TEACHER'S GUIDE

FIGHTER PILOT

Operation Red Flag

Fighter Pilot: Operation Red Flag

Presented by The Boeing Company

As the proud sponsor of *FIGHTER PILOT: OPERATION RED FLAG,* the Boeing Company salutes the men and women of the Allied Forces and recognize their bravery and distinction with which they serve.

Boeing is also committed to ensuring the quality and outcomes of early learning through 12th grade public education throughout the United States. In this endeavor, Boeing is strategically focusing investments by concentrating on teacher effectiveness in public education, especially in the areas of math, science, literacy and school leadership.

Never before has a large format film captured the realistic, but necessary, combat training the air forces of the United States and its Allies endure on the vast Nellis Air Force Base ranges. Only the giant-screen 70mm movie format can strap you into the cockpit of an F-15 fighter, allowing you to see, feel and hear what the pilots of Red Flag experience.

This presentation also honors the gallant fighter pilots from previous generations, like the grandfather of Captain John "Otter" Stratton, the F-15 pilot featured in this film.

Sincerely,
George Muellner
Boeing Air Force Systems,
Vice President and General Manager

In The Film

John ("Otter") Stratton is a young American fighter pilot who flies the F-15 Eagle, arguably the most potent and successful fighter plane ever built. His grandfather was a decorated World War II flying ace, and he intended to follow in his footsteps.

At Red Flag, the international training exercise for air forces of allied countries, many of the world's best pilots meet for the most challenging flying of their careers. Red Flag is the final training for pilots and their air crews before being sent into actual combat. We follow our young pilot as he makes his way through this extraordinary event held in the desert of Nevada.

He is amazed at how complex, challenging and dangerous the exercises are.

He begins to notice team members who were not a part of his childhood vision of heroism, the support team crucial to a successful mission, and to a safe return home. In the aerial combat exercises, there are other pilots who aren't out just to prove themselves, they are helping him — watching his back. And he is doing the same for them. He begins to realize that being a hero is not quite as simple as he once might have thought.

Teacher's Guide

The Forces of Flight lessons were produced by The Boeing Company, under the direction of project leader James Newcomb. For more information and posters to download, go to www.boeing.com/education.

Character and Recognition lessons were written by Thais Johnson, under the direction of Jan Baird and Bob Kresser, Executive Producers of the film, Fighter Pilot: Operation Red Flag.

Building Teamwork activity, *It's Cool To Refuel*, provided by NASA Spacelink. This and more educational resources are available at http://spacelink.msfc.nasa.gov.

Layout and design by Kristi Butler. For additional resources, go to www.fighterpilotfilm.com.

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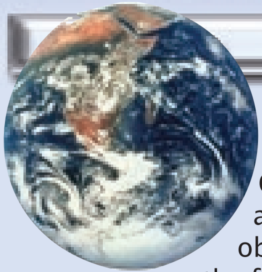
Glossary

The science of flight uses special terminology to identify important concepts. It may be helpful to refer to the definitions when learning about flight.

Aerodynamic: Having a shape that allows for lift and smooth airflow.
Air: A mixture of gases that surrounds earth; this mixture is made up of molecules that take up space and have weight.
Airflow: The motion of air molecules as they flow around an object, such as a wing.
Airfoil: An object with a special shape designed to produce lift when it moves through the air.
Air pressure: The force created by air pushing on a surface.
Angle of attack: The angle of a wing to the oncoming airflow.
Camber: The curve of an airfoil.
Drag: The force that resists the motion of the aircraft through the air.
Force: A measurable push or pull in a certain direction.
Gravity: The force of attraction between two objects.
Laminar flow: The smooth flow of fluid around an object.
Launch angle: The angle at which an airplane takes off most efficiently.
Leading edge: The front edge of an airfoil.
Lift: Upward force produced by air passing over and under the wing of an airplane.
Stall: A breakdown of the airflow over a wing, which suddenly reduces lift.
Stall angle: The angle at which the wing meets the oncoming airflow and the wing stops generating lift.
Thrust: A force created by the engines that pushes an aircraft through the air.
Trailing edge: The back edge of an airfoil.
Turbulent flow: Airflow around an object that does not flow in a smooth stream but swirls about.
Weight: The force with which a body is attracted toward earth or a celestial body by gravitation. Produced by gravity acting upon an object.

Forces of Flight: Gravity



The Basics

Gravity is the invisible force of attraction that exists between two objects. Most of us think of gravity as the force that pulls objects toward Earth and gives us weight. In fact, gravity attracts all objects to one another. However, the force of gravity depends on the size or mass of the two objects. Because Earth is so large, its force of attraction is more noticeable. So the force of attraction that exists between your hand and a ball, for example, is far less apparent than the force that exists between the ball and Earth. Many scientists have contributed to our knowledge of the law of gravity. Galileo Galilei and Sir Isaac Newton are two of the most famous. Today, scientists continue to study gravity and its effects on vehicles, living things, and satellites of all kinds.

The Law of Gravity

Newton realized all objects – not just Earth – exert the force of gravity upon each other, pulling them toward one another, and that the greater an object's mass, the greater the pull it exerts. After numerous scientific observations, Newton devised a mathematical formula to explain this law of gravity. It states: The force of gravity is proportional to the product of the two masses and inversely proportional to the square of the distance between their centers of mass. Put more simply: As objects get closer to each other, the force of their gravitational pull increases. As a result, as a small object is drawn toward a larger one (as the apple falls from the tree limb toward Earth), its speed also increases. This formula was the key to understanding how far planets are from one another and to beginning to understand the structure of the universe.

Newton's Laws of Motion

To understand how things fly, it helps to be acquainted with Newton's three laws of motion. To understand his laws, it also helps to know that two words – "velocity" and "acceleration" – are used differently than in common, everyday language.

1. Newton's first law of motion is also known as the law of inertia. It states: In the absence of force, a body at rest tends to remain at rest, and a body in motion tends to remain in motion, moving at a constant velocity (that is, moving at the same speed and in the same direction). In other words, all objects resist changes to their state of motion. (One cautionary note: The forces of friction are so common that it is extremely difficult to observe a moving object that is completely unaffected by any force whatsoever. Frictional forces always oppose motion, and sometimes they prevent it.) Let's say you're riding a bike. If the bike hits a curb or a large object in the road, the bike stops, but you continue to move and slide forward off the bike seat. Why? The wheel hitting the curb provided the force that changed the bike's state of motion. But there was no force to change your state of motion, and as a result, you slid off the seat.

2. Anytime an object changes velocity (that is, anytime it changes either its speed or its direction, or both) there must be an external force acting upon the object. The change in velocity is called acceleration, regardless of whether the object moves faster, or more slowly, or simply changes directions. Newton's second law of motion states that if an object accelerates (changes speed or direction, or both), the acceleration (the change that is produced) is proportional to the strength of the force. Even in simple, everyday events, the external force is not always obvious. Suppose you're standing still, and then you begin to walk. What was the external force that caused you to accelerate? Here's a clue: it's very difficult to start walking if you're wearing new, smooth-bottomed shoes and standing on slick ice.

Newton's Laws of Motion

1. *Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it.*
2. *The relationship between an object's mass m, its acceleration a, and the applied force F is F = ma. Acceleration and force are vectors. In this law the direction of the force vector is the same as the direction of the acceleration vector.*
3. *For every action there is an equal and opposite reaction.*

3. Newton's third law of motion is also known as the law of action and reaction. It states: For every action there is an equal and opposite reaction. The principle is demonstrated by what happens if you step off a boat onto the shore: As you step toward land, the boat tends to move in the opposite direction, away from shore.

ACTIVITIES

It's easy to think of gravity as negative, because we commonly associate it with being pulled down. However, it's important to note that gravity also holds Earth in orbit around the Sun, keeps us from being catapulted into space, and binds the atmosphere to the planet, allowing us to breathe. There is an up side to the downward pull, so to speak.

The Lowdown on Gravity

This is the simplest of all of the experiments suggested here, and most students will be able to guess the experiment's outcome in advance. However, this simple experiment provides the opportunity to talk about gravity (a word derived from the Latin word for weight) and how weight can affect our ability to fly.

- SUPPLIES: 30 marbles, scissors, one large plastic milk container (clean and dry), one wide rubber band

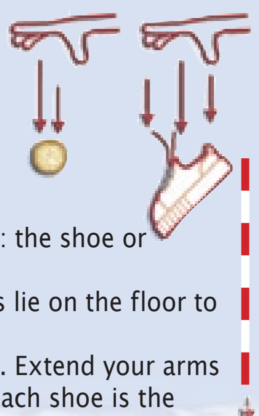
1. Hang the milk container: Cut across the rubber band to make a single strip. Tie one end of the rubber band to the container and the other to a door handle or coat hook.
2. Drop 10 marbles into container. Measure the distance from the container to the floor.
3. Repeat: Add 10 marbles and measure the distance to the floor; then add the final 10 marbles and measure again.

QUESTIONS:

- What were your results?
- How does this demonstrate the force of gravity?
- If something gets heavier, what happens to our ability to lift it? Or, imagine a sparrow grabbing a bowling ball with its feet. Will the sparrow be able to fly with the ball?"

Galileo's Race

This famous experiment is often attributed to Galileo. However, according to many scholars, the attribution may be inaccurate.



- SUPPLIES: One chair, one coin, one pair of shoes.

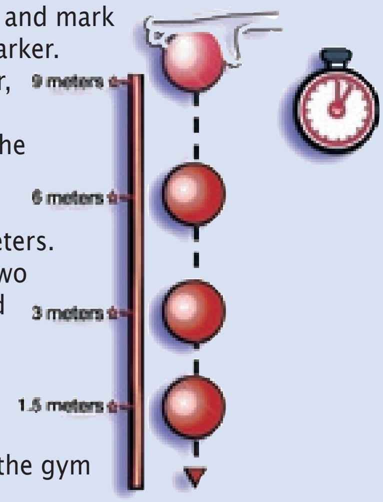
1. Ask each member of the group to predict which object will fall faster: the shoe or the coin. Record their answers.
2. Stand on the chair while your partners lie on the floor to measure the time of impact.
3. Hold the two shoes, one in each hand. Extend your arms straight out from your body so that each shoe is the same height from the floor. Release both shoes at the same time. Did they hit the floor at the same time? Record your observation.
4. Stand in the same position, but this time hold a shoe in one hand and a coin (or some other smaller and lighter object) in the other hand. Release both of these objects at the same time. Did they hit the floor at the same time? Record your observations.

QUESTIONS:

- What were your results?
- Were your predictions accurate?
- What do you think would happen if you dropped the same objects from 6 meters in the air?

Newton's Ball Drop

- SUPPLIES: One large foam ball, 9 meters of string, one marker, a stopwatch.
- Each group should have a teacher, three students (a timer, a measurer, and a recorder).



1. Measure 1.5 meters of string and mark the 1.5 meter point with a marker.
2. The teacher stands on a chair, holds the ball 1.5 meters off the ground as measured by the string, and drops the ball.
3. Measure the amount of time it takes the ball to fall 1.5 meters. Record the number. Repeat two more times at 1.5 meters and record the numbers.
4. Repeat the experiment three times each at 3 meters, 6 meters, and 9 meters up, if possible. Drop the ball from the gym bleachers, if necessary.
5. Then calculate the average time for the drop from each height and plot the averages on a graph of time versus distance. Draw a best-fit line to chart the effects of gravity.

QUESTIONS:

- What were your results?
- What happened to the ball's velocity as it fell from greater heights?

Galileo Galilei, (1564-1642) developed the Law of Falling Objects, demonstrating that two objects of different mass fall at the same speed.

Sir Isaac Newton (1642-1727) developed a mathematical Law of Gravitation that allowed him to measure gravity.

Forces of Flight: Lift

The Basics

Lift is the force that directly opposes the weight of an airplane and holds the airplane in the air. Lift is generated by every part of the airplane, but most of the lift on a normal aircraft is generated by the wings.

Aerodynamic lift is based on Daniel Bernoulli's principle which states that the pressure of a flowing fluid or gas decreases as its velocity increases. To take advantage of this, an airplane wing, like a bird wing, is designed with a distinctive shape called an airfoil. This shape creates the greatest possible lift for the airplane. The shape of an airplane wing, the angle at which the wing meets the airflow and the speed of the airplane all affect the lift.

Newton's third law states that every action has an equal and opposite reaction. Therefore, to produce lift, an airfoil must push downward on the air around it and thus turn the flow of air downward. The upward push by the air is felt as higher air pressure below the airfoil and lower pressure above it. Even a flat-plate airfoil shape, like that found on toy gliders and paper airplanes can turn the flow downward if it is inclined to the flow in a slightly "nose-up" direction.

Lift is a challenging concept, but there are two key elements that must be understood:

1. Air is a fluid. When most of us think of "fluid" we think of liquids, but a fluid can be either a liquid or a gas. To understand how wings work, it might be helpful to think of how fins work in the water.
2. Wings, or airfoils, are shaped in special ways to create maximum lift and minimum drag. Some are flat on the bottom and curved on top, some are curved on both top and bottom. Some are very thin and some are fatter. Different kinds of airplanes and animals such as birds or insects, use different airfoil shapes depending upon their size, composition and speeds they fly.

As engines have become more powerful and planes much faster, the shape of airfoils has changed to maximize lift and minimize drag, but the principle remains the same.

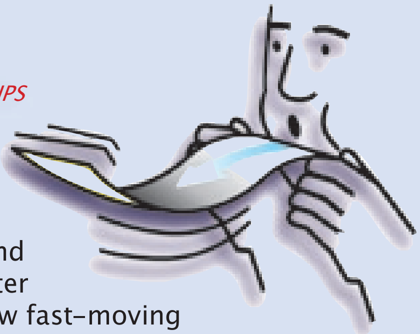
Both Bernoulli and Newton are correct. Integrating the effects of either the pressure or the velocity determines the aerodynamic force on an object. Equations developed by both of them can be used to determine the magnitude and direction of the aerodynamic force.

Daniel Bernoulli, (1700–1782) Swiss mathematician whose work studying the movement of fluids forms the foundation for the study of aerodynamics today.

Sir Isaac Newton, (1642–1727) Isaac Newton's discoveries were so numerous and varied that many consider him to be the father of modern science. Newton helped define the laws of gravity and planetary motion, co-founded the field of calculus, and explained laws of light and color, among many other discoveries.

ACTIVITIES

BERNOULLI'S FLOATING STRIPS



This is a very basic experiment that never ceases to amaze students. It shows how lift works and demonstrates the counter intuitive principle of how fast-moving air lifts a wing.

- SUPPLIES: Scissors, notebook or construction paper.

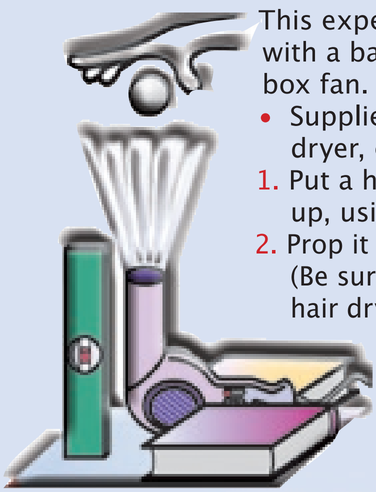
1. Cut a strip of paper, 5 cm by 20 cm. Place the strip between your upper lip and nose and blow through your lips. Write down what happens.
2. Then write down what you think will happen if you blow over the paper by putting the strip just under your lower lip.
3. Put the strip just below your lower lip and blow through your lips.

QUESTIONS

- What were the results?
- Why did your results change depending on the position of the paper?
- How does this illustrate the relationship between air pressure and lift?

HOVER BALL

The hover ball exercise tests students' understanding of the concept of lift. Ask students why the ball does not fly away or fall. (Tip: the ball is raised by the faster-flowing air, not supported on the column of air.)



This experiment also works with a balloon and a standard box fan.

- Supplies: ping-pong ball, hair dryer, carpenter's level, books

1. Put a hair dryer facing straight up, using a level.
2. Prop it up with the books. (Be sure to adequately vent the hair dryer. Leaving it on too long could cause a fire).
3. Turn the dryer to cool and high.
4. Place a ping-pong ball into the airflow.

QUESTIONS:

- Why does it float? (Lift! It's not the air pushing up, it's the air rushing around that is pulling it up.)

THE WING THING

The wing thing is an experiment in which students build a simplified airfoil.

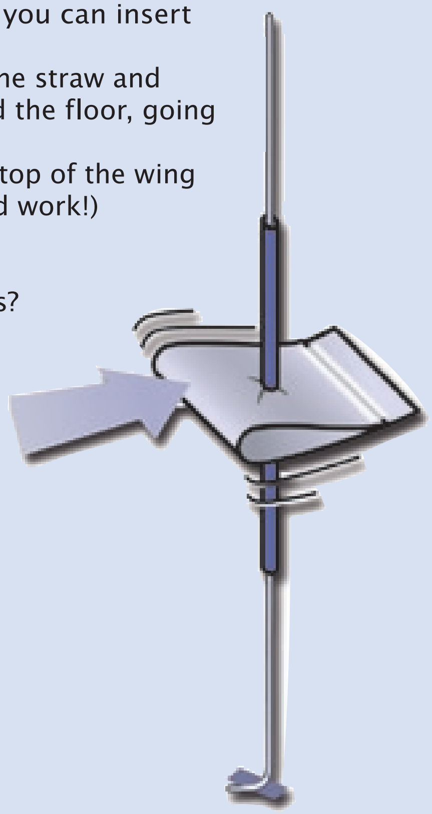
This is a difficult experiment. (The trick is in getting the shape of the airfoil just right, so don't be disappointed if students have trouble.) The airfoil should travel up the string, but often it does not move smoothly.

- Supplies: scissors, notebook or construction paper, string, straw, tape, a fan.

1. Have students cut strips of paper, 10 cm by 15 cm.
2. Fold the strip so that it creates an airfoil. Don't make a crease. Leave about half an inch between the top edge and the bottom edge to create the shape. (An airfoil should have one side longer than the other.)
3. Draw an X in the center of the wing and cut a hole into which you can insert the straw.
4. Put a string through the straw and attach it to a desk and the floor, going straight up and down.
5. Blow the fan over the top of the wing until it rises. (It should work!)

QUESTION:

- What were your results?



Forces of Flight: Drag

The Basics

Drag is the force of resistance caused by air or liquid pressure. If you have ever put your hand out the window of a moving car and felt the wind pushing against it, or walked into the wind on a breezy day and noticed how hard it is to move forward, you have experienced drag.

Drag affects an object's ability to travel through air or fluid in several ways. Drag slows an object down. It forces a powered object to use more fuel. Drag can even pull an object apart if it is not designed to withstand the force of drag.

Once we understand that air is a fluid, the concept of drag becomes fairly easy to understand. Drag can be useful in a parachute, but most of the time, drag is something engineers try to reduce. There are two main kinds of drag: friction drag and form drag.

Friction drag also known as surface drag — is the resistance that comes from rough or protruding surfaces. Imagine the hull of a boat. Over time, tiny sea animals called barnacles can form groupings, or colonies, on the boat. As barnacles collect, they increase resistance and slow a boat's progress in the water. That is why barnacles are scraped off boats' hulls.

Form drag is all about shape. Certain shapes produce more drag than others. Sports cars have low, sleek shapes to minimize resistance. In contrast, delivery trucks aren't meant to go very fast, and so it doesn't matter that their boxy shapes produce a lot of drag. As our manufacturing abilities have improved and our understanding of form drag has become more sophisticated, we have made significant changes in the way we build cars and planes. Planes become more streamlined over time. The changes in shape have been made to minimize drag.

When you throw a baseball, it flies through the air, eventually slows down, curves toward Earth, and hits the ground. Why? Two forces are acting on it. Friction drag — or surface drag — acts on the ball, slowing its speed. Earth's gravity also acts on the ball, pulling it downward.

Wind Tunnels simulate the conditions of an aircraft in flight by forcing a high-speed stream of air to flow past a model of an aircraft or part of an aircraft. The forces of lift and drag are measured. A common way to take those measurements is to track the tension changes in the wires that suspend the models in the air. Wind tunnels were originally invented because the mathematical calculations required to predict the behavior of air on a wing were too complicated to calculate and recalculate every time a design changed. However, as computer models have improved, wind tunnels are used less frequently.

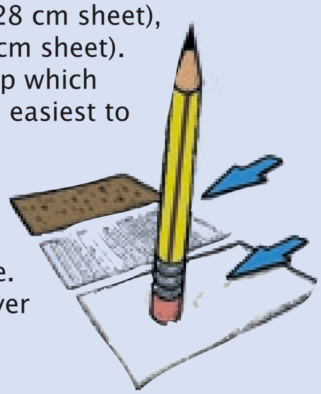
Activity

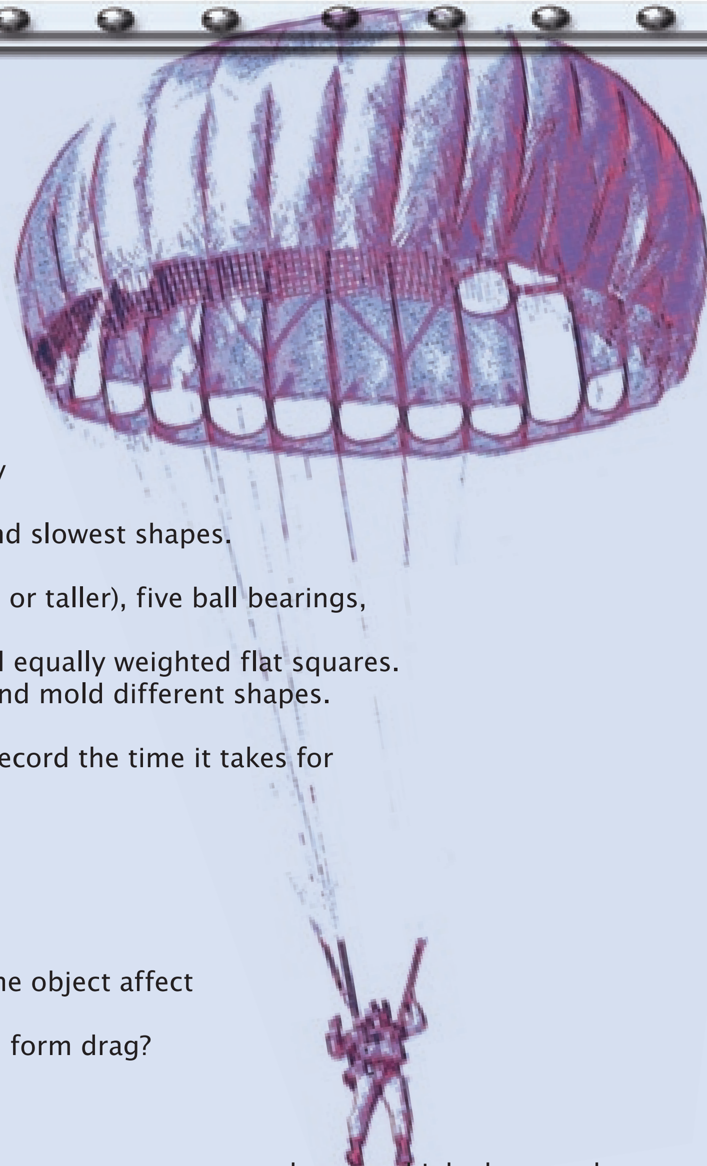
Friction is a Drag

This is the simplest and most intuitive of experiments, but it is important to understand the concept. While we may say, "Of course sandpaper has greater friction and slows the pencil," it's useful to link that understanding to the way that planes are built and to the adaptive evolution of creatures that fly or swim. The smooth surface of an airplane and the smooth skin of a shark both minimize friction drag.

- Supplies: One standard rubber pencil eraser, wax paper (one 21.5 cm by 28 cm sheet), ruled writing paper (one 21.5 cm by 28 cm sheet), sandpaper (one 21.5 cm by 28 cm sheet).

1. Ask each member of your group which paper surface they think will be easiest to run an eraser over. Record their answers.
2. Place the pieces of paper (wax, writing, and sandpaper) next to each other on a desk or table.
3. Gently slide the pencil eraser over each surface. Record your observations.





QUESTIONS:

- What were your results?
- On which type of paper did the eraser move most easily, and on which was it most difficult to move?
- How does this illustrate friction drag?
- How could you apply your findings to aircraft design?

GETTING YOUR BEARINGS

This is an experiment in which students develop different shapes to maximize and minimize drag. Encourage them to do both. This is a good opportunity to time and graph the results of the experiments. Groups of students can compete to build the fastest and slowest shapes.

- SUPPLIES: Tall glass vase or beaker (clear glass, 61 cm or taller), five ball bearings, colored clay.

1. Cut five pieces of colored clay into equally sized and equally weighted flat squares.
2. Place a ball bearing into the center of each square and mold different shapes.
3. Fill the container with water,
4. Drop the shapes into the water, one at a time, and record the time it takes for each shape to reach the bottom.

QUESTIONS:

- Which shape is fastest?
- Which is slowest?
- How does the shape of the object affect its speed?
- How does this illustrate form drag?

DESIGN CHALLENGE

The design challenge is meant to encourage students to think about and compare various man-made and natural shapes for their drag profiles. This challenge is a fun way to make sure that students both understand and can apply this learning. Airplanes are designed to minimize drag. Name four other objects that are designed to minimize drag.

QUESTIONS:

- What similarities do you see between these objects?
- What differences?
- Why do you think they are different?

Ludwig Prandtl (1875-1953) was a German engineer and professor of applied mechanics whose work formed the basis for the modern science of aerodynamics.

Forces of Flight: Thrust

The Basics

Thrust is the force of flight that opposes drag. The push or pull of an airplane's engines propels it forward, generating lift and the ability to fly.

Without thrust, airplanes are just gliders, which can fly only under certain conditions and are not practical for transportation. The Wright Brothers made the first successful powered flight in 1903 in an airplane with two "pusher" propellers. The advent of powered flight made human air travel possible.

There are four main types of systems for producing thrust in modern aircraft: propellers, jet turbine engines, ramjet engines, and rocket engines. Each produces thrust in a different way.

Developing a means of thrust was the final hurdle in getting aircraft off the ground. Thrust is the force that opposes drag caused by air resistance. Thrust can either pull or push an airplane; either way, it gives an airplane forward motion. During takeoff, thrust must be greater than drag (and lift must be greater than weight) so that the airplane can become airborne. For landing, thrust must be less than drag (and lift must be less than weight).

Balancing power and efficiency -- the two biggest factors that affected the Wright brothers' success -- is still the main consideration in designing modern engines today.

Conventional airplanes today use jet engines or propellers to generate thrust. Surprisingly, the engine that powered the Wright brothers' first flight at Kitty Hawk was very similar to the propeller engines that are used today. However, the Wright brothers' plane used a rear-mounted propeller system, which pushed the plane; most propeller airplanes today use a front-mounted propeller, which pulls the plane. The engine of the Wright brothers' plane was not very powerful, and to minimize weight, the plane did not carry much fuel.

Propeller

Propellers are actually airfoils. When they spin, propellers create forward or reverse thrust, depending on which way the blades are angled. A common household fan is an example of a mini propeller. As the speed of the fan increases, it blows more air at an increased rate. The same is true with a propeller.

Jet Turbine Engine

Jet turbine engines, like those on the C-17 Globemaster III, push air through the blades of a spinning turbine, which speeds up the air, compressing it and forcing it out the rear of the engine. The faster moving, higher pressure air coming out of the jet engine pushes the airplane forward.

Ramjet Engine

The ramjet is a variation on the jet turbine engine in which the engine has no moving parts. Because a ramjet has no moving parts, it is much lighter than a jet turbine engine, which makes it ideal for supersonic and hypersonic flight. However, ramjets cannot start flight, and another source of thrust, such as a booster rocket, must get the aircraft moving fast enough so the ramjet can work.

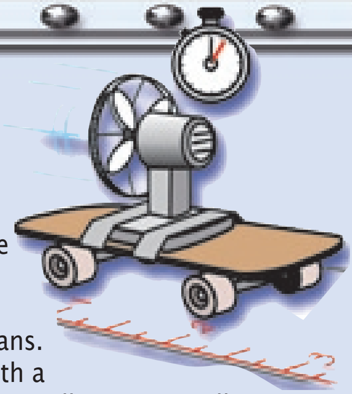
Rocket Engine

The rocket engine is different from the other three engines in that it does not require the presence of outside air to operate. Rockets burn liquid or solid fuels to create thrust, pushing hot exhaust out a nozzle at the back of the engine. Rockets can operate in space, where there is no air.

Wilbur Wright, 1867-1912 & Orville Wright, 1871-1948, American bicycle mechanics and self-taught engineers who made the first successful powered, manned flight. Dr. Hans von Ohain (1911-1998) from Germany, and Sir Frank Whittle (1907-1996) from England, co-inventors of the jet engine, although neither knew of the other's work. Whittle registered his patent for the turbojet engine in 1930, and Ohain was granted a patent for his in 1936. However, Ohain's jet flew first, in 1939. Whittle flew his jet two years later, in 1941.

ACTIVITIES

PROPELLER POWER



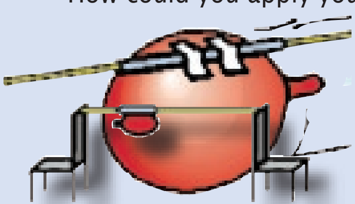
This is often limited to recreating the pusher-style propeller used by the Wright brothers, rather than the pull-type propeller of most fans. However, if you have a fan with a reverse mode, you can create a pull-type propeller.

- SUPPLIES: One skateboard, one powerful household fan, duct tape, one extension cord (at least 2.7 meters in length).

1. Securely tape the fan on the back of a skateboard.
2. Plug the fan into the extension cord.
3. Place the skateboard on a hard, even surface like a linoleum or wood floor.
4. Plug in the extension cord and turn the fan on low.
5. Record how long it takes the skateboard to cover a certain distance.
6. Repeat on medium and high settings over the same distance. Record your results.

QUESTIONS:

- What were your results?
- What keeps the skateboard from flying away?
- How is this similar to the way a propeller engine works?
- How could you apply your findings to airplane design?



JET POWER

This activity simulates part of how a jet works, forcing air out a small opening to generate thrust. Obviously, there is no turbofan, but it makes the point about the power of a jet. Optional: Have students experiment with different types of balloons.

- SUPPLIES: 5 to 6 meters of string (slender enough to slide easily through a straw), one drinking straw, one balloon, tape.

1. Slide the string through the straw.
2. Attach the string to two chairs placed as far apart as possible (make sure the string is tight so that the straw slides easily over the string).
3. Inflate a standard party-sized balloon and hold the opening shut with your fingers while another person tapes the side of the balloon securely to the straw.
4. Release the balloon.

QUESTIONS:

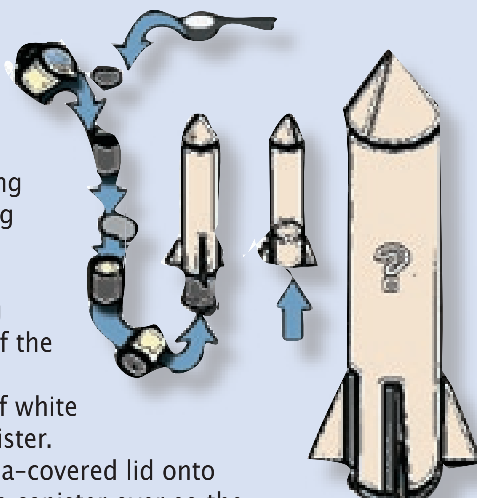
- What were your results?
- How is this similar to the way a jet engine works?

ROCKET POWER

Note: This project is messy! Be sure to put plastic or newspaper on the test area to soak up the vinegar and baking soda mixture, and have towels handy to clean up afterwards.

- SUPPLIES: Baking soda, white vinegar, one clear plastic film canister, (a Fuji film canister works best) one cardboard tube made into a rocket shape (see illustration).

1. Place the rocket-shaped cardboard tube tightly over the film canister (Tip: Make sure to get the cap on very quickly and you have a snug fit!). Do three dry runs to make sure that you can do this very quickly. Try increasing the amount of baking soda and vinegar.
2. Put two to three teaspoons of baking soda inside the lid of the film container.
3. Pour several drops of white vinegar into the canister.
4. Place the baking soda-covered lid onto the canister, turn the canister over so the cap is on the bottom, quickly slide the canister under the rocket.
5. Step back and record what happens. Have students to measure, graph, and compare results of several trials.

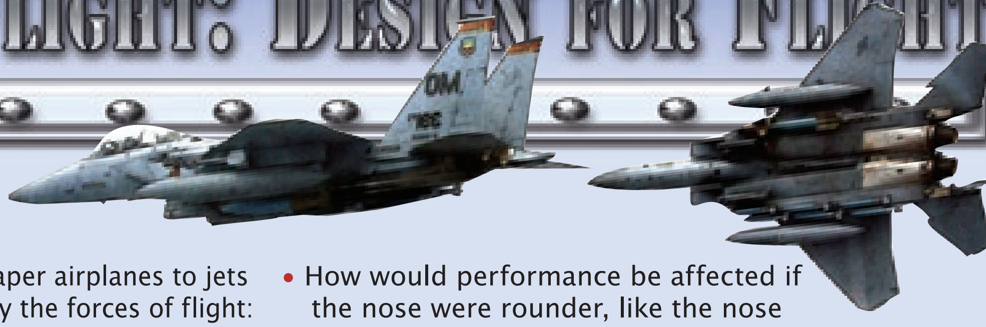


QUESTIONS:

- What happens then?
- How is this similar to the way a rocket engine works?

ROBERT HUTCHINGS GODDARD (1882–1945) an American physicist, considered the father of the rocket age, spent his life demonstrating the fundamental principles of rocket propulsion. He envisioned the exploration of space and, in a report published in 1920, he outlined the possibility of a rocket reaching the Moon, a proposal that drew ridicule when the press publicized the report. In 1926, he launched the first rocket powered by liquid fuel.

Forces of Flight: Design for Flight



Overview

Everything that flies, from birds to paper airplanes to jets to spacecraft, is pushed and pulled by the forces of flight: gravity, lift, drag, and thrust. An aircraft must harness these forces to fly effectively. That's the challenge faced by aircraft designers.

Today's aircraft share some common parts that help to keep them in the air and allow the pilot to control flight. Designers vary the design of these parts to improve performance. They may lengthen the wings, change the shape of the fuselage (body), or use different sources of thrust, depending on whether their goal is to fly faster, fly farther, or carry more weight.

Using what you have learned about the four forces of flight, you can begin to think about aircraft design and draw some scientific conclusion of your own.

Questions to ask about the design of flight:

Commercial Aircraft

- What features allow large airplanes to move heavy payloads over long distances?
  They have big wings for greater lift and big engines to produce lots of thrust.
- What would happen if the wings were shorter?
  There would be less lift, so the airplane would have trouble flying or would be unable to carry as many passengers or as much cargo.
- What would happen if the wings were longer?
  The airplane would fly more slowly because drag would be increased.
- What enables such a large airplane to stay aloft?
  The engines are powerful enough to move the plane forward at the speed necessary to produce lift, and the size and shape of the wings provide lift to keep it aloft.

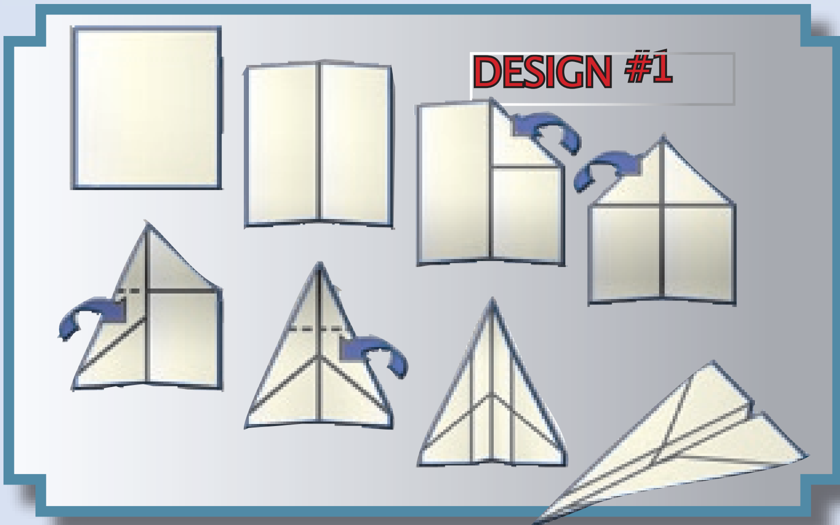
Military Jets

- What design features enable the F-15 Eagle to fly fast and turn quickly?
  It has high-thrust engines with afterburners for speed, thin swept wings to minimize drag, and twin vertical stabilizers for extra control.
- How would performance be affected if the nose were rounder, like the nose of a commercial airplane?
  It would affect the aerodynamics with increased drag, causing the jet to fly more slowly.
- How would performance be affected if the wings were longer?
  High aspect-ratio wings, or longer wings, would create more drag and force the plane to fly more slowly and turn less quickly. This works on other types of aircraft , but not on fighters.
- Why does this jet have two vertical stabilizers?
  They provide additional control and help prevent the aircraft from entering into a spin when performing combat maneuvers.

Rockets

An expendable rocket like the Delta IV is designed to deliver a satellite or scientific spacecraft into orbit. It must cover long distances and reach a target location accurately, but this type of spacecraft does not return to Earth.

- What design features are suited to an expendable rocket, which is designed to cover long distances, reach a target location accurately, but not return to Earth?
  The rocket is mostly engine providing lots of thrust to deliver its payload into space.
- Why doesn't a rocket have wings?
  At such high speeds, wings would provide too much drag, and without air in space, a wing cannot provide lift there.
- In what way is an expendable vehicle more useful for this mission than one that returns to Earth?
  It's easier to design and operate because there is no concern about landing; the only concerns are launching and target accuracy.



ACTIVITY

PAPER AIRPLANE CONTEST

This experiment is meant to encourage students to synthesize what they have learned. As the students choose designs, it may be helpful to remind them of the four forces – gravity, lift, drag, and thrust – and ask questions such as, "How do you think this design will be affected by drag?" Ask students what it means when the nose turns up (too much lift), or when the plane flutters out of control (too much drag). Help students to achieve greater distance by their paper airplanes by adding weight to some of the designs.

- SUPPLIES: Two pieces of paper (preferably heavy construction paper), two pieces of tape (up to 5 cm each), two paper clips, measuring tape (15 meters or more), a stopwatch, a large open room to fly the airplanes (such as a gymnasium or cafeteria).

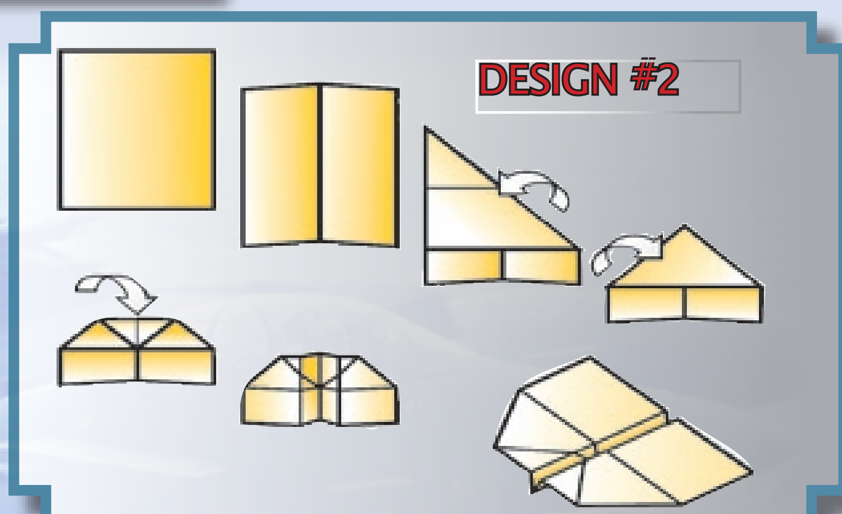
1. Break the class into groups of three to five students, asking each group to design two types of airplanes: one that is designed to fly the greater distance and another that is designed to fly for the longer time.

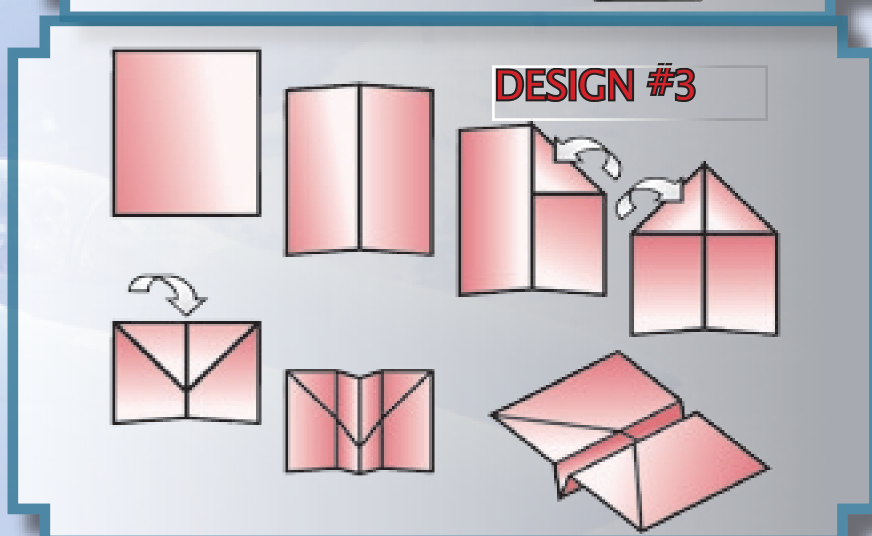
2. Fine-tune the flight performance of your paper airplanes by using the tape strips and paper clips (for example, weigh down the front of your plane with a paper clip to reduce lift).

3. Have each group come up with reasons why the designs they have chosen should work best.

4. Hold a fly-off in which each group competes against another group.

5. The winner advances to fly again. If you have an odd number of groups at any time, you can have the groups draw for a bye in a round.





Building Character

In the Film:

In Fighter Pilot: Operation Red Flag, Capt. Stratton needs to rely on a whole team of people to do their jobs in order for him to do his safely. He counts on them to be individuals of character – those who do their jobs responsibly and with integrity and courage.

Definition:

Char•ac•ter (kar'ik ter), n. the combination of qualities or features that distinguishes one person, group, or things from another. Moral or ethical strength.

Vocabulary

Have students define the following words and describe a situation from their lives that requires them to practice each character trait. Initiate a discussion about the traits and situations that require moral strength.

- Honor
- Integrity
- Courage
- Valor
- Empathy
- Trustworthiness
- Reliability
- Strength
- Self-discipline
- Justice
- Responsibility
- Citizenship
- Bravery
- Respect
- Goals
- Hero
- Fortitude

Written Exercises:

1. Have students keep a Character Building Journal, noting situations in their lives where they have had to make a moral choice.
   a. What was the situation and how did I respond?
   b. Did I respond in a way that was helpful or harmful to my character?
   c. What questions did I ask myself when making my decision?
   d. Would I respond differently if given the chance?

2. Discuss the following moral dilemmas as a class.
   a. It's Billy's mother's birthday on Tuesday and he wants to buy her a present. He's feeling bad because he hasn't saved enough money for the gift he wants to give her. On the way to the mall, he finds a wallet with $20 in it, more than enough money to buy the present. Along with the money in the wallet, he finds an identification card with the name and address of the owner. No one has seen him find the wallet, and no one knows how much money he's saved to buy the present. What should Billy do?
   b. Amy, Melissa and two other friends are going to the amusement park. Anyone under 13 years old gets in for half-price. Although all of the girls are 14, Amy and Melissa are often mistaken for being younger. Since the park won't ask for identification, the other two girls think it's "stupid" for them not to lie and save money. What should Amy and Melissa do?
   c. Stephen and Caitlin are students in their 7th grade social studies class. While taking a test, Caitlin realizes Stephen is copying the answers from her paper. Stephen is a friend of Caitlin's brother, and she knows that last night while she was home studying for the test, the two boys were at the skateboard park. What should Caitlin do?
   d. After James leaves the grocery store he realizes that the cashier gave him too much change in return for his purchase. It's a big store that certainly won't miss the extra five dollars he was given. What should James do?

3. Captain Stratton admires his grandfather and aspires to follow in his footsteps. Interview a grandparent, relative or adult friend you admire, and make a report to your class.

Interview Questions:

- Where and when were you born?
- Where have you lived?
- What is your occupation?
- What games did you play as a young person?
- Did you serve in the armed forces? If so, in what capacity, and what stands out in your memory about the experience?
- How is the world different now from when you were growing up?
- What have you learned that you would most like to pass on to future generations?
- Who is your hero?

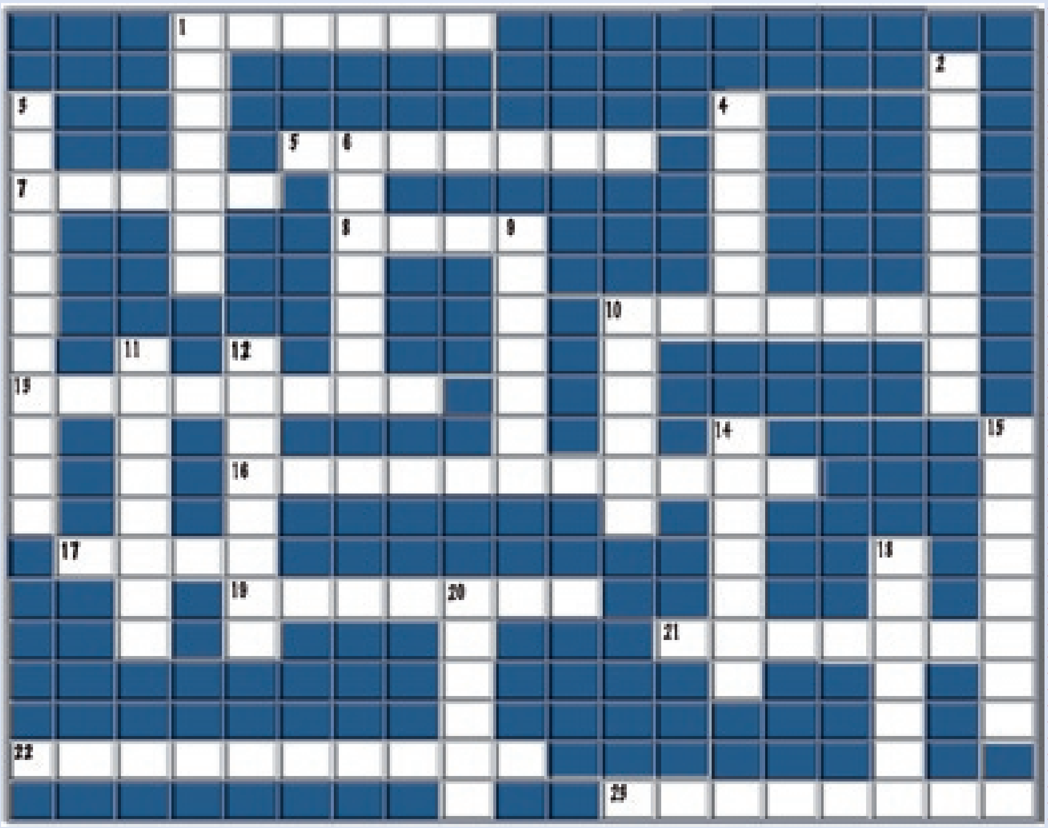
WHO AM I?

a. Cut out words or pictures from magazines or newspapers that describe your outward appearance and the things you enjoy, such as favorite foods, interests, activities, pets, etc.
b. Paste these on the outside of a brown paper bag.
c. Next cut out words or pictures that describe attributes or interests that others would not necessarily know about you, for example: kind, shy, good judgment, honest, fearful, brave, where you were born, future dreams, etc.
d. Put these words or pictures inside the bag.
e. Exchange your bag with another classmate. Describe your classmate to the class based on what you find on the inside and outside of the bag.
f. Write what you have in common with the person with whom you exchanged bag, and what you learned from them.
g. Discuss as a class how getting to know things about each other will help you to work better as classmates.

CHARACTER CROSSWORD

ACROSS:

1 Group of vehicles traveling together usually for protection
5 Courage, valor
7 System for determining the presence of an object
8 Force that resists the motion of the aircraft
10 Where the pilot sits
13 A plan of action
16 Having a shape that allows for lift and smooth airflow
17 The upward force that counteracts gravity
19 Person who holds a position of rank
21 Plane featured pilot's grandfather flew in WW II
22 Pilot's support staff on land (2 words)
23 Invisible radiation wavelengths, just longer than red in the visible spectrum



DOWN:

1 Bravery
2 Traits that form the individual person
3 Force exerted by air (2 words)
4 Daring, noble
6 Name of training exercise profiled in the film FIGHTER PILOT (2 words)
9 Force of attraction between two objects
10 Fighting between groups
11 Preparing
12 Pilot profiled in FIGHTER PILOT film
14 Task or project
15 A group of aircraft and the support team
18 Climate
20 A curved surface, like on an airfoil

For classroom use, please download from www.fighterpilotfilm.com

Answers:

Across:
- *1 Convoy*
- *5 Bravery*
- *7 Radar*
- *8 Drag*
- *10 Cockpit*
- *13 Strategy*
- *16 Aerodynamic*
- *17 Lift*
- *19 Officer*
- *21 Corsair*
- *22 Ground crew*
- *23 Infrared*

Down:
- *1 Courage*
- *2 Character*
- *3 Air pressure*
- *4 Heroic*
- *6 Red Flag*
- *9 Gravity*
- *10 Combat*
- *11 Training*
- *12 Stratton*
- *14 Mission*
- *15 Squadron*
- *18 Weather*
- *20 Camber*

It Takes Teamwork

In the Film:

During the Red Flag exercises, one of the most valuable concepts Captain Stratton learns is the importance of teamwork. He comes to realize a mission cannot be successful without many people carrying out their responsibilities.

Teamwork Building Exercise

Refueling a jet while in flight requires teamwork and precision execution by each team member. To fully understand this challenging process, it helps to understand how aerial refueling works. When jets refuel in flight, the tanker plane reels out a hose that ends in a drogue: a funnel-like basket that guides the fuel and connects the two planes. The hose and drogue trail behind the tanker as it flies. After making visual contact, the pilot approaches the tanker, matches his speed to the tanker, and locks onto the drogue. Special lights on the tanker signal the pilots and make the docking procedure easier. You won't see commercial airlines refueling in flight, however. Only the military and other government agency planes use this procedure.

Activity

It's cool to refuel

This lesson demonstrates the difficulties encountered by jets trying to refuel in mid-air. Students will work together to practice some refueling of their own.

Begin the exercise by discussing the challenges met by jets that try to refuel in flight. (Reference refueling sequence in the film, if students have seen Fighter Pilot.)

Go over the instructions to make sure the students fully understand the activity.

Place the students into groups of four. Make the materials available so that each group can assemble the "refueling apparatus."

- Supplies: Large plastic cups, hole punch, marbles, fan.

Each team will need a large plastic cup, punched as follows: Using the hand-held hole punch, punch two holes near the rim and directly across from one another. Centered between these two holes, press the bottom and side of the cup together, and punch a hole through both. (This should create two holes, one near the bottom on the side and the other on the side near the bottom.) Each team will also need three, two-meter lengths of string or yarn, three small plastic cups and 18 marbles.

Students will:

1. Tie one end of a piece of string to each of the holes near the rim of the plastic cup. Tie one end of the third piece of string to the bottom of the cup by threading it through the two holes at the bottom of the cup. This is the "refueling apparatus."
2. The two students on the team holding the loose ends of the two strings tied to the holes at the top of the cup are the drivers who will steer the "refueling apparatus". These two group members will be responsible for guiding the "refueling apparatus."
3. A third group member will be the refueler. This team member will hold the loose end of the string that is tied to the bottom of the cup. The refueler will use this string to lift the bottom of the cup and dispense the marbles into the waiting cups.
4. The fourth group member will be the recorder. This person will place the three cups that need refueling, randomly in the area of the group. They will also check to see that each cup gets the required amount of marbles. Notes can be taken in the student's science journal.
5. The team members working with the refueling apparatus should then maneuver and work together to dispense five marbles into each of the three cups. The recorder should record the results and write down suggestions on how to improve the groups refueling technique.
6. These positions are not permanent. After each run, the group should switch positions so that each group member is able to try each job.

Optional

1. Place fans in the area where the students are completing the activity. Explain that this represents the turbulent air created in the wake of the refueling plane.
2. Try longer or shorter strings.
3. Have students design a better "refueling apparatus."

DISCUSSION TOPICS AND QUESTIONS:

- Defining goals: Write a clear and concise definition of the team's mission and strategy.
- Communication and roles: Does each member clearly understand the mission?
- Preparation: What do we need to learn and practice to accomplish our goals?
- Keeping the "big picture" in focus and anticipating obstacles: What might deter us from our goals and how will we deal with them?
- How do my individual decisions/choices impact the rest of the team?
- Learn to value and respect each member's contribution to the team: *Can our goals be successfully accomplished without any member of the team?*
- Discuss the challenges met by airplanes that try to refuel in flight.
- Talk about some of the difficulties the groups had and how they might be similar to problems experienced by real refueling jets.

An IMAX® Experience

FIGHTER PILOT: OPERATION RED FLAG

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