientation is if space-time itself is turning. The simple gyroscope will allow GP-B scientists to "see" our invisible, intangible space-time.

ADDITIONAL INFORMATION

When you ride a bicycle and you are going very fast, balancing to stay on the bike is easy. However, when you slow down and stop, you lose the ability to balance. In the Explorations in this activity, you met with resistance when you tried to lift the spinning wheel sideways. When you were on the turning chair or stool, nothing much happened until the person seated tried to twist the spinning wheel into a different vertical plane. Then, if the stool was fairly frictionless, and the person seated on the stool was not too heavy, the person/stool/spinning wheel "unit" would have rotated in one direction when the wheel was twisted the other way. Why does this happen?

Inertia is one of those properties of matter that was accurately noticed by Galileo, then refined by Newton into his 1st Law which says, "objects at rest tend to continue at rest and objects in motion tend to continue in motion, unless outside forces act to change things." The key word is "continue," because it means that objects continue to do the same thing – like going in the same direction, at the same speed – unless some other force (like friction form brakes, air drag, or bumping into something) causes change.

Now, momentum is another idea related to inertia. Momentum is the mass (or weight) of an object multiplied by its speed. For example, of two identical trucks, one going 30 miles per hour and the other going 60 miles per hour, the faster one has twice as much momentum as the slower one. Similarly, a 10,000-pound truck going 60 miles per hour and a 20,000-pound truck going 30 miles per hour both have the same momentum.

To understand a gyroscope, you should also know about centripetal force. This is a force that pulls on an object that is spinning around another object and keeps it from flying off in a straight line. For example, if you tie a rock onto the end of a string and swing it around your head, the string exerts a centripetal force on the rock. If not for the string pulling it back towards the center of its "orbit," the rock would follow Newton's 1st law and continue off in a straight line. (The term centripetal force is used to describe the outward force exerted by the rotating mass.)

To apply this idea to the spinning bike wheel, the rim and tire of the wheel are like a bunch of rocks fused together into a circle and tied to the center (hub) by spokes instead of string. Each part on the outside of the wheel has momentum and wants to keep going in the direction it was pushed. However, it can't because it is being pulled in toward the center by the spoke exerting centripetal force.

The linear momentum (meaning the momentum that keeps the object moving in a straight line) and the centripetal force combine to give the object angular momentum. Angular momentum is what makes the bike wheel tend to keep spinning in the same plane, or going in the same direction, from when a force was first applied to get it spinning. When the bike wheel was suspended by a rope or string, but not spinning, it flopped around in a horizontal plane, its position was totally determined by the force of gravity. When turned into a more vertical plane and set spinning, it stayed vertical because of the angular momentum, despite the pull of gravity.

However, even though the wheel is spinning, gravity is still at work on trying to make it horizontal. To do this, gravity must push the top part of the wheel horizontally away from the string or rope while pushing the bottom part of the wheel horizontally toward the string or rope. Because gravity and the supporting string are the only external forces pushing on the rotating wheel, the effects of these horizontal pushes are unchanged as the wheel rotates. (Remember, bodies in motion tend to stay in motion unless acted upon by an external force.) As the wheel rotates and the parts of the wheel move from the top to the side, the horizontal pushes that gravity gives the wheel at the top and the bottom act to turn the wheel in a counterclockwise direction around a string or rope when seen from above. The external gravity forces cause this motion for every point of the wheel as it spins around its axle. This turning motion around the string is called precession. The precession of the spinning wheel represents a perfect balance among the wheel's mass, how fast it is spinning on its axle, and the effects of the external forces.

EXTENSIONS:

- Research how gyroscopes are used in airplanes, spacecraft and satellites and compare the findings.
- Research and study the NASA Toys in Space Program that refers to using toy gyroscopes in the International Space Station at https://www.nasa.gov/audience/foreducators/microgravity/home/toys-in-space.html.
- Check out the Massachusetts Institute of Technology (MIT) Physics Demo video titled "Bicycle Wheel Gyroscope." https://techtv.mit.edu/videos/717-mit-physics-demo----bicycle-wheel-gyroscope

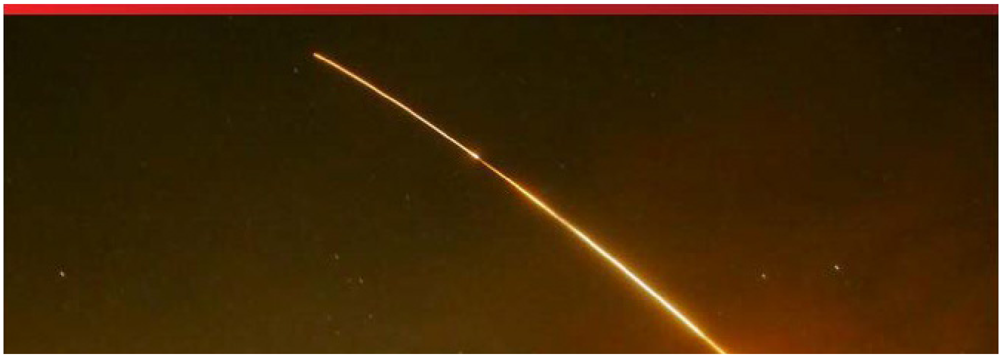
Additional Video Resources:

- Gyroscopes by NASA Video: https://youtu.be/FGc5xb23XFQ
- Gyroscopes in Space by European Space Agency, ESA: https://youtu.be/xQb-N486mA4

Parabolic Propulsion

From NASA Museum in a Box: Propulsion with a Ball Launcher

OBJECTIVE – Students will be able to demonstrate the concept of a parabolic arc by throwing a ball and observing how external factors influence the trajectory. Students will be able to record the time and range for the tennis ball throws and use this information to solve for the highest point of the trajectory.



NATIONAL STANDARDS –

Next Generation Science Standards (www.nextgenscience.org):

Disciplinary Core Idea Progressions

Physical Science Progression

- HS PS2.A: Forces and Motion
- HS PS3.C: Relationship between energy and forces

Crosscutting Concepts

- Systems and system models
- Energy and matter
- Stability and change

Science and Engineering Practices

2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and Interpreting Data
5. Using mathematics and computational thinking
8. Obtaining, evaluating, and communicating information

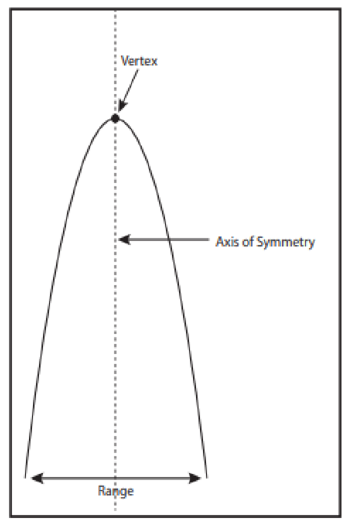


Fig. 1 Parabola

BACKGROUND – (from https://www.nasa.gov/sites/default/files/atoms/files/ball_launcher_5-12.pdf)

Students often see parabolas and may not recognize them. If the students were to draw a graph that represents the path of a projectile fired by a cannon, it would also represent a parabola. The golden arches on a favorite eating establishment are also parabolas.

Notice the drawing of the parabola in Figure 1 above. It looks like an upside down 'U.' Students taking a pre-calculus class learn terms associated with a parabola such as Axis of Symmetry, Vertex, Focus, Directrix, Quadratic Equation, Points, and Locus. For this lesson, the following terms are important to understand: vertex, axis of symmetry, and range.

As shown in Figure 1, the vertex of a parabola represents the high point of the tennis ball flight. It is also the point where it crosses its axis, referred to as the axis of symmetry. The axis of symmetry is most often a vertical line that passes through the parabola's vertex. It divides the parabola into two perfect halves. Range is the horizontal distance from where the ball was tossed to where it hits the ground.

An excellent example of a parabola in action is Alan Shepard's sub-orbital Mercury Program flight aboard Freedom 7 on May 5, 1961. Shepard's flight lasted 15 minutes and 22 seconds during which time his spacecraft reached an altitude of 187.5 kilometers (116.5 miles). Freedom 7 splashed down into the Atlantic Ocean 486 kilometers (302 miles) from the launch site. If Figure 1 represented Shepard's flight, the distance from the vertex to the bottom of the parabola is 187.5 kilometers (116.5 miles). The range from liftoff to splash-down is 486 kilometers (302 miles). The left side of the parabola represents the ascent period, while the right side represents reentry.

Another example of parabolas occurs during NASA's Reduced Gravity Program (RGP), which is managed by Johnson Space Center (video link: https://youtu.be/nJdWUifhkbE). To prepare astronauts for the weightlessness of space, a simulated weightless environment is created in an aircraft that flies a free fall trajectory, which is a parabola. The RGP enables scientists, engineers, astronauts, university students, and even teachers to test equipment and conduct experiments that may be used on a future space flight. Each flight includes 40 parabolas. Also, some of the scenes from the Apollo 13 movie were shot aboard the KC-135, which was used to fly parabolas. The KC-135, known as, the 'vomit comet,' was retired in 2004 and has been replaced by a Navy C-9, a twin-jet variant of the McDonnell Douglas DC-9.

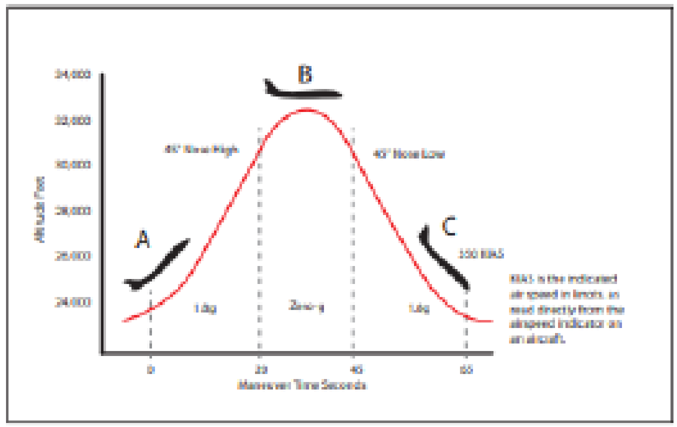
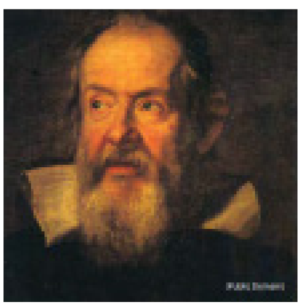


Fig. 2 Flying the parabola



Mathematician, astronomer, physicist, and inventor, Galileo Galilei, studied projectile motion. Galileo knew that a trajectory of a projectile was a parabola. He realized for the first time that a projectile's motion is influenced by two independent motions. One of the motions is influenced by gravity. He discovered that gravity pulls down a projectile according to the equation for a falling body. The second influence demonstrated that horizontal motion is uniform and constant, according to the principle of inertia. Inertia can be considered the tendency of an object to resist any change in its motion.

Galileo realized, even during his earliest experiments, that the speed of a falling body is independent of its weight. Galileo discovered that the nature of this motion is the same for an object that falls straight down as it is for one that moves forward and down at the same time. Therefore, an arrow shot horizontally from a bow falls at the same rate as one that is simply dropped from the same height that it was shot.

Galileo was able to derive an equation for a falling body:

$S = \frac{1}{2}at^2$. (S = distance, a = acceleration due to gravity (9.8m[32ft]/sec²), and t = time)

From the above equation, you can also solve for the following:

Instantaneous velocity of a falling object after a certain elapsed time: $V_i = at$

Average velocity of an object that has been falling for time (averaged over time): $V_{avg} = \frac{1}{2}at$

Launch Angle: The angle that the ball was released when thrown.
Launch Velocity: The initial speed at which the ball was released.

Sample Problem Set:

The following is a set of problems related to throwing a tennis ball with the Chuckit Ball Launcher. Use the formulas you deem most appropriate with your students. The sample problem assumes no air resistance or the height at which the ball was released. These factors can be added later after the students gain a better understanding of a falling body. A tennis ball is thrown and its flight time is 4 seconds. It lands 25 meters from where it was thrown. Remember, in a parabola, it takes half of its flight time to reach the vertex and the other half to reach impact. So, in this case, the time to reach the vertex is 2 seconds.

Now determine the height from the vertex to the ground:

Acceleration due to gravity = 9.8m/sec^2, t = time

Use the equation: $S = \frac{1}{2}at^2$ to solve for distance.

S = Distance, a = $S = \frac{1}{2}\,9.8m/sec^2\,(2.0\,sec)^2$ = 4.9m/sec^2 x (4 sec^2) = 19.6 meters

To convert meters to feet, multiply the number of meters by 3.28 feet/meter:

19.6m (3.28ft/m) = (64.3 feet)

The vertex is 19.6 meters from the ground.

What was the velocity of the tennis ball after 1.5 seconds?

$V_i = at = 9.8m/sec^2$ x 1.5 sec = 14.7 m/sec (48.23 feet/sec)

What was the average velocity of the tennis ball?

$Va = \frac{1}{2}at = \frac{1}{2}$(9.8m/sec^2) (2.0 sec) = (4.9m/sec^2) (2.0 sec) = 9.8m/sec (32.1ft/sec

To determine launch angle:

R = Range
S = Height of vertex in meters

$$\textbf{Launch Angle} = \frac{S}{R} = \frac{\tan\theta}{4}$$

$$\textbf{Launch Angle} = \frac{19.6m}{25m} = \frac{\tan\theta}{4}$$

$$\textbf{Launch Angle} = \frac{78.4m}{25m} = \tan\theta$$

$$\tan\theta\,\frac{78.4m}{25m} = 3.14 = 72.3°$$

Launch angle was 72.3°

To determine launch velocity:

R = Range
a = Acceleration due to gravity (9.8m/sec2)

$$\text{Launch velocity} = Vo = \sqrt{\frac{Ra}{\sin 2\theta}}$$

From trigonometry (trig), we know that:

Sin2θ = (using trig identity) = 2sin2θ cosθ

$$Vo = \sqrt{\frac{Ra}{\sin 2\theta \cos\theta}}$$

$$\sqrt{\frac{25m(9.8m/sec^2)}{2\sin(72.3°)(\cos(72.3°))}} = \sqrt{\frac{245\,\frac{m^2}{sec^2}}{2(.952)(.304)}} = \sqrt{\frac{245\,\frac{m^2}{sec^2}}{.579}}$$

$$= \sqrt{423.1\,\frac{m^2}{sec^2}} = 20.6m/sec$$

Therefore, the launch velocity was 20.6 m/sec

MATERIALS –

a. Chuckit Ball Launcher (bought at a pet store for $6-8)
b. Stopwatch
c. Tape measure or trundle wheel
d. Graph paper
e. Thrown Ball Data Recording and Collection Worksheet (attached at the end)
f. Thrown Ball Data Analysis Worksheet (attached at the end)

MANAGEMENT TIPS:
Predetermine a large open area where students can throw the ball, such as the school's baseball or football field. Have the class divided into groups of seven prior to the start of the activity. Since students will be throwing a tennis ball during the lesson, please stress the importance of safety. Remind students not to throw the ball unless their team is ready. Also, be sure to alert others around you before the tennis ball is thrown by saying "Tally Ho!"

PROCEDURE –
Part 1: In the Classroom
1. Introduce the lesson by displaying the graphic of the parabola, Galileo, and the equation for a falling body. Ask if anyone can explain what you have displayed or how it is used in the real world. Explain how NASA uses a parabola in their reduced gravity program described in the background section.
2. Discuss the equation for a falling body and use the sample problem to highlight the math involved.
3. Explain the procedure for throwing a ball with the Chuckit Ball Launcher stressing the importance of safety. Distribute the Thrown Ball Data Collection Worksheet. Explain that each person will make four throws—three with the Ball Launcher and one regular style (student's arm). If there is wind—students will launch one with the wind, another into the wind, and another in a direction perpendicular to which the wind is blowing. The regular throw can be in any direction. If there is no wind, students can make their throws in any direction. Also, point out to the teams that they are to enter the weather data at the time they are doing the ball throws.
4. Divide the class into teams of seven. Explain when they do the activity one person will be the thrower, one will be the timer, and one team member will be the data recorder. Two of the team members are to be positioned so that they can accurately spot where the ball hits the ground, and the final two team members are to measure the distance from where the ball was thrown to where it hits the ground. The stop watch is to be started when the ball is released and stopped when one of the spotters raises his or her hand to indicate the ball has hit the ground. The time should be given to the recorder and once the distance has been measured, that information is provided to the recorder. Inform the class that it might be easier for one person to complete all three throws and then rotate, and if there is a problem with a throw, redo it. REMIND THE STUDENTS THAT IF THERE IS A PROBLEM, ALERT THE TEACHER IMMEDIATELY.
5. Remind the class to make sure they have gathered all the necessary equipment to complete the activity before going outside—ball launcher, stop watch, tape measure or trundle wheel, and the Thrown Ball Data Collection worksheet.

Part 2: Outside
1. Have each team use different areas of the open area where they are throwing the ball. If at a ball field, one team can throw from the first base towards right field, the second team could throw from second base to the center field area, etc.
2. Have the teams assume their positions and have the first person throw the tennis ball as far as they can. Record the data for this throw.
3. Have the first person rotate to the next position and throw the tennis ball, etc. Make sure that data is recorded for each throw.
4. Once everyone has completed their three throws

with the ball launcher, have them throw the ball without the launcher and record the measurements. As before, have a team member record their time and range for the throw.

5. Make sure all data is recorded and equipment gathered before returning to the classroom.

6. Provide each student with the Thrown Ball Data Analysis and a sheet of graph paper. Have each student calculate the height of the parabola for each of their throws.

7. Knowing the range and the height of the parabola, the student is to use graph paper to sketch each parabola.

8. Use the discussion questions below to facilitate a conversation about the results.

9. Review with the students that the external factors, like the ball's weight, the drag caused by the air resistance, the angle in which the ball was thrown, the launch velocity, and even its spin, affected the trajectory of the tennis ball.

DISCUSSION QUESTIONS – (Suggested answers are in italics.)

1. How did your results compare to the other team members' results?

Results depend on student data

2. How was the trajectory the same for each of your throws? Look at the sketches to answer this question.

Please account for differences.

Launch angle, velocity of the launch, and wind direction all have an impact.

3. Which of the above type of throws most often gave the optimum or best trajectory for the longest throw for your team? What might be some reasons for this?

There are several reasons the students might propose, such as throwing with the wind enabled the ball to travel farther than when thrown into the wind where the air resistance was greater. In addition, under the same conditions, launch angles near 45° will enable a ball to travel farther than a ball launched at any other angle. A ball launched at a 55° launch angle will travel the same distance as a ball launched at a 35° angle with the same launch velocity. Also, a ball launched at a 70° angle will travel the same distance as a ball thrown at a 20° angle with the same launch velocity. Notice how the two angles added together equals 90°.

4. Compare and contrast the trajectory of the tennis ball when thrown by hand and with the Ball Launcher. Why are there differences in the two trajectories?

The Ball Launcher can provide a greater launch velocity than thrown by hand. In almost every case, the Ball Launcher will have the greatest range because of this.

5. Explain why the use of math in looking at a parabola provides more information than just observing the parabola?

Most scientists before Galileo never used math to explain their observations. Galileo demonstrated how math can provide a much better explanation for events in nature than can be made from just observing an event, describing it, and providing an idea to explain the observation.

EXTENSIONS –

- Have the students determine the launch angle and launch velocity for each throw.
- Have students design an experiment that they would test if they could be a participant in the Reduced Gravity Program (RGP).
- Explore reduced gravity flight through algebra: https://er.jsc.nasa.gov/seh/264005main_Algebra_Edu_C9.pdf
- Investigate more about NASA's Parabolic Flight Tests using the following websites:
  - o NASA Brain Bites: What's the Vomit Comet? https://www.youtube.com/watch?v=RJdDVOZrNfY
  - o Parabolic Flights Test Technologies in Microgravity https://www.nasa.gov/centers/armstrong/features/parabolic_flights_06_15.html

Thrown Ball Data Recording Worksheet

Name of Student	Throw 1		Throw 2		Throw 3	
	Time	Range	Time	Range	Time	Range
Student 1						
Student 2						
Student 3						
Student 4						
Student 5						
Student 6						
Indicate for each throw the direction of the throw in reference to the wind. If it is windy, do all three tosses.	With the wind Into the wind No wind If wind, throw perpindicular to the wind. If it is a north wind, throw the ball either to the east or west.		With the wind Into the wind No wind If wind, throw perpindicular to the wind. If it is a north wind, throw the ball either to the east or west.		With the wind Into the wind No wind If wind, throw perpindicular to the wind. If it is a north wind, throw the ball either to the east or west.	

Name: ______________________________ Date: _______________ Time: ____________

Weather:
Wind Speed: __________________ Kilometers Per Hour
Wind Direction: __________________
Location of Activity: ___________________________

Ball Launcher Toss 1	Ball Launcher Toss 2	Ball Launcher Toss 3	No Ball Launcher Arm Toss 4
Start Time: Stop Time: Total flight time (in seconds): Range: (in meters)	Start Time: Stop Time: Total flight time (in seconds): Range: (in meters)	Start Time: Stop Time: Total flight time (in seconds): Range: (in meters)	Start Time: Stop Time: Total flight time (in seconds): Range: (in meters)
Circle wind condition related to direction of thrown ball: Into the wind With the wind Perpendicular to wind No wind	**Circle wind condition related to direction of thrown ball:** Into the wind With the wind Perpendicular to wind No wind	**Circle wind condition related to direction of thrown ball:** Into the wind With the wind Perpendicular to wind No wind	**Circle wind condition related to direction of thrown ball:** Into the wind With the wind Perpendicular to wind No wind
Comments:	Comments:	Comments:	Comments:

Name: ____

Use the Falling Bodies Equation to determine the height of the parabola for each of the throws.

The formula is:

$S = \frac{1}{2}at^2$. (S = height of parabola, a = acceleration due to gravity ($9.8 m/sec^2$), and t = time in seconds)

Height Toss 1: ___________________________________

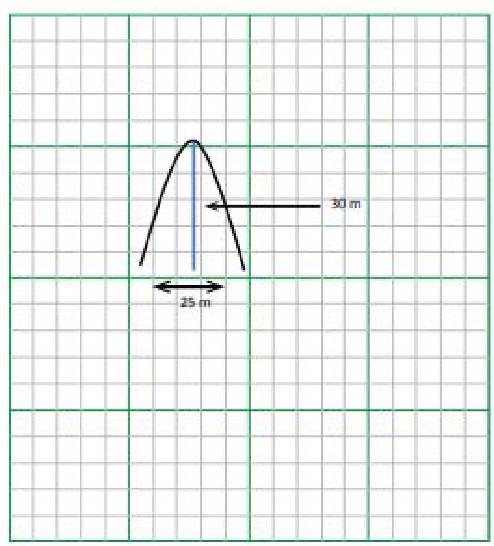
Height Toss 2: ___________________________________

Height Toss 3: ___________________________________

Height Toss 4: ___________________________________

On graph paper, sketch the parabola for each throw.

An example is given: Height 30 meters, range 25 meters.



Solve for other aspects of the ball throw. (As required by the teacher.)

Ball Toss	Launch Angle	Launch Velocity
1		
2		
3		
4		

Launch Angle $= \frac{S}{R} = \frac{\tan\theta}{4}$

Use launch angle to find velocty. If the launch angle is 60°, then you would look up the sin and cos for the 60° in the Launch Velocity Equation.

Launch velocity $= Vo = \sqrt{\frac{Ra}{\sin 2\theta}}$

Teamwork in Aerospace

Based on the NASA Activity and PowerPoint
https://www.grc.nasa.gov/WWW/K-12/airplane/TeamAct/teamwork.html

OBJECTIVE – Students will be able to learn about the importance of teams in the aerospace industry and demonstrate the importance of teamwork.

NATIONAL STANDARDS –

Next Generation Science Standards (www.nextgenscience.org):

Disciplinary Core Idea Progressions

Crosscutting Concepts

- Systems and system models

Science and Engineering Practices

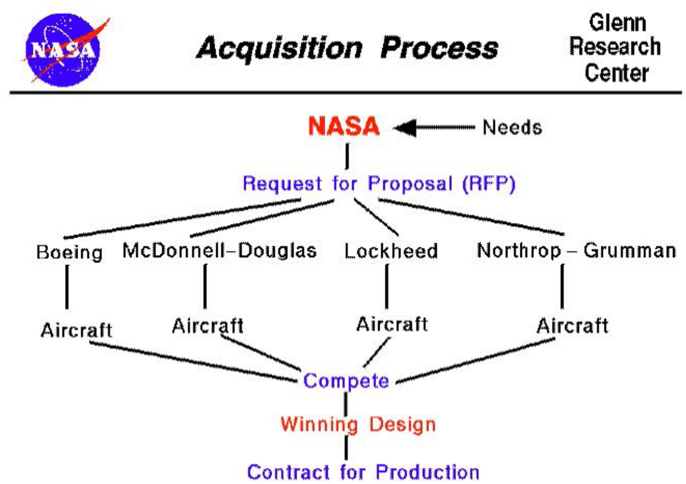
1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
6. Constructing explanations (for science) and designing solutions (for engineering)
8. Obtaining, evaluating and communicating information

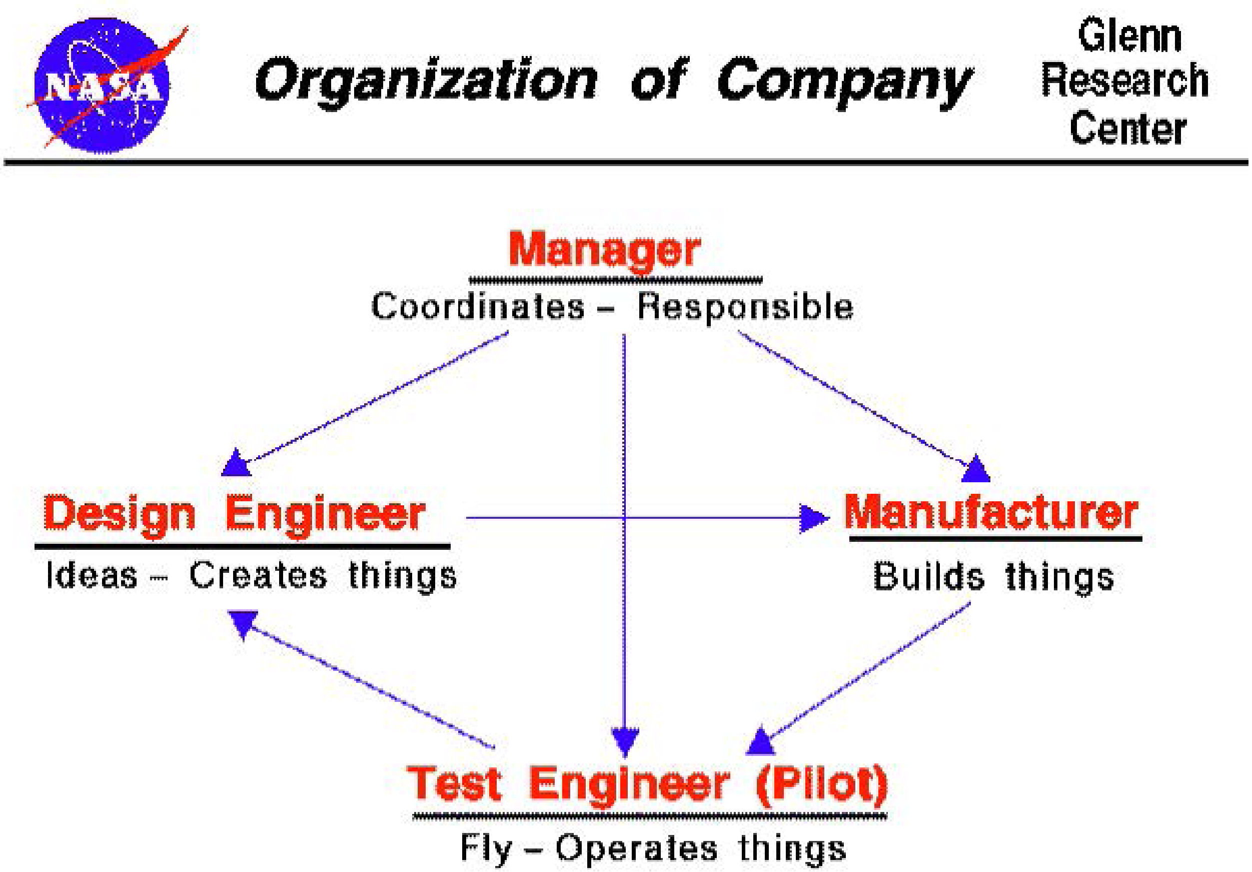
BACKGROUND – (Information from https://www.grc.nasa.gov/WWW/K-12/airplane/TeamAct/background.html)

There are three major parts to the aerospace industry; the research groups like NASA who figure out how aerodynamics and propulsion works, the suppliers like Boeing who make aircraft, and the users like the Air Force who fly the aircraft. People interested in careers in aerospace can join any part of this structure based on their own talents and interest. (Interestingly, the Wright brothers did all three parts themselves between 1900 and 1905!)

The user has some need for an aircraft and a mission that the aircraft is to perform. The needs are determined by the user and the user defines his needs in a Request for Proposal (RFP). The RFP is a document that spells out what the aircraft must do. The user publishes this document and the various suppliers must make a determination if they can design an aircraft which meets the needs of the user. In the best of all worlds, the supplier already has an aircraft that is close and can modify an existing aircraft. If not, the supplier proposes a new design to the user based on results from the research groups. The user normally receives more than one response to the RFP and must determine which design can best meet the mission. The user often conducts a competition between rival suppliers to determine the best aircraft and to lower the cost of the aircraft. The winning design is awarded a contract for production and the supplier produces some agreed upon number of aircraft for the user. This defined process by which the users obtain aircraft from the suppliers is called the acquisition process. Aerospace companies are normally very large. They may have subsidiary units, or even smaller companies, spread around the country to perform a variety of functions.

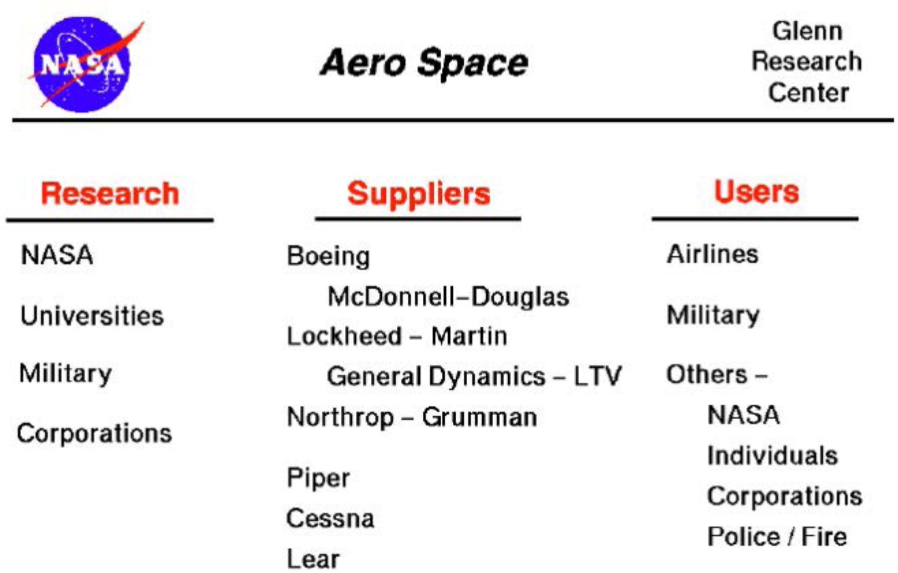
The major functions of any aerospace company are to design, manufacture, and test aircraft. Different groups of people perform these functions and there must be some coordination between the groups. This is one of the roles of management within the company. The managers are also responsible for the operation of the company and make the decisions about the response to RFP's from the users. Normally, the manager is the contact point between the user and the company. Inside the company, the manager has contact with the design, manufacture, and test groups. The designers also receive input from the test group so that they can modify and improve their ideas. The designers provide input to the manufacturing section who then convert the ideas of the designers into physical aircraft. The manufacturers make the airplanes. The test group takes the aircraft from the manufacturers and determines if they meet the needs of the users. They often provide input back to the designers. Most aerospace companies have company test pilots who fly their aircraft before it is turned over to the user.





MATERIALS – per "company" (group)
a. Ten sheets of white 8.5" x 11" copy paper
b. One sheet of 8.5" x 11" colored paper. Each group needs a different color so they can tell which one belongs to their company when the testing is over.
c. Tape
d. Scissors
e. Paper clips
f. Stopwatch
g. Markers
h. Company log and job nameplates

MANAGEMENT TIPS –
Prearrange students into teams of 4 students to form a "company" for best results. Also, arrange the classroom so that each "company" has its own table on which to place the required materials. Do not pass out the colored sheet of paper for the final design until the manager of the company requests the final paper from the teacher. Remind companies of time left for them to finish by giving warning times (10 minutes…5 minutes…2 minutes...1 minute…STOP!) After time is called, each company must send their pilot to the competition area for a presentation to NASA (the "user"). Predetermine a large competition area before the lesson begins. Start the timer when the aircraft leaves the hand of the pilot and stop it when it hits the ground. Fly just one plane at a time. The average ((Flight 1 + Flight 2) /2) of the two flights will be the score.



PROCEDURE – Remember, the emphasis of this activity is not on the aerodynamics of the gliders or who wins the contest, but on the process that produced the plane. Students will have experience with communicating and working as a team and some of the problems that go along with management – worker relationships.

1. Before you begin the lesson, and once you have the attention of the class, throw a paper airplane.
2. Launch a discussion regarding predictions on the lesson related to the paper airplane.
3. Review how aerospace companies work, using the background information provided above as well as the first few slides from the NASA PowerPoint presentation related to this lesson. (https://www.grc.nasa.gov/WWW/K-12/airplane/TeamAct/teamwork.html)

4. Explain to the students that they are going to be asked to do something that they already know how to do: build and fly an airplane, but with a twist. The students will be working together as an aerospace "company".

5. Show the video, "How NASA Used Teamwork to Reach Saturn: Science of Teams" to demonstrate the importance of teamwork in aerospace. (https://youtu.be/e-hPjkBooM4)

6. Ask students to get into their "company groups" that were predetermined, if they are not already sitting at their "company" table. Tell the students to come up with a creative name for their "company". Within the groups, have the team members assign one of the following positions (task cards included at the end of the Procedures) to each person in the "company":

- Manager: Responsible for the operation of the company and makes the decisions about the response to RFP's from the users. The manager is the contact person between the user and the company. The manager also has contact with the Design Engineer, Manufacturer, and Test Engineer.
- Design Engineer: Provides inputs to the manufacturer of how the airplane should be built. Receives inputs from the Test Engineer of problems that occurred in testing so the changes can be made to the airplane.
- Manufacturer: Makes the airplane and changes the airplane with input from the Design Engineer.
- Test Engineer (Pilot): Flies the airplane and communicates any problems to the Design Engineer.

7. Mention that NASA has just issued an RFP for a paper airplane to be used in student outreach activities at the NASA Visitor's Center locations all over the United States. Project or display the RFP below and go over the specific criteria and constraints with the students.

8. Inform the students that you (the teacher) represent NASA (the "user") as the judge of each of the air planes created by the different companies to find the winner of the contract. The awarding of the contract will be determined by a fly-off.

9. Tell students that each company will be building a single prototype aircraft using the colored paper. Pass out a different color of paper to each company.

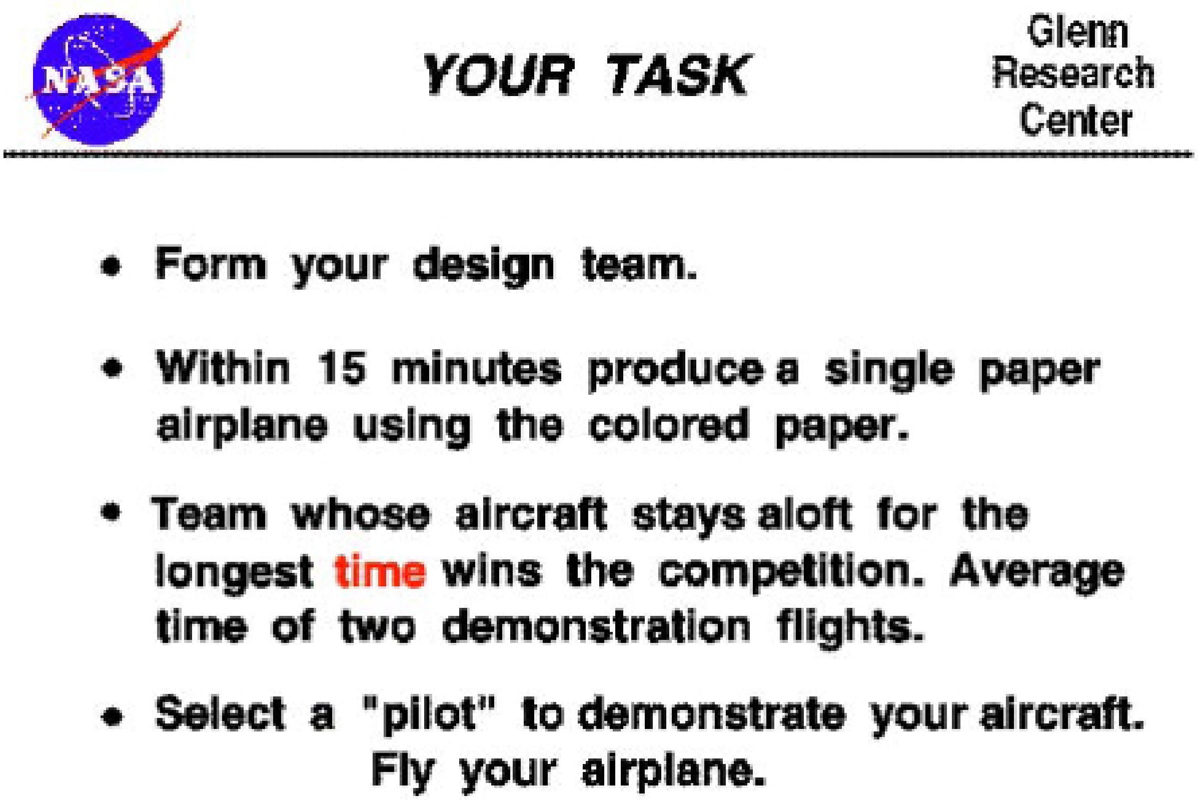
Request for Proposal — Glenn Research Center

- **NASA Glenn Research Center requires a new, paper, glider aircraft for its Visitor Center student projects.**
- **The aircraft is to be hand launched with no other external or internal source of power.**
- **The aircraft is to be optimized for time aloft, not speed or distance travelled.**
- **The aircraft is to be constructed from a single, 8 1/2 x 11 sheet of typing paper.**

10. Let the students know that they will have 15 minutes to produce the aircraft on the official colored paper. The white paper is to be used for testing different aircraft ideas. When the "company" has decided on the final prototype, it should be constructed out of the colored paper. This is the aircraft that will be used for the competition. The "company" may not compete with a white aircraft. If there is no aircraft made from colored paper, the "company" does not have a qualifying prototype.

11. The "company" whose aircraft stays aloft for the longest time wins the competition. Two demonstration flights will be conducted, and the average will be used to determine the winner. Teams may test their aircraft at any time before the final competition, however the contract will be awarded solely on the performance during the fly-off.

12. Make sure the students know that once the 15 minutes are up, the companies need to meet at the competition area (predetermined by the teacher) with all team members present. The Design Engineer (pilot) will be the one demonstrating the aircraft. "Companies" will go one at a time. Below are the rules for the fly-off. This slide is also included with the website listed at #3.



13. Before you start the timer, review the roles in the "company." Tell the students that the only person who may communicate with the user (NASA) is the manager of the "company."

14. Allow students time to build and test their prototype.

15. Conduct the fly-off following the "Management Tips" listed above.

16. After the competition, have the "companies" answer the debriefing questions as a group and have the manager present the group answers to the class. The debriefing questions are included in the Power Point mentioned in #3 as well as at the end of the activity.

17. Evaluate students based on how well they worked as a "company" and the insights they gained from the activity as evidenced by the answers to the debriefing questions.

18. At the conclusion of the activity, show the raw footage of NASA celebrating the Mars Rover Landing by the Associated Press. This video shows the true euphoria that is felt when teamwork is successful. (https://youtu.be/dkVBXW4JeUI)

Task Cards for "Company" Jobs

Manager Tasks

Glenn Research Center

- Keep team focused and on-schedule.
- Resolve any conflicts.
- Communicate with customer.
- Within 15 minutes produce a single paper airplane using the colored paper.
- Team whose aircraft stays aloft for the longest time wins the competition. Average time of two demonstration flights.

Design Engineer Tasks

Glenn Research Center

- Follow the directions of the manager.
- Design aircraft and communicate design to the manufacturer.
- Refine your design based on input from test engineer / pilot.
- Do NOT build.
- Do NOT fly.

Test Engineer – Pilot Tasks

Glenn Research Center

- Follow the directions of the manager.
- Test fly the aircraft produced by the manufacturer.
- Communicate your findings to the design team.
- Do NOT modify the airplane.
- Fly the final competition.

Manufacturer Tasks

Glenn Research Center

- Follow the directions of the manager.
- Construct aircraft based on input from the design engineer and provide aircraft to the test engineer.
- Modify the aircraft based on input from the test engineer / pilot and design engineer.
- Produce the final aircraft using the blue sheet of paper.
- Do NOT design.
- Do NOT fly.

EXTENSIONS:

- Anomalies (something that deviates from what is standard, normal, or expected) can be introduced with such changes as:
  - One member of a company is hired by another company and the person doing that job has to interview to work in another company.
  - There is a shortage of supplies to complete the project.
  - The "user" changes the requirements before the completion of the aircraft.
- Team building Resources:
  - Team building activities: http://nmctso.com/wp-content/uploads/2015/10/DECA-teambuildinggames.pdf (from Ohio DECA Leadership Retreat)
- For more information on aerospace:
  - Careers in Aerospace, Teamwork Activity, Space, Aeronautics http://www.grc.nasa.gov/WWW/K-12/airplane/topics.htm

Name: ______________________________ Date: ______________

COMPANY DEBRIEFING QUESTIONS

Name of Company: ______________________________
Manager: ______________________________
Design Engineer: ______________________________
Manufacturer: ______________________________
Test Engineer (Pilot): ______________________________

After the fly-off competition, have your company come together and answer the questions below:

1. How did your team arrive at a design? Did you consider more than one design?

2. Did everyone participate in the aircraft activity and contribute the skills they were assigned? Explain.

3. Did your company feel constrained or pressured by the time limit? By the paper limit?

4. Did you worry about other teams using your ideas? Explain.

5. Did you share information with your team members? Explain.

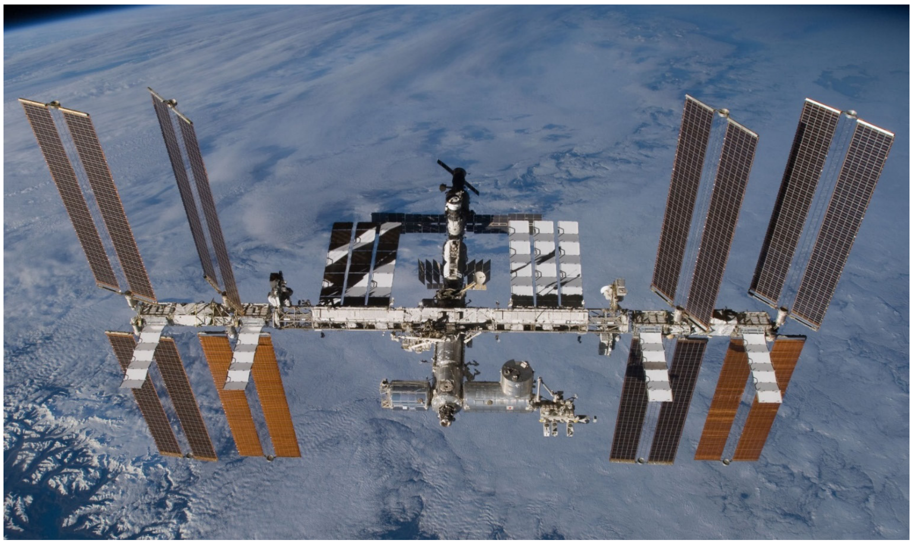
6. How well did you work with your company manager?

7. Working as a team, how would you improve your company's production in the future?

Building the International Space Station

Based on the NASA Activity

OBJECTIVE – Students will be able to learn about the importance of teams in the aerospace industry and demonstrate the importance of teamwork.



NATIONAL STANDARDS –

Next Generation Science Standards (www.nextgenscience.org):

Disciplinary Core Idea Progressions

Life Science Progression

- HS LS1.D: Information processing
- HS LS4.C: Adaptation
- HS LS2.D: Social interactions and group behavior

Crosscutting Concepts

- Systems and system models
- Structure and function

Science and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
6. Constructing explanations (for science) and designing solutions (for engineering)
8. Obtaining, evaluating and communicating information

BACKGROUND – (Information from https://www.nasa.gov/mission_pages/station/cooperation/index.html and https://www.space.com/16748-international-space-station.html)

The International Space Station (ISS) Program's greatest accomplishment is as much a human achievement as it is a technological one—how best to plan, coordinate, and monitor the varied activities of the Program's many organizations. An international partnership of space agencies provides and operates the elements of the ISS. The principals are the space agencies of the United States, Russia, Europe, Japan, and Canada. The ISS has been the most politically complex space exploration program ever undertaken.

Activity Seven: Building the International Space Station

The International Space Station Program brings together international flight crews, multiple launch vehicles, globally distributed launch, operations, training, engineering, and development facilities, communications networks, and the international scientific research community. Elements launched from different countries and continents are not mated together until they reach orbit, and some elements that have been launched later in the assembly sequence were not yet built when the first elements were placed in orbit.

Operating the space station is even more complicated than other space flight endeavors because it is an international program. Each partner has the primary responsibility to manage and run the hardware it provides. Construction, assembly, and operation of the International Space Station requires the support of facilities on the Earth managed by all the international partner agencies and countries involved in the program. These include construction facilities, launch support and processing facilities, mission operations support facilities, research and technology development facilities, and communications facilities.

The first module of the International Space Station, known as Zarya, was placed in orbit on the 20th of November 1998, by a Russian Proton Launch system. On December 3 of that year, a second module, known as Unity, was put into orbit by our Space Shuttle and the two units were joined together. This was the culmination of a long, turbulent process of funding problems and international cooperation. Actual planning began in the 80s; however, dominance of the program by the U.S. didn't set well with many of the countries scheduled to be involved in the project. Over a period of several years, projected costs forced many of the potential partner nations to withdraw support and funding. A continuous downsizing and arguments over its mission almost brought about cancellation of the project.

In 1993, President Clinton gave NASA the task of reorganizing and restructuring the ISS program. Using expertise and existing space hardware, the US and Russia were able to cut projected costs by nearly 40%. The U.S. was able to negotiate an agreement with Russia as a result of this new partnership—the former Soviet Union agreed to stop the sale of ballistic missile components to other countries and to maintain strict control over the export of strategic weapons technology. Another benefit was the expertise and technology gained by the Russians from their experience in long term manned flight aboard the MIR space station. Its main construction was completed between 1998 and 2011, although the station continually evolves to include new missions and experiments. It has been continuously occupied since November 2, 2000.

Involving the U.S., Russia, Canada, Japan, and the participating countries of the European Space Agency, the International Space Station is one of the most ambitious international collaborations ever attempted. The largest space station ever constructed, the ISS continues to be assembled in orbit. It has been visited by over 230 astronauts from 18 countries—and counting, with top participating countries being the United States (145 people) and Russia (46 people) as of early 2018. The ISS currently includes contributions from 15 nations. Current plans call for the space station to be operated through at least 2024 with a possible extension.

The ISS flies at an average altitude of 248 miles (400 kilometers) above Earth. Every 90 minutes, it circles the Earth at a speed of 17,500 miles per hour.

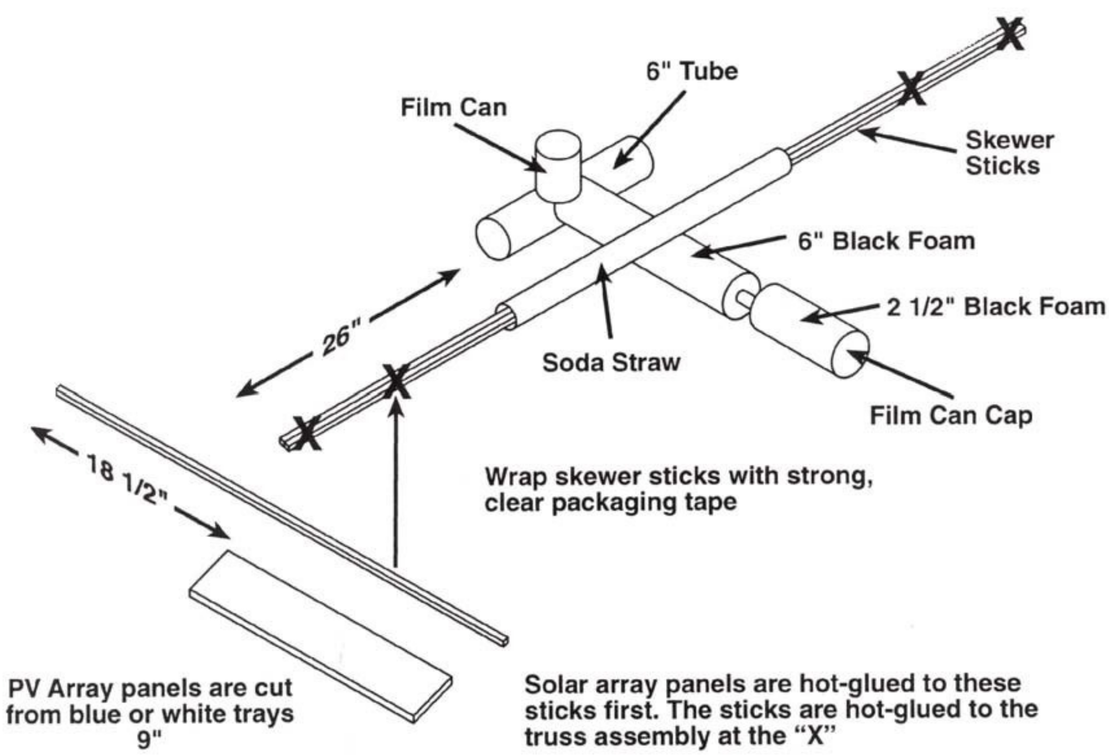
ADDITIONAL VIDEOS FOR BACKGROUND INFORMATION ON THE INTERNATIONAL SPACE STATION:

- Everything About Living in Space by NASA Johnson (https://youtu.be/ouDKD9G9jOE)
- NASA's Tour of the International Space Station by NASA's Marshall Space Flight Center (https://youtu.be/nJj4K4WdRuk)
- Life on the International Space Station by Andy C (https://youtu.be/tgRMAVoHRbk)

MATERIALS (per group) – This model can be built in stages; however, it is recommended that all the supplies are gathered by the first build session.

a. Twelve long bamboo skewer sticks (these can be purchased at grocery stores) or dowel rods
b. Two large straws
c. Eight foam meat trays, preferably the ones that have one side "waffled" and are blue (found at meat markets, blue makes the PV array panels more realistic)
d. Pieces of polyethylene pipe foam insulation (for 1/2" size pipe) or empty toilet paper or paper towel rolls
e. Plastic lids (recycled from used cylindrical containers such as Pringles™ chips) or 35mm film canister caps
f. Packing tape or duct tape
g. Fishing line (to hang the finished model)
h. Hot glue/hot glue guns
i. Super glue

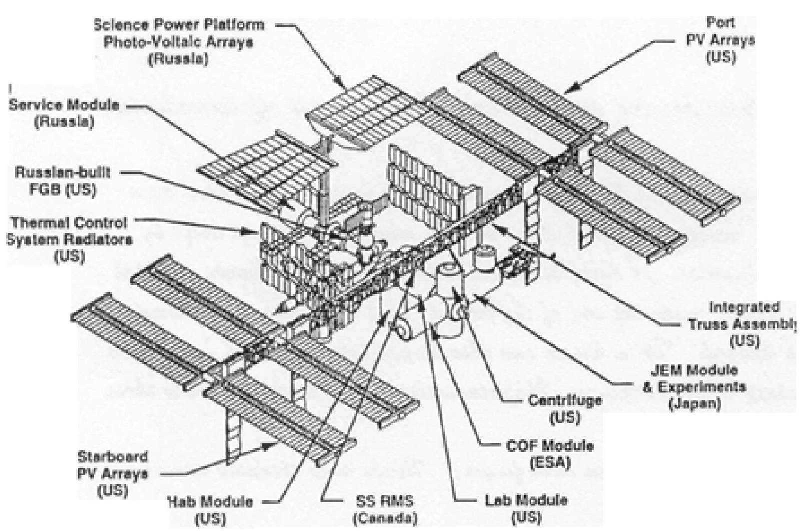
MANAGEMENT TIPS – Divide the class into predetermined groups and have them work together to create the model of the ISS. It is recommended that the Station is built in stages so that students can study each module as an individual lesson. Foam tubing is preferred because it is very light and weight is a factor in how the ISS "mobile" will look when completed, however cylinders made of cardstock or empty toilet paper or paper towel rolls work quite well.



PROCEDURE – Build with small groups of students collaborating to create the ISS model.

1. The bamboo skewer sticks are "stacked" together for the integrated truss assembly component shown in the "International Space Station Assembly" illustration above.
2. These skewer sticks (4-6) are first taped together in the center to hold them in a bundle. This is done by wrapping them with a long, single piece of packaging tape.
3. If your bundle isn't too bulky, you should be able to push a large straw over the bundle covering the tape. Check the illustration above.
4. Using a hot glue gun, bond four skewer sticks at the positions shown on the illustration (noted by the "X"). These will be the frames for attaching the PV Array Panels.
5. Cut out at least 8 PV Array Panels from your supply of foam meat trays. These are 9 inches long and about 2 inches wide.
6. The PV Array Panels are bonded to the bamboo skewer sticks as shown in the illustration.
7. Lengths of pipe foam tubing or empty paper towel/toilet paper rolls are used to make the main modules using the illustration as a guide.
8. Plastic lids or film canister lids are used to "cap" the open tube "modules."
9. Using the "ISS Assembly Complete Illustration" as a guide (below), students can make more modules and arrays to improve accuracy.
10. Once complete, fishing line can be used to hang this replica in a classroom.
11. By using the websites listed below in the Extensions section, students can study each component as it is built into the ISS and a discussion can be facilitated for deeper learning.
12. Optional: Students can complete research questions related to the International Space Station. A student response sheet as well as the suggested research questions and answers are at the end of this activity.
13. Optional: Students can create a special module to connect to the ISS for a specific continuing mission of their choice. They should explain what the mission will be, how the module will appear, how it will be manned, and the explanation of why it is important. They should use a picture (either computer created or other art medium) to show the design. A template is attached at the end of this activity.

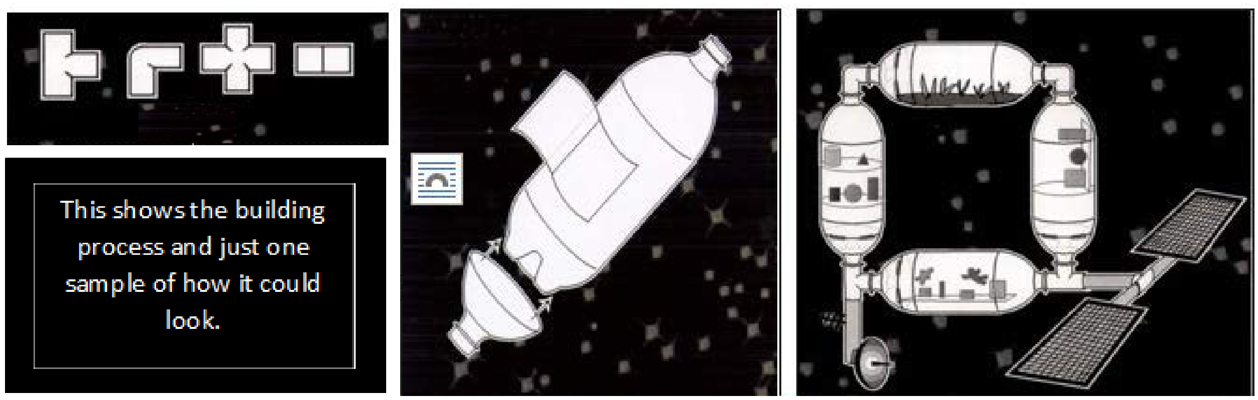
INTERNATIONAL SPACE STATION ILLUSTRATION



International Space Station Assembly Complete

EXTENSIONS:

- Expand this project using clear plastic soda pop bottles. The smaller Coke® or Pepsi® bottles can be used instead of the foam pipe insulation material. Bamboo is very strong and will support quite a bit of weight. To keep the main Integrated Truss Assembly from bending with the additional weight, it is recommended that more sticks be used.
- Construct another type of Space Station Model:
  - Materials needed: PVC pipe connectors, 2-liter soft drink bottles, cardboard, aluminum foil, sharp scissors, glue, other materials for visual effects.
  - Building Tips:
- Connect bottles with PVC joints, then cut the bottles and design the compartments.
- Each of the larger bottles can be filled with tiny "Astronauts" and equipment so that students can see what each module is being used for. The complexity depends upon the age level of students involved in the project.
- Try to include a science laboratory, an equipment and supply storage unit, living quarters, a solar array to power the Station, and a robotic arm to service all parts of the station.



  - Use the "Gallery" section of Boeing's web site listed below to see some very dramatic images of the Space Station. This site has a tremendous amount of information about the ISS.
- Sketch and build a future Space Station using the knowledge gained in this lesson.
- For more information, please visit these International Space Station websites:
  - International Space Station: www.nasa.gov/station
  - Station Science: www.nasa.gov/iss-science
  - ISS (NASA link): http://spaceflight.nasa.gov/station
  - Reference Guide to the International Space Station: https://www.nasa.gov/sites/default/files/atoms/files/np-2015-05-022-jsc-iss-guide-2015-update-111015-508c.pdf
  - Spot the Station (International Space Station worldwide location): https://spotthestation.nasa.gov/
  - ISS (Boeing site): http://www.boeing.com/defense-space/space/spacestation
  - ISS Activity Book: https://www.nasa.gov/sites/default/files/atoms/files/iss_activity_book.pdf

Name: ______________________________ Date: ________________

INTERNATIONAL SPACE STATION RESEARCH QUESTIONS

Please visit www.nasa.gov/station or https://www.boeing.com/space/international-space-station/ to help you discover the answers to the questions about the ISS.

1. What is the volume of the pressurized living and working space aboard the International Space Station?

2. What launch vehicles were used to haul the parts of the Space Station into orbit?

3. What is the purpose of two of the computers in the U.S. Laboratory module?

4. What countries make up the European Space Agency (ESA)?

5. What areas of science have been done in the ISS?

6. How do astronauts aboard the Space Station communicate to students on Earth?

7. What does a typical work day consist of for astronauts aboard the Space Station?

8**.** How high above the Earth does the Space Station orbit?

9. What does the Space Station mean for the future of space travel?

10. How fast does the Space Station Travel and how long does it take to orbit the Earth?

ISS Research Questions (Answers in Italics):
(Use NASA's site www.nasa.gov/station at Boeing's site at:
https://www.boeing.com/space/international-space-station/

1. What is the volume of the pressurized living and working space aboard the International Space Station?
34,700 cubic feet (habitable volume of 14,400 cubic feet); The space station has an internal pressurized volume equal to that of a Boeing 747

2. What launch vehicles were used to haul the parts of the Space Station into orbit?
U.S. Space Shuttle (retired) and the Russian Proton and Soyuz Rockets

3. What is the purpose of two of the computers in the U.S. Laboratory module?
They are dedicated to keeping the station in proper orientation (attitude) as it orbits the Earth once every 90 minutes.

4. What countries make up the European Space Agency (ESA)?
Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom

5. What areas of science have been done in the ISS?
Microgravity, Research and Technology, Space Product development, Space Science, etc.

6. How do astronauts aboard the Space Station communicate to students on Earth?
Astronauts communicate over ham radio sponsored by the ARISS (Amateur Radio on the International Space Station).

7. What does a typical work day consist of for astronauts aboard the Space Station?
In a typical work day, crew members spend 12 hours working, 2 hours exercising, 1.5 hours preparing and eating meals, and 8.5 hours sleeping.

8. How high above the Earth does the Space Station orbit?
About 250 miles above Earth

9. What does the Space Station mean for the future of space travel?
If humans are to travel to other planets, such as Mars, we must understand the effects of such long journeys on the human body. The Space Station allows scientists to understand these effects and study solutions for long-term space travel.

10. How fast does the Space Station Travel and how long does it take to orbit the Earth?
The Space Station travels at about 17,500 miles per hour and it takes 90 minutes to orbit the Earth… that's 16 times a day! (about 5 miles per second is also acceptable)

Activity Seven: Building the International Space Station

Name: ______________________ Date: ______________

Module Name: ______________________

Module purpose/mission: ______________________

Module appearance: (Sketch with appropriate labels)

Module staff: ______________________

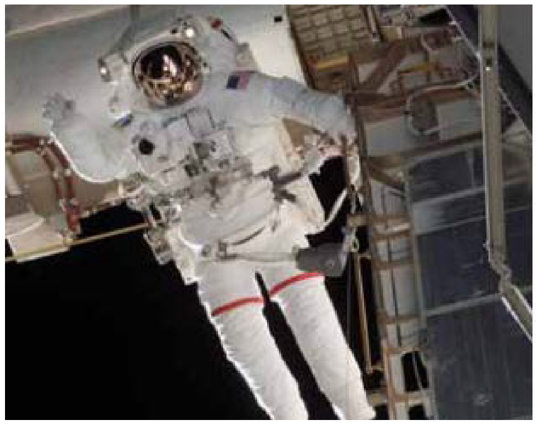
Module justification/importance: ______________________

UNDER PRESSURE

Experimenting with a Hands-On Vacuum Environment and Pressure Suits

Based on NASA's Museum in a Box: Why Do We Really Need Pressure Suits?

OBJECTIVE – Students will be able to create a miniature pressure chamber and observe the effects of various amounts of air pressure. Students will be able to design a prototype for retaining an object at normal pressure, simulating the effects of a pressure suit.



NATIONAL STANDARDS –

Next Generation Science Standards (www.nextgenscience.org):

Disciplinary Core Idea Progressions

Life Science Progression

- HS LS1.A: Structure and function

Physical Science Progression

- HS PS1.A: Structure of matter
- HS PS2.A: Forces and motion
- HS PS3.C: Relationship between energy and forces
- HS PS4.C: Information technologies and instrumentation

Crosscutting Concepts

- Energy and matter
- Systems and system models
- Stability and change
- Structure and function

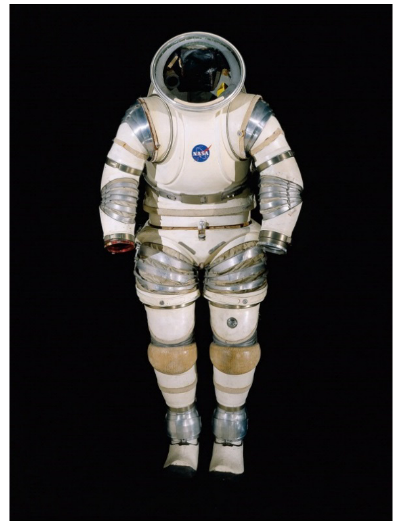
Science and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and Interpreting Data
6. Constructing explanations (for science) and designing solutions (for engineering)
8. Obtaining, evaluating, and communicating information

BACKGROUND – (from https://www.nasa.gov/sites/default/files/atoms/files/dressing_for_altitude.pdf)

Pressure is defined as the amount of force applied per unit area or as the ratio of force to area (P=F/A). The pressure an object exerts can be calculated if its weight (the force of gravity on an object) and the contact surface area are known. For a given force (or weight), the pressure it applies increases as the contact area decreases. Air pressure decreases with increasing altitude.

Humans are relatively permeable to air (it can move easily in and out of our bodies) and that is why our internal pressure stays the same as the pressure of the surrounding (ambient) air. This is the same reason why fish are not crushed in the depths of the ocean; they are permeable to water. Although the atmosphere exerts a significant amount of pressure on everything in our environment, the only time most people are aware of air pressure is when it changes (such as changes in altitude, for example, as you drive up a mountain).



Engineers who design airplanes study air pressure. Airplane cabins are “pressurized.” This means the inside of the plane maintains a constant pressure of about 14 pounds per square inch regardless of the pressure outside of the cabin. At high altitudes, the air has a very low pressure, which affects the way we breathe.

As elevation increases, air pressure decreases, and when we fly at high altitudes, the low pressure in these areas would be impossible for humans to survive in if it weren’t for human made enclosures. In airplanes and spacecraft, internal cabins or cockpits are pressurized to help humans function. Since outside air pressure and density are higher near the ground, commercial aircraft have a higher internal air pressure during takeoff and landing to more closely match the outside air pressure.

Spacewalkers must wear pressurized spacesuits in order to work in space. These suits have pressures significantly lower than the ambient cabin pressure of a spacecraft. This makes spacewalkers subject to decompression sickness, more commonly known as the “bends.” Decompression sickness results from nitrogen bubbles forming in the tissues or blood stream and moving to other areas of the body. Therefore, spacewalking crew members must perform a pre-breathe protocol, which is designed to wash out any excess nitrogen from the body, before a spacewalk.

Because of the human body’s vulnerability in low-pressure environments, there has been years of research and development of methods to help humans both survive and function in low-pressure situations. These situations can be anything from spacewalking astronauts to high altitude pilots and balloonists. The higher the altitude, the more serious the effects on the human body. To understand exactly what would happen if your body was exposed to the vacuum of space, watch this video by SciShow: https://youtu.be/pm6df_SExVw.

Pressure Suits

When high-altitude pilots and astronauts travel above the lower layers of Earth’s atmosphere, the air pressure exerted on them would be significantly reduced if they were not protected from the outside environment by a pressurized cockpit or capsule or a specially designed suit. This reduction in air pressure would be harmful or even fatal to a pilot or astronaut.

To protect pilots from this situation, engineers have developed various types of pressure suits that allow pilots and astronauts to function in these environments. Pressure suits exert pressure on the human body when external environments lack the pressure usually provided by the air at lower altitudes. In the event of aircraft cabin pressure loss at high altitudes, like 70,000 feet, where high-altitude aircraft such as the U-2 fly, engineers have developed partial pressure and full pressure suits. Development of high-altitude pilot suits led to the evolution of the spacesuit. Loss of cabin pressure on aircraft flying at lower altitudes results in hazards to flyers such as loss of consciousness or hypoxia but does not lead to other medical problems experienced by flyers at higher altitudes. So, how does a reduction in air pressure, whether high in Earth’s atmosphere or in space, affect living organisms? The following activities allow students to simulate the effects of reduced pressure on objects and to develop their own “pressure suits” to tackle the challenge of preventing those effects.

MATERIALS (per group) –

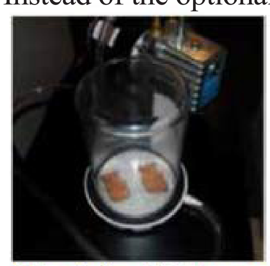
a. Large plastic syringes with caps or pieces of clay to plug the ends of the syringes (must be large enough for a small marshmallow to fit inside easily and can be purchased through a medical supply company or pharmacy)
b. Small marshmallows
c. Various materials for students to develop a pressure suit for their marshmallows (items could include tape, latex or nitrile gloves, and small pieces of paper that could be used to cover the small marshmallow)
d. Student Data Sheets
e. Optional for demonstration purposes: Peep® or large marshmallow and vacuum pump and jar

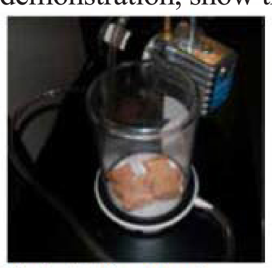
MANAGEMENT TIPS – Advise the students that they should never eat their experiments, even if the materials are edible. Eating during experiments is not a good safety practice. Also, always use a cap or piece of clay to cover the syringe tip opening (don't use your finger as a cap) to avoid injury. When students are designing a pressure suit for their small marshmallow, remind them that the marshmallow encased in the pressure suit needs to fit completely inside the plastic syringe to perform the testing. Activity hints: There are also many variations to a pressure suit that work for this activity: cutting off fingers from rubber gloves (not latex, but thick, cleaning gloves), using tape to restrict expansion, etc.

PROCEDURE –

Part 1: Experimenting with a Marshmallow and a Vacuum Chamber

1. Show the video "What happens to Peeps® in a vacuum chamber?" (https://www.youtube.com/watch?time_continue=171&v=EIvkOCRiSoI) and follow the video with a conversation on what happened to the Peep® when the vacuum chamber was turned on as well as when it was repressurized. Have them explain the reaction.
Optional for demonstration purposes: Introduce the activity by showing the students a marshmallow or Peep® and asking what they think will happen when you place it in the vacuum and why. Discuss the predictions as a class and then place the marshmallow or Peep® in the bell jar. Turn on the vacuum pump and have the students observe how the size changes. Ask the students why they think this is happening. When finished, turn off the pump and repressurize the chamber. Have students observe what happens to the marshmallow or Peep®. If necessary, explain that the air has been forced out of the marshmallow or Peep® during the vacuum process. Based on that piece of information, ask them to explain why the marshmallows are now shriveled once air pressure has been reintroduced.
Note: Instead of the optional demonstration, show the picture below or a video demonstration.


Marshmallow Peeps before the vacuum pump was turned on.


Marshmallow Peeps during air evacuation from pump.


Marshmallow Peeps at full vacuum.


Marshmallow Peeps after repressurization.

2. Discuss the background information with the students. Have them discuss what the purpose of a pressure suit is and the situations in which you would use one (e.g. high-altitude pilots, spacewalkers, high-altitude balloonists, deep-sea divers.)
3. Explain to the students that although watching demonstrations about pressure is helpful, allowing them to create a vacuum and manipulate their own mini vacuum chamber will strengthen their understanding about the effects of air pressure.
4. Allow the students to work in small groups of 2-3, pass out the Student Data Sheet and have them gather the materials.

5. Instruct the students to follow the steps listed on the Student Data Sheet to complete the experiment. Suggested answers are below in italics.
   1. Have students place a small marshmallow inside their syringe.
   2. Have students replace the plunger of the syringe, making sure the rubber piece is about halfway down the syringe.
   3. Once the plunger is in place, have students put the cap or the piece of clay on the tip of the syringe.
   4. Once students have capped the tip of the syringe, ask students to pull back on the plunger, creating a lower pressure environment. Students should note what happens to the marshmallow. (*a. pressure is decreasing, b. the marshmallow expands)*
   5. Also have students push the plunger in as far as they can to create a higher-pressure environment, again noting what happens to the marshmallow.
   (*a. pressure is increasing, b. the marshmallow will shrivel up*)

6. Let students experiment on their own with the marshmallow, noting the effects of changes in air pressure inside the syringe as they do so. Remind students that the effects of pressure on the marshmallow are similar to effects on human bodies as they go higher into Earth's atmosphere and then into space (the higher they go, the less pressure is exerted on them), but also as they travel underwater (the deeper they dive or swim, the more pressure is exerted on them).

Part 2: Designing a Pressure Suit for a Marshmallow

7. Review again the results of the experiment and provide more background information about pressure suits, specifically, and the needs for humans to have the restraint layer of the suit as they function in high altitudes and/or in space.

8. Explain to the students that they will need to design a pressure suit for their marshmallow that will keep it from expanding like it did in the earlier demonstration.

9. Have the students follow the Student Data Sheet to brainstorm and design their pressure suit, making sure to label the materials needed. Remind them that the pressure suit needs to fit on the marshmallow and must still be able to be inserted into the syringe.

10. Allow the students to build their suits from the available materials.

11. Test the designs in the syringe vacuum chamber. If there is room in the syringe, use an unprotected marshmallow as the control inside the chamber. Record results on the Student Data Sheet.

12. Allow students to refine their designs and retest, using a new marshmallow.

13. Finally, have the students present their pressure suit prototypes to the class. Encourage students to explain and share their designs, along with any challenges, hurdles, or failures along the way.

14. Go over the Post-Lab Questions as a class and extend as necessary.

EXTENSIONS

- To better understand how pressure increases as the surface area decreases, have students hold a large book flat on their outstretched hands and notice how much pressure the book puts on it. Then, try to balance the book on the tip of their index fingers. How much pressure does it seem to exert now?
- The NASA Dressing for Altitude: U.S. Aviation Pressure Suits— Wiley Post to Space Shuttle, is a book about the development and operation of pressure suits in aviation and access to space via the Space Shuttle. This book contains more detailed information about pressure suits and can be accessed as a free download in multiple formats for most platforms from the following location: http://www.nasa.gov/connect/ebooks/dress_for_altitude_detail.html.
- Investigate these websites for further information:
  - Space Suit Evolution: https://history.nasa.gov/spacesuits.pdf
  - Bill Nye the Science Guy on Pressure: https://www.youtube.com/watch?v=UDdRNXhIDwA

Name: ______________________________ Date: ______________

UNDER PRESSURE: Student Data Sheet

Part 1: Experimenting with a Marshmallow and a Vacuum Chamber

For this activity, you will be creating a miniature pressure chamber with a large plastic syringe and a cap or piece of clay to seal the tip of the syringe. Follow the instructions below and complete the questions.

Be sure to follow the steps in the correct order so you can create the proper pressure within your chamber.

1) Place a small marshmallow inside your syringe.

2) Replace the plunger of the syringe, making sure the rubber piece is about halfway down the syringe.

3) Once the plunger is in place, put the cap or the piece of clay on the tip of the syringe. **Do not place the cap on the tip of the syringe until the plunger is halfway down the inside of the syringe or you will not be able to properly change the pressure inside your chamber.**

4) Once you have capped the tip of the syringe, pull back on the plunger.
   a) What is happening to the pressure as you pull back on the plunger? Explain this in a complete sentence and draw a picture of the air molecules inside the syringe at this point.

   b) What happened to the marshmallow? Explain in a complete sentence and draw a picture.

5) Now push the plunger in as far as you can.
   a) What is happening to the pressure as you push in the plunger? Explain this in a complete sentence and draw a picture of the air molecules inside the syringe at this point.

b) What happened to the marshmallow? Explain in a complete sentence and draw a picture.

6) Experiment on your own with the marshmallow, noting the effects of changes in air pressure inside the syringe as you do so. The effects of pressure on the marshmallow are similar ti effects on the human bodies as they go higher into Earth's atmosphere and then into space (the higher they go, the less pressure is exerted on them). In addition, increasing the air pressure inside the chamber mimics the effects of traveling underwater (the deeper you dive or swim, the more pressure is exerted on you).

a) Describe some of the effects of your own experimentation with the marshmallow inside the pressure chamber.

Part 2: Designing a Pressure Suit for a Marshmallow

Describe your design for marshmallow pressure suit according to The Engineering Design Process.

1. Ask: State the challenge in your own words. ______________________________

____

____

2. Imagine: Describe your hypothesis or plan of action. ______________________________

____

____

3. Plan: Draw a sketch of your plan and label all materials.

Materials required: ____

____

____

4. Create: Procedure/Notes (What steps did you follow to complete the Design Challenge?)

____

____

____

____

____

5. Experiment: Record your test results on the data chart below.

Test #	Change Made	Observation Notes
1		
2		
3		
4		
5		
6		

6. Improve: Explain how your suit worked and why; identify any areas for improvement.

Type of Suit	Abilities of Suit	Limitations of Suit	Changes from Original Design
Original design: partial or full (circle one)			n/a
1			
2			

Post-Lab Questions

Once you have completed the above activities, answer the following questions:

1) Based on the above activities, explain how a pressure suit would help you if you were working in a high-altitude environment or up in space.

2) What is the difference between a partial pressure suit and a full pressure suit?

3) Take the design you made for your pressure suit, choose two of the following suit requirements, and explain what would have to happen to the design of your suit in order to meet them:

a) Full pressure high-altitude pilot suit

b) Spacesuit designed for working outside the International Space Station

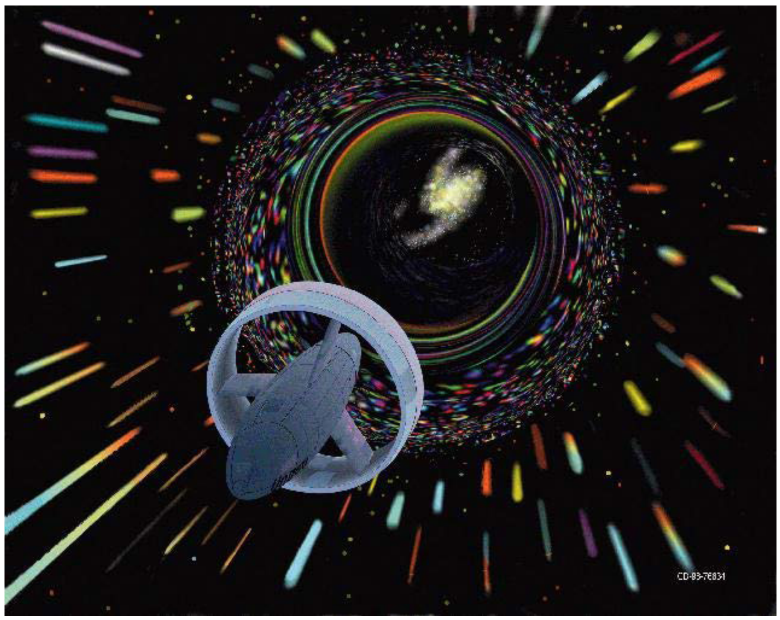
c) Emergency suit for use inside the International Space Station

d) Pressure suit for high-altitude skydiving (high-altitude skydiving occurs at least 23,000 feet above Earth's surface)

WARP IT!

A MIND-BENDING LOOK AT SPACE TRAVEL NEAR THE SPEED OF LIGHT

OBJECTIVE – Students will be able to use their mathematics and problem-solving skills in a theoretical situation related to the speed of light.



NATIONAL STANDARDS –

Next Generation Science Standards (www.nextgenscience.org):

Disciplinary Core Idea Progressions

Earth Science Progression

- HS ESS1.A: The universe and its stars

Physical Science Progression

- HS PS1.A: Structure of matter
- HS PS3.C: Relationship between energy and forces
- HS PS4.C: Information technologies and instrumentation

Crosscutting Concepts

- Patterns
- Energy and matter
- Stability and change

Science and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
8. Obtaining, evaluating and communicating information

BACKGROUND – (from https://www.nasa.gov/centers/glenn/technology/warp/warp.html)

Ever since the sound barrier was broken, people have turned their attention to how we can break the light speed barrier. However, “Warp Drive” or any other term for faster-than-light travel continues to remain at the level of speculation.

The bulk of scientific knowledge concludes that it’s impossible, especially when considering Einstein’s Theory of Relativity. There are certainly some credible concepts in scientific literature, however it’s too soon to know if they are viable. Science fiction writers have given us many images of interstellar travel but traveling at the speed of light is simply imaginary at present.

In the meantime, science moves forward. While NASA is not pursuing interstellar flight, scientists here continue to advance ion propulsion for missions to deep space and beyond using solar electric power. This form of propulsion is the fastest and most efficient to date.

There are many “absurd” theories that have become reality over the years of scientific research. But for the near future, warp drive remains a dream.

If you would like to know more about the theories of interstellar flight, you should visit the Tau Zero Foundation (https://tauzero.aero/). Marc Millis, a former NASA Glenn physicist, founded the organization to consider revolutionary advancements in propulsion. Check out one of his TedTalks for more information as well (https://youtu.be/9doOLHeW8p4).

Imagine now if we could travel in warp drive. According to known scientific theory, when traveling near the speed of light, time is altered. Here’s what the “rocket scientists” predict:

If you were traveling at these percentages of the speed of light for one year	Predicted number of years that would pass by on Earth
90%	2.294
95%	3.202
99%	7.089
99.9%	22.361
99.999%	223.607
100%	Infinite

PROCEDURE – Have students study the chart above and solve the following problems related to the speed of light and the predicted number of years that would pass. The answers are below the question in italics. There is a Student Data Sheet at the end of the activity.

1. Two neighboring families each had a child born on the same day, one year ago. One family leaves on a space trip at 90% of the speed of light and traveled in space for a period of 5 years. The second family stayed home, back here on planet Earth.
   a.How old would the Earth child be, when the space traveling family returns?
   ANSWER: *12 years old because he was 1 year old when the space traveling family left and after 5 years in space (which equates to 11.270 earth years at 90% the speed of light), the earth child would then be 12 years old.*
   b.What grade would the Earth child be in?
   ANSWER: The earth *child would be in 7th grade (or entering 7th grade).*
   c.How old would the space child be and what grade would he be in upon return?
   ANSWER: *The space child would be 6 years old since he was one when he left, and he spent 5 years away at 90% the speed of light. He would be in 1st grade.*
2. If you wanted to beat the record for being the oldest living person on Earth, you would have to beat Methuselah’s (from the Bible) age of 969 years.
   a.How long would it take you at 99.999% of the speed of light to break Methuselah’s record?
   ANSWER: *The record could be broken in a little over 4 (99.999% speed of light) years. The theoretical speed of light at 99.999% is 223.607 and 969 divided by 223.607 is a little over 4 years.*

3. Dapper Dan, an infamous, yet very clever international jewel thief, was apprehended by ace detective, Bullhorn Blodgett, in Cleveland, Ohio. "I've got all the evidence to convict you," said Blodgett, and he was right. Dan pretended to give up without a fight, but just as Blodgett was about to put the handcuffs on the felon, Dan broke loose and escaped into an awaiting spaceship (the getaway vehicle owned by a well paid friend of Dan's). The navigation system on the ship was programmed to accelerate to 99% of the speed of light and had enough fuel for a roundtrip flight of one year. Was old Dapper Dan worried that he might be taken into custody upon return to Earth? Explain your answer and back it up with mathematical calculations.

   ANSW*ER:* *The roundtrip flight of one year at 99% speed of light would be 7.089 years, so when Dapper Dan returned the statute of limitations would have run out on his crime.*

4. A pair of twins, one male, one female, became astronauts. The boy was made commander of a spaceship that was built to fly at 99% of the speed of light. The girl achieved a very high administrative position back on Earth as director of a large communications network. When the twins reached 30 years old, the first twin left Earth on a mission that was programmed to be six space years long. In other words, he would be "out there" for 6 years.

   a.How old was the lady when her brother returned?

   ANSWER: *The lady was 72 years old when her brother returned because when he left, they were 30 years old and he was gone 6 years at 99% the speed of light which means for every year, 7.089 earth years passed. So, 6 times 7 equals 42 and 42 plus 30 equals 72.*

   b.How old was the brother, the spaceship commander upon return to the Earth?

   ANSWER: *The brother was 36 years old upon his return because he was gone for 6 years at 99% the speed of light.*

5. Brad was 34 and Melissa was 22 when they met. It was love at first sight and they decided to get married. When the happy couple told Melissa's parents, her father exploded with anger. "Absolutely not," he said, "Brad is much too old for my Melissa and I'll never give my blessing to this marriage." Melissa cried but Brad, cool dude that he was, said, "Don't worry, I'm in the Space Command and I'll take care of everything. I'll get your dad's permission in just two years." "Oh, Brad, how is that possible?" inquired Melissa.

   a.Explain how Brad knew he could solve the problem.

   ANSWER: *Brad knew he could solve the problem because he would go into space at 99% the speed of light for 2 years, which would be 7.089 earth years for each year. When he returned he and Melissa would both be 36.*

   b.Prove it mathematically.

   ANSWER: *7 x 2 = 14 and Melissa was 22 + 14 = 36. Brad was 34 and, being gone 2 years at 99% the speed of light, when he returned, he was 2 years older or 36!*

EXTENSIONS

- Using these theories with the students, discuss the possibility that one generation of alien astronauts may have been monitoring us since ancient times and they occasionally report our progress back to their home planet.
- Conduct more research on "faster than light space travel" and "warp speed" experiments.
- Engage students in a class discussion by showing the video "Hubble Spots Thousands of Objects Traveling Faster Than Light: NASA's Unexplained Files" (https://youtu.be/RaELad94KZs).

Name: ______________________________ Date: ______________

WARP IT: Travel at the Speed of Light

Please study the chart below and use it to answer the problems.

If you were traveling at these percentages of the speed of light for one year	Predicted number of years that would pass by on Earth
90%	2.294
95%	3.202
99%	7.089
99.9%	22.361
99.999%	223.607
100%	Infinite

1. Two neighboring families each had a child born on the same day, one year ago. One family leaves on a space trip at 90% of the speed of light and traveled in space for a period of 5 years. The second family stayed home, back here on planet Earth.
a. How old would the Earth child be, when the space traveling family returns?
b. What grade would the Earth child be in?
c. How old would the space child be and what grade would he be in upon return?

2. If you wanted to beat the record for being the oldest living person on Earth, you would have to beat Methuselah's (from the Bible) age of 969 years.
a. How long would it take you at 99.999% of the speed of light to break Methuselah's record?

3. Dapper Dan, an infamous, yet very clever international jewel thief, was apprehended by ace detective, Bullhorn Blodgett, in Cleveland, Ohio. "I've got all the evidence to convict you,"said Blodgett, and he was right. Dan pretended to give up without a fight, but just as Blodgett was about to put the handcuffs on the felon, Dan broke loose and escaped into an awaiting spaceship (the get away vehicle owned by a well-paid friend of Dan's). The navigation system on the ship was programmed to accelerate to 99% of the speed of light and had enough fuel for a round trip flight of one year. Was old Dapper Dan worried that he might be taken into custody upon return to Earth? Explain your answer and back it up with mathematical calculations.

4. A pair of twins, one male, one female, became astronauts. The boy was made commander of a spaceship that was built to fly at 99% of the speed of light. The girl achieved a very high administrative position back on Earth as director of a large communications network. When the twins reached 30 years old, the first twin left Earth on a mission that was programmed to be six space years long. In other words, he would be "out there" for 6 years.
a. How old was the lady when her brother returned?
b. How old was the brother, the spaceship commander upon return to the Earth?

5.Brad was 34 and Melissa was 22 when they met. It was love at first sight and they decided to get married. When the happy couple told Melissa's parents, her father exploded with anger."Absolutely not," he said, "Brad is much too old for my Melissa and I'll never give my blessing to this marriage."Melissa cried but Brad, cool dude that he was, said, "Don't worry, I'm in the Space Command and I'll take care of everything. I'll get your dad's permission in just two years." "Oh, Brad, how is that possible?" inquired Melissa.
a. Explain how Brad knew he could solve the problem.
b. Prove it mathematically.

Activity Ten: Simple, Fun, Foam Flying Machine

The SR-71

AS A SIMPLE, FUN, FOAM FLYING MACHINE

OBJECTIVE – An easy, yet fun activity that can be built for about 50 cents and will give the entire squadron an evening of fun. It is also a test of some most unusual flying skills.

NATIONAL STANDARDS –

Next Generation Science Standards (www.nextgenscience.org):

Disciplinary Core Idea Progressions

Physical Science Progression

- PS2.A: Force and motion
- PS2.B: Types of interactions

Cross-cutting Concepts

- Systems and system models

BACKGROUND – This lesson focuses on the construction of the remarkable flying craft, the Blackbird SR-71.

MATERIALS –

a. 14" of pipe foam tubing used to insulate ¾" copper tube.
 ◦ Used as the fuselage
b. Foam meat tray to use as a template (should be larger than a sheet of paper)
 ◦ Used as wings and fins
c. Pointed drinking cups
 ◦ Used as nacelle inlet cones
d. #64 Rubber band (for launch mechanism)
e. 2 nylon cable ties (for launch mechanism)

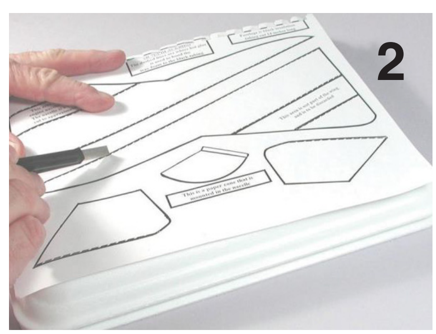
PROCEDURE –

1. The foam tubing is cut to a length of 14 inches. This seems to be the length that flies the best.

2. The template is used to cut out the meat tray foam parts. See page 99 for template.

3. A piece of sandpaper glued to a flat surface, like a paint stirring stick, works well to dress the edges of the foam pieces.

4. The inner wing is glued using a hot glue gun.

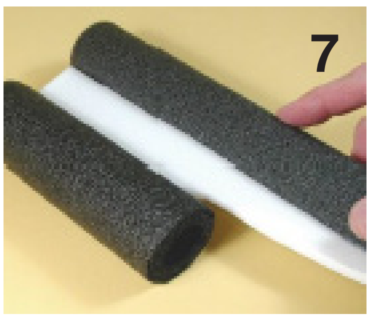


The wings and fins template is placed down on the foam meat tray as shown. Spray the backside of the template with a low-tack glue, like "Elmer's" Spray glue, as this makes it easier to trace and cut. Just be careful when cutting the foam tray - we recommend either a snap-knife (shown) or an X-Acto knife with a #11 blade.

5. NOTE: DON'T use the hot glue on the BLACK FOAM TUBING. It will burn a hole through it. THE WHITE FOAM MEAT TRAY TAKES THE HEAT MUCH BETTER.

6. Cut out the nacelles. These should be about 6 inches long-or the same length as a soda can.

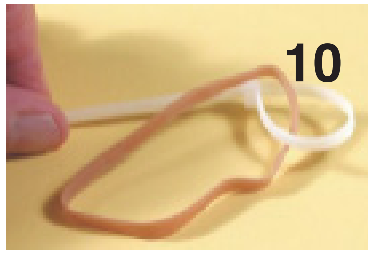
7. The nacelles are glued to the outboard edge of the inner wing panel.



8. Glue the small wing tips to the outside edge of the nacelles.

*Hot glue works on white Styrofoam® but not well on black foam tubing.

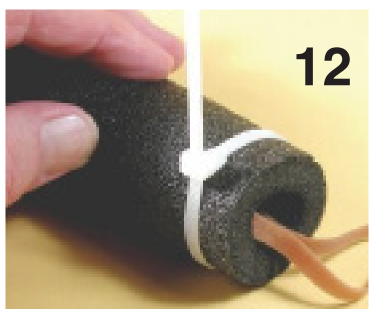
9. The fins are glued into position at this point. Note that they slant inward.



10. It's time to install the "power plant." Using a cable tie, wrap it through a #64 rubber band.Cinch it down to a one inch diameter and cut off the remaining "tail."

11. Stick the cable tie and rubber band into the open end of the fuselage. Leave about 1.5 inches of rubber band sticking out.

12. Take another cable tie and wrap it around the nose, about 3/8ths of an inch from the end of the tube.



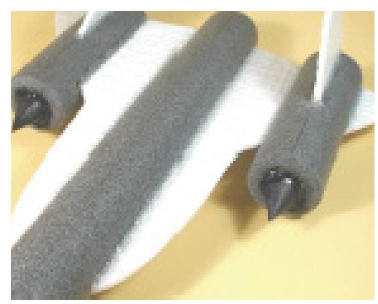
This will then be cinched down very tight to keep the rubber band and inner cable tie from coming out during launch.

13. With a strong tug, cinch this outer cable tie down hard. This will keep your inner rubber band and cable tie from slipping through.

14. Trim the tail off the fuselage tie. It is recommended to put a bead of hot glue on the cable tie so as to cover any sharp egdes.

15. If you wish to install the pointed nacelle tips, use the ends of two drinking cups and hot glue into the nacelles. If you can't find the pointed cups, simply make cones by folding paper.

The nacelle points can be made from drinking cups.



Here they've been installed with hot glue.

THE SR-71 CONSTRUCTION ILLUSTRATION.

This illustration shows how all of the pieces are to be placed. Use this as a guide along with the how-to sequence of images.

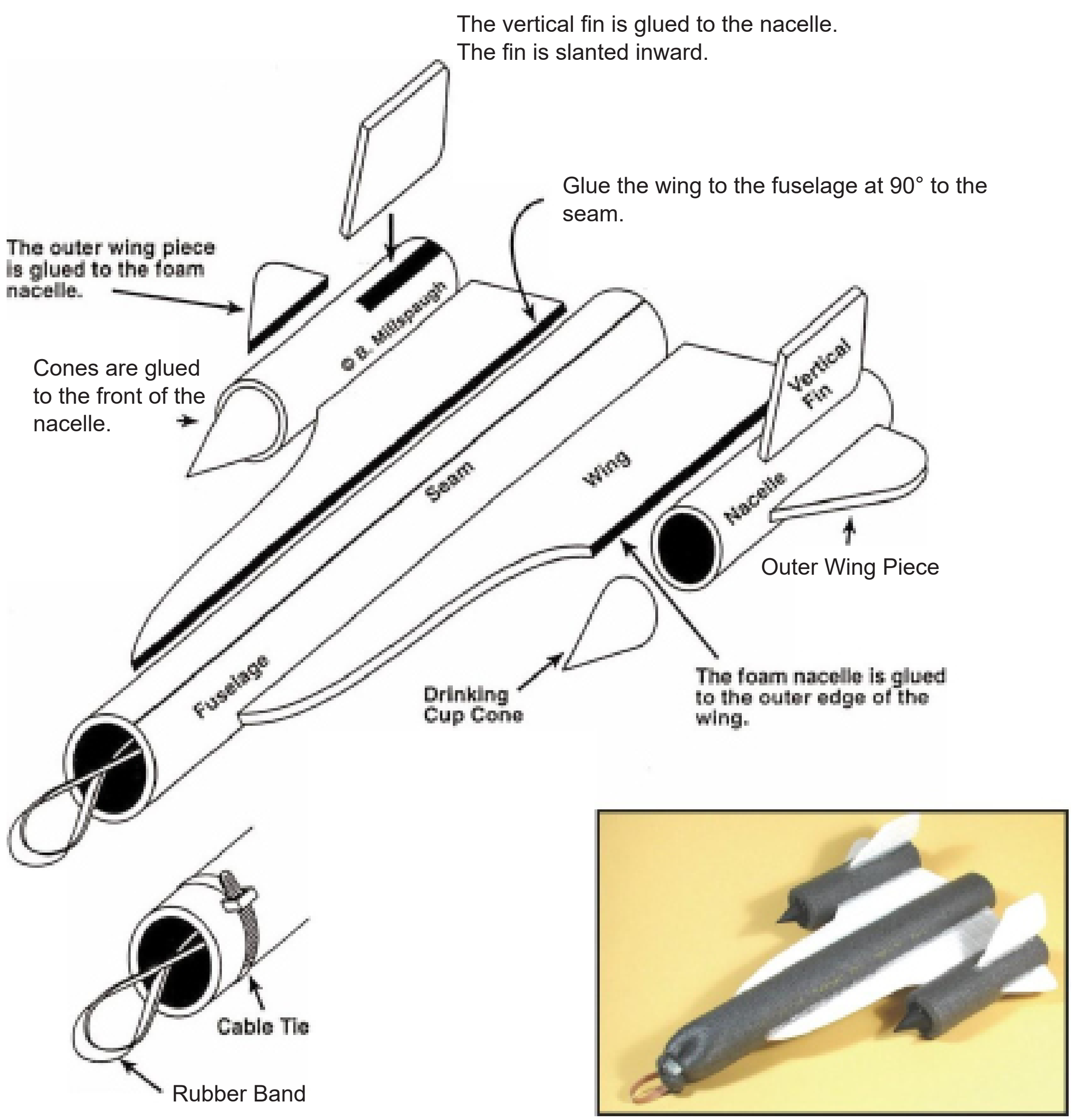


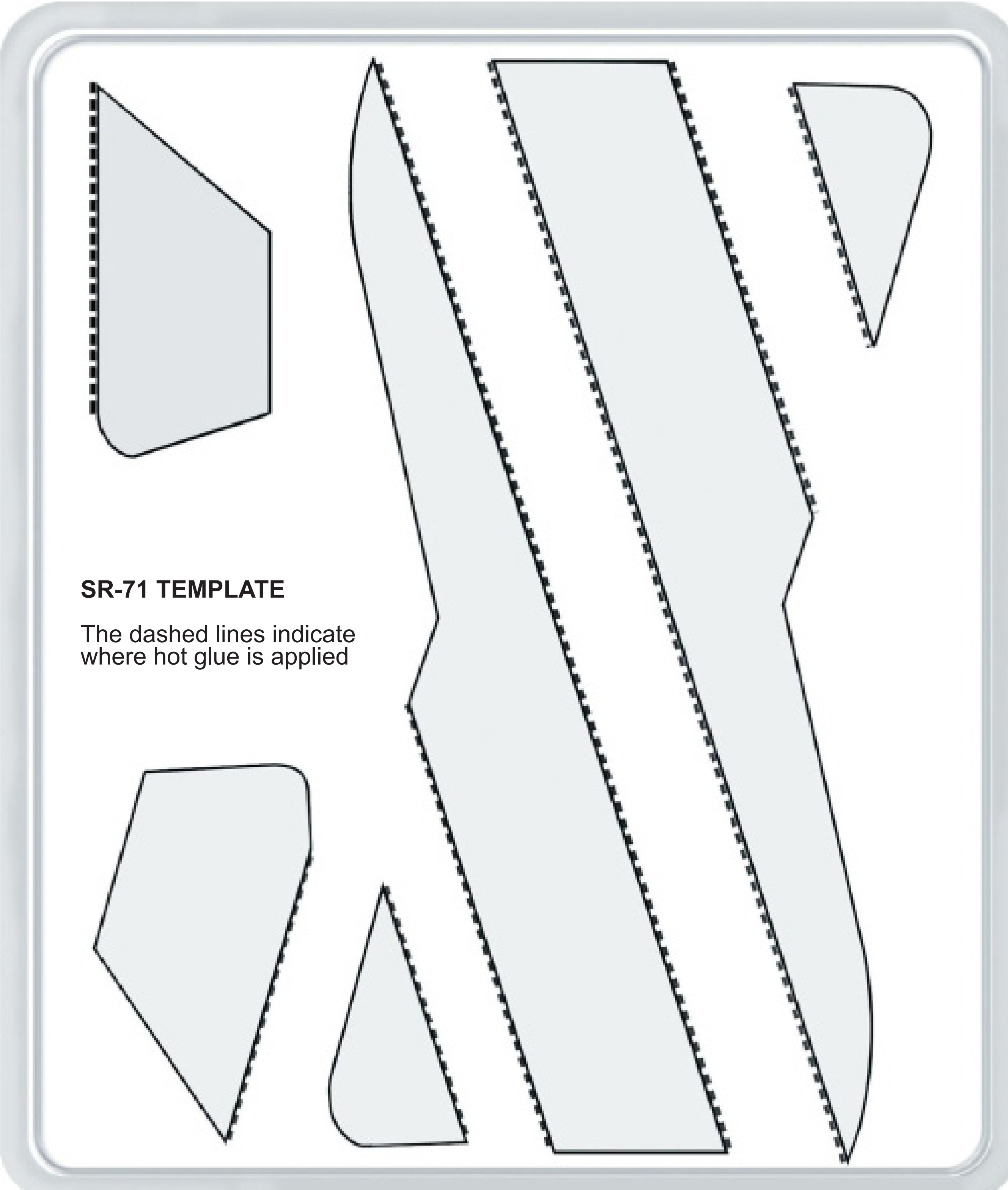
Illustration by Seth Stewart 2000

TO FLY THE SR-71

a. Pinch the end opposite the rubber band with your forefinger and thumb.

b. Put the other thumb into the rubber band. Pull the rubber band to about 4-6 inches.

c. When you launch the SR-71, pitch outward in a slight arc.



SR-71 TEMPLATE

The dashed lines indicate
where hot glue is applied

BUILD A REAL LOW-FLYING HOVERCRAFT

OBJECTIVE – To create, out of easily-obtainable materials, a working hovercraft that will "fly" across most smooth surfaces.

NATIONAL STANDARDS –

Next Generation Science Standards (www.nextgenscience.org):

Disciplinary Core Idea Progressions

Physical Science Progression

- PS2.A: Force and motion

MATERIALS –

The rough estimate of the cost for this project is about $200. The materials include:

a. A 48" pre-cut round 1/2 inch plywood tabletop

b. A gas-powered leaf blower. The builder can also use an electric leaf blower or even a canister-type vacuum cleaner with a blower fitting.

c. A thick plastic sheet. The one used in this project was a 10 mm thick drop cloth.

d. Electric saber saw

e. A large roll of duct tape

f. Three tubes of 1/2"pipe foam insulation (for the"bumper" on the edge of the plywood piece)

PROCEDURE –

There are two options: (1) buy a precut plywood tabletop or (2) purchase a 4' x 4' square of 1/2 inch plywood and cut it with a saw. This project is based on purchasing a round tabletop just to avoid the possibility of a problem when cutting into a blank sheet. It is recommended that the plywood piece be round since pointed corners can cause injury.

Once the plywood piece is ready, a small hole must be cut near the edge of the tabletop to mount the "nozzle" or mouth of the leaf blower. The smaller hole should almost be a "press-fit" for the nozzle of the leaf blower to fit into. The best procedure is to trace around the nozzle end and then cut it. The smaller hole should be approximately 1/2 the distance from the center to the edge of the plywood tabletop. Next comes the skirt.

A large sheet of 10 mm plastic is carefully cut and duct taped to the tabletop board. Once this is in place, a smaller coffee-can plastic lid is screwed to the underside. Next, a series of 2 inch holes are cut in the plastic skirt and this is where the air from the leaf blower moves outward near the surface of the floor. The leaf blower is mounted in the hole and sealed so that it doesn't leak. Attach the tubing to the outer edge as a "bumper." Once everything is ready, a common patio chair is placed on the hovercraft and the engine is started. If all works well, it should scoot across the floor with one or more adults "on board"!

A saber saw was used to cut a small mounting hole for the leaf blower. Notice the wearing of eye protection.

A 10 mm plastic sheet is laid under the tabletop at this point and a cut is made about 18 inches away from the plywood.

Next, a more accurate cut is made. In this case, one of the cadets is using a pen as a guide while the other cadet is making the cut.

The skirt is now duct taped to the tabletop piece. To make a really good seal, it is recommended that a second layer of tape be applied.

When finished, the skirt should look something like this.

The skirt on the flip side should be a reasonably tight fit.

A smaller disk, preferably made from a polypropylene lid from a coffee can, will be mounted on the underside of the hovercraft.

The cadets make sure it is centered by using a measuring tape 90 degrees apart.

The smaller disk is now screwed into place. This lid forms a “donut hole” when the skirt is inflated. The rest of the skirt, out to the edge, will form the donut shape itself.

Tubing is attached to the edge as a "bumper."

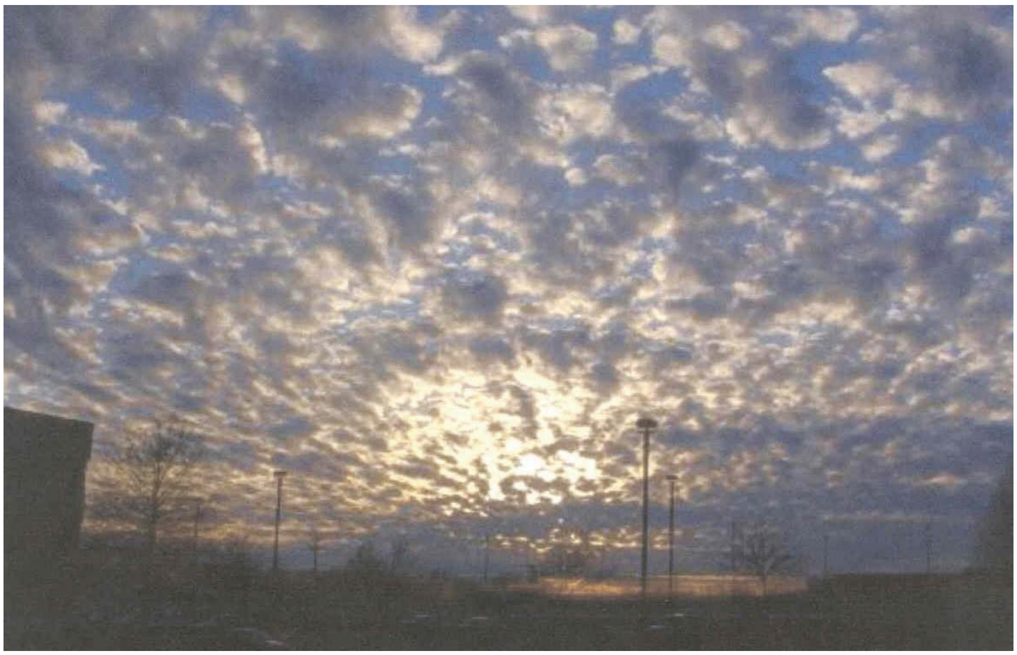
The leaf blower is now installed.

Duct tape is used to seal it in place so that little or no air will be able to leak around it.

IT FLIES!!
A common patio chair is placed on the plywood board and a cadet gets to be the first test pilot.

BECOME A SQUADRON WEATHER OFFICER

OBJECTIVE – To become aware of what is known as "pilot weather." There are certain aspects that are more important to pilots than an in-depth understanding of the science of meteorology.



NATIONAL STANDARDS –

Next Generation Science Standards (www.nextgenscience.org):

Disciplinary Core Idea Progressions

Earth Space Science Progression

- ESS2.A: Earth materials and systems
- ESS2.D: Weather and climate
- ESS3.B: Natural hazards

Cross-cutting Concepts

- Systems and system models

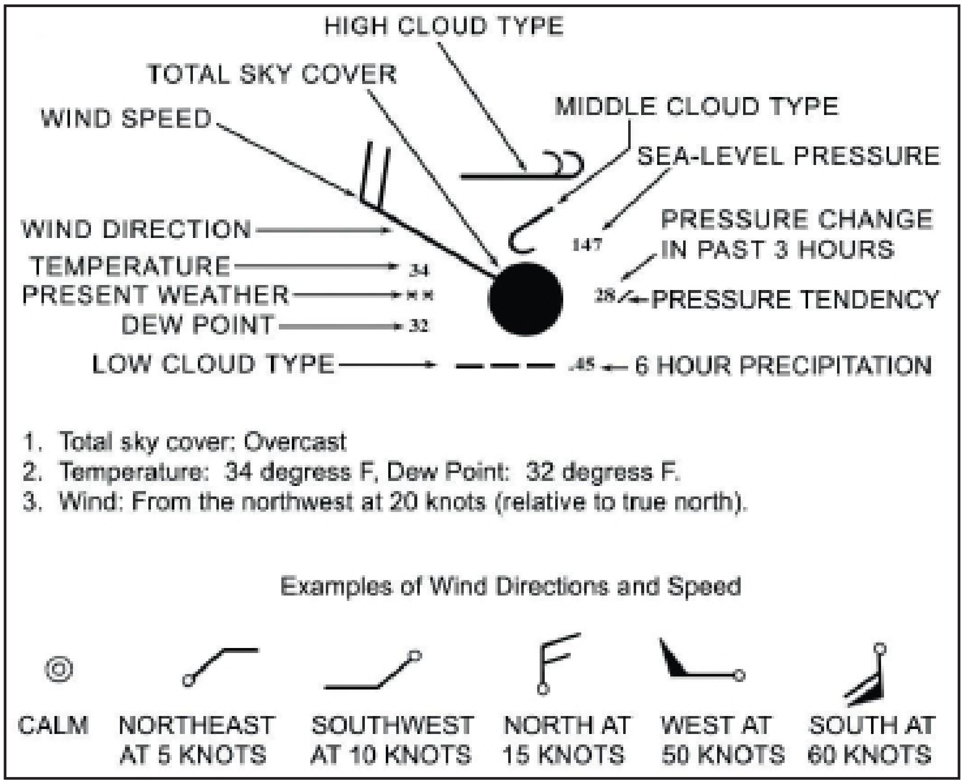
WEATHER INFORMATION OF SPECIAL INTEREST TO PILOTS

Before starting a long and boring experience trying to learn weather theory, let's take a look at a Station Model of the Surface Analysis Chart. You may wonder why this particular item was used. The surface analysis chart has been around for several decades and pilots have used it to get an overall picture of the weather that may be encountered en route to a destination.

Activity Twelve: Become A Squadron Weather Officer

When you look at the Surface Analysis Chart, you will see that every major city has a "symbol" with a lot of strange information around it. This is pilot information. Let's find out more.

This is a Station Model and it gives information important to pilots. This might be Oklahoma City; it might be Oshkosh, Wisconsin; it might be Las Vegas, Nevada, and on and on.



Surface Analysis Chart Station Model which is a guide for the SAC Illustration.

The National Oceanic and Atmospheric Administration and the Federal Aviation Administration produced this book, "Aviation Weather Services" (Advisory Circular AC 00-45E) which contains a wealth of information about the science and technology surrounding the study of aviation weather.

Now you can own a weather station for about the price of a tank of gasoline for your car! This EnviraStation has a wealth of information including barometric pressure in both millibars and inches, barometric trend, outside ambient temperature, humidity, inside temperature, date and time. It also shows clouds at the very top (although it is not easily seen in this photograph). The EnviraStation has a monitor that sits outside so that local atmospheric conditions can be read indoors.

Look at the station model as you would the face of a clock. Let's start at noon and go "clockwise."

1.The High Cloud Types - If a pilot is going to fly at high altitudes, he/she wants to know if these clouds might be of a type that is threatening to the overall safety along the route of flight.

2.The middle cloud types -These clouds, because of their location can also present a problem if they contain severe weather that may affect the safety and visibility of the flight. If a pilot is not rated to fly in clouds, an overcast at any level may present a problem of legality. An example of this would be having an "under-cast" develop (where the pilot is on top of an overcast) and, if only VFR rated, the pilot would have to descend through the clouds to make an approach to land. This means that during this descent through the clouds, the pilot would not only be illegal, he/ she would be a threat to other aircraft flying in the vicinity.

3.Sea-Level Pressure - The barometric pressure is especially important because it is used to set the correct altimeter. A constant monitoring of the pressure is essential for a safe and legal flight.

4.The pressure change and pressure tendency is a forecaster of changing weather. If the barometric tendency is falling, this could easily indicate a deteriorating weather situation. As the barometer falls, again, a pilot has to make corrections to instruments to know the exact altitude the aircraft is flying to maintain legality and safety along the route of flight.

5.Regarding the 6 hour precipitation symbol, this gives the pilot a "history" of the environment into which he/she is flying. If the weather has been a hazard in the past 6 hours, there is a good chance that conditions might very well be hazardous when the pilot approaches the area along the route of flight.

6.Low Cloud Type - This is especially important to a pilot because it gives him/her an idea of what conditions are going to be like close to the airport. If the clouds are low and dense, there is a possibility that fog may exist and that would require the pilot to take action to go to another airport or, if instrument qualified, make sure that he is legal to continue with a landing.

7.The Dew Point - If the dew point comes within 4° F of the temperature, there is a likelihood that fog will be forming. The dew point is that temperature at which the humidity within the air condenses out to form water, i.e. saturation.

8.Present Weather - This is especially important to a pilot because it gives the pilot a look at what's going on, or was going on at the time the data was collected by the local observer. If the weather is threatening to the safety or legality of the flight,the pilot should know this immediately.

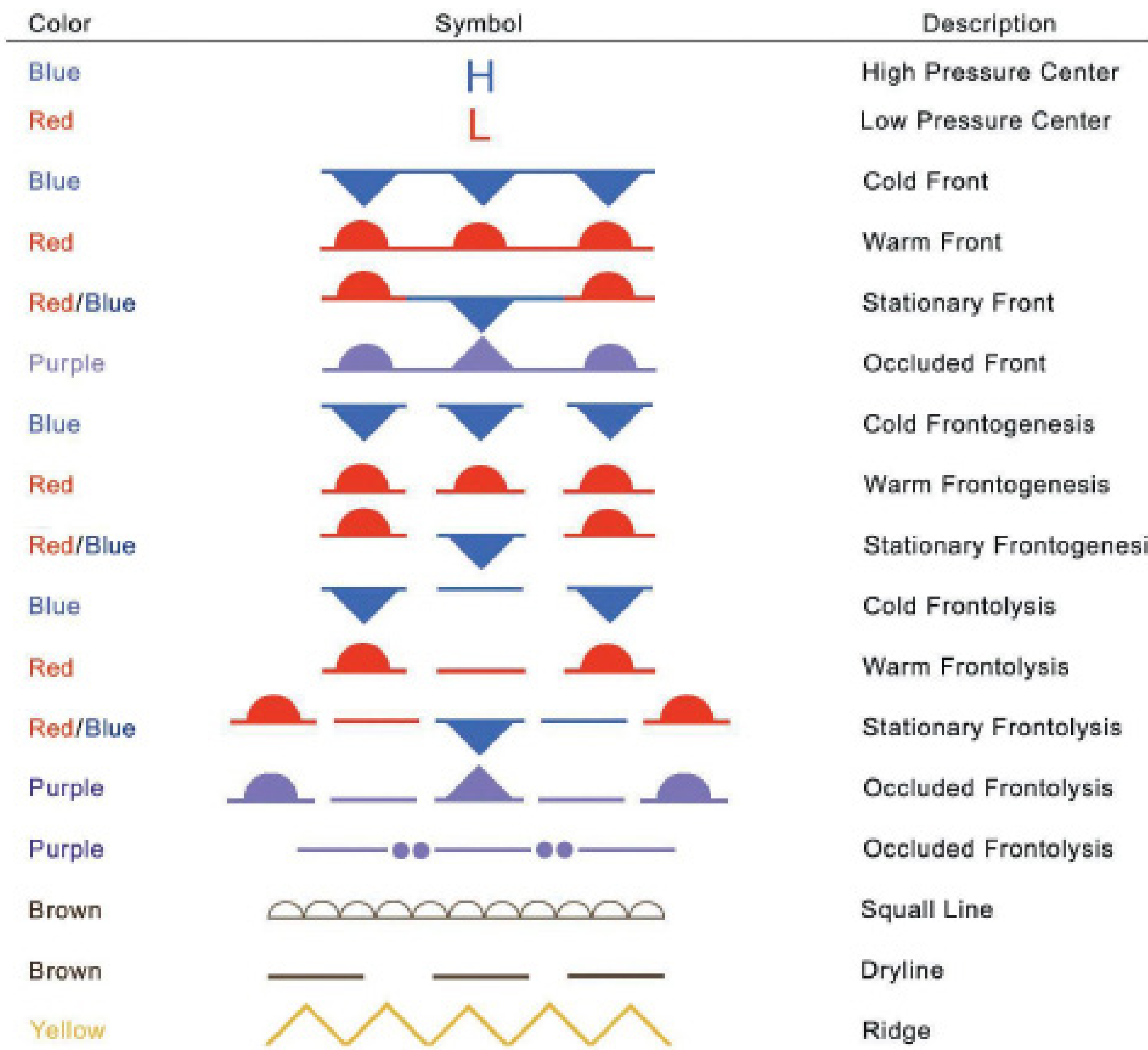
9.The temperature - This information is especially important in relation to the dew point. The temperature can also be an indicator of the possibility of icing conditions and of course, this may be a threat to the safety of the flight if the aircraft is not equipped with anti-icing equipment.

10.Wind Direction / Wind Velocity - Wind is defined as air in motion. If the aircraft is part of the moving environment, then the pilot is going to have to make corrections in the direction of flight to maintain a desired flight path across the ground. If the wind is very high at the point of intended landing, then it may exceed the skill level and legality of the pilot. If that condition exists, corrections or alterations must be made to land safely, possibly at another airport.

11.Total Sky Cover - This is the first thing a pilot will observe when studying the Surface Analysis Chart. This gives a knowledgeable pilot a quick picture of what's happening along the route of flight or at the destination.

12.Remember, everything you're looking at is HISTORY.

(See symbols on Surface Analysis Chart page 111.)



THE ACTUAL SURFACE ANALYSIS CHART

The Surface Analysis Chart shown in this example was taken from the AVIATION WEATHER SERVICES ACE 00-45E advisory circular, page 5-3.

In "Section 5" of this ACE 00-45E, it states at the beginning:
SURFACE ANALYSIS CHART
The surface analysis chart is a computer-generated chart, with frontal analysis by HPC forecasters, transmitted every 3 hours covering the contiguous 48 and adjacent areas. Figure 5-1 is a sample surface analysis chart and 5-2 illustrates the symbols depicting fronts and pressure centers.

VALID TIME - This is very important because it tells the planner when the data was gathered. It is but one of several pieces of information a pilot can use to "forecast" the weather along the route of flight. The Aviation Weather book has this to say:
"Valid time of the chart corresponds to the time of the plotted observations. A date-time group UCT or Universal Coordinated Time tells the user when conditions portrayed on the chart occurred."

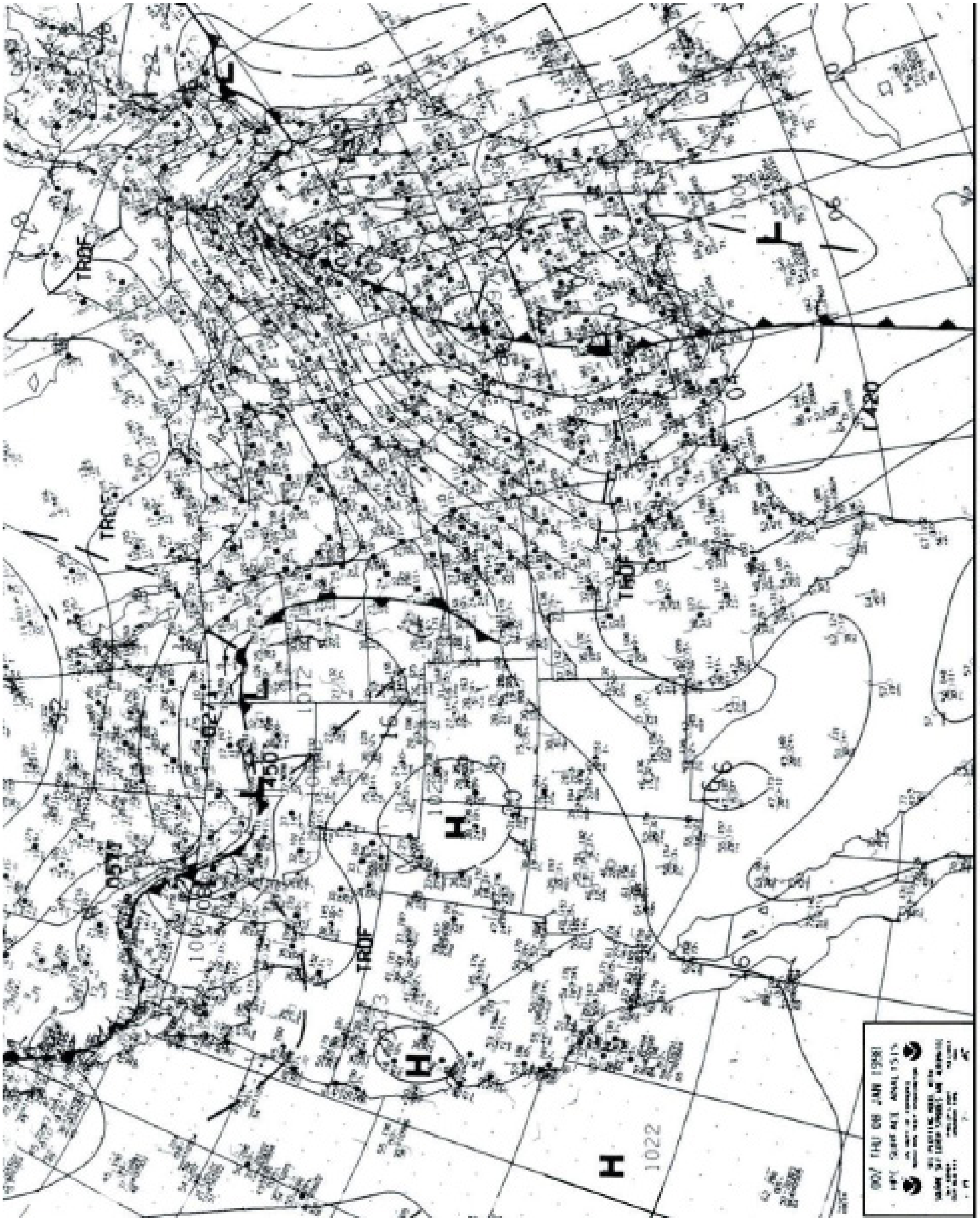


Figure 5-1. Surface Analysis Chart

ISOBARS - Isobars are solid lines depicting the sea level pressure pattern and usually space at intervals of 4 millibars. Each isobar is labeled. For example, 1032 signifies 1,032.0 millibars.

PRESSURE SYSTEMS - The letter "L" denotes a lower pressure center, and the letter "H" denotes a high pressure center. The pressure of each center is indicated by a three- or four-digit number that is the central pressure.

FRONTS - The analysis shows positions and types of fronts by the symbols shown in Figure 5-2 (symbols). The symbols on the front indicate the type of front and point in the direction toward which the front is moving. If the front has arrowhead-shaped symbols, it is a cold front. If the front has half-moon symbols, it is a warm front. If there is a number near a front, these are "classification" designations and the senior member is urged to look these up on page 5-1 of the Aviation Weather ACE 00-45E Advisory Circular (text).

TROUGHS AND RIDGES - A trough of low pressure with significant weather will be depicted as a thick, dashed line running through the center of the trough and identified with the word, "TROF." The symbol for a ridge of high pressure is rarely, if at all, depicted.

OTHER INFORMATION - The observations from a number of stations are plotted on the chart to aid in analyzing and interpreting the surface weather features. These plotted observations are referred to as station models. There are two primary types of station models plotted on the chart. Those with a round station symbol are observations taken by observers. The locations with a square station symbol indicated the sky cover was determined by an automated system. Other plotting models that appear over water on the chart are data from ships, buoys, and offshore oil platforms.

USING THE CHART - The surface analysis chart provides a ready means of locating pressure systems and fronts. It also gives an overview of winds, temperatures, and dew point temperatures at chart time. When using the chart, keep in mind that weather moves and conditions change. Using the surface analysis chart in conjunction with other information gives a more complete weather picture.

AUTHOR'S PHILOSOPHY FOR THIS ACTIVITY

For many years, the author taught an aviation ground school for a high school in a pre-career program. The Jeppesen Aviation Fundamentals textbook was used and of all the chapters, the students feared the unit on weather. It took a while, but it was found they were receptive to learning about meteorology when it was connected directly to "what a pilot really needs to know." Before opening the book, a brief coverage of the "basic science" was taught for about two weeks. We would go through each facet of weather science before connecting it to charts, new symbols, and available services. Here's how it was approached:

1. Air is to a pilot as water is to a sailor. It is home! So, what is air like - we can't see it but we can study it.
2. Air is made up of molecules (Nitrogen, Oxygen, Carbon Dioxide, etc.)
3. Air in motion is wind. What do molecules do when they start to move? (Examples - cyclones, tornadoes, etc.)
4. Air down close
5. Air up high - why does a pilot care?
6. Water in the atmosphere?
7. What is pressure? Why do we care?
8. What is drag?
9. Hot air?
10. Cold air?
11. Frozen air?
12. Solid air?
13. What is a cloud?
14. **NOW....put an airplane in the picture...**
15. When an airplane leaves the ground (relating back to #1) it enters an environment for which it was designed. As air starts to move around the airplane, what changes occur?
16. Does air density affect an airplane?
17. You hear on the news about 190 mph winds in a tornado...yet many airplanes fly at those speeds all the time - why aren't they torn up like a barn is when a tornado hits it?

18. What happens to an airplane when air goes straight up or straight down?
19. We can't let a big string out that goes all the way from the airplane to the ground (like a boat dropping an anchor)...we use differences in pressure to do this.
21. When the air gets really cold, airplanes fly better. Why?
22. When the moisture in the air becomes visible, it means a cloud might be forming. A cloud on the ground is known as fog. Is it difficult to drive through really thick fog? What about flying or landing in thick fog? Is fog up in the sky really a cloud?
23. Are some clouds more threatening to an airplane than others?
24. Why are clouds called the "Sign Posts of the Sky?"
25. OKAY...Take a look at the station symbol (no need to open the textbook yet...we're getting there). As I indicated earlier, can you see how each one piece of information has some relationship to the needs of a pilot?
26.Each day, in the class, we would start clockwise and spend the entire period on just one or two segments of the station model. We would cover that component, discuss its importance to a pilot, and then go on. By the end of the station model, they had little or no fear of meteorology and were willing to see what else was available in the way of pilot-related information.

REALITY WEATHER FROM LOCAL TV AND THE WEATHER CHANNEL®.

When you are watching television and the local, or national, weather forecaster is giving you conditions and forecasts, these are generally not aimed specifically at pilots. They are aimed at the general public; however, it is information that is usable by a pilot.

Pilots can, however, use the Weather Channel® and local TV to get some of the data that was featured above.

VISITS FROM GOVERNMENT OR TV WEATHER PERSONALITIES

Schools and even CAP squadrons can request, as a guest speaker, a visit from a local TV weather personality. They will usually do this without charge and it is a great "drawing" item to have the weather person visit your squadron.

A VISIT FROM A GOVERNMENT WEATHER OFFICIAL

A Civil Air Patrol squadron staff member (now Weather Officer) can request a guest speaker by calling any office of the Federal Aviation Administration. These officials will give the squadron an overview of the job and in the case of a composite or cadet squadron, give the individual a career overview. This may just be the "spark" that turns a cadet, or younger senior member, on to a career in meteorology.

Ah-h-h-h! Good flying weather! Temperature was 72 degrees (F), visibility was 100+ miles and the winds were light and variable. This is a condition jokingly called "Severe Clear" by pilots.

These clouds are a sign of fair weather. They are known as Cirrus and are located at very high altitudes. Generally, the barometric pressure is high and conditions like this make pilots want to go flying!

If clouds are the sign posts of the sky, what would you say about these towering cumulus? If a cloud is puffed upward this means that some force (turbulence) shaped it that way. If you drew "force lines" on this image, what would they look like?

These are the very dangerous "Mammato" clouds. These are often an indication of dangerous, violent weather....

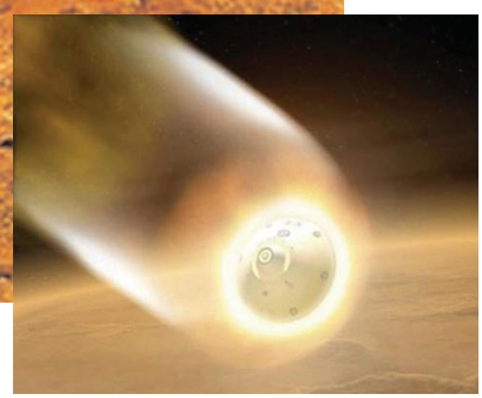
...Like this.

Some very beautiful scenery...flight above the clouds.

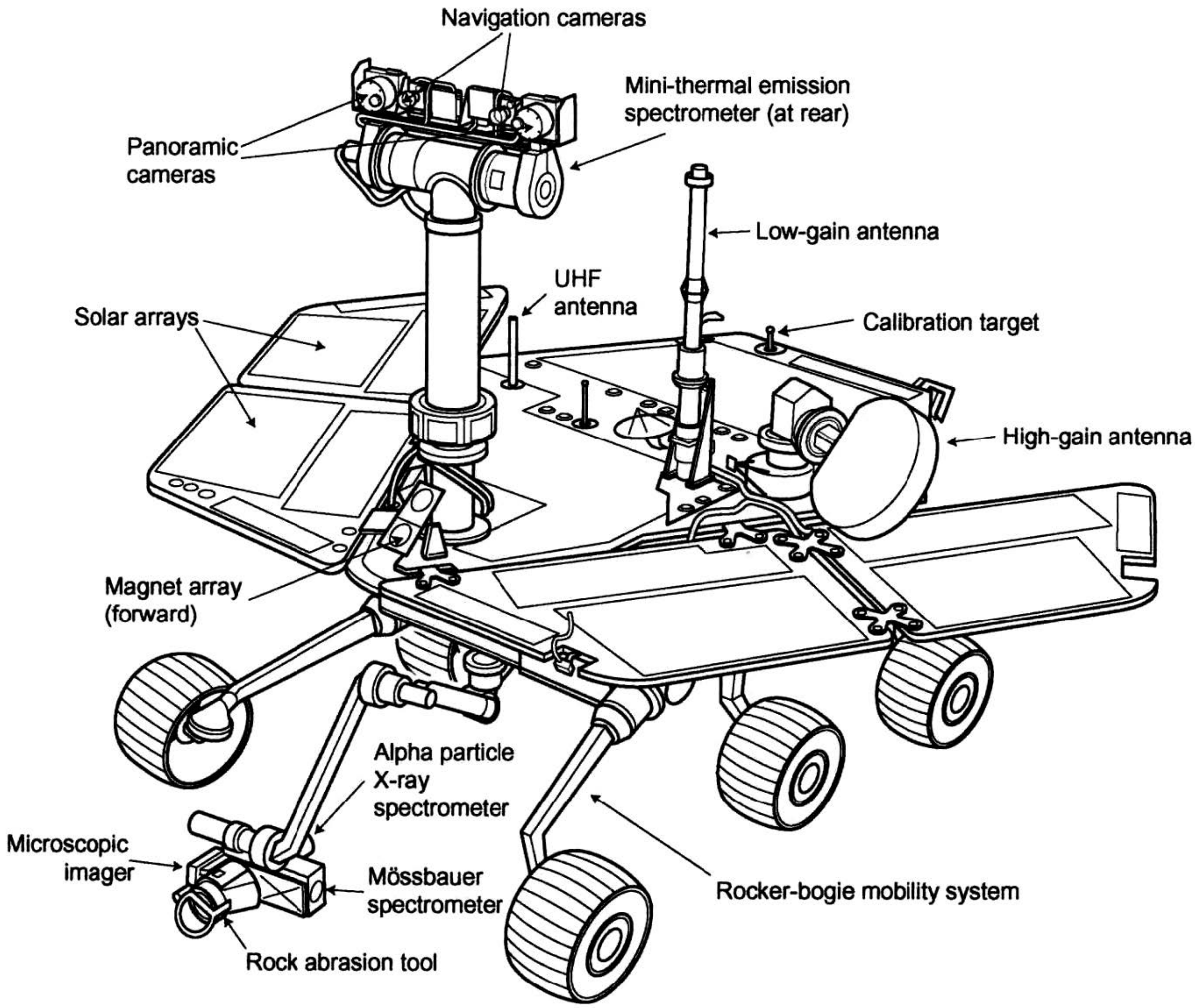
BUILD A RADIO CONTROLLED MARS SPIRIT ROVER

OBJECTIVE – This is a project that can be used at conferences, workshops, recruiting sessions, air shows and other events. It is a “standoff-scale” replica of the Mars Spirit Rover and it is powered using the running chassis of a radio controlled model race car.

The incredibly powerful Delta II rocket carried the Martian craft to its destination in space. According to NASA “Quick Facts,” Spirit was launched on June 10, 2003 and landed on January 4, 2004. The distance flown, including orbits, was 303 million miles.



After a blazing entry into the Martian atmosphere, the craft was lowered to the surface of Mars.



Mars Exploration Rover

SPACECRAFT

Each of the two Mars Exploration Rover spacecraft resembles a nested set of Russian dolls. The rover traveled to Mars tucked inside a folded-up lander wrapped in airbags. The lander in turn was encased in a protective aeroshell. Finally, a disc-shaped cruise stage was attached to the aeroshell on one side and to the Delta II launch vehicle on the other.

(The following description was written prior to the launching of the Rovers).

Cruise stage

The cruise stage provides capabilities needed during the seven-month passage to Mars but not later in the mission, such as a propulsion system for trajectory correction maneuvers. Approximately 2.6 meters (8.5 feet) in diameter and 1.6 meters (5.2 feet) tall, the disc-shaped cruise stage is outfitted with solar panels and antennas on one face, and with fuel tanks and the aeroshell on the other. Around the rim sit thrusters, a star scanner, and a Sun sensor.

The propulsion system uses hydrazine propellant stored in two titanium tanks. Since the entire spacecraft spins at about two rotations per minute, fuel in the tanks is pushed outward toward outlets and through fuel lines to two clusters of thrusters. Each cluster has four thrusters pointing in different directions. The star scanner and Sun sensor help the spacecraft determine its orientation. Since the rover's solar arrays are tucked away inside the aeroshell for the trip, the cruise stage needs its own for electrical energy. The arrays could generate more than 600 watts when the spacecraft was about as far from the Sun as Earth is, and generate about half that much as it nears Mars.

The cruise stage also carries a system for carrying excess heat away from the rover's computer with a pumped Freon loop and rim-mounted radiators.

Entry, Descent and Landing System

The system for getting each rover safely through Mars' atmosphere and onto the surface relies on an aeroshell, a parachute, and airbags. The aeroshell has two parts: a heat shield that faces forward and a backshell. Both are based on designs used successfully by NASA's Viking Mars landers in 1976 and Mars Pathfinder in 1997.

The parachute is attached to the backshell and opens to about 15 meters (49 feet) in diameter. The parachute design was tested under simulated Martian conditions in a large wind tunnel at NASA's Ames Research Center near Sunnyvale, California.

The backshell carries a deceleration meter used to determine the right moment for deploying the parachute. Solid-fuel rockets mounted on the underside of the shell reduce vertical velocity and any excessive horizontal velocity just before landing.

The airbags, based on Pathfinder's design, cushion the impact of the lander on the surface. Each of the four faces of the folded-up lander is equipped with an envelope of six airbags stitched together. Explosive gas generators rapidly inflate the airbags to a pressure of about 6900 Pascal (one pound per square inch). Each airbag has double bladders to support impact pressure and, to protect the bladders from sharp rocks, six layers of a special cloth woven from polymer fiber that is five times stronger than steel, are attached. The fiber material, Vectran, is used in the strings of archery bows and tennis racquets.

Lander

The lander, besides deploying the airbags, can set the rover right-side-up, if necessary, and provides an adjustable platform from which the rover can roll onto Mars' surface. It also carries a radar altimeter used for timing some descent events, as well as two antennas.

The lander's basic structure is four triangular petals made of graphite-epoxy composite material. Three petals are each attached with a hinge to an edge of the central base petal. The rover stays fastened to the base petal during the flight and landing. When folded up, the lander's petals form a tetrahedral box around the stowed rover. Any of the petals could end up on the bottom when the airbag-cushioned bundle rolls to a stop after landing. Electric motors at the hinges have enough torque to push the lander open, righting the rover, if it lands on one of the side petals.

Other motors retract the deflated airbags. An apron made out of the same type of tough fabric as the airbags stretches over ribs and cables connected to the petals, providing a surface that the rover can drive over to get off of the lander. The side petals can also be adjusted up or down from the plane of the base petal to accommodate uneven terrain and improve the rover's path for driving off of the lander.

Nearly four million people have a special connection to the Mars Exploration Rover project by having their names recorded on each mission's lander. Each of the two landers carries a DVD containing millions of names of people around the world collected during a "Send Your Name to Mars" campaign, which ended in November 2002.

Rover

At the heart of each Mars Exploration Rover spacecraft is the rover. This is the mobile geological laboratory that will study the landing site and travel to examine selected rocks up close.

The Mars Exploration Rovers differ in many ways from their only predecessor, Mars Pathfinder's Sojourner rover. Sojourner was about 65 centimeters (2 feet) long and weighed 10 kilograms (22 pounds).

Each Mars Exploration Rover is 1.6 meters (5.2 feet) long and weighs 174 kilograms (384 pounds). Sojourner traveled a total distance equal to the length of about one football field during its 12 weeks of activity on Mars. Each Mars Exploration Rover is expected to travel six to ten times that distance during its three-month prime mission. Pathfinder's lander, not Sojourner, housed that mission's main telecommunications, camera and computer functions. The Mars Exploration Rovers carry equipment for those functions onboard and do not interact with their landers any further once they roll off.

On each Mars Exploration Rover, the core structure is made of composite honeycomb material insulated with a high-tech material called aerogel. This core body, called the warm electronics box, is topped with a triangular surface called the rover equipment deck. The deck is populated with three antennas, a camera mast, and a panel of solar cells. Additional solar panels are connected by hinges to the edges of the triangle. The solar panels fold up to fit inside the lander for the trip to Mars, and deploy to form a total area of 1.3 square meters (14 square feet) of three-layer photovoltaic cells. Each layer is of different materials: gallium indium phosphorus, gallium arsenide, and germanium. The array can produce nearly 900 watt-hours of energy per Martian day, or sol. However, by the end of the 90-sol mission, the energy generating capability is reduced to about 600 watt-hours per sol because of accumulating dust and the change in season. The solar array repeatedly recharges two lithium-ion batteries inside the warm electronics box.

Doing sport utility vehicles one better, each rover is equipped with six-wheel drive. A rocker-bogie suspension system, which bends at its joints rather than using any springs, allows rolling over rocks bigger than the wheel diameter of 26 centimeters (10 inches). The distribution of mass on the vehicle is arranged so that the center of mass is near the pivot point of the rocker-bogie system. That enables the rover to tolerate a tilt of up to 45 degrees in any direction without overturning, although onboard computers are programmed to prevent tilts of more than 30 degrees. Independent steering of the front and rear wheels allows the rover to turn in place or drive in gradual arcs.

The rover has navigation software and hazard-avoiding capabilities it can use to make its own way toward a destination identified to it in a daily set of commands. It can move at up to 5 centimeters (2 inches) per second on flat hard ground, but under automated control with hazard avoidance, it travels at an average speed about one-fifth of that.

Two stereo pairs of hazard-identification cameras are mounted below the deck, one pair at the front of the rover and the other at the rear. Besides supporting automated navigation, the one on the front also provides imaging of what the rover's arm is doing. Two other stereo camera pairs sit high on a mast rising from the deck: the panoramic camera included as one of the science instruments, and a wider-angle, lower-resolution navigation camera pair. The mast also doubles as a periscope for another one of the science instruments, the miniature thermal emission spectrometer.

The rest of the science instruments are at the end of an arm, called the "instrument deployment device," which tucks under the front of the rover while the vehicle is traveling. The arm extends forward when the rover is in position to examine a particular rock or patch of soil.

Batteries and other components that are not designed to survive cold Martian nights reside in the warm electronics box. Nighttime temperatures may fall as low as -105° C (-157° F). The batteries need to be kept above -20° C (-4° F) for when they are supplying power, and above 0° C (32° F) when being recharged. Heat inside the warm electronics box comes from a combination of electrical heaters, eight radioisotope heater units and heat given off by electronics components.

Each radioisotope heater unit produces about one watt of heat and contains about 2.7 grams (0.1 ounce) of plutonium dioxide as a pellet about the size and shape of the eraser on the end of a standard pencil. Each pellet is encapsulated in a metal cladding of platinum-rhodium alloy and surrounded by multiple layers of carbon-graphite composite material, making the complete unit about the size and shape of a C-cell battery. This design of multiple protective layers has been tested extensively, and the heater units are expected to contain their plutonium dioxide under a wide range of launch and orbital-reentry accident conditions. Other spacecraft, including Mars Pathfinder's Sojourner rover, have used radioisotope heater units to keep electronic systems warm and working.

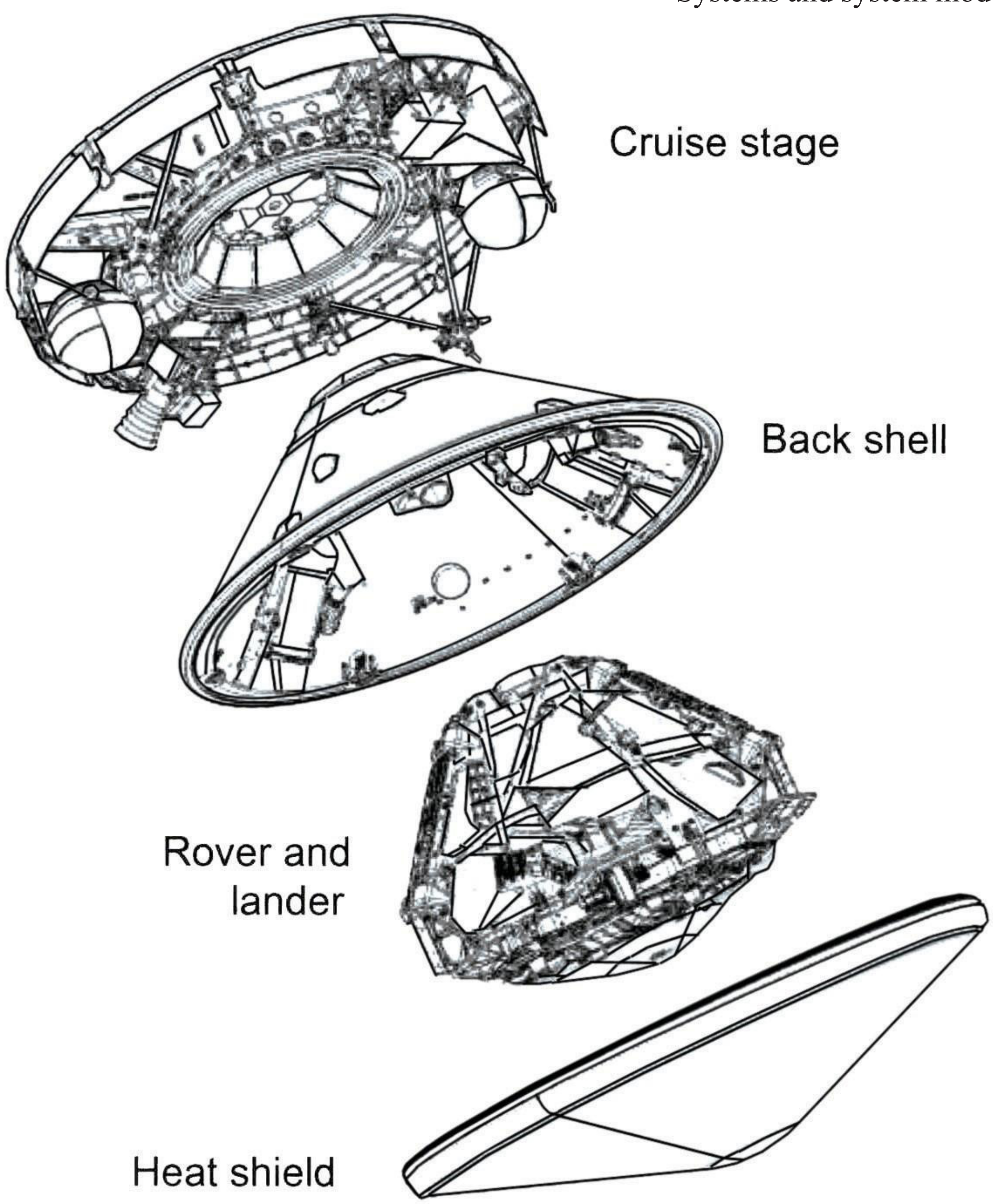
The computer in each Mars Exploration Rover runs with a 32-bit Rad 6000 microprocessor, a radiation-hardened version of the PowerPC chip used in some models of Macintosh computers, operating at a speed of 20 million instructions per second. Onboard memory includes 128 megabytes of random access memory, augmented by 256 megabytes of flash memory and smaller amounts of other non-volatile memory, which allows the system to retain data even without power.

NATIONAL STANDARDS –
Next Generation Science Standards (www.nextgenscience.org):

Disciplinary Core Idea Progressions

Earth Space Science Progression
- ESS2.A: Earth materials and systems
- ESS2.D: Weather and climate
- ESS3.B: Natural hazards

Cross-cutting Concepts
- Systems and system models

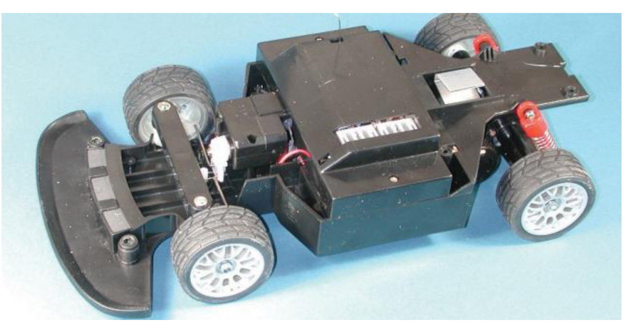


Flight System stages.

Activity Thirteen: Radio Controlled Mars Rover

Retro-firing rockets and a parachute were used to slow the aeroshell down after it entered the atmosphere; then a series of inflated spheres allowed it to bounce to a stop. The mechanism opened up and the rover was given a signal from Earth to start its exploration.

This 1/12 scale model Corvette is an inexpensive model car that would work for this lesson.



After the body is removed, the running chassis will look like this.

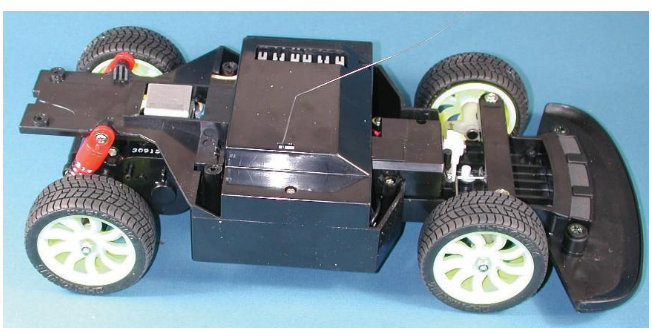
MATERIALS –

- **a.** Remote Controlled 1/12 scale model car (body removed)
- **b.** Set of 6 wheels and tires
- **c.** Two frame braces
- **d.** 1/4 inch foam board
- **e.** Epoxy or Hot glue and glue gun
- **f.** Toilet overflow tube
- **g.** Plastic "T"
- **h.** Dremel Tool
- **i.** Optional items: Gold foil, blue and yellow paint

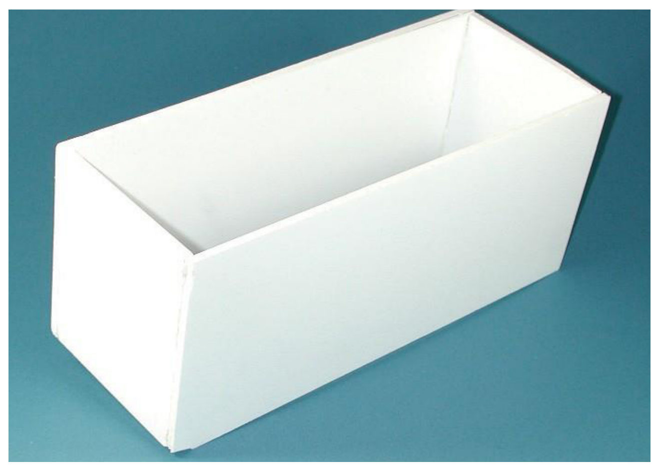
PROCEDURE – Let's build a Mars Spirit here on planet Earth. This is a relatively inexpensive model.

1. One of the first items to change is the wheel set. The frame braces will carry the two front wheels as you will see later in the activity.

*It should be noted that our model is not an exact replica, however, the more you make it look like the real thing, the better. Look at the "Mars Exploration Rover" diagram and you will see that we did not include a low-gain antenna, a high-gain antenna and a carrier for the front arm. These can be added, but be aware, they can also be broken easily. Study the illustration and then get as creative as you can to make it even more fun... and, radio controlled.



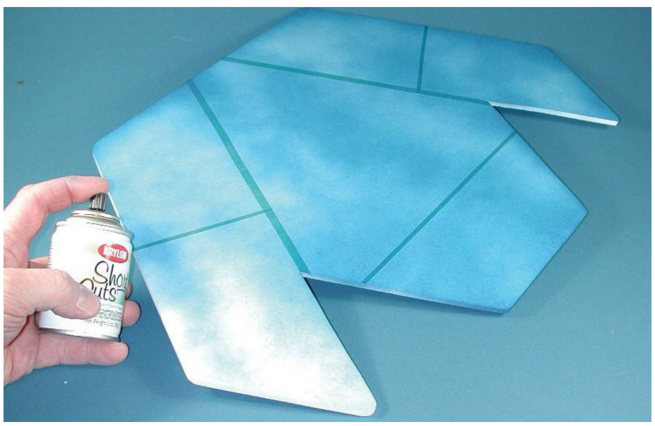
2. The wheels and tires were mounted according to instructions and this is what your Mars Spirit will have to negotiate the "Red Planet." Remove the tires from the R/C and mount four of these new wheels and tires to the R/C chassis.



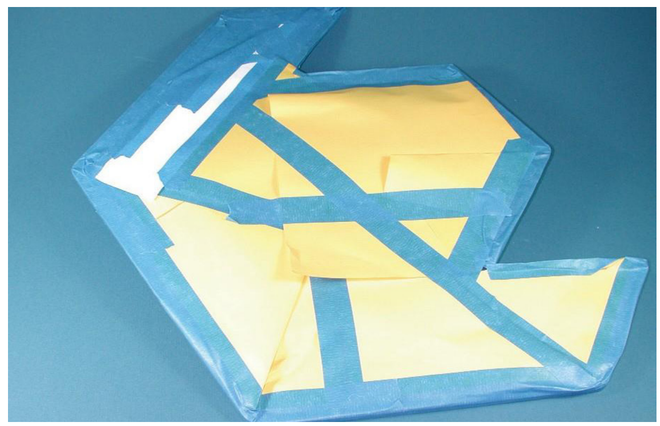
3. Use ¼ inch foam board to make the "box" or main body of the Mars Spirit. These are cut so that they fit the powered chassis as shown. The reason specific numbers were not given is because not everyone will be using this exact R/C car. A certain amount of "eyeball" engineering will have to be used to make it work with other cars. Just remember the goal is to make a rectangular foam board box.

4. Five minute epoxy or hot glue can be used to bond the box parts together.

5. The solar panels should look like this and if the builder wants to really make it look “right,” tape off the lines and spray the surface medium blue.

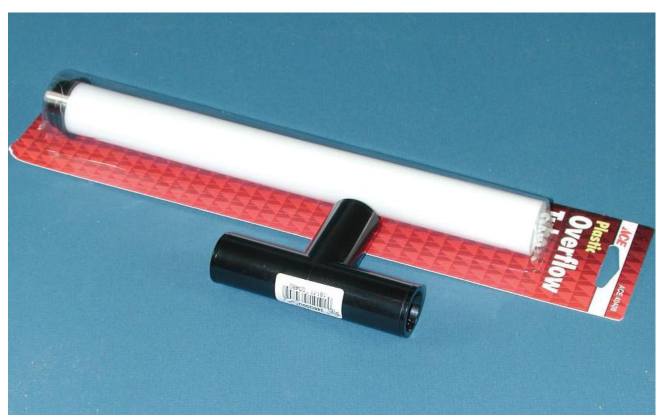


6. The first coat should be a mist followed, in about 15 minutes, with two color coats.



7. Once thoroughly dry, the solar panel is masked off on the upper side and the lower side is painted yellow.

...like this!

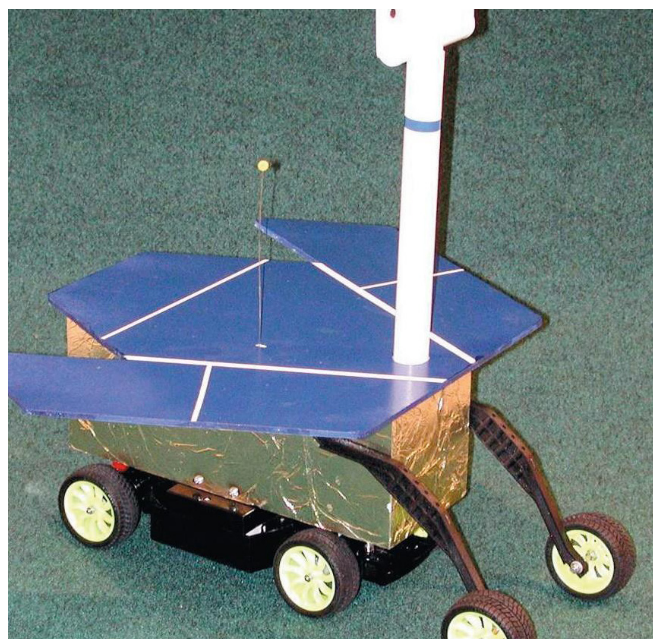


8. The toilet overflow tube and a plastic “T” will make the post that carries the “navigation cameras and the mini-thermal emission spectrometer.”

9. A Dremel Moto Tool was used to make a hole in the Solar Array panels so we could mount the camera post. The post is then fitted and bonded with epoxy.

10. This image shows how the box was glued together-- how the foil was glued to the box---and how the frame braces were mounted to the box. Again the frame braces will carry the front wheel assembly.

11. Our "cameras" were made from a couple of buttons purchased at a fabric store. They add a bit of humor to the little Spirit Rover.



Ideally, the carpet or background should be red to represent the Martian surface. Here's your fully powered, six-wheeled Mars Spirit Rover.
A good additional purchase to ensure power for this rover would be a battery charger that works on a small radio control craft like this. Get ready for the fun!

CIVIL AIR PATROL
gocivilairpatrol.com

AIR FORCE ASSOCIATION
afa.org

PARTNERS IN AEROSPACE AND STEM EDUCATION