THE AEROSPACE EDUCATION EXCELLENCE AWARD PROGRAM

AEX I

Activity Booklet

for
Grades K-6

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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 Bernoulli Basics Demonstrations

12 Activity One: Sled Kites – A Form of the Very First Flying Machine

18 Activity Two: The Great Uncle Wiggly Wings – A Parachute Adventure

25 Activity Three: Back to Basics – Paper Airplanes

32 Activity Four: Blast off Basics – For the Littlest Rocket Scientists

35 Activity Five: Mr. Lifter: Up, We Go! – Using a “Rocket” to Lift Weight–Instead of a Wing

41 Activity Six: Comet Capers – For the Littlest Astronomers

45 Activity Seven: Goddard Rocketeering

51 Activity Eight: Playground Planets with Goddard Rocketeering

53 Activity Nine: Space Junk Rockets – From Trash to Treasure

58 Activity Ten: Cosmic Cuisine – Space Food for the Littlest Astronauts

65 Activity Eleven: Hands on at the Space Station

69 Activity Twelve: Physiology Fun – The Human Body in Space

77 Activity Thirteen: Be a NASA Scientist – Creating Classroom Technology Spin-offs

84 Who are Air Traffic Controllers? Coloring and Activity Book

Careers activity provided by the National Air Traffic Controllers Association (NATCA) https://natca.org/index.php/acronyms-breakdown/kids-corner

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, homeschools, 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

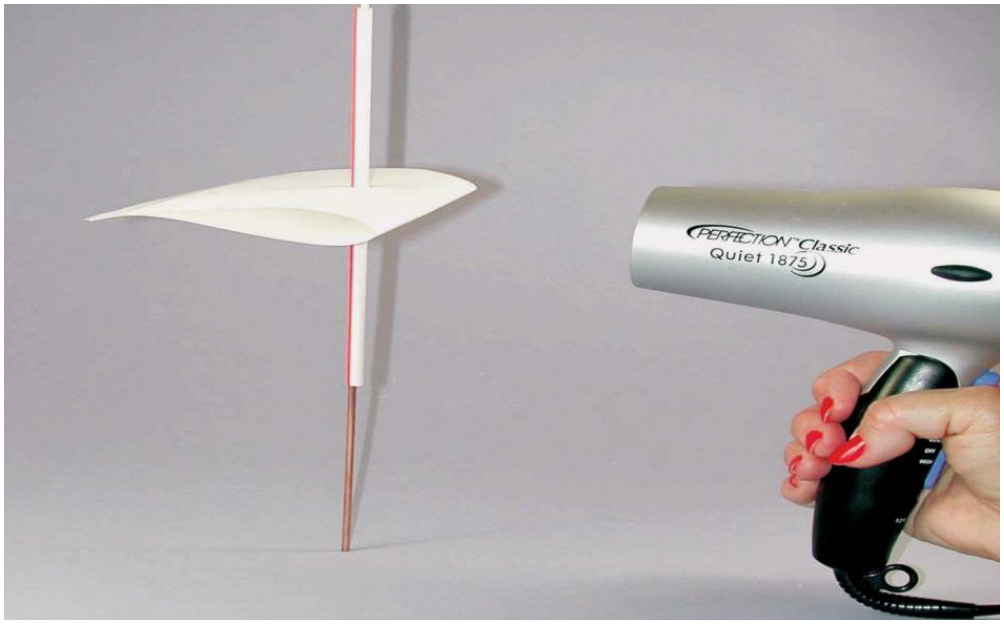
- Newton's first law states, "Objects at rest, or objects in motion, will remain at rest, or in motion, unless acted upon by an unbalanced (outside) force."
- Newton's second law states, "Force equals mass times acceleration."
- And his famous third law states, "For every action, there is an equal and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

BERNOULLI BASICS
WING ON A STICK

OBJECTIVE – Students will observe/create 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
- ES PS2.A: Forces and Motion
- ES PS3.C: Relationship between energy and forces

Crosscutting Concepts
- Systems and system models
- Structure and function

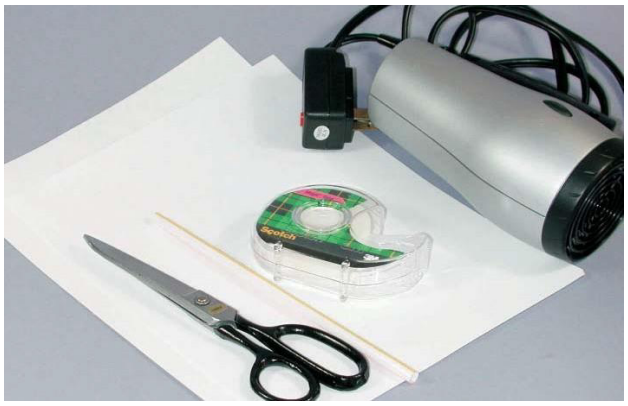
Science and Engineering Practices
1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
6. Constructing explanations (for science) and designing solutions (for engineering)

Bernoulli Basics Demonstration #1

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

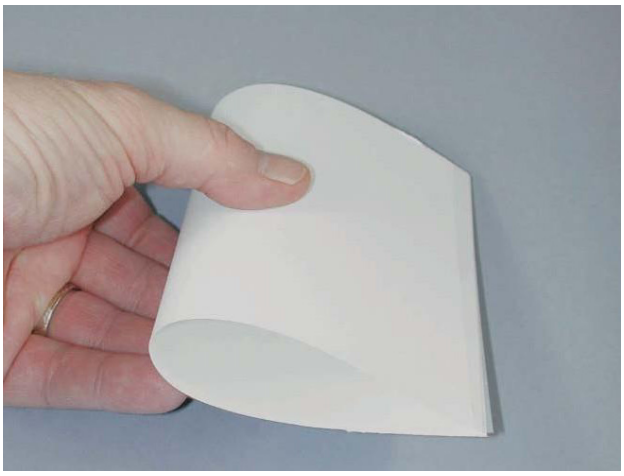
1. To make the airfoil, use about ½ of a sheet of card stock.

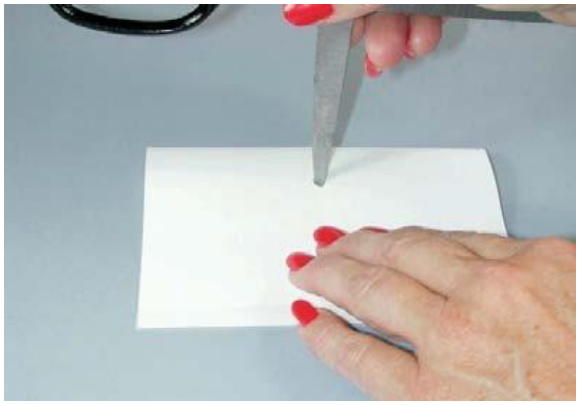
2. Fold the paper so that the chord (a line from the front to the rear of a wing) is about 4 inches long. Tape the trailing edge together with Scotch tape.

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.

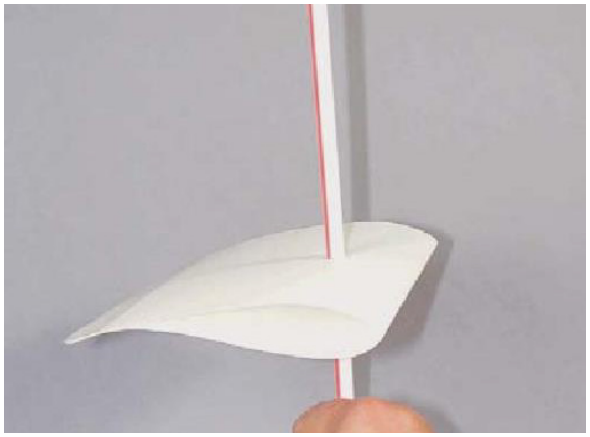
4. At the point of maximum curvature in the airfoil shape, mount a straw by punching a hole with a sharp pencil or pen. Spend some time shaping the airfoil so that the leading edge (closest to the hand in this photo) is gently rounded.

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.

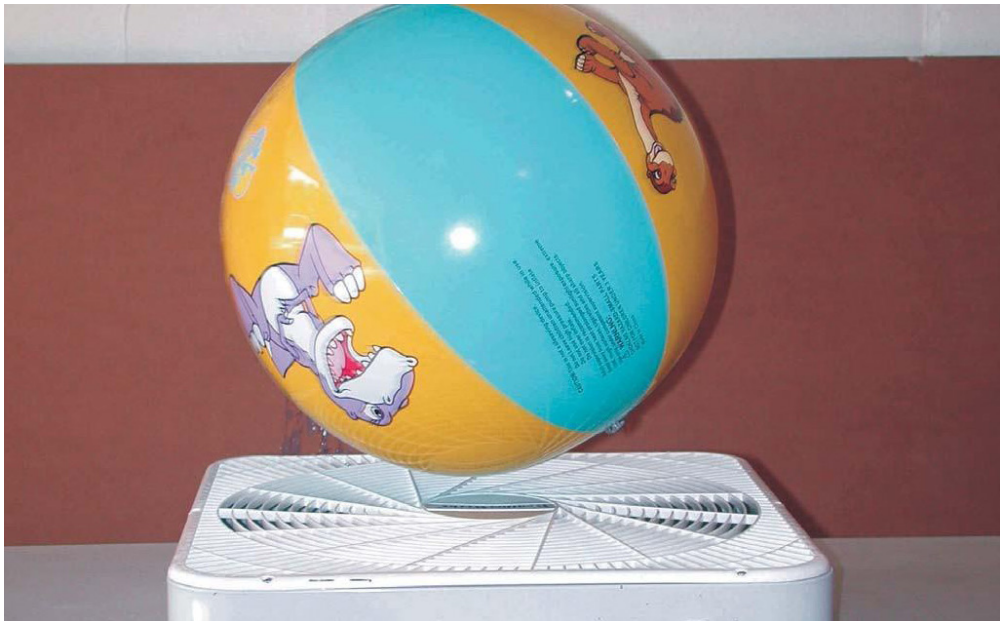
10. If the wing wants to go round and round, you might add a”rudder” by taping a piece of card stock to the back, or trailing edge.

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.



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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

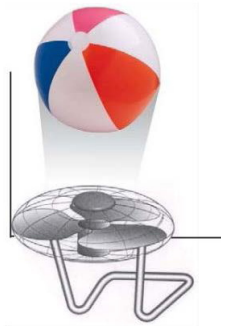
MATERIALS

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

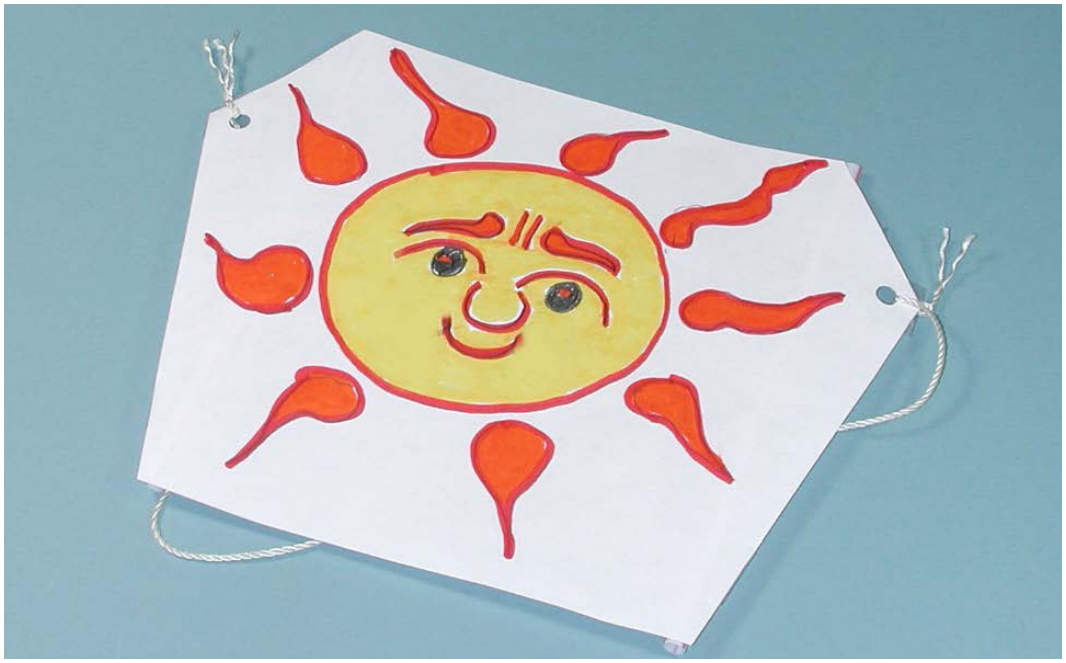
What to do: Hold a ping-pong ball over a flexible straw. As you blow into the straw, let go of the ball. What happens? Experiment with holding the straw in different ways. For example, can you tilt the straw and still keep the ball in the air? Hint: You can use any lightweight ball or a small balloon,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

SLED KITES

A FORM OF THE VERY FIRST FLYING MACHINE

OBJECTIVE – Students will be able to construct and fly a simple sled kite and demonstrate how to control its altitude.



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- PS1.A: Structure of Matter
- PS2.A: Forces and Motion
- PS3.C: Relationship between energy and forces

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- 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)
8. Obtaining, evaluating, and communicating information

BACKGROUND – Historians do not all agree on the origin of kites. There is evidence that kites were first used by natives in the South Sea Islands. It is speculated that they attached bait to the tail of a kite and used it to fish off shore. This practice, by the way, is still used in the Solomon Islands. Other historians believe that the kite originated in China over 2000 years ago. They used their kites for many different occasions including warfare. Marco Polo recorded seeing man-carrying kites being used to observe enemy activity.

The Japanese were also heavily involved in building and flying kites. They even developed the art of "air combat" with kites. In their competitions, the kite flyers would maneuver to see who could disable the opponent's control lines.

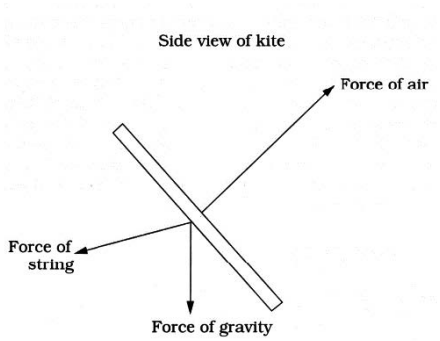
In American history, Benjamin Franklin used a kite to "catch" electricity and a British teacher by the name of George Pocock made a kite that was large enough and strong enough to pull a carriage. He claimed that he built and flew one that carried his daughter, Martha.

Octave Chanute (1832-1910) was a civil engineer whose specialty was building bridges for railways. He used his knowledge of engineering to build large box kites and even built a variety of gliders. He was a close friend of the Wright brothers and much of the structural technology that went into the design of the Wright Flyer was based on Chanute's kite experience. Much of the strength designed into the Wright's biplane glider (and eventually their airplane) was based on the Pratt truss that was adapted from bridge technology. To this day, box kites and biplanes both use this technology for strength.

This activity uses a sled kite, which has a parawing. A parawing is a type of airfoil that depends on air moving over the wing's shape to generate lift, similar to a parasail. During the 1960s, NASA had a Paraglider Research Vehicle (Paresev) to see if the parawing concept would work as a parachute landing system on the Gemini Spacecraft. NASA never went with using this concept on a spacecraft, but their work on parawings helped to improve the sport of hang gliding.

AERODYNAMICS 101
Teaching the Flight of Kites

There are three forces acting upon a flying kite. The force of gravity is pulling down, the force of the air is pushing up, and the force of the string controls the altitude. When the kite is in stable flight, all of these forces are balanced. If the forces weren't balanced, the kite would move in the direction of the greatest force. An example would be gravity. This would cause the kite to fall.



Newton's third law, "...for every action there is an equal and opposite reaction", can be applied to a kite in flight. The force of the air is the action and the kite moving upward is the reaction. As the particles of air in motion (wind) hit the kite, they bounce off. Because the kite is at an angle, it pushes the air particles downward. This makes the kite move upward. The kite pushes the air down and back and at the same time the air pushes up and forward on the kite. This is known as lift.

Some kites have tails and tails add stability. They keep the kite from "darting" around while in flight. If a kite "darts" around, the flow of air will become erratic and move more in one direction than another. Sometimes, a kite will get turned completely sideways and this causes it to stall and it falls to the ground. The sled kite works quite well without a tail, but experimentation is encouraged. For more information on how kites fly, visit https://youtu.be/mc3AUuuj9_I (SciShow Kids: How to Make a Kite)

MATERIALS (per kite)

- **a.** Sled Kite Template (copied on cardstock/heavy paper)
- **b.** Student Data Sheet
- **c.** Two straws for each student (straight straws)
- **d.** Two 45 cm lengths of string
- **e.** One 1-meter length of string
- **f.** Crepe paper (for the kite tail)
- **g.** Scotch™ or similar household tape
- **h.** Metric ruler
- **i.** Scissors
- **j.** One Paper clip
- **k.** Single-hole paper punch (can be shared with the class)
- **l.** Markers, crayons, colored pencils
- **m.** Optional Extension: Selection of materials/paper (copy paper, newspaper, tissue paper, mylar, wax paper, gift wrap, fabric, etc.)

PROCEDURE

1. Show students a kite or a picture of a kite. Ask if they know how kites were used in history, besides just for fun on a windy day. Use the background information provided to have a discussion related to the history of kites and specifically parawings.

2. Inform the students that they are going to do an experiment today to construct a kite and to help understand how kites fly. They will also discuss how we can control the altitude (height) of kites.

3. Make copies of the Sled Kite Template and the Student Data Sheet and distribute to students.

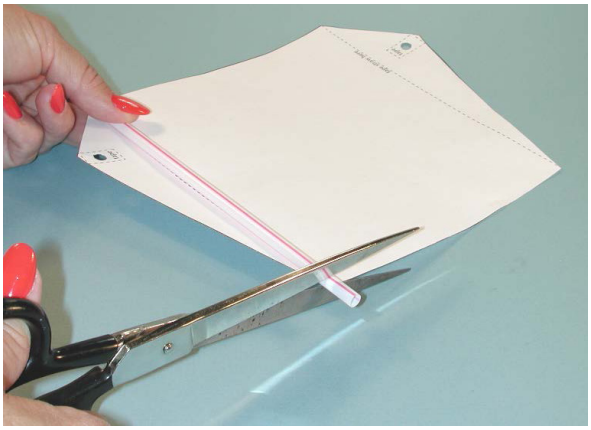
4. Instruct students to decorate the top of the sled kit using crayons, markers, etc. (time permitting) and then carefully cut out the sled kite.

5. Have the students cut the length of the two straws to fit onto the sled kite template in the area marked for straws and then secure the straws in place with tape.

6. Take 2-3 pieces of tape and place them in the marked area on the pattern that covers the black circles.

7. Using the single-hole paper punch, punch out two holes as shown on the template.

8. Cut two pieces of string to a length of 45 centimeters each using the metric ruler to measure.
(You can precut these for scaffolding purposes.)



5. Two straight straws are trimmed to it the template.

5. The straws are taped to the template.

9. Taking one piece of string at a time, have the students tie the string through each hole and make sure they are tightly knotted. Be careful not to tear the paper.

10. Instruct them to tie the opposite end of each string piece to one end of the paper clip.

11. Next, take the 1 meter string and tie it to the other end of the paper clip.

12. Congratulate your students on completing the sled kite! (To get a better idea of how it is assembled, follow the "how-to" on the next page.)

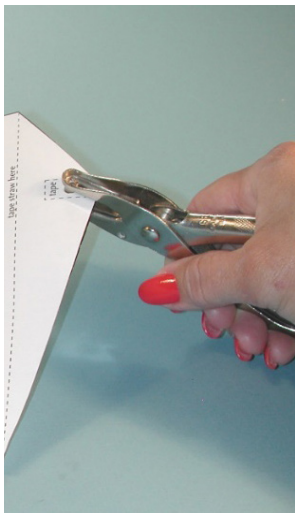
13. Go over the Student Data Sheet with the class and make sure the experiment is understood.

a. Students will fly the kite at different speeds and record data.

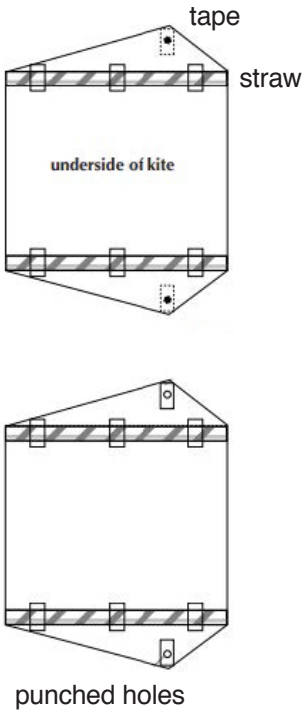
b. Students will create a tail for their sled kite out of crepe paper and experiment with there action to flying with a tail added as well as experiment with the length of the tail.

EXTENSIONS

- Allow students to experiment with a variety of materials for the kite. Use the sled kite as a template to see how the kite flies differently when it is made of cloth, copy paper, newspaper, tissue paper, mylar, wax paper, gift wrap, etc.
- Have the students rewrite the directions of how to build the kite.
- Have a relay race with the kite to sustain flight and record the length of time to complete the relay race.



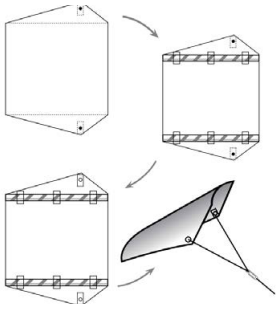
7. Punch two holes



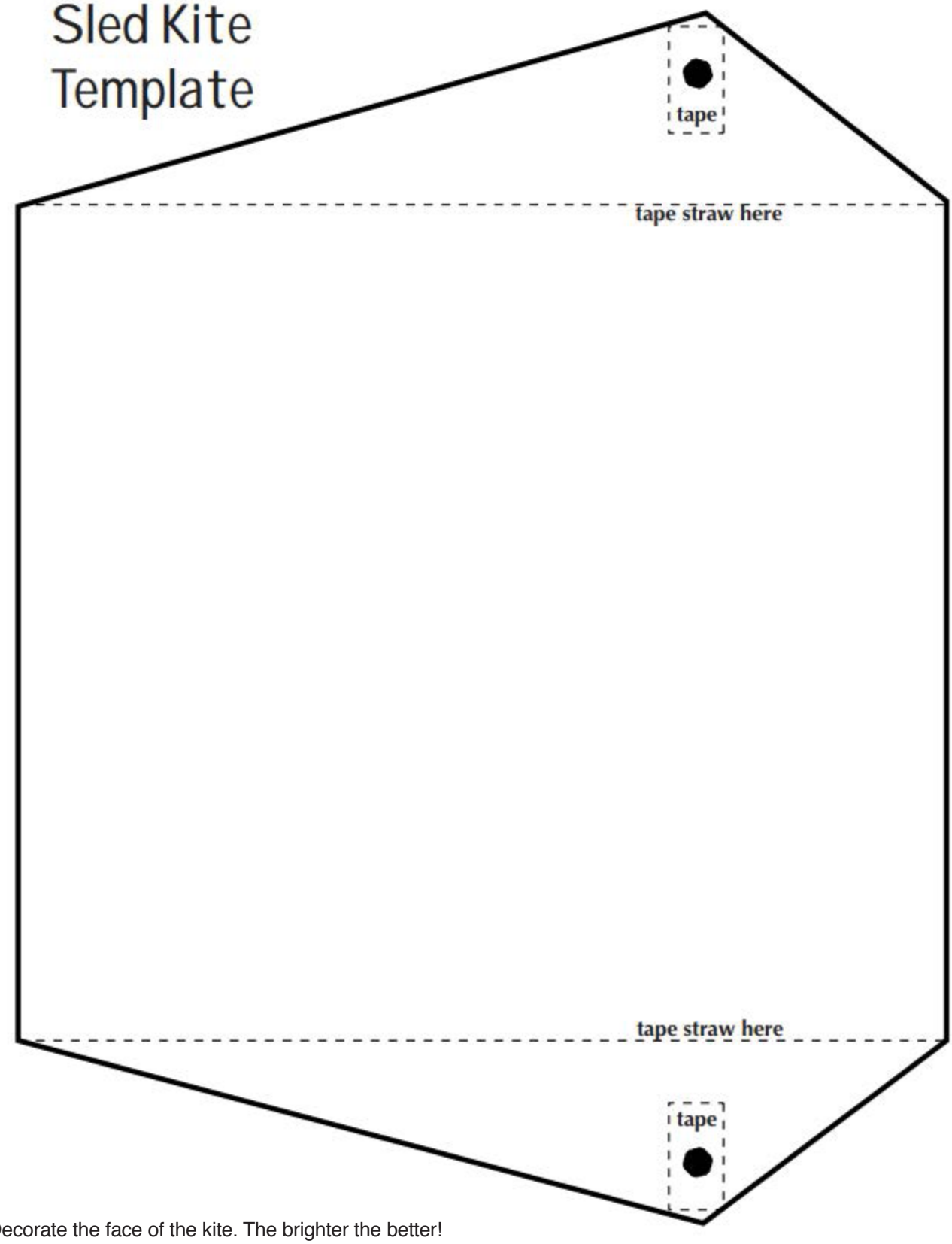
Holes are punched on the template where the black dots are shown. To give more strength, it is recommended that a piece of strong, nylon reinforced, packing tape is put where the hole is punched.

The string is attached at the points where the holes were punched. The open ends are attached to a paper clip as shown. A single string is tied to the other end of the paper clip and the kite is ready to fly.

To fly the kite, go to an open area and run with it until it gains altitude. You now have the first ever "flying machine."

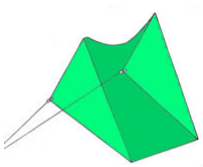


Sled Kite Template



Decorate the face of the kite. The brighter the better!

Sled Kites: A Flying Journal



Name _____ Date _____

Weather _____

Ask: What happened….
When I walked with my sled kite: _____

_____

When I ran with my sled kite: _____

_____

Imagine and Plan: Draw a sketch of where you would add a tail to your sled kit and label the starting length.

Create: Add a tail to your sled kite and make a prediction as to how the flight performance will be changed. _____

_____

Experiment: After I added a tail to my sled kite, it flew like this: _____

_____

What happens when I shorten the tail to my sled kite? _____

_____

What happens if I lengthen the tail to my sled kite? _____

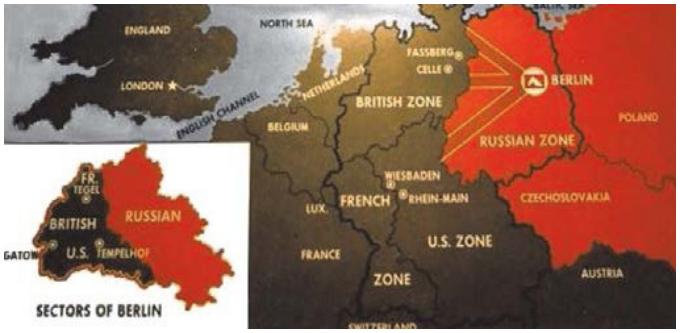
_____

Improve: How could you improve on your sled kite? What other materials could you use? _____

_____

THE GREAT UNCLE WIGGLY WINGS
A PARACHUTE ADVENTURE

OBJECTIVE – Students will be able to construct a parachute that can carry cargo (candy or paperclips) as well as learn about the history of parachutes and Col. Gail Halvorsen's efforts to bring happiness to the children of WWII by dropping treats to them by parachute.



NATIONAL STANDARDS –

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

Disciplinary Core Idea Progressions

Physical Science Progression

- PS2.A: Forces and Motion
- 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)

National Curriculum Standards for Social Studies (https://www.socialstudies.org/standards)

Themes

1. Culture
2. Time, Continuity, and Change
3. People, Places and Environments
6. Power, Authority, and Governance
9. Global Connections
10. Civic Ideals and Practices

BACKGROUND – THE CANDY BOMBER STORY

At the end of WWII, a defeated Germany was divided amongst the victors. The Soviet Union (USSR) took control of the Eastern half of Germany. The Western half was divided amongst the Allied forces of the USA, Great Britain, and France. The city of Berlin was sitting in the middle of the Eastern sector and it was governed by a union of the four powers, called the Allied Control Council. The objective of this council was to control and rebuild the war-torn city of Berlin.

Generally, traffic moved throughout the city and much-needed supplies for everyday living for the 2,008,943 Berliners came in without any difficulty. There were many disagreements on the Council as to how the city should be rebuilt. As a result, Joseph Stalin, the leader of the USSR, wanted the US, Great Britain, and France out of Berlin. On the morning of April 9th, 1948, Stalin ordered all American Military personnel maintaining communications equipment out of the Eastern Zone. On June 21st, a US military supply train was halted and it was moved back to the Western sector by a Soviet engine. On the 24th of June, 1948, all land and water access to West Berlin was cut off by the Soviets. There were to be no more supplies to be moved into Berlin. The Allies were certainly not going to stand for this. Diplomacy failed, ground invasions were planned, and World War III was eminent. U.S. military commander, General Lucius Clay, had a plan by which an armed convoy through Soviet-controlled Berlin would break the blockade and this action would almost certainly create a war.

British Commander Sir Brian Robertson offered an alternative plan: supply the city by air. It was determined that the city's daily food ration would be 646 tons of flour and wheat, 125 tons of cereal, 64 tons of cooking fat, 109 tons of meat and fish, 180 tons of dehydrated potatoes, 180 tons of sugar, 11 tons of coffee, 19 tons of powdered milk, 5 tons of whole milk for children, 3 tons of fresh yeast for baking, 144 tons of dehydrated vegetables, 38 tons of salt, and 10 tons of cheese. In total, 1,534 tons would be needed daily to keep over 2 million people alive. These figures did not include other necessities, like coal and fuel.

Earlier, in 1945, an agreement was made between all the powers, including the Soviet Union, that three 20-mile-wide air corridors would be established providing access to Berlin. The pact was signed and agreed upon by all the allied powers including the USSR. When the blockade began, the Soviets thought that surely the U.S., Great Britain, and France would leave. They were wrong, and on June 26, the first American C-47 Skytrain cargo planes landed at Templehof Airport, foreshadowing the great operation that was to come. The great Berlin Airlift began. This great undertaking was commanded by General William H. Tunner and he was known as the "transportation expert to end all transportation experts" by his commander, General Curtis LeMay.

Life for the people of Berlin was very difficult. Had it not been for the Airlift, thousands would have died from starvation and disease. One of the most poignant stories to come out of the Berlin Airlift was that of 1st Lt. Gail Halvorsen, a pilot for the US Air Force. Lt. Halvorsen had a hobby of making home movies. On one of his days off, he decided to visit the city he was saving. At Templehof, he noticed that near the end of one of the main Airlift runways, a group of children were watching the planes land. He went over to them and started a conversation. They were especially fascinated with him once they found out he was one of the pilots who was flying in their life-giving supplies.

He noticed that they did not ask him for handouts of gum or chocolate. He reached into his pocket and found that he only had two sticks of Wrigley's Doublemint gum. He told the children that if they didn't fight over it, he would drop some candy to them, by parachute, the next day when he flew over. They were very courteous and distributed the pieces of gum equally amongst themselves. Before he left, one child asked him how they would know it was him when he dropped the candy. He said, "I'll wiggle my wings!"

True to his word, the very next day on approach to Berlin, he rocked the airplane and dropped some chocolate bars attached to a handkerchief parachute to the children waiting below. Every day, the number of children would increase and he made several more drops. Soon there was a stack of mail at the Base Operations addressed to "Uncle Wiggly Wings," "The Chocolate Flyer," and the "Chocolate Uncle." Eventually he was

"called on the carpet" by his commander because some local newspaper reporter published a picture of Halverson's plane going by with tiny parachutes trailing it. His commander wasn't happy about it, but General Tunner thought it was just the kind of morale boost that the operation needed. It was eventually dubbed, "Operation Little Vittles!" The "Operation" continued and over three tons of candy was dropped over Berlin; some even landed in the Soviet Sector. For this simple, kindhearted gesture, Halvorsen became the most recognized pilot of the Berlin Airlift.

PARACHUTES 101

Teaching the History and Aerodynamics of a Parachute (from Project SOAR)
(For a video on parachutes by SciShow Kids, visit https://youtu.be/w4Jgh9V9gwE)

Parachute comes from the French word meaning "guard against falling." A parachute slows an object's fall from a great height. This device is affected by two forces: gravity pulling it down toward the center of the Earth, and air resisting that movement. Ultimately, the pull of gravity is greater than air resistance so the parachute is slowed down but not stopped. The larger the parachute's surface, or canopy, the slower the fall. A person with a parachute falls at about 5.5 m per second. Older parachutes had a a round shaped canopy, but now they are more like arches or boxes. They have fabric compartments, called cells, in which the air can be trapped. These new parachute designs can descend more slowly than the older designs. Modern parachutes can be steered by pulling on guide lines. Whereas older parachutes were made of silk, today most parachutes are made of nylon because it is stronger and cheaper.

In the fifteenth century, Leonardo da Vinci is credited with designing the first parachute, but his idea never left the drawing board. In 1783, the Montgolfier brothers developed the hot air balloon as a means of manned flight. Parachuting became a practical method of escape.

During the 1900s, Charles Broadwick, a famed balloonist, developed a body harness which is like those used by modern parachutists. His daughter, Tiny, is reported to have made the world's first free-fall jump with a manually operated parachute in 1913. Although Tiny greatly impressed military personnel in 1915 with her courage and skill as she demonstrated a pack parachute, military officials took no real interest in the Broadwick design as an aerial life preserver. The Allied aviators fought World War I without parachutes.

Balloon-type parachutes were available but the pilots refused to use them for a variety of reasons. When released from a speeding airplane, a parachute could rip in the wind blast or snag in the airplane's tail. Falling at the same rate of speed as the pilot, the plane could collide with the falling man. It was also possible for the parachute to get tangled in the propeller blades. Many pilots considered it their duty to go down with the ship or to ride the crippled airplane in for a crash landing.

In 1917, an Allied pilot witnessed a German pilot using a parachute after his (the German's) plane had been attacked. The German waved to the Allied pilot. This escape was of great interest to the Allies, and following the armistice (temporary agreement to end fighting to discuss terms for peace), the United States Congress set up a Parachute Board at McCook Field in Dayton, Ohio, to work out a practical parachute for emergency escape from aircraft. Many designs from various countries were considered and tested with dummies. The most promising was designed by Floyd Smith.

It was not until October 1922, that a young U.S. Air Corps test pilot, Lt. Harold Harris, was dramatically saved from death by using a manually operated parachute when his aircraft failed. It was after this that the U.S. Air Corps began insisting that pilots carry parachutes with them on flights and know how to use them.

Activity 2: The Great Uncle Wiggly Wings

MATERIALS

- **a.** Student Data Sheet
- **b.** Paper dinner-sized napkin (one per parachute)
- **c.** Two 45 cm lengths of string (per parachute)
- **d.** Paper clip (one per parachute)
- **e.** Round dot stickers or hole reinforcement labels (5 each)
- **f.** Candy/object to be tied to the parachute (small chocolate bar, Tootsie Roll™, paperclips, etc.)
- **g.** Masking tape (if needed to attach the object to the parachute)
- **h.** Metric ruler (if measuring and cutting own string)
- **i.** Scissors (if measuring and cutting own string)
- **j.** Parachute drop location (ex. desk, chair, stage, bleachers, playground: anywhere that provides height for the drop)
- **k.** Timers/stopwatches (optional)
- **l.** Optional Extension: Selection of materials/paper (cloth, newspaper, tissue paper, mylar, wax paper, gift wrap, fabric, etc.)
- **m.** Mercedes and the Chocolate Pilot by Margot Theis Raven (optional)

MANAGEMENT TIP:

- Consider making this a collaborative activity. Have each student create his/her own parachute, but encourage the dropping and data collection to be a group activity. It is much easier to time the descent of parachutes in a group setting.
- If food allergies are an issue, modify the "cargo" by providing copious amounts of paper clips and have the students try to design a parachute to drop the largest amount possible.
- For younger students, have a class data chart displayed in the front of the room.

PROCEDURE

1. Show students a toy parachute or a picture of a parachute and hold up a bar of chocolate. Ask if anyone knows what the two of them have in common. Use the background information provided to share the story of Col. Gail Halvorsen or read the book Mercedes and the Chocolate Pilot by Margot Theis Raven. Facilitate a discussion on the engineering of the parachute to drop the candy.

2. Further explore the aerodynamics of parachutes by performing a few optional experiments.

3. Hold a textbook (or similar object of weight) in one hand and a wadded piece of paper in your other hand. Ask students to predict which one will hit the ground first when dropped from the same height. Ask students to observe closely to see which hits the ground first. Drop both items. Discuss what happened. (They hit the ground at the same time.) Repeat the demonstration using a jumbo paperclip and a shoe (or other similar object of weight). Ask students if all objects,when dropped at the same height, hit the ground at the same time. Ask students if they can think of any exceptions.

4. Hold a jumbo paper clip in one hand and a jumbo paper clip attached to a napkin parachute in the other hand. Ask students to predict which one will hit the ground first. Ask students to observe closely to see which hits the ground first. Drop both items. (The paper clip without the napkin hits the ground first.)

5. Discuss the results of the experiment. Ask students the following questions:

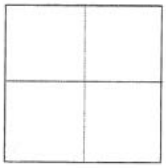
- **i.** What force caused all of the objects to fall towards the ground? (gravity)
- **ii.** Why did the parachute float down instead of falling straight to the ground like all of the other objects? (Answers will vary.)

Explain that air helped the napkin that was shaped like a parachute to float. Not only was gravity pulling it down, but due to the shape of the napkin, a force called air resistance was working against gravity. To help students better understand air resistance, ask them if they have ever held their hand out of the car window. If the car is not moving, they do not feel any air resistance. If the car is moving, and the palm of their hand is facing forward in the direction the car is traveling, they feel more air rushing against their hand that wants to push their hand backward. This is air resistance. It wants to slow motion.

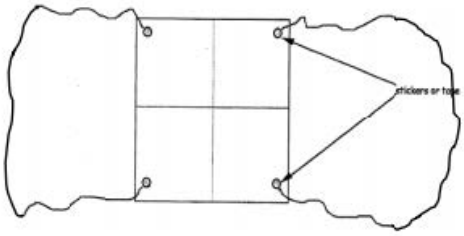
Of course, in the case of the paperclip parachute, gravity ended up being more powerful than the force of air resistance because the parachute with the paper clip eventually hit the ground. Air resistance was also affecting the other objects that were dropped. So, why didn't they float to the ground? (Their weight and shape worked with gravity in such a way that air resistance didn't stand a chance of slowing the objects down.)

6. Inform the students that they are going to do an experiment today to construct a parachute that will be able to support cargo, similar to the parachutes used by Uncle Wiggly Wings.

7. Lead students through the assembly of the napkin parachutes.



- Distribute a paper dinner-sized napkin, 5 reinforcement labels, strings, and one paper clip to each student.
- Have students open the napkin on their desk. They should see that the folds in the napkin divide it into 4 equal parts.



- Take one piece of string and attach the end of it to one of the corners of the napkin using a round dot sticker. Curl the end of the string into a "c" shape before placing the sticker on the end of the string. This will reinforce the connection. Take the other end of the string and stick it to another corner of the napkin on either side of the first one. Repeat this with the second piece of string.

- Have a partner hold the napkin so that the strings are hanging down toward the ground. Have the other student attach both strings to a paper clip using their last round dot sticker or challenge them to see how to slip the string into the paper clip without having to use the sticker. Once this is done, the student should help his/her partner do the same.

8. Congratulate your students on completing the parachute!

9. Distribute copies of the Student Data Sheet to students and go over the instructions. Clarify any questions and make sure that the students understand the "drop zone" location and the safety precautions for using the "drop zone".

10. Have students test the parachute without adding any "cargo". Record observations on the Student Data Sheet.

11. Follow the Student Data Sheet directions and attach the "cargo" (a miniature candy, like the Hershey™ miniatures, or more paper clips) to the end of the strings. You can use tape or a paper clip to attach the candy to the strings.

12. Drop the parachute, with the added "cargo", and record observations and complete follow up questions.

13. After all students have filled out the Student Data Sheet, facilitate a discussion on observations and conclusions during the experiment.

14. Use the following questions to guide a discussion:

•What two forces were pulling or pushing on the parachute? (Gravity and air resistance, respectively.)

•Why do you think the parachute fell faster when mass was added to it? (Weight and gravity "teamed up" to beat air resistance. Even though the parachute itself had the right shape and was light, the weight being attached to it was eventually too much for it.)

•What could be done to make the parachute gently float to the ground with even more cargo attached to it? (Answers will vary. Hopefully, someone will suggest making a larger parachute.)

•Why are experiments like this important? (We learn things that work and do not work. This is important before providing a product to people.)

•Why are parachutes important? (Refer to the background information.)

•Does anyone know of anything else in nature that uses a parachute design besides humans? (Baby spiders form a parachute-like web and float to a new location. Dandelions, when blown, have a parachute design that lets their "parachute" float a seed to a new location.)

EXTENSIONS

•Allow students to experiment with a variety of materials for the parachute. See how the parachute works if it is made of cloth, newspaper, tissue paper, mylar, wax paper, gift wrap,etc.

•Allow students to make parachutes of different sizes (different sized canopies), shapes (circular canopy, rectangular canopy, triangular canopy), and/or materials (garbage bag, construction paper, fabric).

•Allow students to cut a hole in the top of the parachute canopy. Talk about the change in the descent time of the parachute.

•Invite a local utility company or firefighter to bring a bucket truck and drop the different parachutes.

•Have the students illustrate the story of Uncle Wiggly Wings.

•Have students drop their parachutes in order to try to land on a target on the ground.

•Play the Uncle Wiggly Wings Song by Holverson Music: https://youtu.be/qmklLOi62Fg

Parachutes: Delivering Happiness

Name _____ Date _____

Ask: What happened when I dropped my parachute with no cargo attached?

_____

_____

Record your observations on the chart below.

Trial	# of seconds	Describe what happened. (Straight down, float left, opened, etc.)
Trial #1		
Trial #2		
Trial #3		

Imagine and **Plan**: Draw a sketch of your parachute with the cargo attached.

Create: Add cargo to your parachute and make a prediction as to how the descent (drop rate) will be changed.

_____

Experiment: Drop your parachute with the cargo attached and record your observations on the chart

Trial	# of seconds	Describe what happened. (Straight down, float left, opened, etc.)
Trial #1		
Trial #2		
Trial #3		

Improve: How could you improve on your parachute? What other materials could you use?

_____

_____

BACK TO BASICS
PAPER AIRPLANES

OBJECTIVE – Students will be able to construct and fly a classic paper airplane to create a lesson in controlled flight.

NATIONAL STANDARDS –
Next Generation Science Standards (www.nextgenscience.org):
- Disciplinary Core Idea Progressions
  - Physical Science Progression
    - PS2.A: Forces and Motion
    - 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
  - **6**. Constructing explanations (for science) and designing solutions (for engineering)
  - **8**. Obtaining, evaluating, and communicating information

BACKGROUND – There are at least three significant historical examples of how paper was used in early experimentations with flight: (1) The Japanese and Chinese were both known to use paper for the construction of kites. (2) The French Montgolfier family had a paper business and early experiments with paper bags over an open-hearth fire led the way to a successful, man-carrying hot air balloon. (3) Sir George Cayley, an English inventor, used paper to construct small gliders. He is given credit with building several successful paper and wood gliders which had the shape of modern aircraft. The models had wings, a stick fuselage, and stabilizers on the tail. George Cayley lived in the early 19th Century and his gliders were created around 1812. In relation to historical examples with a connection to a paper airplane, the Wright Brothers first experimented with glider controls, much like the paper airplane controls mentioned in AEROSPACE 101 below, before adding power. The Wright Brothers could have achieved sustained flight by having control of their aircraft. In this lesson, students are asked to build a paper airplane. A paper airplane is a real "flying machine." This means that it uses the energy of the atmosphere to provide lift and control.

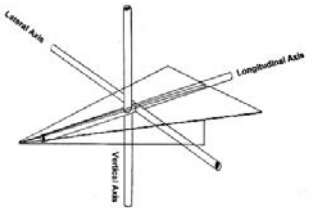
AEROSPACE 101

How to teach the principles of flight using a paper airplane
For more background information, please visit https://youtu.be/QoTbgSSTB3E.

- As mentioned, a paper airplane is a flying machine. Our model has a delta, or triangular, wing configuration.

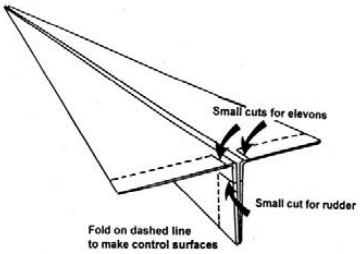
- When small "elevons" are incorporated into the trailing (aft) edge of each wing, the paper airplane's flight can be controlled. A real life example of this is seen in the XB-70 Valkyrie created by NA SA(https://www.nasa.gov/centers/armstrong/news/FactSheets/FS-084-DFRC.html). Pay careful attention to its shape and notice the elevons.

- In flight, the model becomes three-dimensional. The paper airplane is a machine that uses the forces of the atmosphere to achieve flight and changes in direction.



- Because it is three-dimensional, the paper airplane has three axes around which it can move. The axis going through the middle (wingtip to wingtip) is known as the lateral axis. Movement along this axis is known as "pitch," i.e., nose-up or nose-down. The axis going through the nose to tail is called the longitudinal axis. Movement along this axis is known as "roll." The axis going through the paper airplane from top to bottom is the vertical axis. Rotation along this axis is called "yaw."

- The elevons mentioned above can be used to control the flight of the paper airplane. This illustration shows how to build these control surfaces into the wing.



- When the elevons are put in a position where one is up and the other is down, it will cause the model to "roll" when moving through the air. This is a rotation around the longitudinal axis.

- If a cut is made in the aft portion of the fuselage, a rudder will be created. This will make the model "yaw," or rotate around its vertical axis.

- Pitch, roll, and yaw demonstrate the three-dimensional controls of the aircraft.

- When the paper airplane is launched, gravity starts to pull it back to the Earth. The aircraft will glide forward, literally "skiing" on the air. This means that it is getting some lift from the environment because lift opposes gravity. The actual landing zone is determined by the amount of thrust (the act of throwing the paper airplane), the amount of drag created by the air, and the settings of the elevons.

- As the model flies through the air, it immediately starts a descent. This creates an angle to the flat surface upon which it will land. This is called the angle of descent. Assuming the builder is standing straight up, and the floor is flat, the angle of descent creates a right triangle. The hypotenuse can be varied by settings on the elevons. When the elevons are in a slightly up position, the nose will pitch up and create a longer glide path, thus, extending the length of the hypotenuse!

- If a paper airplane wants to turn to the left, use the aerodynamic controls (elevons and rudder) to correct it the other way. If the nose wants to pitch up or down, correct it by making it pitch in the opposite direction. In other words, use aerodynamic methods to correct the model in flight.
- It should be remembered that in flight, you (the pilot) are in control of the aircraft, or the aircraft is in control of you! Without control, it would be like driving a car without a steering wheel or brakes!

Activity 3: Paper Airplanes

MATERIALS (per paper airplane)

a. One piece of 8.5" x 11" copy paper
b. Scissors
c. Student Data Sheet
d. Masking or Scotch™ tape (optional)
e. Straws (optional for showing the axes of rotation)

PROCEDURE

1. Engage the students by telling them that you are going to have a Paper Airplane Contest, not for "longest flight" purposes, but for the design aspect.

2. Give each student a piece of paper and ask them to create their best paper airplane. Take some time to talk about the differences in the models before testing them.

3. Allow the students to test the models and observe the flight patterns. Facilitate a discussion about the similarities and differences between the physical look of the paper airplanes, as well as the flight paths.

4. Bring the class back together and point out that there are many ways to fold a paper airplane, but they all have two things in common. The aircraft is made of paper and its purpose is to fly.

5. Provide background information on the first paper models of airplanes as well as the Wright Brothers'glider.

6. Lead students through the creation of a traditional delta-wing paper airplane following the directions below, making sure to create the elevons and optional rudder (for older students) by cutting slits in the paper airplane.

7. Go over the AEROSPACE 101 information and have the students hold their models to demonstrate the 3 axes of rotation: lateral, longitudinal, and vertical, as well as the movements of pitch, roll, and yaw.

8. Provide students with the challenge of throwing the paper airplane towards a target (hula hoop, plastic garbage bag, etc.) for students to land their paper airplane on. See who can land on the target. If missed, have them adjust one of the control surfaces and try again.

9. Pass out the Student Data Sheet and give them 5 tries making sure that they are recording changes and results.

10. As an extension, use the second Student Data Sheet to have the students test different variables of paper airplane flight (nose weight, angle of throw, speed of throw, setting of elevons, etc.) with the desirable outcome being the longest flight possible.

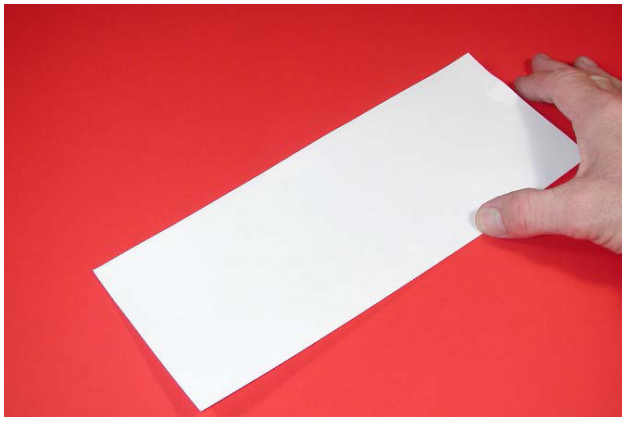
11. Remind students to test one variable at a time or divide your class into groups and have each group of students test a different variable.

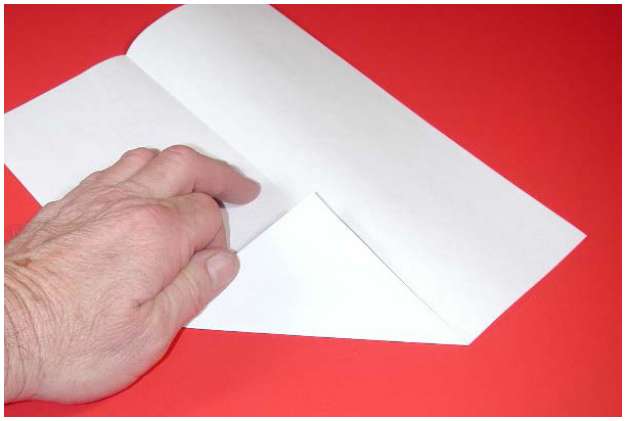
12. After testing is done, facilitate a discussion so that groups can share data with the class and graph results if desired.

13. This lesson can be used multiple times with different paper airplane designs. Consider having students lead the creation of the paper airplane to be used with this lesson or look for designs on the Internet. There are several web sites that feature outstanding creations. For example, paperairplaneshq and www.foldnfly.com are great websites with step by step instructions to create paper airplanes.

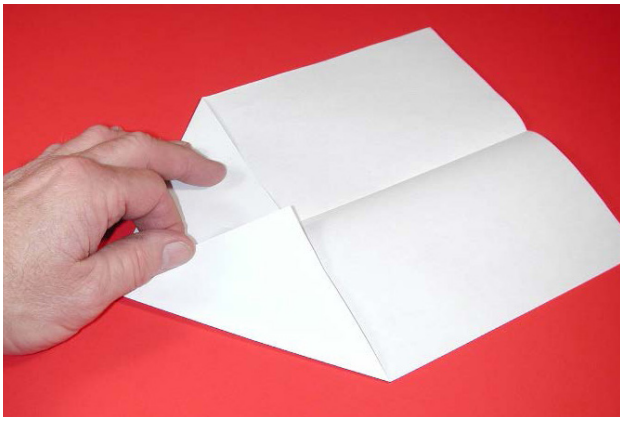
14. To continue the study of using paper to construct aircraft, check out the following website, http://www.fiddlersgreen.net/, which has model airplanes constructed from folding and cutting paper.

SIMPLE DELTA WING PAPER AIRPLANE



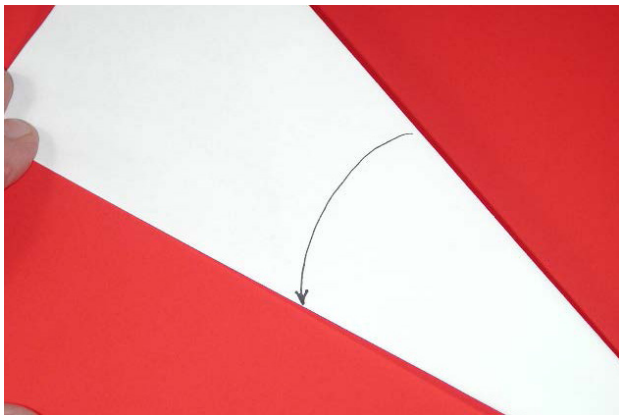


To make a traditional delta-wing paper airplane, the first fold is longwise. Some teachers call this "folding it like a hot dog bun." Using the illustration as a guide, first fold one of the edges back to the center as shown.



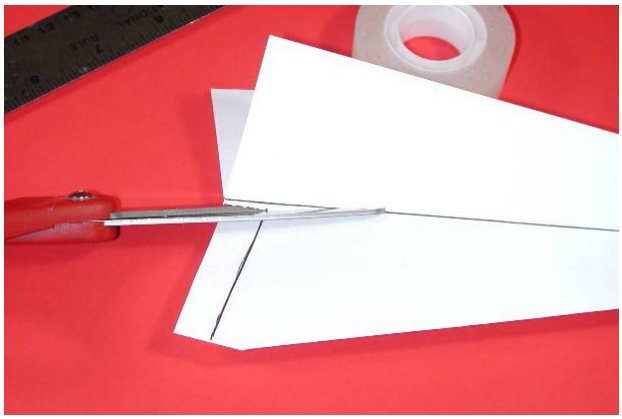
The same fold is made on the opposite side. It has been found that creasing the folded edges with a thumbnail makes a better-looking finished model.

The next fold brings the outer edge to the center as shown. Refer to the illustration if you need help on this step. It is repeated on the opposite side. Make sure that the folds are crisp and that both sides are equal.

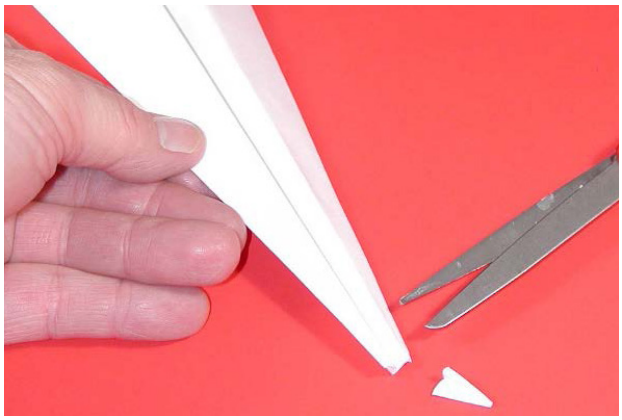


For the next fold, instruct students to “make the upper edge of the wing match the lower edge of the fuselage.” By matching the two edges, a perfect wing will be created. As before, use the illustration as a guide on this critical fold.

Tape, either masking or Scotch™ brand, can be used to hold the model together.



As explained in the text, and shown in the illustration, two elevons are made by cutting two slits into the back, or trailing edge, of the wing. The slits allow the builder to make two equal control surfaces.



To make the model safer, it is recommended that the sharp nose be cut off as shown. This reduces the risk of injury in the event a plane accidentally goes towards another student.

For a video of this process, please visit https://youtu.be/V-rBmbBSGlA by JustOrigami.

Back to Basics: THE PAPER AIRPLANE
Student Data Sheet

Name _____ Date _____

1. Write one fact that you learned while listening to the background information on paper airplanes.

_____

_____

2. Match the three axes of rotation (lateral, vertical, longitudinal) to the movement that goes with each axis (pitch, yaw, or roll) to describe how airplanes can move in the sky.

a)Axis:_____ Movement: Pitch

b)Axis:_____ Movement: Yaw

c)Axis:_____ Movement: Roll

3. Aim your paper airplane at the target (hula hoop, plastic garbage bag, etc.) and try to get your aircraft to land on it. If your plane misses, adjust one of the control surfaces and try again. Make sure to record your changes and results on the chart below.

Trial #	Change Made	Results
1		
2		
3		
4		
5		

4. What did you learn about using the control surfaces of your airplane? Explain.

_____

_____

_____

_____

_____

EXTENSION ACTIVITY

5. Test different variables of paper airplane flight (nose weight, angle of throw, speed of throw, setting of elevons, etc.) to try to have the longest flight possible. You can do this individually or as a team.

   Record your test results on the data chart below. Make sure you do at least 5 trial flights before testing a different variable and record flight time. If you switch to a different variable using the same chart, make note of the variable change.

Trial #	Describe Variable Tested	Results (Length of the Flight in Seconds)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

6. After looking at all the different variables tested in your class, explain which variable produced the longest flight; identify any areas for improvement.

_____

_____

_____

_____

BLAST OFF BASICS
FOR THE LITTLEST ROCKET SCIENTISTS

OBJECTIVE – Students will be able to investigate the basics of what makes a rocket fly using a balloon.

NATIONAL STANDARDS –

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

Disciplinary Core Idea Progressions

Physical Science Progression

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

Crosscutting Concepts

- Systems and system models
- Cause and effect
- 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)

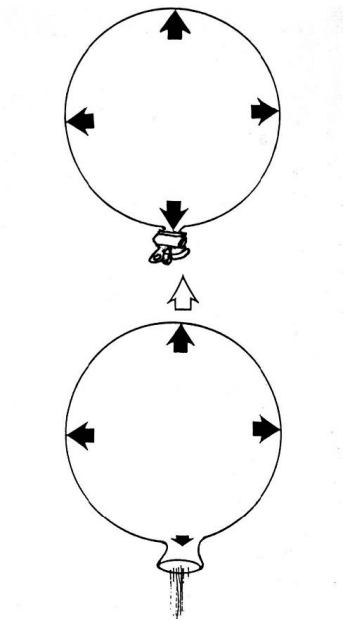
BACKGROUND – Sir Isaac Newton (1642-1727), a brilliant English scientist, laid the foundation for the science of rocketry. His third law is the heart of rocketry because the action of the rocket engine produces forward motion. Newton's third law states, "…for every action, there is an equal and opposite reaction." For children, a toy balloon clearly shows how this law works. The action is the pressure released and the reaction is the balloon moving in the opposite direction.

MATERIALS

a. Student Data Sheet
b. One balloon for each child
c. "Bulldog Clips" (12 for about $4) for clipping and launching.
d. Box fan (used to create moving air)
e. Balloon hand pumps (optional)

ROCKET SCIENCE 101

TEACHING CHILDREN WHY THE TOY BALLOON IS LIKE A ROCKET
Please visit https://youtu.be/iV3NXFkdUyw for more information on how balloons are like rockets.



- The arrows represent pressure (if you use your finger to press on something, your finger is now the arrow).
- When the balloon is inflated, all the arrows are the same—the pressure is equal in all directions.
- When the clamp is released, air flows out. One arrow is smaller because the pressure has been released.
- Look at the arrow opposite the opening; it's still large. That is why the balloon moves in that direction.
- It doesn't have to push against anything and that's why it can fly in space!

PROCEDURE (This activity can be used as an introduction to the "Mr. Lifter" lesson.)

1. Show students a balloon and ask if they know what it is called. When they inform you that it is a balloon, tell them that it might look like a balloon, but it is actually a rocket engine.

2. Blow up the balloon and hold it closed. Have the students predict what might happen if you let it go.

3. Release the balloon and talk about the reaction. Facilitate a conversation about how a balloon is like a rocket using the background information provided. There is also a larger "Rocket Science 101" insert at the beginning of this publication.

4. Pass out the Student Data Sheet and go over the experiment.

5. Hand out a balloon to each student and ask them to blow it up. You may want to have balloon hand pumps available or extra adults to facilitate the inflating of the balloons.

6. Have the students work through each question individually or as a small group. For younger students, you could test each variable, discuss, and write responses together as a class. Facilitate a class discussion on the results of the experiment.

BLAST OFF BASICS

Name _____

1. When I held my balloon opening down… _____

_____

_____

2. When I held my balloon opening sideways… _____

_____

_____

3. When I held my balloon opening up… _____

_____

_____

4. When the air was moving, my balloon… _____

_____

_____

5. When the air was still, my balloon… _____

_____

_____

6. Make your own question and answer it. _____

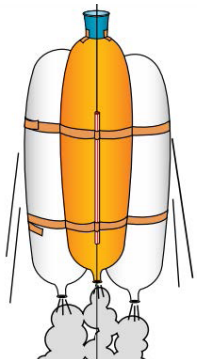
_____

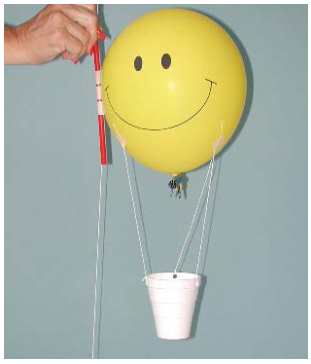
_____

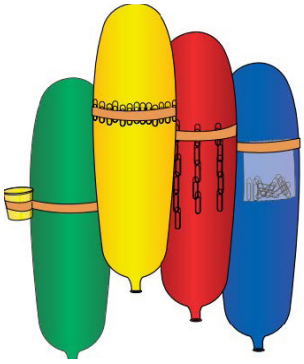
MR. LIFTER: UP WE GO!

USING A "ROCKET" TO LIFT WEIGHT - INSTEAD OF A WING

OBJECTIVE – Students will be able to construct balloon-powered rockets to determine the amount of initial thrust needed to launch the rocket to the classroom ceiling. Students will be able to extend critical thinking and creativity to see if additional weights affect performance and engineer a way to get the greatest payload possible to the classroom ceiling.







NATIONAL STANDARDS –

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

Disciplinary Core Idea Progressions

Physical Science Progression

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

Crosscutting Concepts

- Systems and system models
- Cause and effect
- Scale, proportion, and quantity
- 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)

BACKGROUND

Please visit "Make a Balloon Rocket" (https://youtu.be/KMX7zgaLC0w) by SciShow Kids for an idea of how to construct the basic rocket. NOTE: The rocket in the video travels horizontally and the rocket in this lesson travels vertically.

Heavy lift launchers are a major part of NASA's research program because it is necessary that heavy payloads be lifted into orbit. The payloads include large satellites used for scientific purposes, space station module replacements, supplies for the International Space Station, as well as departure stages that help propel spacecraft carrying people to the Moon and Mars. NASA has had many designs for the heavy lift launcher. The Ares V is one that never completely came to fruition, but definitely was at the

forefront of the heavy lifters that we have today (http://www.spacelaunchreport.com/ares5.html).

It is extremely challenging for NASA to launch heavy payloads to orbit. The rockets have to have a massive amount of thrust from powerful engines and lots of propellants. There is definitely a market for commercial space companies to fulfill this need and there will continue to be a need for heavy lifters in the future.

ROCKET SCIENCE 101

Teaching children about the mathematics of gravity

- Please see the **"Rocket Science 101"** insert at the beginning of this publication for rocket background information.

- Depending upon the class, teachers might only want to approach this from Newton's third law, "…for every action there is an equal and opposite reaction."

- For students in the upper grade levels who are ready for it, the **Educational Brief, Microgravity: Fall into Mathematics** may help with some history about gravity. The eight page brief covers the lives of Galileo Galilei, Isaac Newton, and Albert Einstein as well as several mathematical formulae developed covering gravity and microgravity. The NASA brief is located at the following link: https://er.jsc.nasa.gov/seh/Fall_Into_Mathematics.pdf.

MATERIALS

a. Large binder clips (one per "launch zone")
b. Fishing line or smooth string (one per "launch zone")
c. Meter Stick (one per "launch zone" for measuring)
d. 3 Balloons per group (long balloons work better from a party store or look online for balloons labeled 524 or 5" x 24")
e. Masking tape (1 meter)
f. String (1 meter)
g. Two straight drinking straws
h. Small 3 oz bathroom cup (1 per team)
i. Sandwich sized fold-over plastic bag (1 per team: holds materials but can also be used in design. How ever, do not mention use in design. This is part of the creativity element.)
j. Scissors
k. Paper clips (small ones, about 25-30 per group)
l. Balloon hand pumps (optional)

Tips for Management of Lesson

- Prep the classroom by setting up "launch zones" where you have the fishing line already connected to the ceiling. You can easily use binder clips tied to the fishing line to attach the fishing line to the metal frame that supports the ceiling tiles if you have a suspended ceiling. Make sure the fishing line reaches the floor and that you have open space around the "launch zone".
- You can assign teams or tables to a specific "launch zone" to help with the testing traffic.
- Explain how to use the straw as a guide for the rockets before construction begins on the balloon rocket. Show the students that the fishing line is fed through the straw to guide it up the line when the balloon is released.
- Mention that it is extremely important that one person holds the end of the fishing line taut to the floor. If the line has slack, the balloon rocket will not work as efficiently.
- Keep a small supply of replacement balloons. Some will have a small pinhole from the factory. ****Most importantly:** Try not to give too much information to the students. This is a lesson in creativity and problem solving. Explain the challenge and how to use the straw for stability and mention that they can use all or part of the materials provided to them. There are three balloons to use, but only three.

PROCEDURE

1. Show students a balloon and ask if they know what it is called. When they inform you that it is a balloon, tell them that it might look like a balloon, but it is actually a rocket engine.
2. Blow up the balloon and hold it closed. Have the students predict what might happen if you let it go.
3. Release the balloon and talk about the reaction. Facilitate a conversation on why the balloon went out of control around the classroom and how we could possibly harness that release of energy.
4. Discuss how a balloon is like a rocket using the background information provided. Show the video,"Make a Balloon Rocket" (https://youtu.be/KMX7zgaLC0w) from SciShow Kids to give an idea of how a horizontal rocket launch works. Also mention the special class of heavy lifters that NASA is currently looking for from the commercial world.
5. Divide your class into teams of two or three students and explain the design challenge:

   NASA is looking for a new commercial space company to design the next heavy lifter to propel heavy payloads into orbit. Your team is challenged to design and build the most efficient heavy-lift rocket. Each team has received identical parts to construct your rocket. The team that can lift the greatest payload (paper clips) into space (the ceiling) will be declared the winner.
6. Provide each team with an identical kit of building materials (3 balloons, 1 meter of string, 1 meter of masking tape, a 3 oz drinking cup, and 2 straight straws all in a sandwich sized plastic fold-over bag). The materials are not to be touched until after they have sketched their design. Mention that they can use any or all of the materials, but no more will be given to the team. Also, mention that the materials may be manipulated in any way, but they will not be replaced with new materials.
7. Review the launching procedure, including the assigned "launch zone". Mention again how the straw guides the rocket up the fishing line and that it must be held taut to the floor when launched. Remind students that there are only three balloons for each team. The teams can launch as many times as they would like, but each time should improve the amount of paper clips lifted up to "space".
8. Pass out the Student Data Sheet and have students follow the Engineering Design Process to sketch and build

their heavy lifter rocket as well as record data during the testing process. Make sure to remind them that they will not be able to touch materials or build until a sketch has been created.

9. Be sure to set a limit for the amount of time for the building and testing. Once the testing has ended, bring the class back together for a conclusion discussion.

10. Engage the class in the following conversations from NASA's Heavy Lifting Lesson (Rocket Heavy Lifting):

a. Why is NASA so supportive of commercial space companies?

- NASA's space efforts are aimed at expanding our horizons in space. Although their space rockets are easily capable of launching communications, weather, and Earth resources satellites, NASA continually looks beyond. NASA explores, and when it pioneers a new technology, it seeks to turn over continued development to U.S.commercial interests. That way, NASA can focus on and advance to the next new horizon. NASA's current new horizons include the first permanent bases on the Moon and the first human expeditions to Mars. These are demanding challenges. When they are met, commercial space companies will follow, permitting NASA to move on to even greater challenges.

a. Why is it so important to construct efficient heavy-lift vehicles?

- Traveling into space is a very difficult and expensive endeavor. Huge rockets and tremendous amounts of propellants are required to accomplish the job. With some rockets, launch costs were approximately $20,000 per kilogram of payload delivered into Earth's orbit. If that cost were to continue, imagine staying at a space hotel where it would cost about $10,000 for a half liter bottle of drinking water! Improving heavy-lift rockets (lighter rocket structures, more propellant efficient engines, etc.) will enable us to accomplish much more in space at far more reasonable costs!

11. Allow time for students to share their designs and discoveries. Consider having a showcase of rockets!
a. Have each team describe their design to the class. How many balloons did they use? How many paper clips did their rocket carry to the ceiling? How did they attach the paper clips to the balloon? What problems did they encounter? How did they solve those problems?

MR. LIFTER

Engineering Design Process Student Data Sheet

Name _____ Date _____

Ask: How can you design a Heavy Lift Launch Vehicle that can carry a payload (paper clips) to space (the ceiling) with the supplies that you are given?

_____

_____

_____

Imagine: From the supplies given, what could you use to hold paper clips?

_____

_____

Plan: Sketch your idea for how to build the launch vehicle below. Make sure to label the materials.

Create and **Experiment**: Collaborate with your team and build the launch vehicle. Experiment using the chart below. Measure and record the distance Mr. Lifter travels when you add the following payload.

1 paper clip _____ cm
3 paper clips _____ cm
5 paper clips _____ cm
7 paper clips _____ cm

Improve: How could you innovate your original design to carry more mass?

_____

_____

Before continuing to the next step of the Mr. Lifter Design Challenge write a brief summary of your launch vehicle using correct science and technology terms (e.g., lift, payload, mass, thrust).

_____

_____

******Continue onto the reverse side of the paper for the "Mr. Lifter Rocket Mission Report".**

MR. LIFTER
ROCKET MISSION REPORT

Team Member Names:

_____

_____

_____

_____

_____

Flight Test	Predict How Much Mass Your Rocket Will Lift 1 Paper Clip = 2g	Actual Mass Lifted
1.		
2.		
3.		
4.		
5.		

Make a sketch of your best rocket

Describe your first rocket.

_____

_____

_____

_____

How did you change your rocket to make it carry more mass?

_____

_____

_____

_____

What other ways could you change your rocket to improve it?

_____

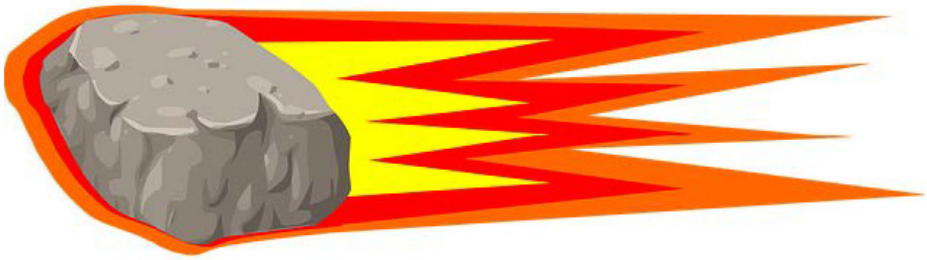
_____

_____

_____

COMET CAPERS
FOR THE LITTLEST ASTRONOMERS

OBJECTIVE – Students will be able to learn about comets and build a hands on model.



NATIONAL STANDARDS –

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

Disciplinary Core Idea Progressions

Earth Space Science Progression

- ESS1.A: The universe and its stars

Physical Science Progression

- PS1.A: Structure of Matter

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)

BACKGROUND – Comets have been known since ancient times and there are Chinese records of Halley's Comet that go back two hundred years before Christ. As of 1995, 878 comets have been cataloged and their orbits calculated.

Comets are sometimes called "icy mudballs" or "dirty snowballs." They are a mixture of ice—both water and frozen gases—and dust particles that date as far back as the beginning of the solar system. Comets have "parts." They are:

- Nucleus -This is a center made up of ice, gas, dust, and a few other solids.
- Coma - The coma is a dense cloud of water, carbon dioxide, and other gases that have sublimed from the nucleus.
- Hydrogen cloud- Some comets have a huge envelope of hydrogen around it.
- Dust tail - This tail can be millions of kilometers long and composed of dust particles driven off the nucleus by escaping gasses.
- Ion tail - This is a tail that is composed of plasma with rays and streamers caused by the comet's interaction with the solar wind.

Comets are invisible except when they are near the Sun. Most comets have an eccentric orbit which takes them far beyond the orbit of Pluto. Most are seen once and then disappear for hundreds of years (only the short and intermediate-period comets, like Halley's, stay within the orbit of Pluto for a significant fraction of their orbits).

For more on comets, please visit Comets and Asteroids! By SciShow Kids (https://youtu.be/02wrLS-ue1Q) or Comets by Peekaboo Kidz (https://youtu.be/-_6nYgel4JI).

COMET TIDBITS

- Comets follow a regular orbit around the Sun.
- Bits of comets crossing the Earth's path become meteoroids.
- Scientists think that about 100,000 million comets orbit the Sun.
- A comet is made of dirty ice, dust, and gas. Think of it as a very dirty iceberg.
- A comet's tail can be millions of miles in length, but the amount of matter it contains can be held in a large bookbag.
- The three main parts of a comet include the coma, nucleus, and tail.

MATERIALS
a. Student Data Sheet
b. Small Styrofoam ball
c. Skewer stick (blunted by cutting off the pointed end)
d. Tinsel (preferably "ice blue" in color)
e. Scotch® tape

PROCEDURE
(For an upper elementary version of this activity, please see https://space-place.nasa.gov/comet-stick/en/)

1. Show the students a picture of a comet. (https://www.nasa.gov/comets) Ask if anyone knows what it is called, where you can find it, or what it is made of.

2. Facilitate a conversation about comets using the background information provided. There is more information located at the NASA website listed above.

3. Lead students through the construction of the comet following the instructions below:
- **i.** Pass out the materials (skewer stick, Styrofoam ball, and tinsel) to each student. Make sure to have tape available as well.
- **ii.** Instruct the students to push the Styrofoam ball into the skewer. The skewer will become a handle for the comet model.
- **iii.** Tape pieces of tinsel (about 12" long) to the top of the ball (opposite the skewer).
- **iv.** Pull the tinsel down around the ball as shown in the picture.

4. Once the comet has been constructed, pass out the Student Data Sheet.

5. Have the students sketch the comet and label the parts mentioned in the background information. For younger students, you could sketch and label together as a class.

6. Allow students time to share their sketch as well as point to the different parts on the model of the comet.

EXTENSION
(Note: This activity should not be done in a classroom with certain food allergies.)

FOLLOW-UP FUN!
Make an Edible Ice Cream Comet

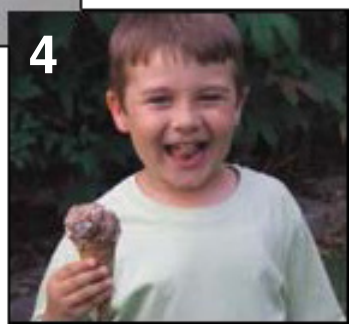
1. Collect these materials:

- vanilla ice cream
- paper baking cup like those for cupcakes
- vanilla wafers
- chocolate wafers
- ice cream cones
- a rolling pin
- spoons
- zipper-locking plastic bag
- wax paper

Even though this is not an accurate model of a comet, it is fun and an easy way to remember the concept that a comet is made of ice and rock.

2. Make some dirt!
Put your wafers inside the plastic bag, push out the air, and seal the top. Roll it with the rolling pin to make your dirt.

3. Make a comet!
Pour your dirt onto the wax paper and then roll a scoop of ice cream in it until it is completely covered with crumbs. Then take the comet and place it in a paper cupcake cup and put it in the freezer for 20 minutes.



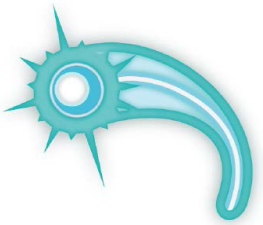
4. Eat your comet!
Remove the comet from the freezer and place it on your ice cream cone. Pretend to be the sun and melt that comet in your mouth and enjoy.

Quick Comet Facts
No two comets are alike. They differ in size, shape, and what they're made of.
Comet tails are a result of solar wind. Energy and particles from the sun push on the comet. This force pushes dust and gas behind the comet. The ion dust and gas have different weights, so they separate, making two separate tails.

Once scientists saw a third tail, which was a smaller tail forming just between the dust and gas tail. They discovered is was made of salt.

Comet tails have been discovered to be so long that the Voyager 2 passed through one that was thousands of miles away!

COMET CAPERS



Name _____

1. Draw a picture of your comet.

Please make sure to label the coma, nucleus, and tail.

2. What are real comets made of?

_____

_____

_____

_____

3. Write one fact you learned about comets in this lesson.

_____

_____

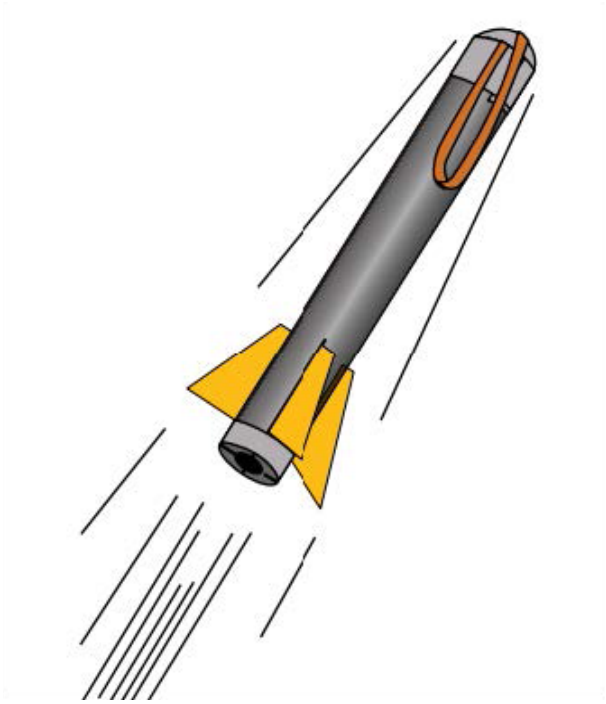
_____

_____

_____

GODDARD ROCKETEERING

OBJECTIVE – Students will be able to learn about the history of Robert Goddard who pioneered liquid-propelled, controlled rocket flight. Students will also build a flying, rubber band-powered, foam model of Goddard's 1931 rocket.



NATIONAL STANDARDS –

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

Disciplinary Core Idea Progressions

Physical Science Progression

- PS2.A: Forces and Motion
- PS3.B: Conservation of energy and energy transfer
- PS3.C: Relationship between energy and forces

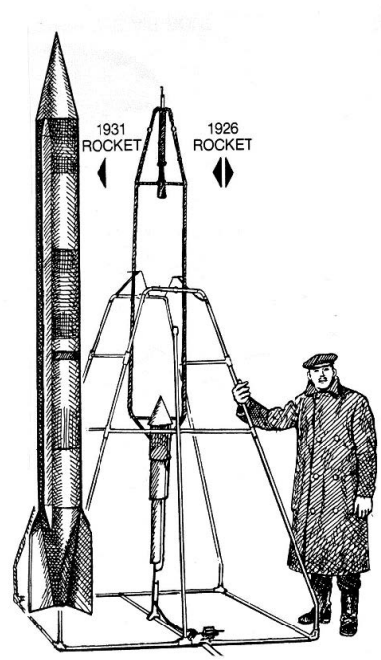
Crosscutting Concepts

- 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
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– Rockets have been known to exist for centuries, but all of the thrust devices employed in these primitive "fire arrows," as the Chinese called them, were made of solid materials and once ignited, were uncontrollable.



Robert Hutchings Goddard, who is considered to be the Father of Modern Rocketry, was born in Worcester, Massachusetts, and as a boy, developed an interest in space travel. Later, as a scientist, he pioneered the technology of using liquids for thrust power instead of the uncontrol-lable solid fuels. By using a combination of liquids, rather than solids, Goddard was able to vary the volume of fuel flow and thus, get control of the amount of thrust produced. This paved the way for manned, rocket-powered craft.

In 1926, near Auburn, Massachusetts, Dr. Goddard successfully launched the world's first liquid-propelled rocket. To give a comparison of its potential, a liquid-fueled rocket the size of an automobile engine, produces approximately 3,000 times more power. Goddard's research opened the "door to space flight." To be able to go into space, man had to first break the sound barrier. On October 14, 1947, Charles E. "Chuck" Yeager accomplished this feat when his rocket-powered Bell XS-1 exceeded the speed of sound.

During his lifetime, Robert Goddard's work received little attention from his country and from his fellow scientists; however, after his death, the government recognized his great contributions and awarded his family the Congressional Gold Medal. For more information please visit Robert Goddard by SciShow Space (https://youtu.be/jSIq1XsdUqA). ROCKET SCIENCE 101 - (From the NASA Rockets Educators Guide: Foam Rocket https://www.nasa. gov/pdf/295787main_Rockets_Foam_Rocket.pdf)

The foam rocket flies ballistically. It receives its entire thrust from the force produced by the elastic rubber band. The rubber band is stretched. When the rocket is released, the rubber band quickly returns to its original length, launching the foam rocket in the process. Technically, the foam rocket is a rocket in appearance only. The thrust of real rockets typically continues for several seconds or minutes, causing continuous acceleration, until propellants are exhausted. The foam rocket gets a quick pull and then coasts. Furthermore, the mass of the foam rocket doesn't change in flight. Real rockets consume propellants and their total mass diminishes. Nevertheless, the flight of a foam rocket is similar to that of real rockets. Its motion and course is affected by gravity and by drag or friction with the atmosphere. The ability to fly foam rockets repeatedly (without refueling) makes them ideal for classroom investigations on rocket motion.

The launch of a foam rocket is a good demonstration of Newton's third law of motion. The contraction of the rubber band produces an action force that propels the rocket forward while exerting an opposite and equal force on the launcher.

In flight, foam rockets are stabilized by their fins. The fins, like feathers on an arrow, keep the rocket pointed in the desired direction. If launched straight up, the foam rocket will climb until its momentum is overcome by gravity and air drag. At the very top of the flight, the rocket momentarily becomes unstable. It flops over as the fins catch air. The rocket becomes stable again when it falls back to the ground. When the foam rocket is launched at an angle of less than 90 degrees, its path is an arc whose shape is determined by the launch angle. For high launch angles, the arc is steep, and for low angles, it is broad. When launching a ballistic rocket straight up (neglecting air currents) the rocket will fall straight back to its launch site when its upward motion stops. If the rocket is launched at an angle of less than 90 degrees, it will land at some distance from the launch site. How far away from the launch site is dependent on four things. These are: gravity, launch angle, initial velocity, and atmospheric drag.

Gravity causes the foam rocket to decelerate as it climbs upward and then causes it to accelerate as it falls back to the ground. The launch angle works with gravity to shape the flight path. Initial velocity and drag affects the flight time.

MATERIALS
a. 30 cm –long pieces of polyethylene foam pipe insulation (for ½" size pipe)
b. Styrofoam food tray or Styrofoam plates
c. Rubber band (size 64)
d. Scissors
e. Rocket construction instructions
f. Student Data Sheet
g. Duct tape
h. Eye protection
i. Meter stick (optional—for use with NASA plans)
j. Thumb tack (optional—for use with NASA plans)
k. Trundle wheel or measuring tape (optional – for use by class)

MANAGEMENT TIP – Precut the foam pipe into 30 cm pieces. The launch area should be a large room with a high ceiling, like a cafeteria or gymnasium. If the wind is calm, this lesson could also be conducted outside. It also may be helpful to have the students sitting in collaborative groups of 3-4 to help with construction.

1. Engage the students by showing them the interactive animated rocket launch game (http://www.science netlinks.com/interactives/gravity.html) that has different challenges related to launching a rocket. Experiment with different launch angles and allow students to see how the flight path of the rocket is changed when different launch angles are used. Be sure to keep the thrust the same when showing the students how angles change the flight path.

2. Inform the students that they are going to create their own rockets today and experiment with changing the launch angle to have the rocket travel the greatest distance.

3. Use the background information to facilitate a discussion on Robert Goddard, the Father of Modern Rocketry. Explain to the students the historical significance of his invention of the liquid fueled rocket.

4. Pass out the materials needed to construct the rocket to the collaborative groups. There should be enough materials for each student to make his/her own rocket. Sitting in the collaborative groups will help with overall construction of the rockets.

5. Guide the class in the procedures for constructing a foam rocket (https://www.nasa.gov/pdf/295787main_Rockets_Foam_Rocket.pdf).

6. Taking the 30 cm length of pipe foam, cut four equally spaced slits at one end of the tube. The slits should be 8-10 cm long. The fins will be mounted through the slits.

7. Cut a 12 cm length of duct tape down the middle to make two pieces. Place one piece over the other,sticky to shiny side, to make the tape double-strong.

8. Slip a rubber band over the tape and press the tape around the nose end of the rocket (opposite the end with the slits). Press the tape tightly and reinforce it with another length of tape wrapped around the tube.

9. Cut the fin pairs from the foam food tray or foam plate. Refer to the fin diagram on the next page. Both fin pairs should be notched so that they can be slid together as shown in the diagram. Different fin shapes can be used, but they should still "nest" together.

10. Slide the nested fins into the slits cut in the rear end of the rocket. Close off the slits with a piece of duct tape wrapped around the foam tube. The rocket is finished.

11. Model for the students how to launch the Goddard Rocket.
- Put one thumb into the rubber band at the "nose end".
- Pull on the fin end of the rocket to stretch the rubber band to about 4 inches.
- To launch the rocket, let go of the fin end of the rocket. You can pitch it forward in a slight arc.

12. Direct the students to follow the Student Data Sheet to conduct the experiment on how the length of the stretched rubber band affects the distance that the rocket travels and record observations. Remind students to try to keep the launch angle the same for all the trials. Have the students complete the chart as well as answer the questions.

13. At the conclusion of the activity, have the students share and compare their results with the other group members and even as a class, discussing discoveries made during the experiment.

EXTENSIONS

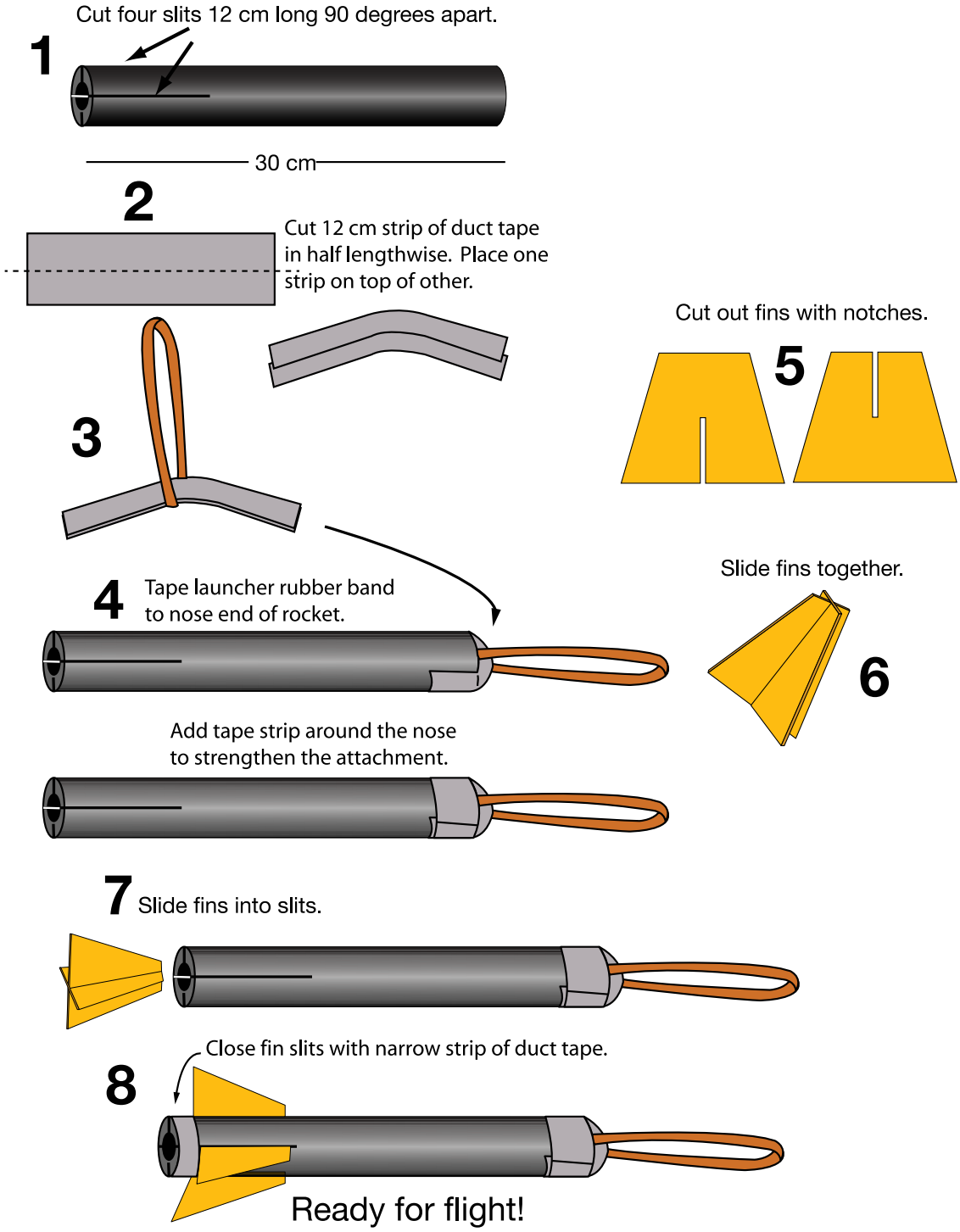
- Hold an accuracy competition and have the students aim the rockets at a target like a bucket or a paper bulls-eye.

- Have the students write about potential practical uses for the foam rocket (e.g. delivering messages).

- Challenge the students to create different kinds of fins for the foam rocket. Ideas could be a space shuttle orbiter or future rocket planes.

- Visit the following websites for more information on Goddard and rocketry.
  - o National Aviation Hall of Fame: Dr. Robert Goddard biography
    http://www.nationalaviation.org/goddard-robert/
  - o NASA Rockets Educator Guide
    http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Rockets.html

Build a Foam Rocket



Source: http://www.nasa.gov/pdf/295787main_Rockets_Foam_Rocket.pdf

LAUNCH LOG: GODDARD ROCKETEERING

Name _____ Date _____

Ask: What propels your rocket? _____

_____

How does Newton's 3rd Law (for every action, there is an equal and opposite reaction) apply to your rocket?

_____

_____

Imagine, Plan, Create: Draw a sketch of your rocket, including the details of your fins.

Number of Fins: _____
Fin Shape Sketch:

Experiment: Adjust the length that you are pulling back on the rubber band according to the chart below. Try your best to keep the angle of release the same for each trial.

Length of Stretched Rubber band	Distance Traveled	Observations
1"		
2"		
3"		
4"		
5"		

Does the length of the stretched rubber band effect the distance the rocket travels after it is released? Explain.

_____

_____

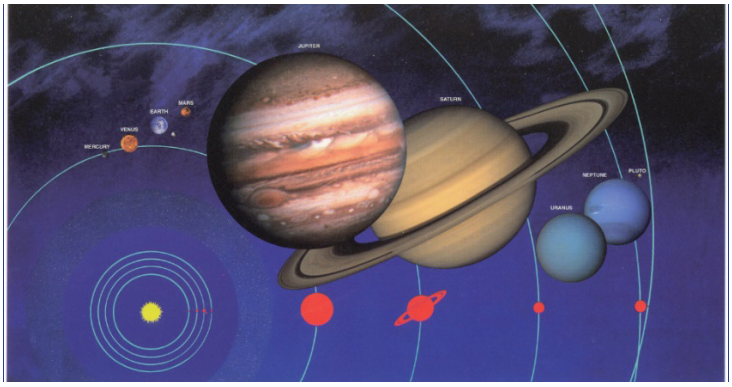
Improve: How could you improve on your rocket? What other variables could you test?

_____

_____

PLAYGROUND PLANETS
WITH GODDARD ROCKETEERING

OBJECTIVE – Students will be able to use their Goddard Rockets to participate in a hands-on activity that combines model rocketry, astronomy, and the playground.



NATIONAL STANDARDS –

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

Disciplinary Core Idea Progressions

Earth Space Science Progression

- ESS1.B: Earth and the solar system

Physical Science Progression

- PS2.A: Forces and Motion
- PS3.B: Conservation of energy and energy transfer
- PS3.C: Relationship between energy and forces

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

BACKGROUND – For more information, please see Solar System 101 (https://youtu.be/libKVRa01L8). As of 2006, there are 8 solar system objects in our solar system that are classified as planets. Pluto was reclassified from "planet" to "dwarf planet" in 2006. A dwarf planet is smaller in size than other objects classified as planets. Additionally, Pluto was reclassified as a dwarf planet because it did not "dominate" its orbital path around the sun.

The order of the planets starting at our Sun is:

1. Mercury
2. Venus
3. Earth
4. Mars
5. Jupiter
6. Saturn
7. Uranus
8. Neptune

Activity 8: Playground Planets

MATERIALS

a. The Goddard Rocket (complete and ready to fly from AEX I Lesson 7: Goddard Rocketeering) or any rocket that can be launched a long distance.
b. NASA Solar System Lithograph Set (https://www.nasa.gov/sites/default/files/files/Solar_System_Lithograph_Set.pdf)
c. A playground or a wide-open space
d. Prior knowledge of the order of the planets in our solar system

PROCEDURE –

1. Build a Goddard Rocket using the AEX I Lesson 7: Goddard Rocketeering lesson. You can also use any rocket that can be launched a long distance in place of the Goddard Rocket.

2. Prior to class, strategically place the "planets" (NASA lithographs) at various locations throughout the playground.

3. Review the order of the planets orbiting our Sun. Use a mnemonic device to help students remember the planet order such as My (Mercury) Very (Venus) Educated (Earth) Mother (Mars)J ust (Jupiter) Served (Saturn) Us (Uranus) Nachos (Neptune) or My Very Easy Method Just Speeds Up Naming. The first letter of each word gives you the first letter of the planets, in order: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. You could also have the students make up their own silly sentence to help remember the order. A song could be used as well. Please see links in the "Extensions" portion of this lesson for music videos.

4. Explain to the students that depending on which planet they start from, they have to launch their rocket and land in the vicinity of the next planet in order. "Landing" could be a large circle drawn in the dirt, sand, or on the grass, around the "planet".

5. Select a "launch site" of the Sun, and then have small groups of students "launch" their rockets toward any planet.

6. Before the students go to their rocket, remind them that the next planet they are aiming for should be the next planet in order of our solar system. If they happen to land on Neptune, the planet "chain" will start over and they should aim for Mercury.

7. The goal is to travel through the solar system in order and land back on the planet of origin.

8. Consider using a whistle or loud signal to announce launches. The students hear the signal and know that at the signal, they must have identified the next planet in order and be ready to launch. This keeps them excited and having fun with the activity.

9. At the end of class, students will have a more internalized idea of the order of the planets in our solar system and the Goddard Rocket goes home!

EXTENSIONS

- Use a song to teach the order of the planets. Planets Song: https://www.youtube.com/watch?time_continue=15&v=noiwY7kQ5NQ or Outer Space: "We are the Planets", The Solar System Song by StoryBots: https://www.youtube.com/watch?v=ZHAqT4hXnMw

- Create a solar system trivia quiz using the information on the back of the lithographs and have the students launch their rockets to the correct answer.

- Instead of having students go in order of the solar system, have them launch the rockets from the Sun each time and keep track of which planet the rocket lands on. Take the data collected and make a simple graph of the results.

SPACE JUNK ROCKETS
FROM TRASH TO TREASURE

OBJECTIVE – Students will be able to create a rocket with a propulsion system using only common household items.

NATIONAL STANDARDS –
Next Generation Science Standards (www.nextgenscience.org):
Disciplinary Core Idea Progressions
Physical Science Progression
- PS2.A: Forces and Motion
- PS3.B: Conservation of energy and energy transfer
- 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
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

MATERIALS
Materials may vary. Use common household paper, foam, and plastic items. There must also be a safe propulsion system (i.e. stored energy release (rubber bands) or water or air power).
Example materials: "Rocket Junk" includes filing folders, meat trays, cone-shaped drinking cups, rubber bands, pipe foam insulation, Styrofoam™, Easter eggs, film canisters (can be found online), toilet paper cylinders, paper towel cylinders, white glue, and index cards.

PROCEDURE

1. Engage the students and provide a visual display of what rockets can look like by showing the video, "How NASA, SpaceX, and Blue Origin's Monster Rockets Compare" (https://youtu.be/mD1_UdW4qqQ) by Tech Insider.

2. Collect materials for junk rockets such as: fuselage (pipe foam insulation, cardboard cylinders, construction paper, film canisters), nosecone (funnel-shaped paper drinking cup, construction paper, Styrofoam eggs, etc.), propulsion system (different sized rubber bands), and fins (3x5 cards, foam meat tray, cardboard, etc.)

3. Divide students into collaborative groups.

4. Provide each group with standard construction materials: scissors, tape, markers, glue.

5. Allow each group time to plan and come up with a design for building their junk rocket, including a propulsion system. The plan should include a sketch of the prototype with the propulsion system labeled, a materials list, as well as how they will test their junk rocket. Please see the attached student pages.

6. As groups finish the required paperwork, the supplies will be given to them to begin the building and testing phase.

> **a.** As an extension to the activity to include math concepts, the groups could approach the "supplier" (teacher or another student) and purchase the required items. Each material could have a cost attached and the junk rocket company purchasing the supplies could submit a cost sheet to the teacher.

7. Allow time for the groups to build and test the rockets, recording the data on the student page.

8. Have groups present their final prototype to the class.

EXAMPLE (ONLY IF NEEDED) —this junk rocket is called the "TP Torpedo!" It is made from a toilet paper cylinder, a cone-shaped drinking cup, one rubber band, a drinking straw, and index cards for the fins. The range of this "space junk rocket" has been recorded as more than 60 feet!

a. The "junk" part of this activity is a cylinder from a roll of toilet paper or paper towels. A folded paper tube would work as well.

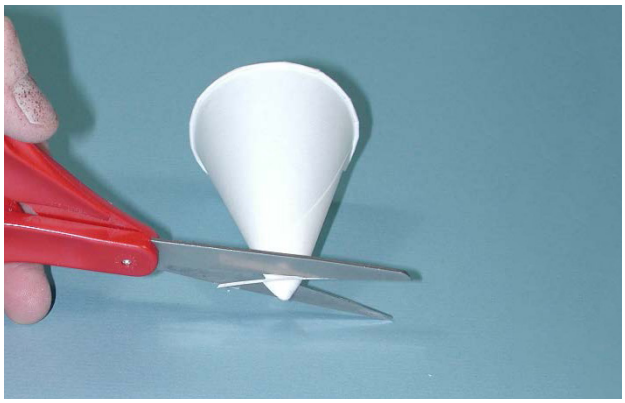
b. The cone-shaped drinking cup will be attached to the top of the toilet paper cylinder.

c. Fins are made of index cards and attached to the toilet paper cylinder.

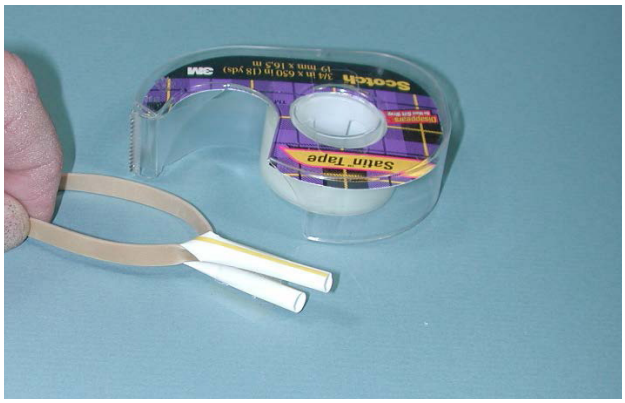
d. The "propulsion" mechanism will be a rubber band that is secured inside a drinking cup.

e. To launch this rocket, the builder simply puts one thumb in the bottom of the fuselage (cylinder), stretches the rubber band with the other, and releases the rubber band.
Another example can be found by visiting "Soda Bottle Rocketship: Recycle Craft (https://youtu.be/PGBflTrBrG4).

"TP Torpedo" Steps:

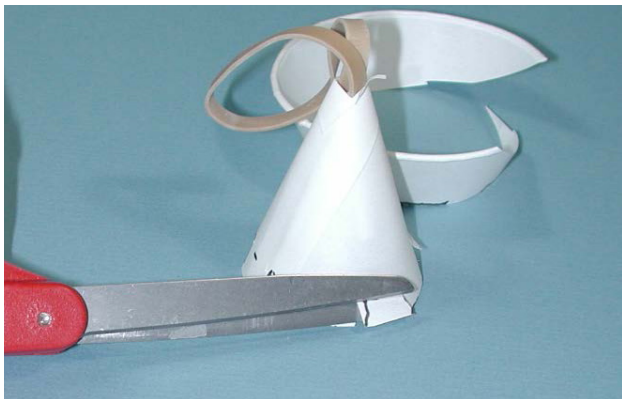


Step 1: The tip is cut off of a cone-shaped drinking cup as shown.

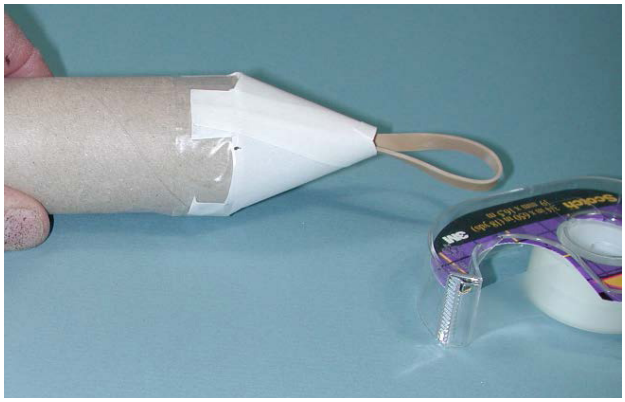


Step 2: A piece of soda straw is bent over and taped to a rubber band.

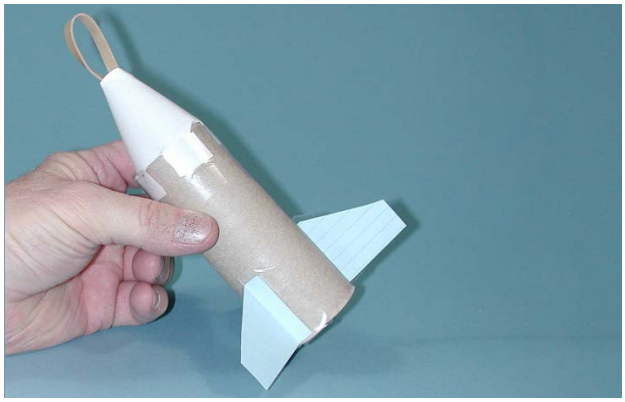
Step 3: The rubber band is drawn through the hole in the cup. To keep the rubber band and straw from pulling through the hole, it is recommended that you hot glue both of these to the inside of the cup.



Step 4: The cone is now cut so that it fits the top of the toilet paper cylinder.



Step 5: Small tabs cut into the cup allow it to be taped to the cylinder.



Step 6: Fins made of index cards are taped to the cylinder. Your "T.P. Torpedo" Space Junk Rocket is complete!

THE ENGINEERING DESIGN PROCESS: SPACE JUNK ROCKET

Name _____ Date _____

Describe your design for a rocket and its performance according to The Engineering Design Process.

1. Ask: State the "Engineering a Space Junk Rocket Design Challenge" in your own words.

_____

_____

_____

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

_____

_____

_____

3. Plan: Draw a sketch of your plan.

Materials required:

_____

_____

_____

_____

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

_____

_____

_____

_____

_____

5. Experiment: Record your test results on the data chart below. (Make sure you do at least 10 test-flights and record any changes and distance traveled.)

Test #	Change Made	Distance Traveled
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

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

_____

_____

_____

_____

COSMIC CUISINE

SPACE FOOD FOR THE LITTLEST ASTRONAUTS

OBJECTIVE – Students will be able to investigate the different types of food that astronauts eat in the microgravity environment of space with a focus on rehydratable food. Students will be able to define the terms hydrate, dehydrate, and rehydrate.

NATIONAL STANDARDS –

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

Disciplinary Core Idea Progressions

- Earth Space Science Progression
  - ESS3.C: Human impacts on Earth systems
- Life Science
  - LS2.A: Interdependent relationships in ecosystems
  - LS4.C: Adaptation
- Physical Science Progression
  - PS1.A: Structure of Matter

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)

BACKGROUND –

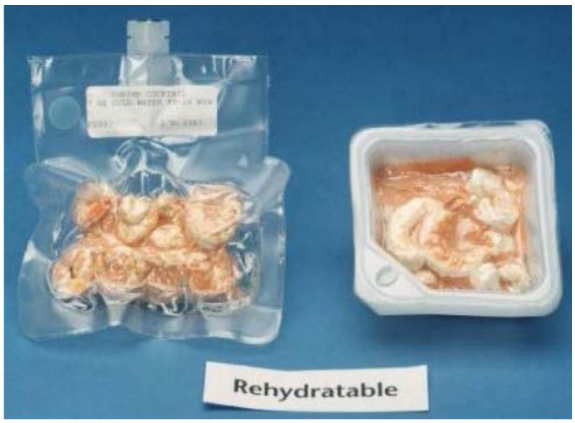
Information from NASA's Space Food and Nutrition Educator's Guide, https://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Space_Food_and_Nutrition_Educator_Guide.html and https://www.nasa.gov/pdf/71426main_FS-2002-10-079-JSC.pdf.

For videos to show the students on space food, please visit "Chris Hadfield's Space Kitchen" (https://youtu.be/AZx0RIV0wss) or "How Does Food get Delivered to Space?" (https://youtu.be/u3zYG98ah04).

In many ways, living in space is not very different from living on Earth. In other ways, it is quite different. Astronauts in orbit above Earth must do the same things inside their spacecraft to live as we do on Earth. They have to eat, work as a part of a team, exercise, relax, maintain hygiene, and sleep. The only significant differences from living on Earth are that they operate in the confined space of the International Space Station (ISS) or the space shuttle orbiter cabin and everything inside the cabin appears to "float," which is an effect of microgravity.

Travelers have known for a long time that condensing food will make their journey easier. It is no different in the space program. Hikers use rehydratable foods so they do not have to carry very much weight. This makes it easier to travel. All weight going into space raises the fuel consumption at lift-off. It is important to eliminate as much weight as possible. Because the fuel cells on the Space Shuttle produce water as a byproduct, water is easily attainable. Therefore, taking food along that can be rehydrated (adding water) with this water make sense because it reduces the amount of weight on liftoff. The rehydrated foods also take up much less space, and space is a valuable commodity onboard the Space Shuttle.

What would your food be like in space? NASA has several types of food that fly on the space shuttle and the International Space Station (ISS). Which sounds the best to you?



Rehydratable items require astronauts to add water to them before eating or drinking.

Rehydratable items are helpful because they weigh less on Earth. All weight going into space increases the amount of fuel needed at liftoff. It is important to take as little weight as possible on the trip into space. Since most food items are 90% water, taking the water out makes the food items weigh less. Rehydratable items are also helpful because they do not take up a lot of space.

NASA used a lot of rehydratable foods for space shuttle flights because the space shuttles produce their own water. Unlike the space shuttles, extra water cannot be made on the ISS. Water on the ISS is recycled. So, the astronauts on the ISS do not eat as many rehydratable foods as the shuttle astronauts.

Rehydratable food is packaged in clear plastic pouches with a white plastic piece located at the top of the pouch where water is added. Foods packaged in rehydratable containers include soups like cream of mushroom, casseroles like macaroni and cheese and chicken and rice, appetizers like shrimp cocktail, and breakfast foods like scrambled eggs and cereals. Breakfast cereals are prepared by packaging the cereal in a rehydratable package with nonfat dry milk (powder) and sugar, if needed. Water is added to the package just before the cereal is eaten.

Intermediate moisture food is packaged in clear plastic pouches, called a snack pack, that is cut open with scissors. The food usually has 15-30% moisture in it, but you will not see any water droplets. The moisture is usually bonded with sugar or salt that is part of the food item. Intermediate moisture foods include dried fruits, dried beef, and trail mix.

Natural form foods are foods like chocolate covered peanut candies, cookies, nuts, and granola bars. These foods are repackaged in single serving snack packs, like the intermediate moisture food.

Thermostabilized and irradiated foods are two other types of foods that astronauts eat. These two types of foods are a little more difficult to explain, but food items such as tuna and other meats usually fit into these two food categories. The picture on the right is a picture of irradiated turkey.

Fresh food refers to a small amount of fresh fruits, vegetables, and bread products that are packed, but they must be eaten within the first few days after they arrive in space. This is because fresh foods spoil quickly. These items include bananas, apples, carrot and celery sticks, breakfast rolls, and flour tortillas.

All the food pouches have several little blue Velcro dots, called velcoins, attached to them. They hold the food pouches to meal trays. Astronauts have their own set of silverware, which includes a knife, two spoons, a fork, and a pair of scissors (for opening pouches). Clean up is done using alcohol wipes.

Pictures Credit from NASA: https://www.nasa.gov/audience/formedia/presskits/spacefood/gallery_main.html

MATERIALS (Note: This activity should be modified according to food allergies in the classroom.)
a. Resealable plastic sandwich bags
b. Variety of rehydratable foods or drinks such as instant chocolate pudding, instant oatmeal (variety of flavors, including the kind with dried apples), powdered soup, non-fat dry milk, Tang®, instant mashed potatoes, etc.). Make sure that the rehydratable food works with room temperature water as some require warm water.
c. Straws
d. Spoons
e. Small cups of water (1-1.5 ounces per cup)
f. Sharpie™ (for labeling the bags with numbers/letters)

MANAGEMENT TIP: Prior to beginning the lesson, create "cosmic cuisine" bags for the students with 2 tablespoons of one of the rehydratable foods or beverages. The small cups of water should be prepared in advance as well and contain 1-1.5 tablespoons of water. Make sure to label the meal bags with numbers/letters so that no one sitting together in a group has the same rehydratable "cosmic cuisine".

PROCEDURE

1. Inform the students that today they will be scientists working for NASA to prepare food to send to the International Space Station. Mention that it is very different to eat and drink in space.

2. Show students a video of astronauts eating in space from the NASA gallery of Living in Space videos: https://spaceflight.nasa.gov/gallery/video/living/html/food.html .

3. Use the background information to go over the different types of food that astronauts eat while living and working in space. Talk about the differences in the various types of astronaut food.

4. Tell the students that NASA needs their help! The "cosmic cuisine" has gotten all mixed up and needs scientists to identify the contents of each meal bag.

5. Distribute the Student Data Sheet along with a "cosmic cuisine" bag to each student.

6. Instruct students to use their senses of hearing and sight to observe the contents in the bag. Have them record or sketch their observations in the hearing and sight boxes on their paper.

7. Ask the students to predict what is in the "cosmic cuisine" bag using just their sense of sight and hearing. Have them write the prediction on the Student Data Sheet.

8. Facilitate a class discussion by having the students compare the overall appearances of their "cosmic cuisine." Based on what is being discussed, have the students vote on whether the contents in the bags are the same or different for all the students.

9. Scientists have a special way to smell items called wafting. Instruct students to place their nose a little above and in front of the bag and use their hands to move the air above the bag toward their nose. Remind them to not place their nose directly over the bag. Show the students how to properly "waft" what is in the bag. It is like grabbing the smell and bringing it toward their nose. Have students carefully open their bags. With the bag sitting on the table, and following the proper wafting techniques,have the students smell their "cosmic cuisine" and record their descriptions in the first "smell" box.

10. Students should then make a second prediction on their paper. Again, lead a discussion on how the "cosmic cuisine" smells and ask if they think the contents are the same or different.

11. Remind the students of the rehydratable food that was discussed at the beginning of the lesson. Talk about how space food that requires water has it removed before it is taken into space. Ask who remembers why this happens. (To create more space for other packed items and to reduce the weight of the food items.)

12. Write the word "hydrate" on the board and go over that the word means "to supply water." When we remove water, we say it has been "dehydrated." The prefix "de" means "undoing" or "without." When water is added back to food, the food is being "rehydrated." The prefix "re" means "again." Help students to draw the conclusion that "rehydrate" means to "add water again." Students can remember the definition of "hydrate" by remembering what a fire hydrant does. It provides water to fire fighters, similar to the definition of hydrate meaning "to supply water."

13. Show students a noodle or a packet of a flavored-drink. Ask students what happens when noodles are cooked in water or when water is added to a drink mix. Explain that the item can change shape or even change in terms of its state of matter. For example, the noodle becomes soft and bendable. The drink mix powder is a solid, but when water is added, it becomes a liquid.

14. Ask students to answer the question regarding what they think will happen to their item once the contents of their bag are hydrated.

15. With the bags sitting on the students desks, ensure that the bags are open wide enough for students to pour in their cup of water. Have students hydrate their bags and then seal the bag. Then, have students gently squish (knead) the bag.

16. Have students complete the "hearing" and "sight" portions of the second "4 of 5 senses" chart. Tell them that they will not open the bags to smell or touch at this time. While students are doing this, distribute a straw and spoon to each student.

17. Have students write their third and final prediction as to what is inside their individual bag before they taste the contents.

18. Tell students that because they have just made an astronaut meal, they need to taste the contents of their bag to help solve the mystery. Since this is astronaut food, however, they will need to taste and/or consume the contents of the bag like astronauts. They may choose the most appropriate method from the options below:

a. Cut one of the corners of the bag and squeeze the contents into the mouth.
b. Cut a small slit or open the top slightly and insert a straw.
c. Provided the mystery food did not surprisingly turn out to be a drink, open the bag and eat the contents with a spoon. Students could experiment and decide which is/are the best way(s) to eat their meal in space.

19. Once the contents of the bag are nearly gone, allow students to open their bag to smell and touch the food. Allow them to record their results on their paper.

20. Ask students to follow the final set of directions at the bottom of their paper by writing what their food tasted like on the back of the paper and their final answer as to what the mystery meal is. Ask them to explain why they were surprised or not surprised by the results compared to their first prediction.

21. Review the definitions of hydrate, dehydrate, and rehydrate. Ask a student to remind you why making rehydratable food is the best choice for food in space. (Preparing the food inside plastic bags prevents water from escaping inside the space shuttle cabin. Also, removing water from the items here on Earth makes it easier to pack the food to go into space. It also reduces weight because water adds weight.) Talk about if anything was surprising in this activity as well as whether or not they would like to be an astronaut and eat this food in space.

Additional Video Resources:

- **Living and Working in Space: Advanced Food Tech** (https://www.youtube.com/watch?v=zQEPKKmQGG0)
- **Former NASA Astronaut Explains How Food Is Different in Space | WIRED** (https://www.youtube.com/watch?v=E36F4XG5zcY) Please note, this video is 17 minutes long. It is best to use clips from this video for your class rather than showing it in its entirety.
- **Tasting Astronaut Food: Inside NASA's Space Food Systems Laboratory** (https://www.youtube.com/watch?v=6vVle67Tfjc) Please note, this video is 19 minutes long. It is best to use clips from this video for your class rather than showing it in its entirety.
- **What It's Like To Eat Food In Space** (https://www.youtube.com/watch?v=OINZX0SFVn8)

COSMIC CUISINE

Name: _____

Predictions:

1. First Prediction: I think it is _____

2. Second Prediction: I think it is _____

3. Third Prediction: I think it is _____

Hearing	Sight	Smell	Touch

Question:

What do you think will happen when you rehydrate the material in the bag?
(Use good science words like liquid, solid, color, think, thin, etc.)

_____

_____

_____

_____

Smell and touch AFTER the bag is nearly empty!

Hearing	Sight	Smell	Touch

EXTENTION (For Upper Elementary)

Please answer the following questions:

1. What changes happened as you rehydrated your space food?

2. What did your meal taste like? Include your final answer as to what was in the bag and why you were surprised or not surprised.

3. Do you think that the temperature of the water makes a difference? How?

4. Why did you use a ziplock bag instead of a bowl?

5. What other foods could be taken on the Space Shuttle and rehydrated?

6. Write the steps (procedure) to make a rehydrated food or drink.

HANDS ON AT THE SPACE STATION

OBJECTIVE – Students will be able to understand how astronauts cope with engineering problems while wearing bulky, protective space suits, specifically space gloves.

Image from https://www.nasa.gov/image-feature/international-space-station-43

NATIONAL STANDARDS –

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

Disciplinary Core Idea Progressions

Life Science Progression

- LS1.D: Information processing
- LS4.C: Adaptation

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
3. Planning and carrying out investigations
4. Analyzing and interpreting data
6. Constructing explanations (for science) and designing solutions (for engineering)

Activity 11: Hands on at the Space Station

BACKGROUND – "Special" flight suits have been around since the 1920s when pioneering aviators needed protection and supplemental oxygen while attempting high altitude records. Long before that, deep sea divers used bulky suits to explore sunken ships and other ocean treasures. Space suits came into prominence during the 1950s when test pilots like A. Scott Crossfield were routinely flying aircraft, like the X-15, to the edge of our atmosphere.

Like the rest of the body, the hands have to be protected from the hostile environment of space. To do this, bulky gloves are required, and these restrict movement of the wrist and fingers. When a simple task can't be performed, students are used to just removing their gloves; however, it comes as quite a surprise when they realize that, in space, you can't remove the gloves due to the harsh environment of the International Space Station.

In this activity, ski gloves are used to simulate "space gloves." Students are asked to perform simple timed tasks like picking up coins and stacking them in a wrapper or constructing a figure with Legos™. After completing the tasks without gloves and recording the amount of time it took to complete the task, the students are then asked to complete it again, this time slipping on a common pair of ski gloves which simulate wearing the "space gloves." The once simple task soon becomes quite difficult and complicated. This is a fun activity that can be easily performed during one class period.

Additional videos to provide background information on the International Space Station:
- Everything About Living in Space by NASA Johnson (https://youtu.be/ouDKD9G9jOE)
- Take a Tour of the Space Station by SciShow Kids (https://youtu.be/SOCixRhRGDw)
- International Space Station: Facts for Kids by Kids Love Learning (https://youtu.be/x-64L3httIM)
- NASA's Tour of the International Space Station by NASA's Marshall Space FlightCenter (https://youtu.be/nJj4K4WdRuk)

MATERIALS (One set of materials per team)

a. Student Data Sheet per student (attached at the end of the lesson)
b. One pair of ski gloves (one pair per team)

Task materials (can have for each team or set up a rotation for teams to go to stations):

c. Coin wrapper and coins (pennies work well)
d. One ballpoint pen
e. A piece of heavy string
f. A toy construction set like Lego™, Erector™, or Tinker Toy™
g. A bolt, two washers, and a nut that fits the bolt

PROCEDURE

1. Show students a pair of winter gloves and ask them to discuss when we wear these gloves. Ask if they know how gloves are related to astronauts. Use the background information to have a discussion related to why astronauts wear gloves in space.

2. Inform the students that they are going to do an experiment today to help understand why astronauts have to practice tasks wearing gloves.

3. Pass out the Student Data Sheet.

4. Introduce the five tasks that are listed on the Student Data Sheet.
- **a.** Pick up 10 coins and place in a wrapper.
- **b.** Loop string through a washer and tie it.
- **c.** Write name, address, and phone number with pen.
- **d.** Assemble the bolt, washer, and nut, securing with 5 turns.
- **e.** Construct an object following directions (using a construction set like Lego™).

5. Explain to the students that they are going to work in pairs and complete these tasks with their bare hands. One student will be the timer while the other student completes the task. The time will be recorded and then the roles will be switched, and the activity will be repeated so that each student will have his/her own time on his/her own data sheet.

6. After each student has had a turn completing the task and recording the time, give each group of students a pair of "Space Gloves" and have them repeat the activity, taking turns timing and completing the different tasks.

7. When the pairs have finished recording all of the times, instruct them to find the difference between the recorded times it took to do the task without gloves compared to how long it took with gloves. Use scaffolding, if needed, and instruct students to subtract the time it took without gloves from the time it took with gloves to get the difference.

8. Have the students fill out the questions at the end of the Student Data Sheet.

9. Once everyone is finished, facilitate a class discussion on the results of the experiment. Make sure to discuss the last question regarding why astronauts practice so much while wearing the gloves before working in space.

DISCUSSION (RECOMMENDATION) - There is a NASA publication called *Spacesuit Guidebook*, which is located online through the NASA Technical Reports Server at https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19910009290.pdf . This has a wealth of information about all of the components that are built into an astronaut's protective clothing. The *Guidebook* explains the inside workings of the spacesuit and its various components.

EXTRA RESOURCES:

- "Space Educator's Handbook – The Spacesuit" can be found at https://er.jsc.nasa.gov/seh/seh.html or https://er.jsc.nasa.gov/SEH/suitnasa.html

- StarChild "Wardrobe for Space" – Get more information on spacesuits at https://starchild.gsfc.nasa.gov/docs/StarChild/space_level1/wardrobe.html or https://starchild.gsfc.nasa.gov/docs/StarChild/space_level2/wardrobe.html

- NASA Suited for Spacewalking is a great activity guide for upper elementary students. https://www.nasa.gov/pdf/143159main_Suited_for_Spacewalking.pdf

CREDITS: Based on an original lesson created by middle school teacher, Lauren Allwein.

HANDS ON AT THE SPACE STATION STUDENT DATA SHEET

Name _____ Date _____

1. Describe the overall challenge in your own words.

_____

_____

2. Choose one of the tasks below and predict how you think it will be different to complete it while wearing the "Space Gloves".

_____

_____

3. Perform all the tasks without gloves and record your times on the data chart below. Put on the "Space Gloves" and perform the tasks again, making sure to record the time. Finally, calculate the difference in the amount of time the task took without gloves compared to the amount of time with gloves.

Task	Time without gloves	Time with "Space Gloves"	Difference (in time)
Pick up 10 coins and place them in the wrapper.			
Loop string through a washer and tie it.			
Write name, address, and phone number with a pen.			
Assemble the bolt, washer, and nut, securing with 5 turns.			
Construct an object following directions (using a construction set like Lego™).			

4. Explain which task took the longest time wearing "Space Gloves" compared to using your bare hands and give your reasons as to why it was more complicated with the gloves.

_____

_____

5. Why do you think it is important for astronauts to practice tasks while wearing space gloves?

_____

_____

PHYSIOLOGY FUN
THE HUMAN BODY IN SPACE

OBJECTIVE – Students will be able to experiment to learn about the human body reaction to space flight as well as the importance of exercising when exposed to long periods of weightlessness in space.

NATIONAL STANDARDS –

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

Disciplinary Core Idea Progressions

Earth Space Science Progression

- ESS3.C: Human impacts on Earth systems

Life Science

- LS2.A: Interdependent relationships in ecosystems
- LS4.C: Adaptation

Crosscutting Concepts

- Cause and effect
- Systems and system models
- 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 various NASA links: https://www.nasa.gov/hrp/bodyinspace, http://www.nasa.gov/pdf/64247main_ffs_factsheets_fitness.pdf and http://www.nasa.gov/pdf/146854main_Get_A_Leg_Up_Educator.pdf

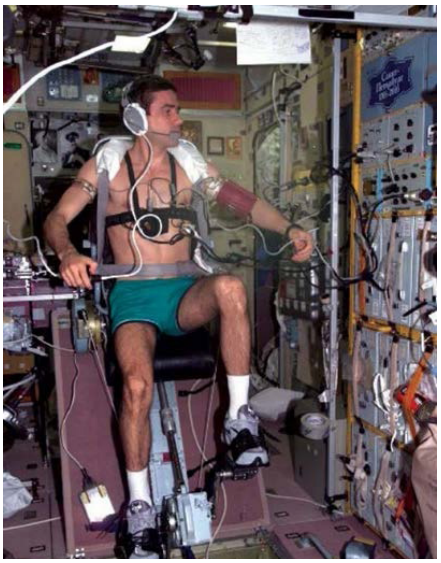
Trading Earth's environment for the environment of space is exciting. As the environment changes, so will an astronaut's body change. Less gravity is one of the major changes of living in space. Traveling to Mars, and perhaps into deep space, will involve living in space for months or years. How will an astronaut's body change and adapt as a result of living in a reduced gravity environment for that long?

All astronauts and cosmonauts experience a phenomenon known as "Puffy Head, Bird Legs." When in a condition of microgravity, astronauts report a feeling of "stuffiness," especially in the sinuses, and a "fullness" in the head. There is also a puffiness of the face that can be easily measured. Where aerospace medical specialists measure various parts of the body, such as face and legs, it clearly shows that changes occur in the shape of the legs. Astronauts call this condition "bird legs."

Measurements taken of the leg circumference during space flight on astronauts with larger legs show a proportionally larger decrease in leg volume than those with smaller legs. This is explained by the fact that the more muscle a person has in his/her limbs, the more fluid and blood flow is required to nourish those muscles. The more fluid and blood there is, the more there is to lose. It has shown that a fluid shift actually begins during the launch sequence. This is due to the astronaut having been seated in the space shuttle in a reclining position with his/her legs elevated, sometimes for several hours prior to launch.

Here on planet Earth, our muscles and bones work as a unit against the forces of gravity. This "bone-muscle" effort keeps us balanced and able to do work. In space, on the other hand, muscles are not used to any degree and as a result, will atrophy after a short period of time. Bones decrease in diameter and become less dense.

Muscles also become smaller and weaker. The actual muscle changes due to the nature of their use in space. As a result, astronauts not only have to exercise their muscles, they must also stretch them to maintain length and density. If astronauts don't maintain a strict regimen of exercise, they will, upon return to planet Earth, find that they are unable to function as before. Similar situations exist when bedridden patients are not able to move about for long periods of time.



In the weightlessness of space, there is no resistance against the astronaut's body. Astronauts walk a resistance treadmill approximately thirty minutes a day to keep the muscles in tone. The exercise in this lesson is just one example of how astronauts keep in shape while in space.

Pictures Credit from NASA:
https://www.nasa.gov/hrp/bodyinspace

MATERIALS (Consider any medical issues that may limit a student's participation in this activity.)

a) Masking tape (1 roll per pair of students)
b) Tape measure (found at the fabric store-1 per pair of students)
c) Set of elastic exercise bands
d) Bicycle tube
e) Broom handle, strong stick, or a PVC pipe piece (24" long)
f) Stopwatch
g) Student Data Sheet
h) Calculators (optional)

MANAGEMENT TIP: Prior to beginning the lesson, arrange the students in predetermined pairs. Consider pairing one male and one female for data collection purposes. You could also form groups of three as long as there is one male and one female in each group.

PROCEDURE
Show the students the video, "5 Ways Space Travel Affects the Human Body" (https://youtu.be/HSrVO5C9kwQ) by Scientific American Space Lab to spark curiosity of how the human body reacts in space.

PART 1: "Puffy Head, Bird Legs"

1. Engage the students by asking them the question, "On Earth, how can I simulate the fluid shift felt by astronauts when they enter space?" Allow the class some time to brainstorm ideas.

2. Show them the short video clip, "Microgravity and the Human Body," from the Foundations of Science website https://www.youtube.com/watch?v=kwEjFznfZ0c.

3. Next, share with them the following information:
While on Earth, gravity causes most of the body's fluids to be distributed below the heart. In contrast, living in space with less gravity allows fluids in the body to spread equally throughout the body. When astronauts first travel into space, they feel as if they have a cold and their faces look puffy. Many astronauts talk about not feeling thirsty because of this fluid shift. The body records this shift as an increase in blood volume. The body takes care of this fluid shift by eliminating what it thinks are extra fluids as it would normally – that's right – through the kidneys—resulting in visits to the restroom. Once this "extra fluid" is flushed from the body, astronauts adjust to space and usually feel fine. Puffy faces and chicken legs are short-term changes that astronauts feel. Within three days of returning to Earth, the fluid level of the astronauts return to normal, and the body is "back to normal." In this experiment, you will mimic this fluid shift felt in space by staying in a reclined position for a certain amount of time. You will record the effect this position has on your body's fluid distribution.

4. Inform the students that they will be taking turns acting as an aeromedical scientist or an astronaut for the investigation on how space flight affects the human body. The procedure will be repeated and the students will switch roles after the initial experiment.

5. Divide the students into the predetermined pairs and pass out the Student Data Sheet, along with the rest of the materials. For younger students, have a few volunteers at the front of the classroom and record data as a class.

6. Tell the students that data will be collected during the activity from measurements taken when the astronaut is standing and reclining.

7. Lead a discussion on a hypothesis (educated guess) about how their body will react to the experiment.

8. Point out to the students that during the early portions of the head-down orientation, a student's stroke volume increases from about 75 ml/beat to about 90 ml/beat. This is entirely expected because there is a rush of fluids to the upper part of the body and the heart then has more blood to force out during each beat. In addition, to compensate for this increase in stroke volume (to keep cardiac output relatively stable), the subject's heart rate decreases. Therefore, during the portion of this student investigation where you are determining cardiac output, don't be surprised when you obtain lower values for the subject's heart rate. This is normal.

9. To begin the investigation, have the students designate one of the partners as the astronaut. The other student is the aeromedical scientist.

10. Have the aeromedical scientist take an accurate standing pulse rate of the astronaut. For younger students, have them count the subject's pulse for 60 seconds. Lead this activity as a class instructing the students when to start counting and when to stop. For older students, according to the Baylor College of Medicine, "…To get the test subject's STANDING pulse, have the test subject stand up for 3 minutes, then sit down and the 'pulse taker' should take the test subject's pulse for 15 seconds. Multiply this pulse rate by 4 to get the standing pulse rate." Record this pulse on the data table in the "standing pulse rate" box.

11. Also, measure the circumference (distance around) of the astronaut's forehead and calf. To do this, place a piece of masking tape on the astronaut's forehead and calf. Use this as the point from where the measurements are taken. The tape should be left in position throughout the experiment.

12. Start with the forehead and wrap the measuring tape around the head to find the circumference. Measure to the nearest millimeter. Make sure to pull the tape measure firmly around the head, but not so tight that there are "dents" in the skin. Record the measurement on the data table.

13. Continue with measuring the circumference of the calf using the tape as a reference. Again, measure to the nearest millimeter and record the number on the table. Remember to be as accurate as possible.

14. Next, have the astronaut lie down on the floor with his/her feet or legs flat out in front of him/her. While the astronaut is lying down, take initial measurements of the pulse rate and calf and forehead circumferences to the nearest millimeter.

15. Then, have the astronaut continue to lie down and elevate his/her feet on the seat of a chair. Begin timing for 5 minutes, recording the start time on the data chart. After 5 minutes, measure the circumference of the forehead and calf and record it on the table in the appropriate places. While the astronaut is lying down, look at his facial characteristics and record these on the data sheet. Also, ask the astronaut about his/her own feelings or sensations and record this as well. Finally, take the pulse in this position. Take the pulse for 15 seconds and multiply it by 4 to get an accurate pulse rate. Record this on the data table in the correct box for "pulse rate after 5 minutes."

16. After another 5 minutes have passed, repeat the same procedures and record them in the table where it says "After 10 minutes."

17. Finally, repeat the same procedures again and record in the "After 15 minutes" boxes.

18. After recording the data for the 15 minute time, have the astronaut slowly sit up and reorient themselves.

19. Have the students switch roles and repeat steps 8-15 so that each student can experience being an astronaut and an aeromedical scientist.

20. Instruct the students to work together to answer the follow-up question on the front of the Student Data Sheet.

21. Discuss the front of the Student Data Sheet as a class and allow time to share results. Ask the students to compare their individual data with that of the class. Identify patterns that are found. Students should find that their forehead measurements will increase while lying down and that their calf measurements will decrease. The pulse rate will speed up at first and then slow down. Encourage the students to ask additional questions and possibly design additional experiments.

PART 2: "Exercising in Space"

1. Engage the students by discussing their favorite ways to exercise on Earth. Next, talk about if those same activities could be done in microgravity. Mention the challenges associated with exercising in space.

2. Show them the short video clip, "Astronauts Exercising in SpaceVideo," from the NASA archives website. (http://archive.org/details/MSFC-0700447)

3. Use the background information (http://www.nasa.gov/pdf/64247main_ffs_factsheets_fitness.pdf) to go into more detail regarding the exercise equipment that is available to the astronauts, as well as why it is important for the astronauts to exercise regularly in space.

4. Inform the students that they are going to be tasked with the challenge of creating two different exercises that astronauts could perform in microgravity. The goal of these exercises is an increased heart rate. Knowing the correct way to take your heart rate (pulse) will be crucial in evaluating the exercises that are created. Your heart rate, or pulse, is the number of times that your heart beats in one minute.

5. Review the proper way to take a heart rate, or pulse, with the class so that the students all understand the method. Please see the information in Part 1 of the lesson. There is helpful information on the website http://www.cchs.net/health/health-info/docs/0900/0984.asp?index=5508 as far as the correct procedure. This site also lists the normal heart rate at rest as well as the targeted heart rate during exercise.

6. Show the students the materials that they are going to use to design the exercises. (The bicycle tube is slipped around the broom handle stick to make a slip knot. This can be used by having the student step through the loop and exercising by pulling the stick toward the chest. The exercise bands can be used in several different ways to exercise the upper and lower body.)

7. Explain to the students that there are numerous exercises that can be done "in orbit" with devices such as these. Essentially, what the astronaut is doing is using one set of muscles against another. In this case, the straightened legs are providing the base for the band and the arm muscles are pulling away from the feet. This example exercise can be done in complete microgravity.

8. Pass out the materials for Part 2. The students should already have the Student Data Sheet and be paired with partners (preferably boy/girl) for the activity. Inform them that they will be taking turns acting as astronauts and exercise physiologists for the investigation. Each exercise will be repeated and the students will switch roles to collect the data.

9. Tell the students that data will be collected during the activity from the heart rates taken by following the data chart. Remind the students to be sure to describe the exercise in detail on the Student Data Sheet. Also, point out that a repetition, or rep, is when the exercise has been completed one time.

10. To begin the investigation, have the students designate one of the partners as the exercise physiologist and one as the astronaut. This role will be switched for each exercise.

11. Ask the students to design two exercises that astronauts could do in orbit. These exercises must help strengthen muscles in microgravity and must be able to be done with the materials provided based on the exercise hardware on the Space Station (see background information). Instruct the students to remember to follow the chart and collect data by taking a heart rate during the repetitions of the described exercise. Make sure that they explain why this exercise would work in space, using the data collected for females and males.

12. Instruct the students to work together to answer the follow-up question on the Data Collection Sheet when they have collected all of their data.

13. Have the students identify the most effective exercise that has the highest heart rate.

14. Discuss the back of the Student Data Sheet as a class and allow the time to share results, as well as demonstrate their most effective exercise. Students should find that their heart rate will speed up from resting to the 1 minute mark. Also, the more repetitions that are completed, the higher the heart rate should become. Talk about why this exercise is optimal for increased heart rate.

EXTENSIONS

• Explain the experiment in writing. Talk about how to improve the experiment and identify any mistakes that may have been made and how they have affected the results.
• Research the different exercise machines that NASA has for astronauts to use and design a new microgravity exercise machine.
• Visit the following websites for more information:

◦ NASA Get A Leg Up Lesson
http://www.nasa.gov/pdf/146854main_Get_A_Leg_Up_Educator.pdf

◦ TEACH Engineering: The Heart of the Matter Lesson
http://www.teachengineering.org/view_lesson.php

◦ NASA Lesson: Turn the Beat Upside Down (focus on cardiac output)
http://www.evolvemedia.com/docs/portfolio/cdrom/nasa/science/cardio/fluid/58decline.pdf

◦ Civil Air Patrol International Space Station: Puffy Head, Bird Legs
http://www.capmembers.com/media/cms/ssm3_4F9678E6718AB.pdf

◦ NASA Human Research: Physiology
http://www.nasa.gov/exploration/humanresearch/areas_study/physiology/index.html

◦ Article from Space.com: Trip to Mars Would Turn Astronauts Into Weaklings
http://www.space.com/8978-trip-mars-turn-astronauts-weaklings.html

◦ Exercise Equipment That is Used by Astronauts
http://www.livestrong.com/article/316255-exercise-equipment-used-astronauts/

◦ The Effects of Zero Gravity and Exercise
http://www.livestrong.com/article/362352-the-effects-of-zero-gravity-exercise/

◦ Wired Science: No Pain, No Gain in Space: Astronauts Need Better Workouts
http://www.wired.com/wiredscience/2009/04/astromuscles/

◦ NASA Exercising in Space Videos
https://www.nasa.gov/audience/foreducators/stem-on-station/ditl_exercising

◦ Space Doc: Weightlessness
http://www.spacedoc.com/weightlessness.html

ISS026E029180

PHYSIOLOGY FUN STUDENT DATA SHEET

Name: _____
Partner: _____
Date: _____

PART 1: "Puffy Head, Bird Legs"

	Standing	Lying Flat	After 5 min.	After 10 min.	After 15 min.
Pulse Rate					
Forehead Circumference (mm)					
Calf Circumference (mm)					
Facial Observations					
Feelings					

What changes did you notice after the astronaut was lying down?

_____

_____

_____

_____

How does that change relate to the "puffy head, bird legs" that astronauts experience in microgravity?

_____

_____

_____

_____

PART 2: "Exercising in Space"

_____

_____

PART 2: "Exercising in Space"

Exercise Repetition Chart	Resting Heart Rate	Heart rate after 10 reps.	Heart rate after 20 reps.	Heart rate after 30 reps.	Heart rate after 40 reps.
Male					
Female					

Description of Exercise:

Exercise Repetition Chart	Resting Heart Rate	Heart rate after 10 reps.	Heart rate after 20 reps.	Heart rate after 30 reps.	Heart rate after 40 reps.
Male					
Female					

What happened to the heart rate after completing 40 reps compared to 10 reps of the exercises?

Did you notice a difference between male and female data that was collected?

What is the most effective exercise that you created to get the heart pumping? Explain.

BE A NASA SCIENTIST
CREATING CLASSROOM TECHNOLOGY SPIN-OFFS

OBJECTIVE – Students will be able to learn about the everyday spin-offs that were created as a direct result of NASA technology and then act as a NASA scientist and study objects in the classroom to turn into spin-offs.

NATIONAL STANDARDS –
Next Generation Science Standards (www.nextgenscience.org):
- Disciplinary Core Idea Progressions
  - Earth Space Science Progression
    - ESS3.C: Human impacts on Earth systems
  - Life Science
    - LS2.D: Social interactions and group behavior
  - Physical Science Progression
    - PS4.A: Information technologies and instrumentation
- Science and Engineering Practices
  - **1**. Asking questions (for science) and defining problems (for engineering)

BACKGROUND – (More information can be found at https://spin-off.nasa.gov/)
(See NASA video for additional info: https://youtu.be/zz2AFNlE-WY)

A spin-off is a secondary application or use for a technology created for another purpose. In the case of NASA, the primary purpose of a new technology has something to do with the Space Program. However, this same technology can be used in the commercial or private sector to make life better for all of us. Things used to build rockets can help us every day. Examples of spin-offs are:

- Dentists use a lot of things from NASA. One of them is a material used in braces. This material is stronger than steel. It is hard to break. It even lets the dentist make the braces invisible.
- Racing swimsuits use a NASA spin-off. NASA found a way to make airplanes fly faster. Small lines were cut into the metal used to cover airplanes. The same idea can be used to make swimsuits. The suits help swimmers move through the water a lot faster.
- Sports shoes are better because man walked on the Moon. Moon boots were made to protect astronauts' feet when they walked on the Moon. The same kind of padding helps protect us when we run/jump.
- NASA has helped make riding bikes safer. Bicycle helmets have saved many lives. They are made from foam used in aircraft seats.
- Everyone loves shiny balloons. Mylar balloons are made with material used on satellites. It makes them shiny. Mylar is also put on space suits. It keeps astronauts from getting too hot or cold in space.
- Sunglasses have been changed thanks to NASA. The great thing about these glasses is that they let in the good light and keep out the bad light! Some light from the Sun can cause eye problems. The new sunglasses are great for people who spend a lot of time outdoors. They don't scratch or break like other glasses. This helps them last longer, too. The film used on the glasses was first made for space helmets and windows.

MATERIALS
a. NASA Spin-offs website: https://spin-off.nasa.gov/
b. Random items (such as gum, a 2-liter bottle, a straw, a ruler, etc.)
c. Paper and pencil (to record thinking)

PROCEDURE

1. Show an example of a NASA Spin-off and discuss how the item came to be used as a normal part of our "Earth life".

2. Facilitate a discussion on various NASA Spin-offs and how they are useful to us using the background information provided. Talk about the items intended purpose for NASA and how we adapted the item to our needs here on Earth.

3. Set up stations around the room with random predetermined objects found in the classroom and divide the students into groups for the purpose of traveling to the different stations.

4. Tell the students that today they are going to think like NASA scientists and look at common items found in the classroom for uses outside of their intended purpose.

5. Instruct the students to think of 5-10 different ways to use the objects, besides their common current uses. Tell students that they can redesign the objects if necessary.

6. Pass out paper to each student so that they can record their creative thinking. Allow them to set up the paper in whatever manner works the best for recording their thinking. For younger students, hold up the item and have a class conversation on creative uses, recording them in the front of the classroom.

7. Facilitate a class discussion after the groups have rotated to all of the stations and share the creative uses that the students wrote down on their papers. Find the most innovative ideas for a "Classroom Spin-off."

EXTENSIONS

Oscars have been awarded for nearly a century, but some winners found the gold coating wore off. In 2016, Epner Technology began gold-plating the statuettes, using a technique improved in part for the Mars Orbiter Laser Altimeter. Epner guarantees the coating for life. Credits: ©A.M.P.A.S.

• Have the students select the objects in the classroom for others to use to come up with other purposes.
• NASA Space Place Spin-offs memory game (browser must support Java): https://spaceplace.nasa.gov/spinoffs/en/
• NASA Technology Transfer Program: https://spin-off.nasa.gov/Spinoff2008/tech_benefits.html
• Visit the YouTube Channel, NASA Spin-offs, for up-to-date information on current NASA technology https://www.youtube.com/user/NASASpinoff/videos
  ◦ Spin-off 2015 by NASA Spin-off (https://youtu.be/ivw7AzkykOY)
  ◦ Spin-off 2018 by NASA Spin-off (https://youtu.be/-LlyyKOzr9Q)
  ◦ Earth Day 2018: NASA technology that benefits the planet by NASA Spin-off (https://youtu.be/5xZQk9fLyFs)
• Read each story that follows. Choose for which use you think NASA invented it. Cut out the strip that best describes that use and glue it in the box under the story.

Used in space suits

Used to protect the eyes of welders

Used on heat pumps for satellite cooling

Used in space telescopes

Used on spacecraft to help control flight

Used as a smoke and fire detector for Skylab

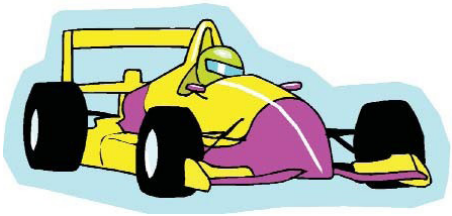
Life can be tough for a baby pig. A mother pig can squash a piglet by accident. Or, she may not feed it. These problems cause hog farmers to lose a lot of pigs.

NASA has come up with a solution. It is a robotic mother pig. The robot keeps piglet formula cool until it is needed. Then, the robot pours the formula into a heating chamber. At feeding time, a heat lamp warms up the machine to hog-body temperature. The robot pig then lets the piglets know it's time to eat. It does this by grunting like a mother pig!

In the past, farmers would have needed a lot of machines to do this job. These machines take up a lot of room. They need to be worked on a lot. The NASA machines are about the size of a quarter. It has no moving parts. It can heat and cool the milk.

It may not look like a pig, but it's warm and tasty like a pig. The best part is it says a piglet's favorite words - "dinner time"!

Hopefully, you've never had to get up in the middle of the night because of a smoke detector. By law, smoke detectors have to be placed in all new homes. They help save lives.
Does your house have a smoke detector?



The powerful engines on race cars make a lot of heat. This can cause the drivers' temperature to rise. That makes them tired and dried out. The driver might even get sick. So, more and more drivers are wearing cool suits. Cold liquids move through tubes in the suits. This keeps the drivers' temperature down.

A group of kindergarten kids are standing in a line. They're getting ready for a test. You would never know it by looking at them. It's an eye test. But, this one is as quick as taking a picture. This machine takes pictures of the children's eyes.

The system includes a special camera, lens, and electronic flash. The flash sends light into the child's eyes. The light is reflected from the back of the eye to the camera lens. Once the picture is made, it is studied.

The pictures show many kinds of vision problems. What is so special about this system? During most eye exams, the doctor asks questions. The answers are used to see what problems the child is having. The new system isn't like the old ways of eye screening. It doesn't need an answer from the child, and it takes only a few seconds for the test.

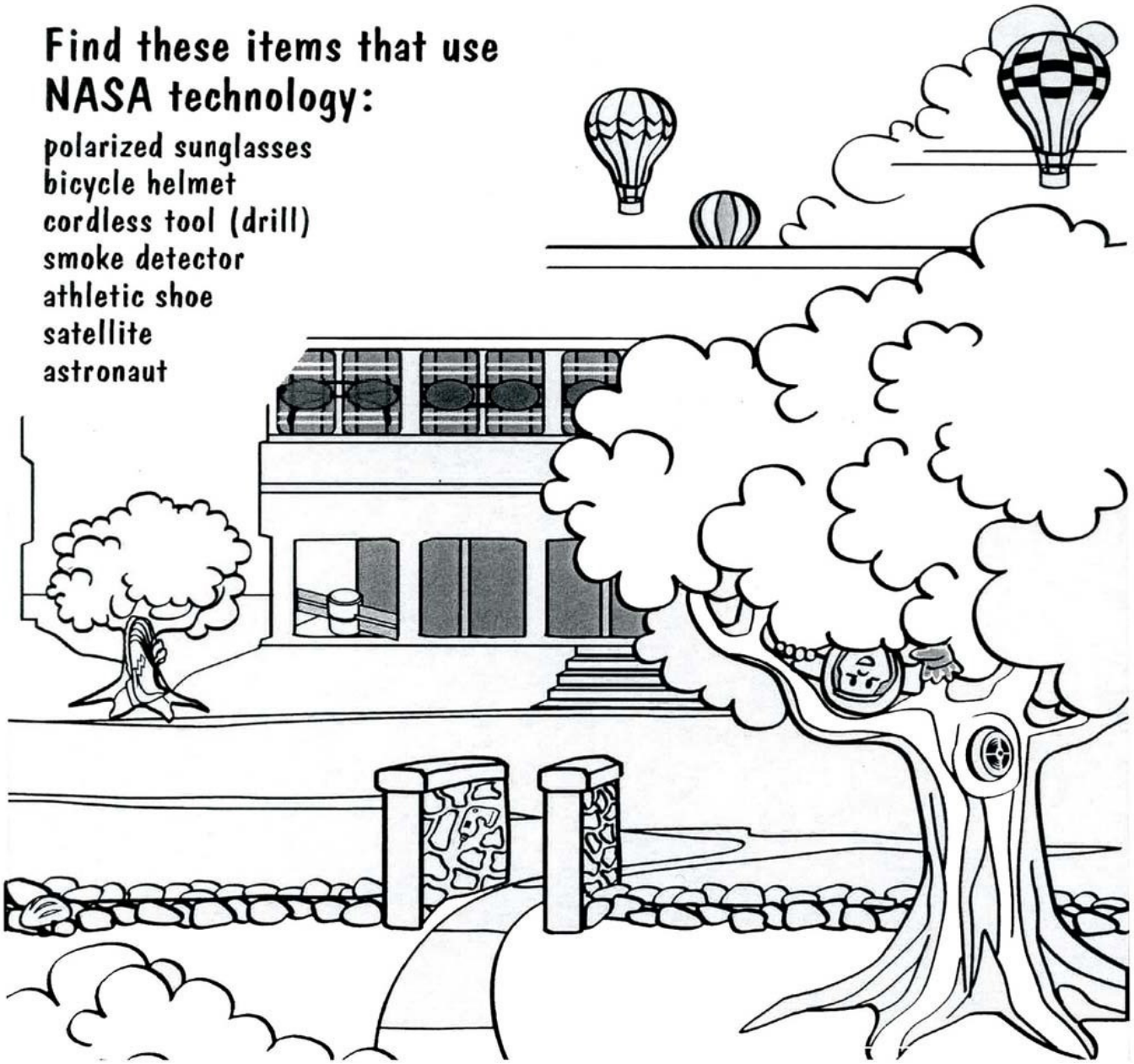
These sunglasses protect your eyes. The great thing about these glasses is that they let the good light in. They keep the bad light out! Some light from the Sun can cause eye problems. The new sunglasses are great for people who spend a lot of time outdoors. They don't scratch or break like other lenses. This helps them last longer, too.

Joystick controllers are used for lots of things now. They can be used for computer games. People with disabilities can use them to steer cars and wheelchairs. The grip of the joystick goes back and forth. This lets users make the most of their natural hand movements. This lets them play their best game. The joystick can move like a plane's control stick. This makes it seem as if you are really flying. This new joystick makes playing three-dimensional games a lot more fun.

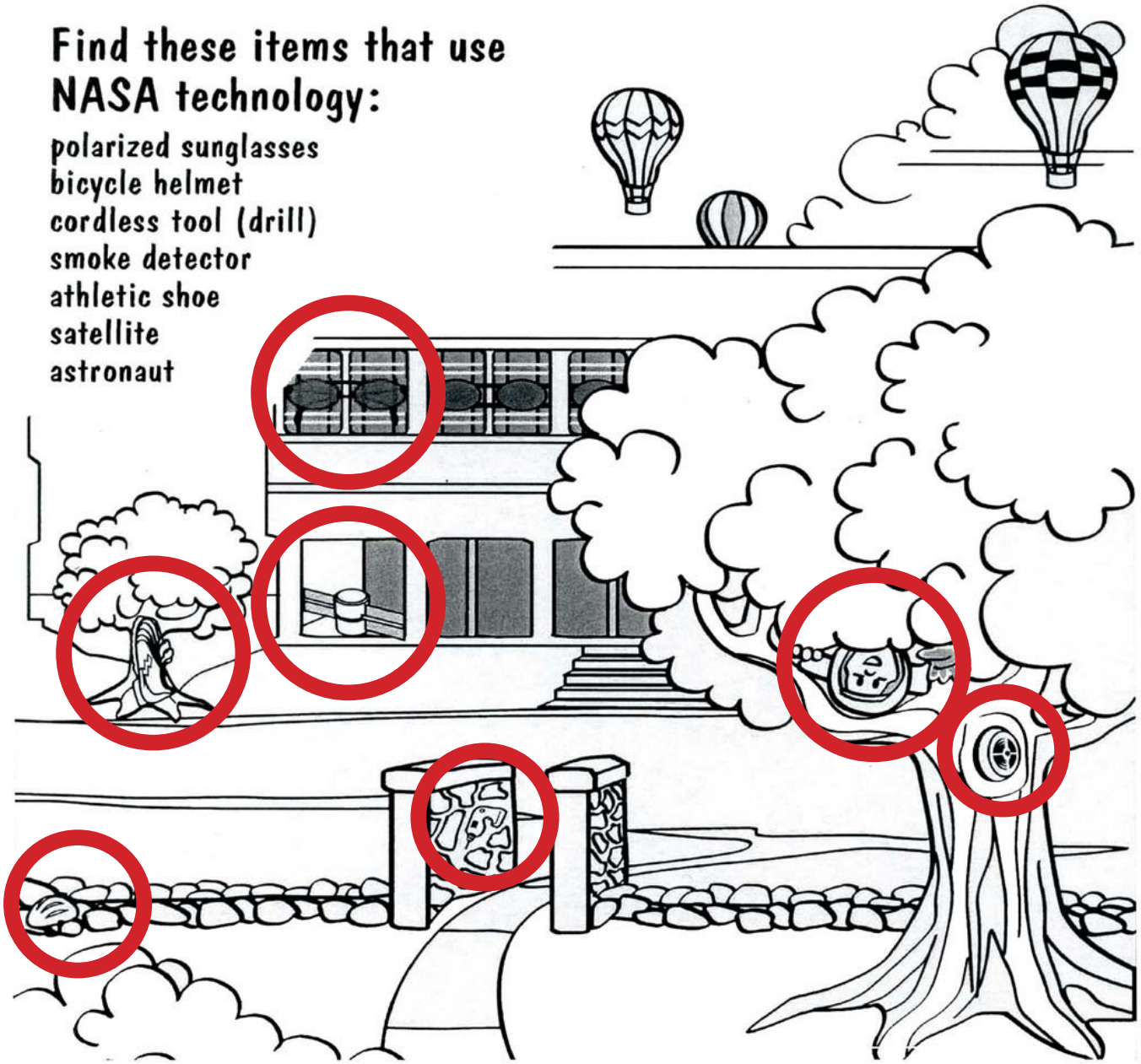
Back on Earth Hidden Pictures

Find these items that use NASA technology:

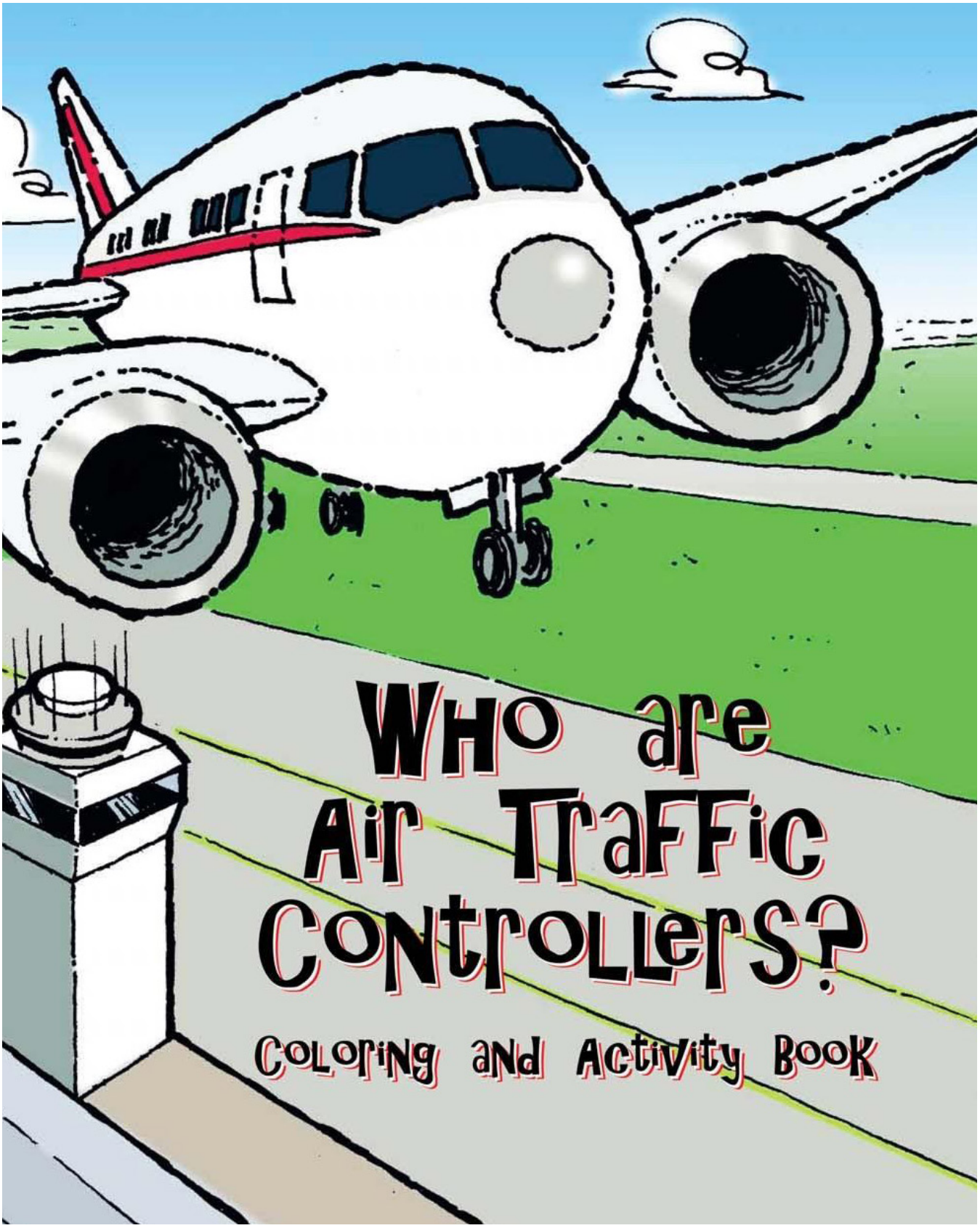
polarized sunglasses
bicycle helmet
cordless tool (drill)
smoke detector
athletic shoe
satellite
astronaut



Back on Earth Hidden Pictures



ANSWER KEY

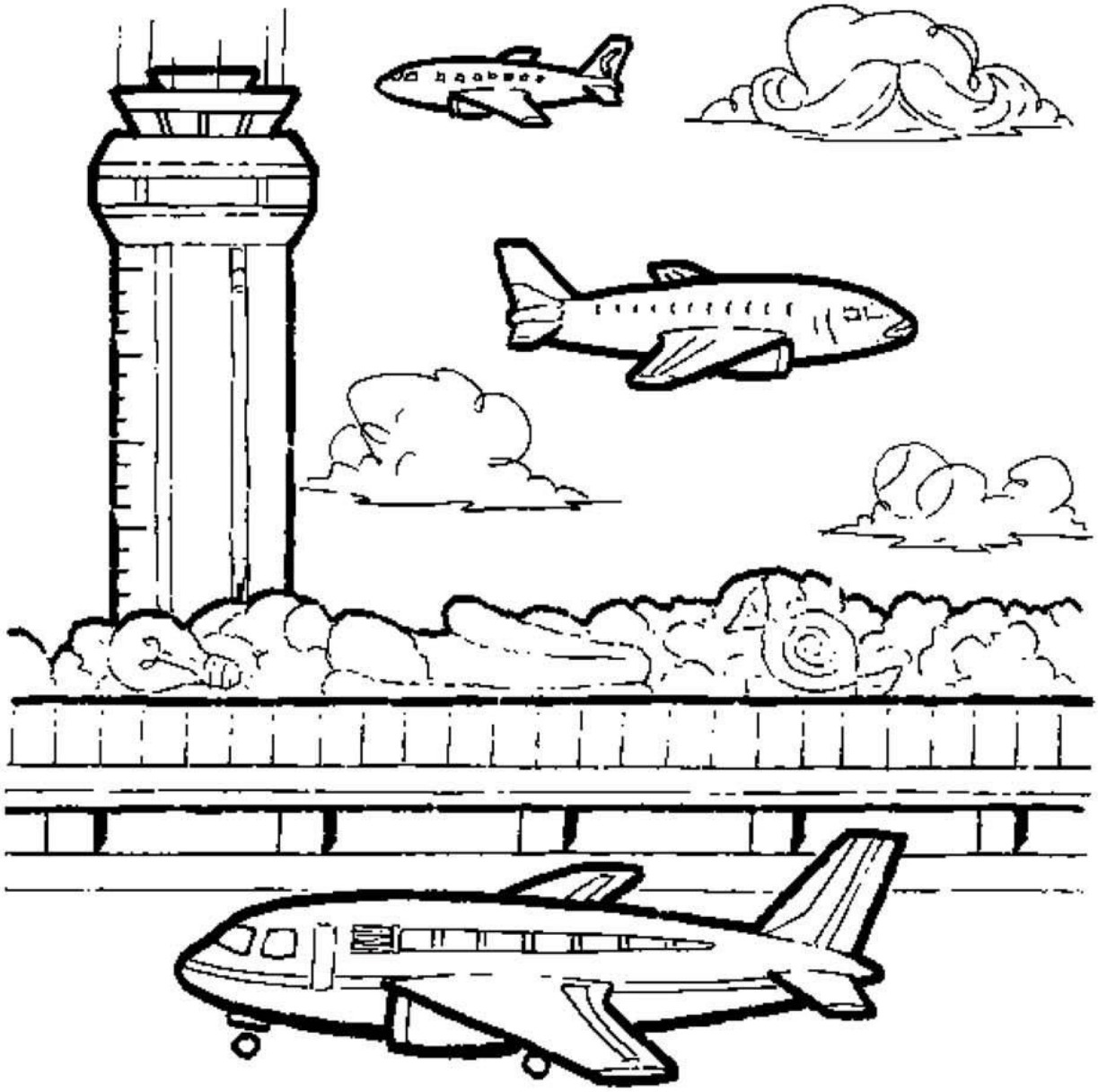

Who are Air Traffic Controllers?
Coloring and Activity Book

Everyday, over 2 million people travel across our nation's skies.

Can you spot the six things wrong with this picture?

Answers: upside down clock, deer with purse, octopus in suitcase, pant leg cut off, ticket agent holding sock, deer wearing necklace

And everyday, air traffic controllers are at work keeping air travelers safe.

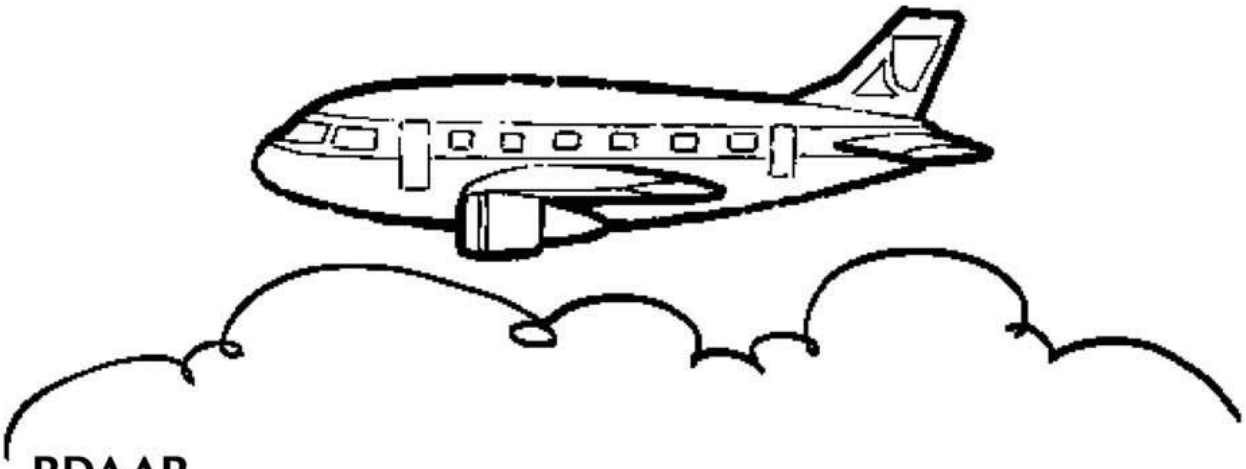


Can you find the 10 objects hidden in this picture?

Answers: paintbrush, lightbulb, ruler, pencil, baseball, fish, loafer ,candy, mustache, boomerang

Air traffic controllers work to safely separate aircraft as they travel across the sky.

Unscramble the letters to see some of the equipment controllers use.



RDAAR ___ ___ ___ ___ ___

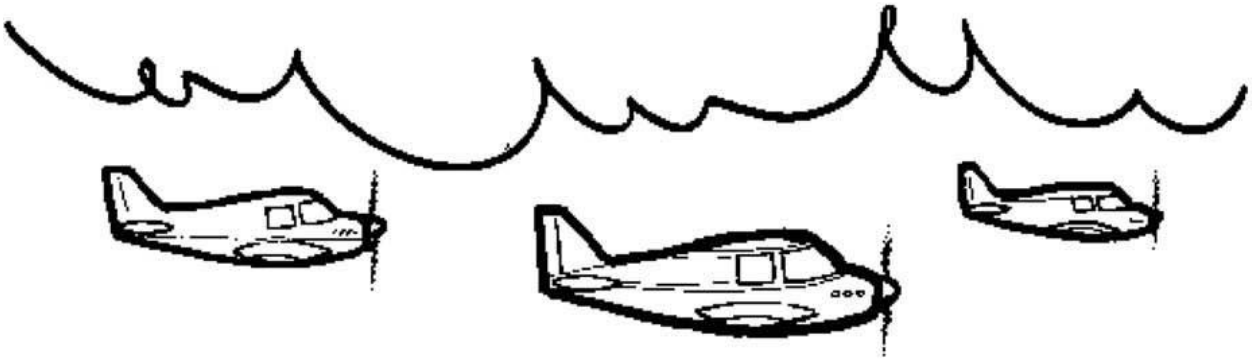
PASM ___ ___ ___ ___

OIARD ___ ___ ___ ___ ___

PUMOCRTE ___ ___ ___ ___ ___ ___ ___ ___

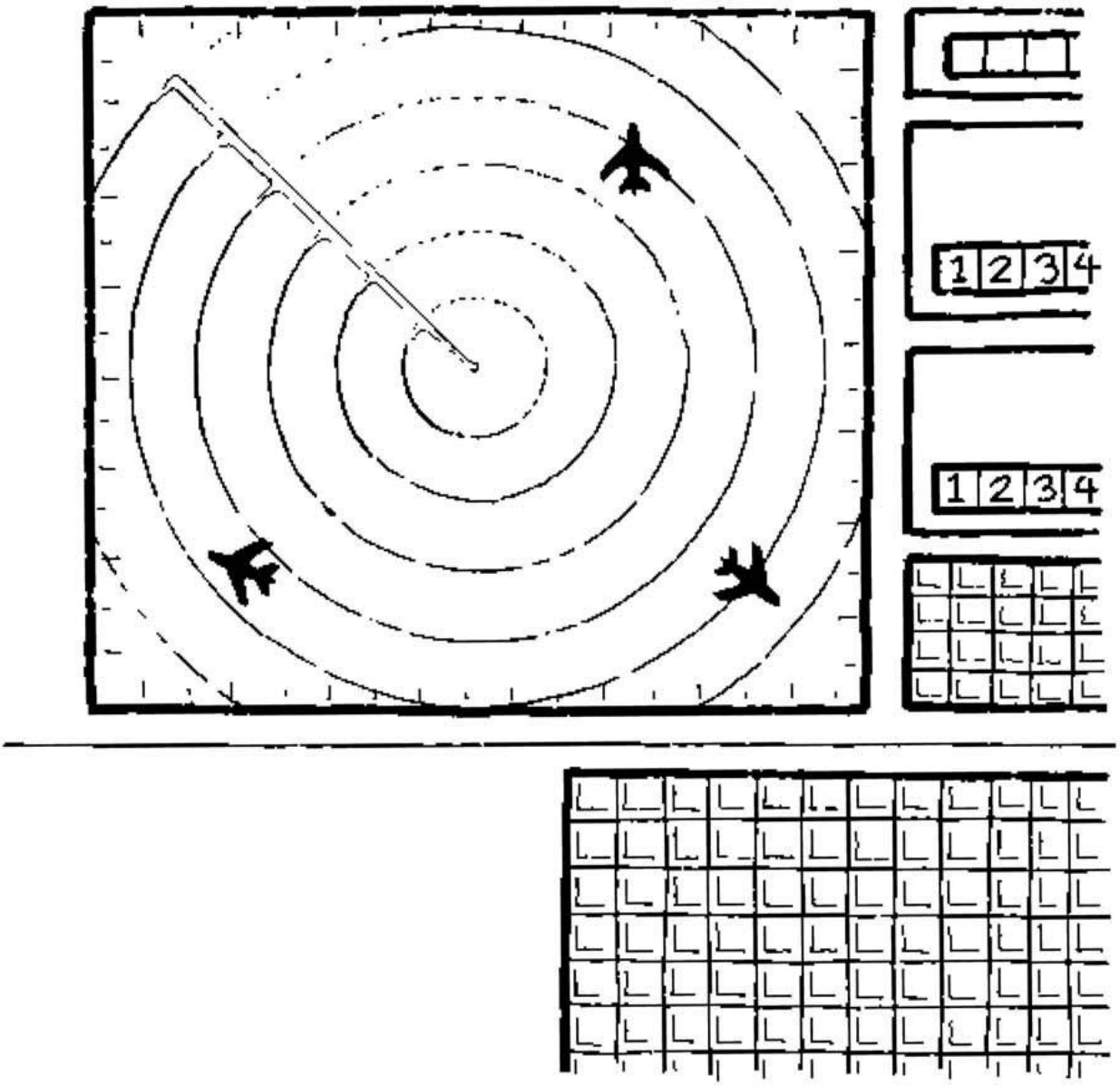
SHATEDE ___ ___ ___ ___ ___ ___ ___

OLUCBNSIRA ___ ___ ___ ___ ___ ___ ___ ___ ___ ___



Answers: RADAR, MAPS, RADIO, COMPUTER, HEADSET, BINOCULARS

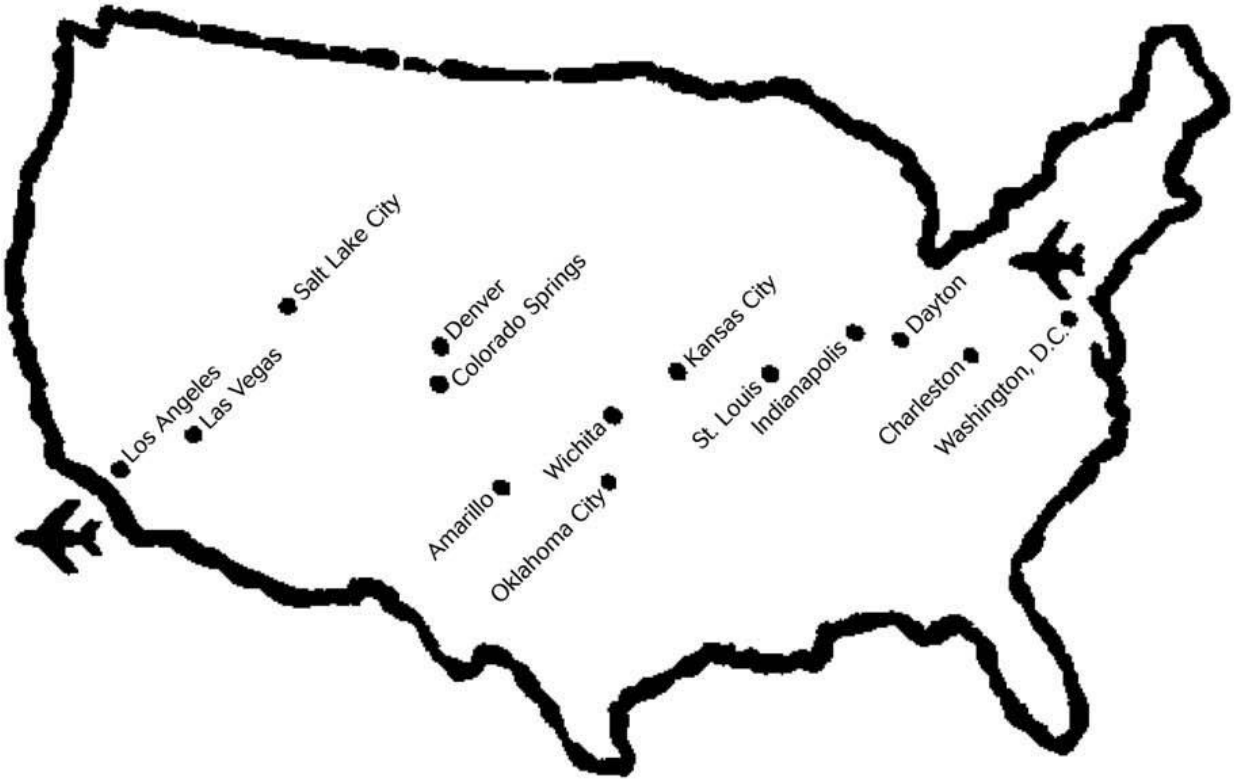
Air traffic controllers use radar to track aircraft.



Can you draw five more airplanes on the controller's radar scope? (And remember keep them safely separated.)

Air traffic controllers work together in a rhythm similar to runners in a relay race.

A controller will work an aircraft until it reaches the end of his defined airspace - and then will hand it off to the next controller - similar to a runner handing the baton off after running his leg of the race.



Can you follow the plane's journey as the air traffic controllers work together to move the aircraft from Washington, D.C. to Los Angeles, California?

Air traffic controllers work in three different types of facilities.

Some controllers work in the glass enclosed towers you see at airports. They give pilots taxi and take off clearance. Once the aircraft reaches the edge of the tower's jurisdiction - it is handed off to the controller in the TRACON.

Terminal Radar Approach Control (TRACON)

Controllers also work in radar rooms called TRACONs - which are located either at the base of the airport tower or in a building completely separate from the airport.

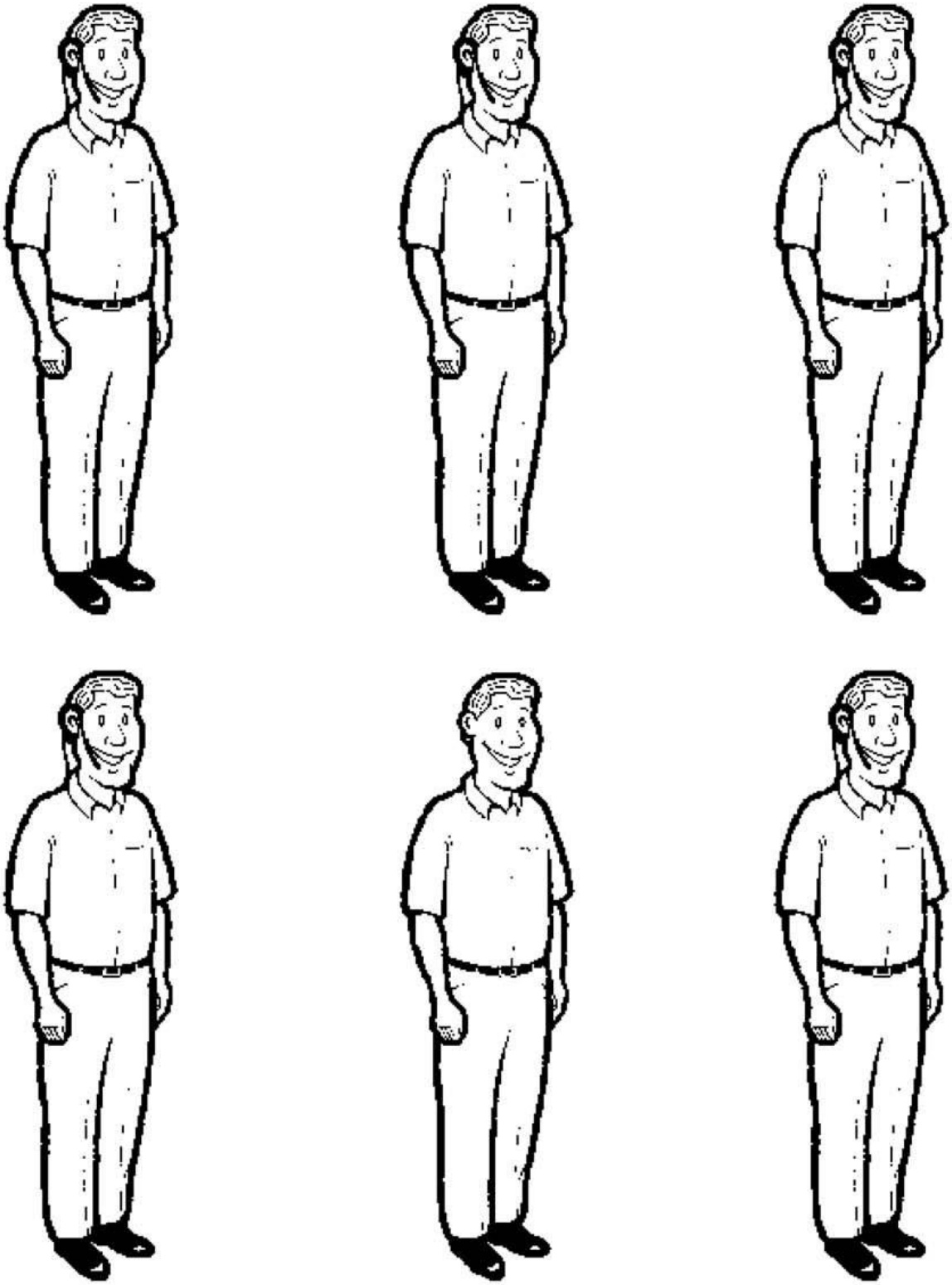
These controllers provide service to the aircraft until it reaches the edge of the facility's airspace then they hand it off to the center.

Air Route Traffic Control Center

Controllers in centers work at 20 facilities across the country, and will provide service to the aircraft for the majority of its journey.

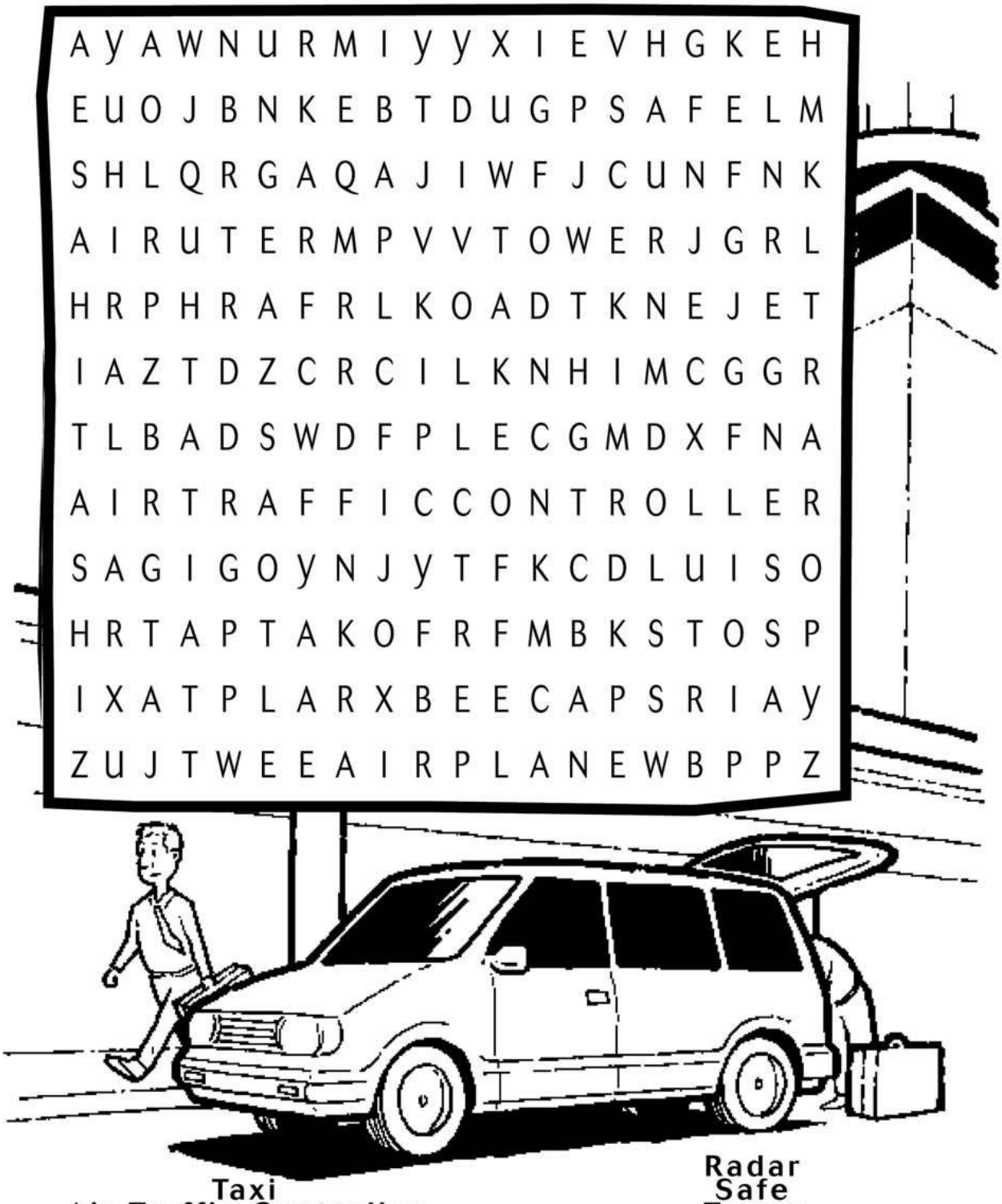
A typical center is responsible for more than 100,000 square miles of airspace generally extending over a number of states.

Which air traffic controller is different from the others?



Find the aviation-related words.

A y A W N U R M I y y X I E V H G K E H
E U O J B N K E B T D U G P S A F E L M
S H L Q R G A Q A J I W F J C U N F N K
A I R U T E R M P V V T O W E R J G R L
H R P H R A F R L K O A D T K N E J E T
I A Z T D Z C R C I L K N H I M C G G R
T L B A D S W D F P L E C G M D X F N A
A I R T R A F F I C C O N T R O L L E R
S A G I G O y N J y T F K C D L U I S O
H R T A P T A K O F R F M B K S T O S P
I X A T P L A R X B E E C A P S R I A y
Z U J T W E E A I R P L A N E W B P P Z



Taxi
Air Traffic Controller
Runway
Passenger

Radar
Safe
Tower
Take off
Airspace
Airplane

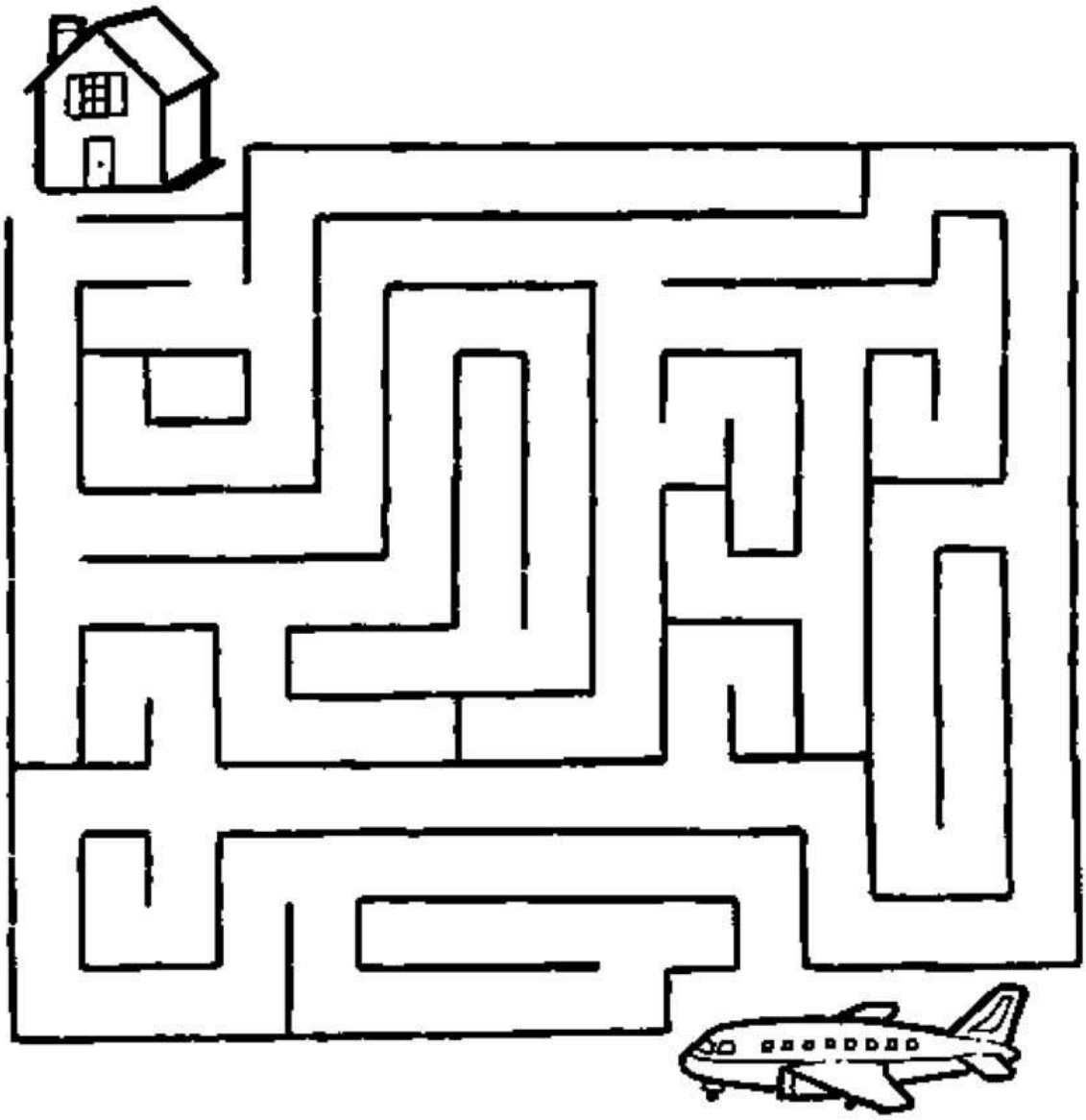
The National Air Traffic Controllers Association is the union that represents air traffic controllers and other aviation safety related personnel.

NATCA strives to improve its members working conditions.

All the things in the boxes are in the picture above. Can you find and color them in?

NATCA continually works to improve and enhance aviation safety, and we proudly provide the safest air traffic control system in the world.

National Air Traffic Controllers Association:
We Guide You Home



Help the air traffic controller guide the airplane passengers through the maze to get home.

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