Fun-damentals of Flight

STEM Activities with the Hess Cargo Plane and Jet

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Baylor College of Medicine

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// Contents

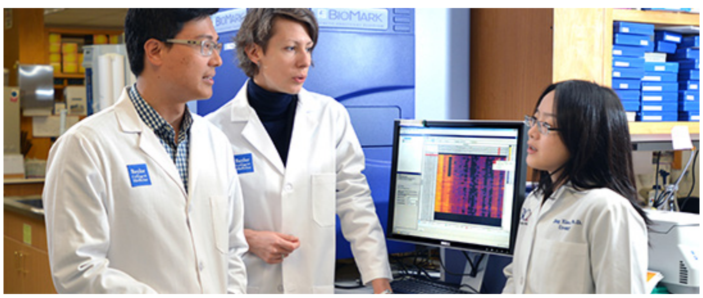
ORDER OF ACTIVITIES AND HESS TOY AVAILABILITY

- The order of the activities may be changed if it is determined that it will create a more logical progression.
- The 2021 Hess Cargo Plane and Jet is available at www.hesstoytruck.com while supplies last.

// Baylor College of Medicine

Baylor College of Medicine (Baylor) is a health sciences university that creates knowledge and applies science and discoveries to further education, healthcare and community service locally and globally. In addition to its School of Medicine, Baylor includes a Graduate School of Biomedical Sciences, School of Health Professions, and National School of Tropical Medicine.

Located in the heart of the Texas Medical Center, the world's largest health sciences complex, Baylor is surrounded by other leading healthcare and research institutions. This concentration of expertise has helped support the development of collaborations that advance every aspect of the College's mission.



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With eight affiliated teaching hospitals and partnerships with major institutions, such as the University of Houston, Rice University and NASA, Baylor has a diversity of resources unparalleled at other academic health centers. The College also partners with community leaders to serve Houston, Texas, and the world through outreach initiatives, innovative healthcare delivery models and research focused on specific community needs. Its educational outreach programs reach students at all levels, from elementary school through college, creating a pipeline of learners interested in science and medicine.

Baylor is ranked by the National Institutes of Health at #1 in Texas and #20 in the nation among all medical schools based on NIH funding. Twelve departments rank in the top 30, including a ranking of #1 in genetics. US News & World Report Best Medical Schools ranks Baylor #22 in the nation among research intensive schools and #17 in primary care. Baylor is the highest ranked medical school in Texas based on USNWR. Baylor is also ranked in all eight program specialty categories by USNWR.

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The Center for Educational Outreach at Baylor College of Medicine provides a wide range of educational programs and resources that help prepare and encourage students to pursue careers in medicine and the health sciences. Offerings include teacher professional development and curricular materials that improve the STEM content knowledge and skills of K–12 students. Educators can earn continuing education credits via the Center's face-to-face workshops or online courses, some of which are tailored to meet the needs and requirements of individual schools or school districts.

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Teacher resources BioEd Online℠ and SuperSTAAR℠ are dynamic STEM teacher websites that provide coursework, streaming video presentations, teaching slide sets, inquiry-based classroom activities and complete teaching modules for grades Pre-K to 12. BioEd Online materials feature an integrated, hands-on approach to teaching STEM. Each inquiry-based unit is aligned with national and state science education standards.

// Hess Corporation

Hess Corporation is a leading global independent energy company engaged in the exploration and production of crude oil and natural gas. We are committed to being a trusted energy partner by maintaining the highest corporate citizenship standards while helping meet the world's energy needs in a safe, environmentally responsible, and socially sensitive way. Social Responsibility (SR), one of the six Hess Values, is foundational to the culture of our company and to our engagement with our communities. It includes protecting the health and safety of our workforce, safeguarding the environment and creating a long-lasting positive impact on the communities where we operate. In 2020, our social investments totaled nearly $11 million, with $2.7 million going toward education projects. We are also proud to have consistently been recognized as a leader in the oil and gas industry for our sustainability performance and commitment to diversity, equity and inclusion in our workplace. Hess has been recognized as one of the 100 Best Corporate Citizens by 3BL for 13 consecutive years, along with 11 consecutive years as a member of the Dow Jones Sustainability Index North America. In addition, Hess has been recognized as one of America's Most Responsible Companies by Newsweek Magazine and ranked a Top 50 Employer by STEM Workforce Diversity Magazine (13 consecutive years), Equal Opportunity Magazine (3 consecutive years), Minority Engineer Magazine (4 consecutive years), Women Engineer Magazine (9 consecutive years) and Careers & the disABLED Magazine (11 consecutive years).

The Hess Toy Truck Story

The Hess company was founded in 1933 when Leon Hess bought a second-hand truck and started a business delivering fuel oil to homes in New Jersey. By the time Mr. Hess passed away in 1999, at the age of 85, Hess Corporation had grown into one of the world's largest energy companies including oil exploration, production, storage and more than 1,300 gas stations along the east coast. Not long after opening the first Hess branded gas station in 1960, Leon Hess decided to offer families a fun, high quality and affordable toy for the holidays as a goodwill gesture to customers. With that decision, he created a toy for kids of all ages, the Hess Toy Truck, which has become a hallmark of the holiday season, with a new model released each year. Leon Hess wanted a toy truck made with outstanding craftsmanship and innovative use of electronics. He wanted to offer it at a price families could afford, and with batteries included. A concept that endures to this day 58 years later. The Hess Toy Truck remains a beloved holiday tradition and among the largest selling toys in the country every year, now offered exclusively at www.hesstoytruck.com.

How It's Made

It takes a long time (and a lot of STEM) to create a Hess Toy Truck. The process of developing each new toy starts two to three years before the truck goes on sale. Some trucks have taken as long as six years to go from concept to market. Initial drawings and feature concepts are reviewed, and the toys begin to evolve. The top two or three designs go to the next round, where they are transformed from drawings to handmade models. The models are evaluated for safety, functionality, playability, durability and value. Eventually, the new Hess Toy Truck is chosen. A Hess Toy Truck is generally comprised of up to 300 small, hard plastic pieces. A tooling, or mold, for each piece must be cut to precise measurements. Once the toolings are made and tested, the pieces are produced and meticulously assembled. Then, as anyone who has unpacked a Hess Toy Truck knows, the final toy is placed —very carefully—into the toy box.

// The STEM of Airplane Flight

Airplane flight is full of science, technology, engineering and mathematics (STEM) teaching opportunities. The activities that follow are loaded with STEM concepts and skills. The science of the flight of an airplane involves four opposing forces: lift, weight, thrust and drag. Each force contributes to the motion that enables flight.

- **Lift** is the upward force that elevates an airplane off the ground and keeps it airborne. Lift works in opposition to weight and is dependent on shape, size and velocity of the aircraft, with most of the lift being generated by the wings.
- **Weight** refers to the pull of Earth's gravity on the total mass of an airplane and its load. Weight works in opposition to lift.
- **Thrust** is the forward push on an airplane produced by its engines. Thrust works in opposition to drag.
- **Drag** is the force of friction on the surface of an airplane that works against its forward motion. Drag works in opposition to thrust.

Engineers design the body, wings and tail of an airplane to make air flow around it. Thrust from the engines and lift, generated mostly from the design of the wings, get the airplane off the ground. The shape of the plane reduces the drag of friction with the air that impedes flight. Through technology, materials are created that produce strong but light air frames, rugged engines and the various instruments needed for flight control and navigation. All of these things are heavily dependent on mathematics. For example, an airplane will not get off the ground if its weight is greater than the lift generated by its motion.

THE IMPORTANCE OF INTEGRATING STEM

STEM is an acronym used to identify the academic subjects of science, technology, engineering and mathematics. By highlighting the inter-relatedness of these subjects, the STEM acronym encourages schools, districts and educators to integrate STEM content rather than teach each subject separately.

The STEM approach is important for workforce development and economic growth. Many careers are available in STEM-based fields, and forecasts indicate that in the future, there will be more STEM-based jobs than qualified workers to fill them.

BEFORE UNPACKING THE 2021 HESS CARGO PLANE AND JET

01 Unpack and set up each plane in a private area not visible to students.

02 Retain the boxes and packing material and place them in a location students cannot see.

03 The boxes and packing material will be needed in the last activity.

04 Refer to Activity 06 Thinking Inside the Box to learn why students should not have advance knowledge of how the planes were packed.

DOWNLOAD THE PREVIOUS HESS TOY STEM GUIDES

- STEM to the Rescue (2020)
  www.bioedonline.org/lessons-and-more/focus-on-stem/stem-to-the-rescue/
- Towing the Load with the Hess Tow Truck Rescue Team (2019)
  www.bioedonline.org/lessons-and-more/focus-on-stem/towing-the-load-with-the-hess-tow-truck-rescue-team/
- On the Road with Vehicle Performance (2018)
  www.bioedonline.org/lessons-and-more/focus-on-stem/on-the-road-with-vehicle-performance/
- Simple and Compound Machines (2017)
  www.bioedonline.org/lessons-and-more/focus-on-stem/simple-and-compound-machines/
- Force, Motion, Friction and Energy (2016)
  www.bioedonline.org/lessons-and-more/focus-on-stem/force-motion-friction-and-energy/

SHORT HESS STEM SPRINT VIDEOS

Demonstrations of the science and technology of Hess Toy Trucks from previous years are available at the following site.

- https://www.youtube.com/user/hesstoytruck

// Tools to Teach STEM

Hess Toy Trucks are much more than toys for children or collectors' items for adults. They are useful teaching tools that offer a variety of practical and fun ways to teach STEM subjects, such as force and motion and simple and complex machines. STEM is the acronym for science, technology, engineering and mathematics. It denotes an integrated approach for developing many products and processes we depend upon each day. It is also one of the fastest growing categories for jobs.

Activities in this guide use the 2021 Hess Cargo Plane and Jet to explore practical aviation transportation issues, such as designing and loading cargo, aeronautic design and maneuverability. The guide even explores the challenges of making and shipping the toy itself. The activities can be used sequentially as a unit or inserted into an existing curriculum. While designed for grades 3–8, they can easily be adapted for higher and lower grades. All activities support the Three Dimensions of Science Learning in the Next Generation Science Standards. Some activities include student pages that can be used for assessment or placed in science notebooks.

The Cargo Plane is an impressive, six-turbine engine, heavy-load transport aircraft. Colored in white with a green undercarriage, bold green striping, sparkling chrome nose cone and accents, the plane includes free-rolling, foldable landing gear and 32 high-visibility lights that provide an impressive glow. A quick press of the taillight will release the rear cargo bay doors to provide access to the Jet. A hidden slide out ramp makes loading and unloading the expansive, internally illuminated cargo bay a breeze. With a nearly 14-inch-long fuselage and 15-inch wingspan, the Cargo Plane is the largest Hess vehicle ever!

The accompanying Jet completes this formidable flying duo. Designed for speed and aerodynamic maneuverability, the sleek Jet roars to action with a combination of button and motion activity sounds! Three top-mounted buttons will flash the engine lights and activate realistic takeoff, flyby and landing sounds. Tilting the jet activates the Climb/Dive, Bank and Cruise motion sounds. The striking bold white and green colors are enhanced with finely detailed inlays and chrome nose cone and accents. The jet also has free rolling, folding landing gear and two sets of spring-loaded retractable wings which allow it to travel covertly inside its cargo plane partner or fly solo missions.

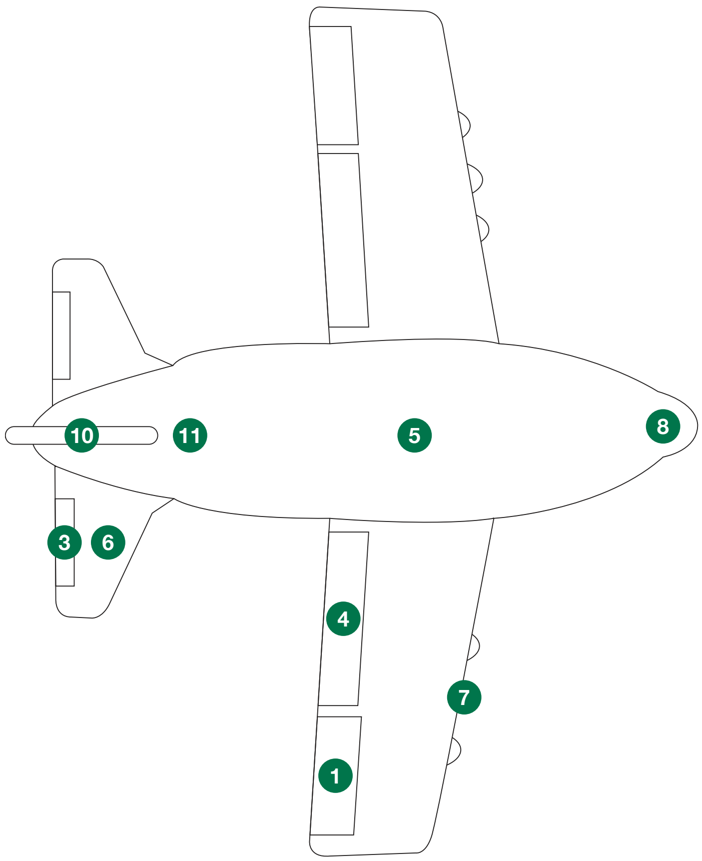
STEM Careers

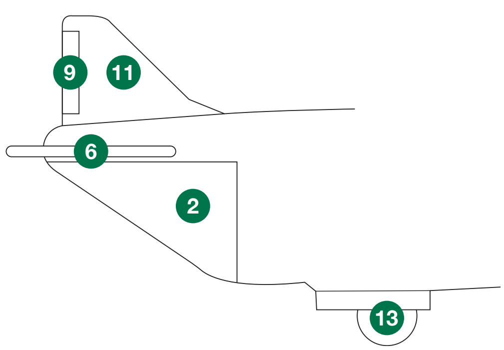
Skilled workers for STEM fields are always in demand, with job openings exceeding the number of prepared candidates. This guide provides powerful, stimulating STEM learning experiences that relate to many STEM fields, such as the Example Careers listed below. These careers require competency in science, technology, engineering and mathematics.

EXAMPLE CAREERS

- Airplane Pilot
- Automotive Technologist
- Biologist
- Chemist
- Civil Engineer
- Computer Scientist
- Electrical Engineer
- Environmental Scientist
- Geoscientist
- Graphic Designer
- Load Logistics Specialist
- Manufacturing Engineer
- Marketing Specialist
- Mechanical Engineer
- Medical Scientist
- Petrophysics Engineer
- Robotics Engineer
- Safety Engineer
- Software Developer
- Structural Engineer
- Technical Writer
- Toy Designer
- Transportation Engineer
- Website Developer

// Hess Cargo Plane: Parts and Specifications





Airplane Parts

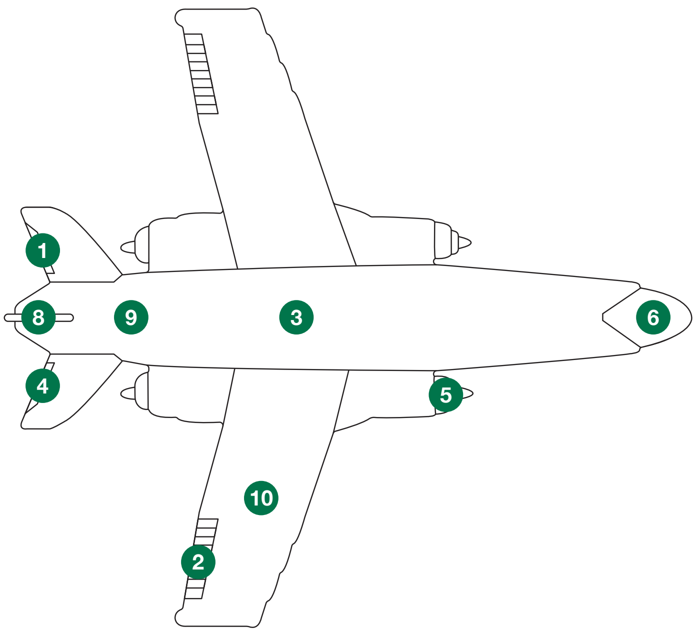
1. Aileron
2. Cargo doors
3. Elevator
4. Flaps
5. Fuselage
6. Horizontal stabilizer
7. Jet engines
8. Nose
9. Rudder
10. Tail
11. Vertical stabilizer
12. Wings
13. Wheels

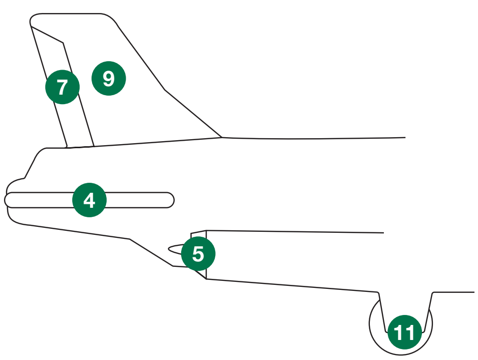
Specifications

Length: 13 ⅛" - Nose to tail
Width: 15" - Wingspan
Height: 5 ⅝" - Wheels to tail
Weight: 6.4 ounces (182 grams)

// With a nearly 14-inch-long fuselage and 15-inch wingspan, the Cargo Plane is the largest Hess vehicle ever!

// Hess Jet: Parts and Specifications





Airplane Parts

1. Elevator
2. Flaps
3. Fuselage
4. Horizontal stabilizer
5. Jet engines
6. Nose
7. Rudder
8. Tail
9. Vertical stabilizer
10. Wings
11. Wheels

Specifications

Length: 9 ½" - Nose to tail
Width: 7 ⅞" - Wingspan
Height: 2 ¾" - Wheels to tail
Weight: 6.4 ounces (182 grams)

// In a full-size version of the Hess Jet, the jet engines produce the thrust, propelling the jet forward.

01

Controlling Airplanes in Flight

Suggested Grades **3–8**

Suggested Grades **3–8**

// **01** Controlling Airplanes in Flight

The Question

How are airplanes controlled in flight?

Where's the STEM

Let's think about how a car works. Turn the key or push a button to start the engine and press on the gas pedal. The car engine releases energy by consuming fuel (gasoline, natural gas), which is transmitted to the wheels that begin turning. In electric vehicles, electricity from batteries power electric motors that drive the wheels. Friction of the tires with the ground produces a force that moves the car forward. Turning the steering wheel causes the front wheels to turn to the left or right, sending the car in a new direction. A car is a great example of how principles of science, technology, engineering and mathematics (STEM) all are involved in an everyday activity, such as transportation.

The Hess Cargo Plane and Jet have many things in common with a car. Like cars, they transport cargo and people. Planes have wheels or landing gear and a steering wheel, called a yoke or a stick (like a computer game joystick). Also, like cars, planes have engines that provide a force. However, there are important differences.

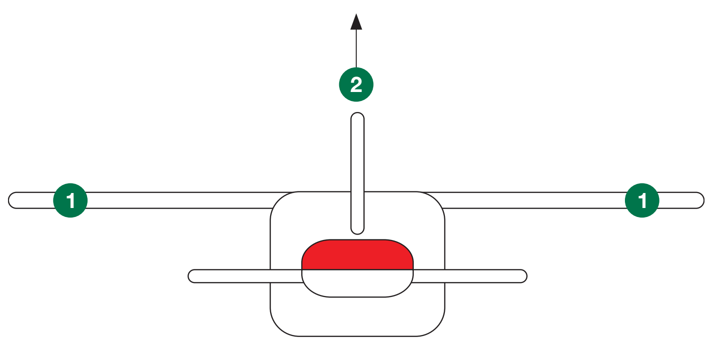
Thrust in planes is created by jet engines that take in air, combine with fuel, ignite the fuel and blow hot pressured air out the back to propel the planes forward. The engines are not connected to the wheels. When the planes take off, the jet engines push the plane forward and the wheels just spin as they roll across the runway reducing friction of the aircraft with the ground. Once in the air, the wheels can retract into the plane to reduce drag friction with the air. The wheels on both Hess planes retract.

The biggest difference between planes and cars or trucks, besides flying, is how the planes are controlled. **Moving the yoke or the stick causes planes to climb, descend, bank to the left, or bank to the right**. How do they accomplish this?

STEM principles are the answer. Airplanes have control surfaces—ailerons and flaps on the wings, elevators on the horizontal tail and a rudder on the vertical tail. When ailerons, flaps and elevators are tilted from their straight position, air passing around the airplane is deflected either up or down. This exerts an action force on the air, which produces an opposite but equal reaction force on the plane. This is Isaac Newton's Third Law of Motion at work. For every action, there is an opposite and equal reaction.

While all control surfaces may be operated simultaneously, let's look at them individually to see how they work.

The Hess Cargo Plane



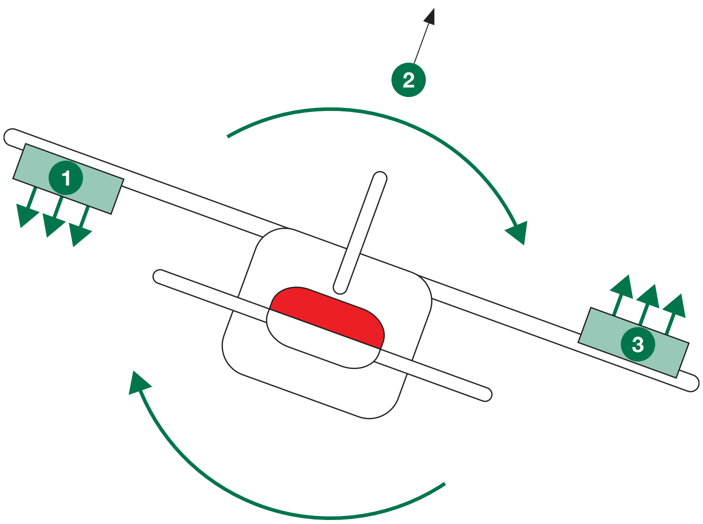
Rear view of the Hess Cargo Plane

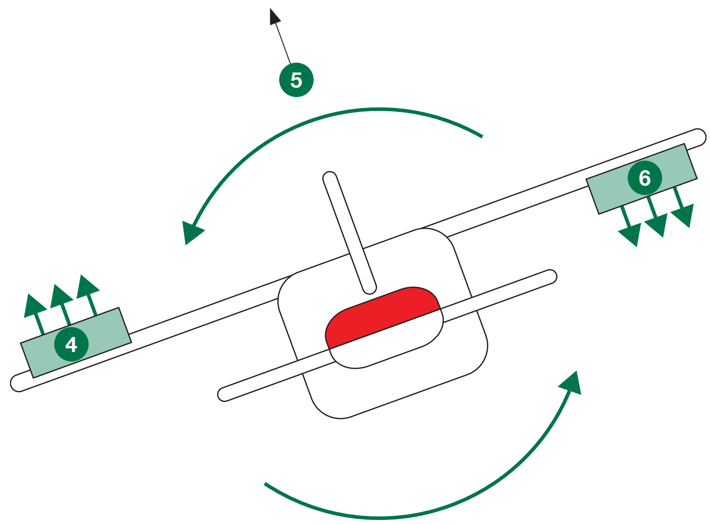
1. No control surfaces deployed. Plane flies straight and level.
2. Lift direction.

AILERONS

Ailerons are located near the wing tips. You can see embossments, small indentations, on the wing tips of the Hess Cargo Plane. They don't move on the toy, but this is where the ailerons are located on real planes.

When the pilot wants to turn to the right or left, one aileron goes up and the other one goes down. Air hits the up-tilted aileron surface and directs air upward creating an action force. In turn this produces a reaction force that pushes that wing down. At the same time, the other aileron directs air downward pushing that wing up. As a result, the plane turns.



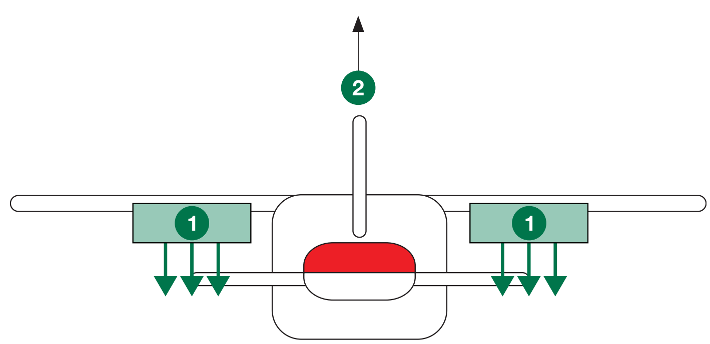


1. Left aileron down. Plane rolls and turns right.
2. Lift direction.
3. Right aileron up.

4. Left aileron up. Plane rolls and turns left.
5. Lift direction.
6. Right aileron down.

FLAPS

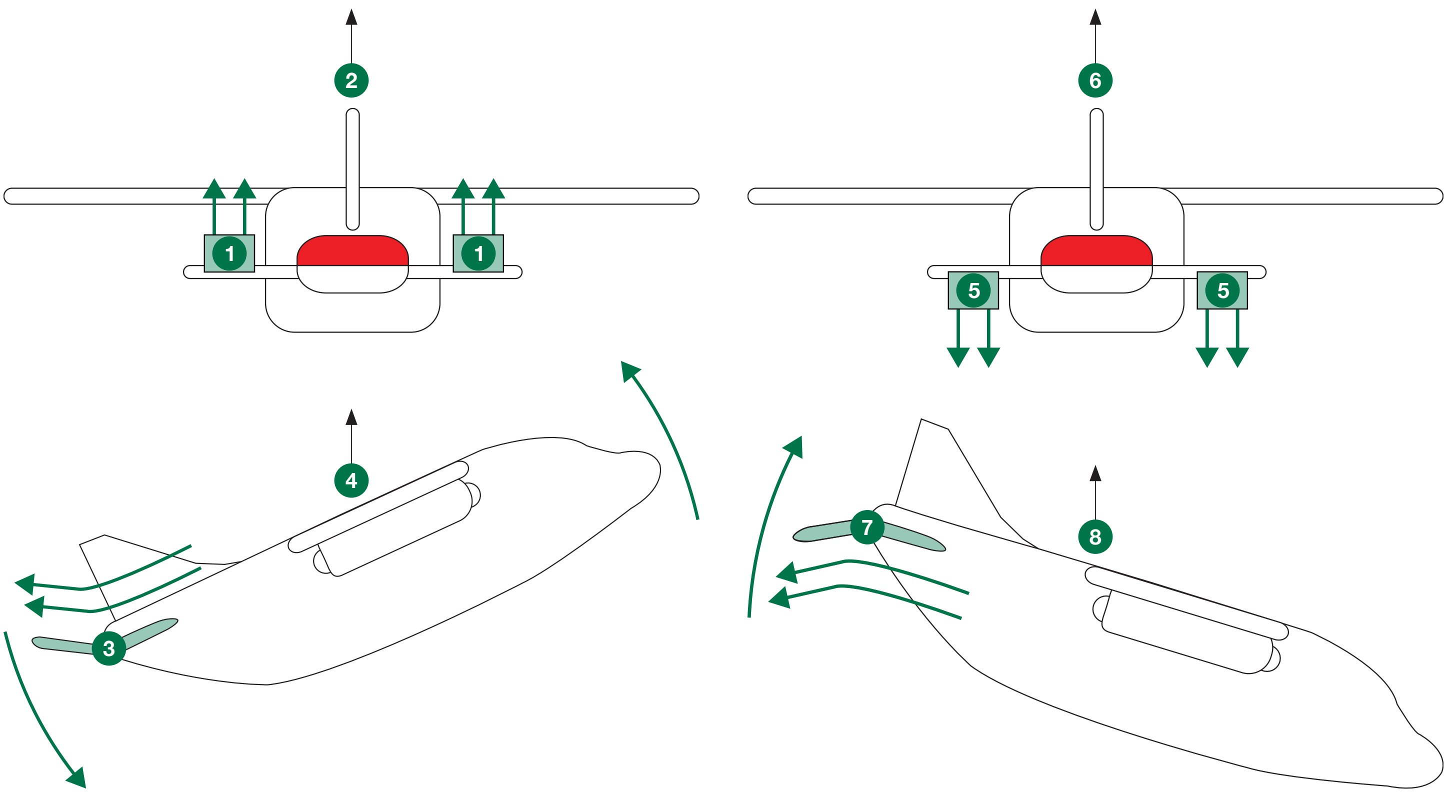
Flaps, located on the wings near the body or fuselage, work together to increase lift, keeping the plane airborne at lower speeds. The increased lift is useful for takeoffs and landings. Flaps only tilt or extend downward, forcing air down to produce an opposite upward reaction force to increase lift. Flaps are retracted during flight to reduce drag on the aircraft.



1. Both flaps down. Plane slows, but maintains lift.
2. Lift direction.

ELEVATORS

Elevators are located in the horizontal tail. They both tilt up or down together. When tilted up, the airflow over them is directed upward. This is an action force that produces an opposite and equal reaction force pushing the tail downward. With the airplane tail down, the nose of the plane points up causing the plane to climb. When the elevators tilt down, airflow is directed down. The reaction force pushes the tail up and the nose down. The plane descends.

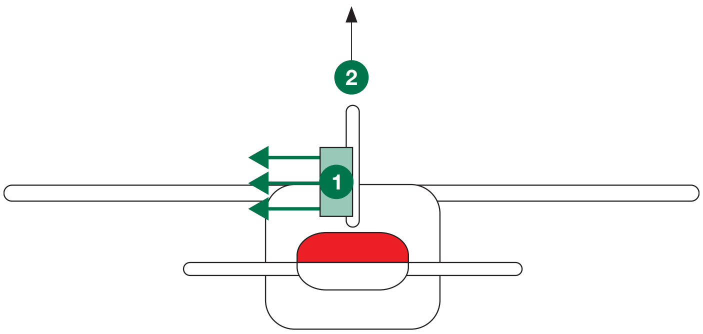


1. Both elevators up. Tails goes down and nose up.
2. Lift direction.
3. Side view of elevators. Plane climbs.
4. Lift direction.

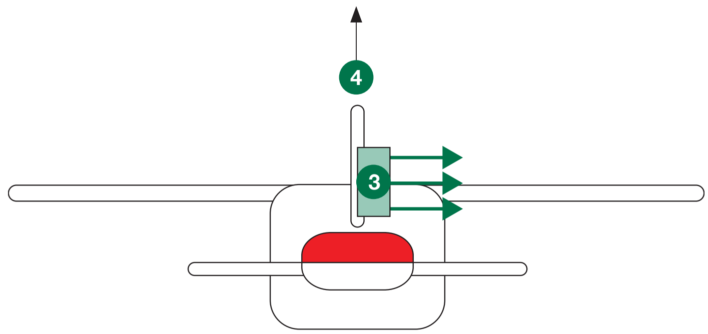
5. Both elevators down. Tails goes up and nose down.
6. Lift direction.
7. Side view of elevators. Plane descends as total lift is reduced.
8. Lift direction.

RUDDER

The rudder is located on the vertical stabilizer. It swings to the left or right. In flight, small adjustments of the rudder are used to control sidewards slip of the airplane's tail in crosswinds. In some small planes, the rudder assists with steering the plane on the ground during takeoff, landing and taxiing.



1. Rudder deflects air to the left and plane yaws to the left.
2. Lift direction.



3. Rudder deflects air to the right and plane yaws to the right.
4. Lift direction.

> When ailerons, flaps and elevators are tilted from their straight position, this exerts an action force on the air, which produces an opposite but equal reaction force on the plane.

In this activity, **students will investigate flight controls by constructing paper airplanes** and adjusting their flight paths with ailerons and elevators.

Materials

PER INVESTIGATION TEAM

- Hess Cargo Plane and Jet for each team of students
- Letter size sheets of normal weight or construction paper, at least one sheet per student to begin. (If available, use uncrumpled sheets of paper from the recycle bin.)
- Paper airplane instruction sheet
- Eye protection for flight tests

FOR THE CLASS

- Clear tape
- Scissors

Management Tips

- Have students conduct this activity in teams of 2–4 individuals.
- Small pieces of colored tape or dots placed on the Hess Cargo Plane can help students learn which control surface is which.
- Place the tape and scissors in a central location for students to use. Also, build and display a completed paper airplane for them to compare.
- Have students write their names on the planes they construct so that they may identify their own planes when the flight tests begin.
- Instruct students to wear eye protection when conducting flight tests.

Procedure

01 Start by having student teams examine the wings and tail of the Hess Cargo Plane. Point out the indentations on the wings for the ailerons, flaps and elevators. Ask, *what are these for*? Tell students that the real ailerons are for turning the plane. The flaps provide extra lift at low speeds. The elevators make the plane ascend (climb) or descend (move downward).

02 Next, have students examine the Hess Jet to compare the control surfaces with those on the Hess Cargo Plane. Students may notice that the wings on the jet are shaped differently and they do not have flaps.

03 Tell students they will learn how these control devices work by making paper airplanes. Distribute the instruction sheet and paper for folding.

04 Demonstrate how to make the airplane, tape its wings and make the four small cuts in the rear of the wings. Place the plane in a central location for examination by students. Make tape and scissors available in the central location.

05 Avoid having students fly their paper planes in your classroom due to the risk of hitting someone in the face. Pick an open area, such as a hallway or activity room for test-flights. Have students wear eye protection for the flight tests.

06 When all students have completed their planes, go to the flight test area and have students test their planes to see how well they fly. **A good flight is one that travels a long distance and follows a straight path**.

07 After students have executed a couple of flights, have them investigate how the small flaps they've cut into the wings affect the flight. Bend the flaps up or down depending upon the test:

- Both flaps bent upward
- Both flaps bent downward
- Right flap up and left flap down
- Left flap up and right flap down

Important: When both flaps are tilted up or are tilted down, they represent elevators. When one flap is up and the other is down, they represent ailerons.

Wrap It Up

Discuss the flight results. *What happened to the flight when both flaps were bent up? Bent down? Right up and left down? Left up and right down?* [With both flaps up, the plane will climb steeply. With both flaps down, the plane will dive. With one flap up and the other down, the plane will spiral.]

Ask students why the planes behaved the way they did in the various trials. Relate the movement to Isaac Newton's Third Law of Motion. (Air deflected in one direction by the control surfaces is accompanied by a movement of the plane in the opposite direction.)

Return to the Hess Cargo Plane. Review the locations of the ailerons and elevators. Students should now be more knowledgable about how these devices work to control the airplane. Ask students to speculate on what the flaps on the front wings do.

The tests in this activity only explore the roles of the ailerons and elevators. Flaps on the Hess Cargo Plane are located next to the fuselage on the trailing edges of the large wings. They provide extra lift.

> // The biggest difference between planes and cars or trucks, besides flying, is how the planes are controlled.

// Designing and Building an Airplane

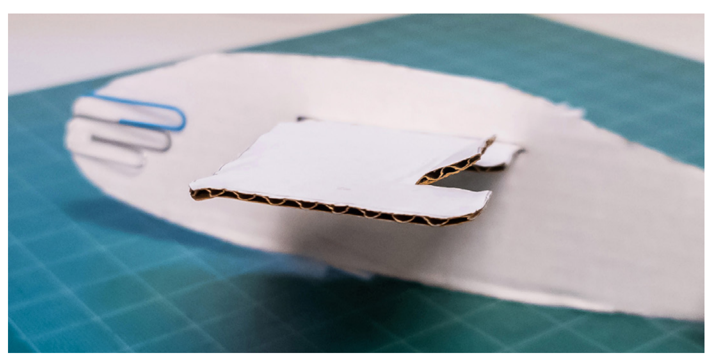
Extension

Challenge students to design and build an airplane with wings and a tail section like the Hess Cargo Plane. Have the students construct their plane out of cardstock, cardboard or a material alike. Their designs should include working ailerons and flaps on the front wings and elevators on the rear wings.

Materials

PER STUDENT OR INVESTIGATION TEAM

- Cardstock or cardboard
- Pencil, pen or marker
- Scissors
- Ruler
- Paperclips (optional)
- Tape (optional)
- X-Acto knife (optional with teacher supervision)



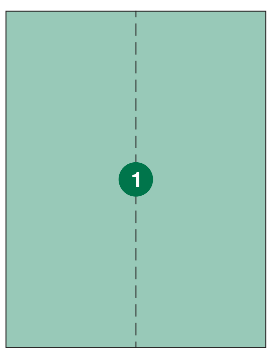
// Build a Paper Airplane

Instructions

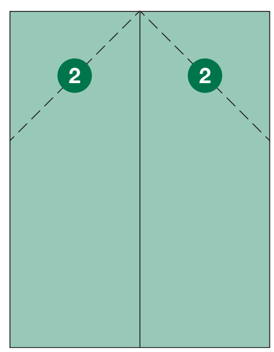
Make a paper airplane according to the instructions below. Your teacher will provide the tape and scissors when you need it. **Do not fly your paper airplane until told to do so.**

YOU WILL NEED

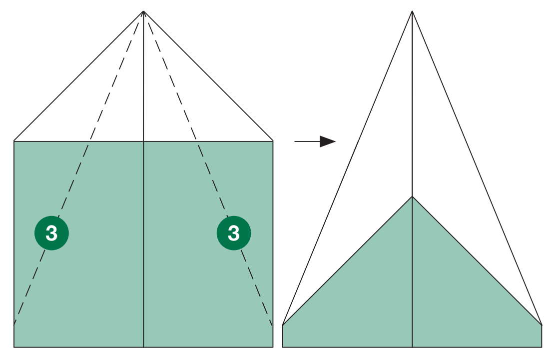
- One sheet of paper (8.5 x 11 in)
- One piece of clear tape
- Scissors



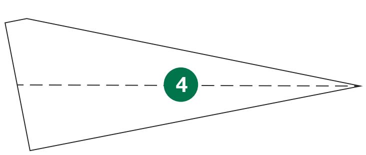
1.
Fold paper to make crease down the middle and then open flat.



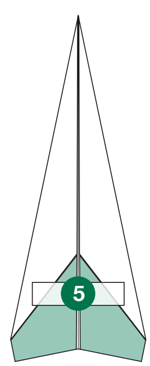
2.
Fold along dashed lines to have upper corners meet in the middle.



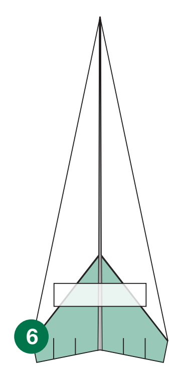
3.
Fold along dashed lines to have corners meet in the middle.



4.
Fold the middle up and lay on side. Fold down wing from each side along dashed line.



5.
Tape wings together to hold their shape.

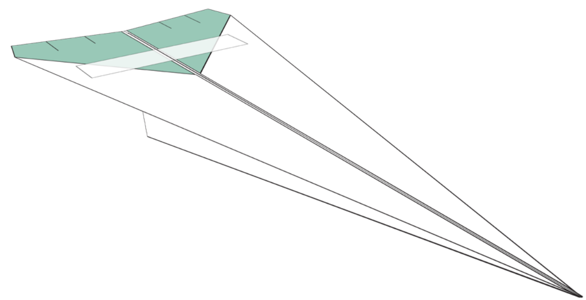


6.
Make four small cuts in rear of wings

// Paper Airplane Flight Tests

NAME ______________________ **DATE** ______________________

Instructions



01 Proceed to the airplane test-flight area designated by your teacher. Conduct the test-flights listed below and record your observations in the logs.

Observation Log Part One

FLIGHT NUMBER	CONTROL SURFACES CONFIGURATION	OBSERVATIONS DESCRIBE THE FLIGHT
	No control adjustment. Learn how your paper airplane flies.	
	Both flaps tilted down.	
	Both flaps tilted up.	
	Right flap up. Left flap down.	
	Left flap up. Right flap down.	

// Paper Airplane Flight Tests

Observation Log Part Two

Explain why you think the airplane flew differently when you adjusted the flaps.

02

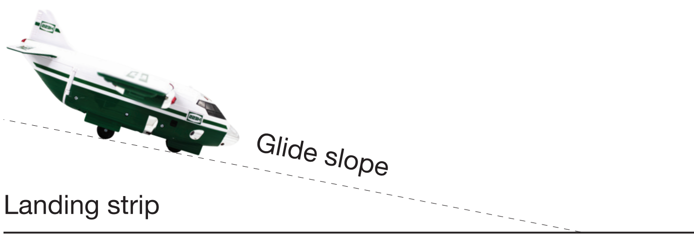
Glide Slope

Suggested Grades **4–8**

// 02 Glide Slope

The Question

What is the best approach angle (glide slope) for the Hess Cargo Plane to land safely on short runways?



Where's the STEM

Cargo planes are designed to carry heavy loads while generating sufficient lift to take off from and land on short runways. With this capability, cargo planes are ideal for bringing emergency supplies and equipment to disaster areas around the world. They are also ideal for transporting supplies to isolated communities.

In this activity, teams of students will investigate which glide slope (AKA glide path) is needed for the Hess Cargo Plane to safely land on a short, primitive runway. Using science and mathematics, flight crews (student teams) will conduct short runway landings to determine the best glide slope angle and landing speed. Students will roll their Hess Cargo Planes down an inclined plane to simulate different glide slope angles. **The goal of the activity is to determine the relationship between the glide slope angle and the distance the plane rolls before stopping**. Knowing this, pilots can choose the correct glide slope to prevent hard landings and avoid striking trees, rocks, or other obstacles surrounding short landing strips.

Materials

PER INVESTIGATION TEAM

- Hess Cargo Plane and Jet
- Paper protractor (printing master provided) A plastic protractor instead of a paper protractor can be used. Protractors are optional for lower grades.
- Student data and observation sheet

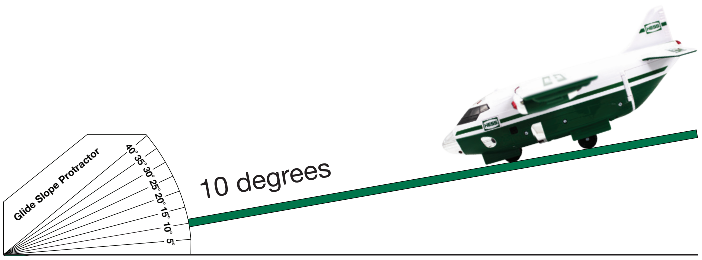
FOR THE CLASS

- Inclined planes made with a smooth wooden board 3 to 4-feet-long, stiff cardboard or heavy foamboard. (See Management Tips for details.)
- Boxes, books, other available objects for supporting the upper end of the inclined planes.
- Tape measure (metric preferred)
- Masking or painter's tape

Management Tips

- Have students conduct this activity in teams of 2–4 individuals.
- If using thick (¾" or thicker) boards for inclined planes, tape a piece of heavy stock paper to the lower end of the inclined planes where they touch the floor. The paper will smooth out the bump that occurs when the plane rolls off the end of the board. (See diagram.) Place a piece of tape near the upper end of the inclined plane as a starting line to ensure that the plane starts from the same place every time.
- Help teams keep the lower ends of their inclined planes from moving by using some tape to hold them in place. The inclined planes tend to slip when students raise or lower the upper end of the planes to adjust their angles.
- The Glide Slope Investigations work best on hard, smooth floors. Carpets with a tight nap (pile) may work but the Hess Cargo Plane will likely not roll as far due to friction of the wheels with the carpet surface.
- Print the Glide Slope Protractors on heavy card stock paper. If working with younger students, you may want to cut out and fold the protractors yourself. Tape the protractors to the floor at the lower end of the inclined planes. This will enable teams to measure the inclined plane angles as they conduct investigations in 5-degree increments.

- For younger students, explain that the protractor is a tool used to measure angles. **Demonstrate where the angle to be measured is found on the inclined plane** (see diagram below). Point out the numbers on the protractor and explain that they are used to measure how much the inclined plane has been raised at one end (i.e., the size of the angle).



- Another measurement adaptation for younger students is to put numbered tape-strips on the floor every few inches. Instead of using a tape measure, students would report the farthest tape-strip the nose of the cargo plane reaches.

Procedure

01 Set up one or more inclined planes on the floor for the activity. If only one inclined plane is available for the activity, work out a sharing test schedule for the teams.

02 Demonstrate how to use the inclined plane. Show the effects of a steep and of a gentle inclined plane on the landing rollout of the Hess Cargo Plane. The cargo area of the plane should be empty.

03 Demonstrate how to use the protractor for measuring the inclined plane angle. Also demonstrate how to measure how far the plane rolls off the inclined plane. Use a measuring tape and record the distance in cm from the base of the inclined plane. Or, use tape to mark 5 or 10 cm intervals on the floor.

04 Provide copies of the student data recording and observation page. For younger students, you may conduct this activity as a class.

Wrap It Up

Discuss student team results. Use the following questions as prompts.

- *What is the best angle of the inclined plane for a short landing rollout?*
- *How far did the plane roll across the floor for each different angle tried?*
- *What happens if the angle of the inclined plane is too steep?* [Crash.]
- *What is the relationship of the angle of the inclined plane and the speed of the cargo plane on touchdown?* [A steeper inclined plane or glide slope causes the plane to travel faster on touchdown.]

Additional Background Information for Discussion

The Glide Slope Investigation is an approximation of what really happens when cargo planes like the Hess Cargo Plane come in for a landing. The glide slope angle of the inclined plane determines how fast the Hess Cargo Plane travels at the moment when it rolls on the runway (floor). The steeper the inclined plane, the faster the Hess Cargo Plane travels and the farther it rolls before it stops due to friction with the floor.

In real airplane flight, there is a minimum speed the plane must fly to maintain horizontal flight. Slightly less and the plane slowly descends. Slightly more and the plane ascends. Much slower than the minimum speed, and the plane stalls and falls from the sky.

The landing goal of all airplane flight is to dissipate both forward and downward energy at the moment of touchdown. Since cargo planes like the Hess Cargo Plane often land on grassy fields or dirt strips in remote areas, the pilots have to adjust the glide slope to clear obstructions like trees or rocky hills before touching down. Reducing engine thrust and employing control surfaces (flaps and elevators—see glossary), the pilots adjust the speed and lift of the cargo plane to make a safe landing. Control surfaces increase the drag or friction with the air to slow the plane.

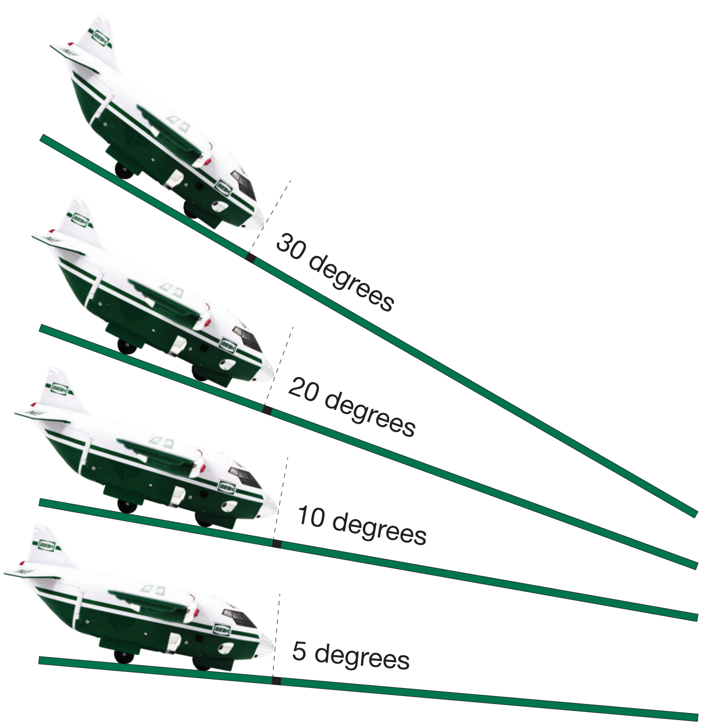
Remote locations usually have short runways and the pilots use both landing gear breaks and thrust reversers to quickly bring the plane to a stop. Thrust reversers are small vanes that move into the engine exhaust to redirect their thrust forward.

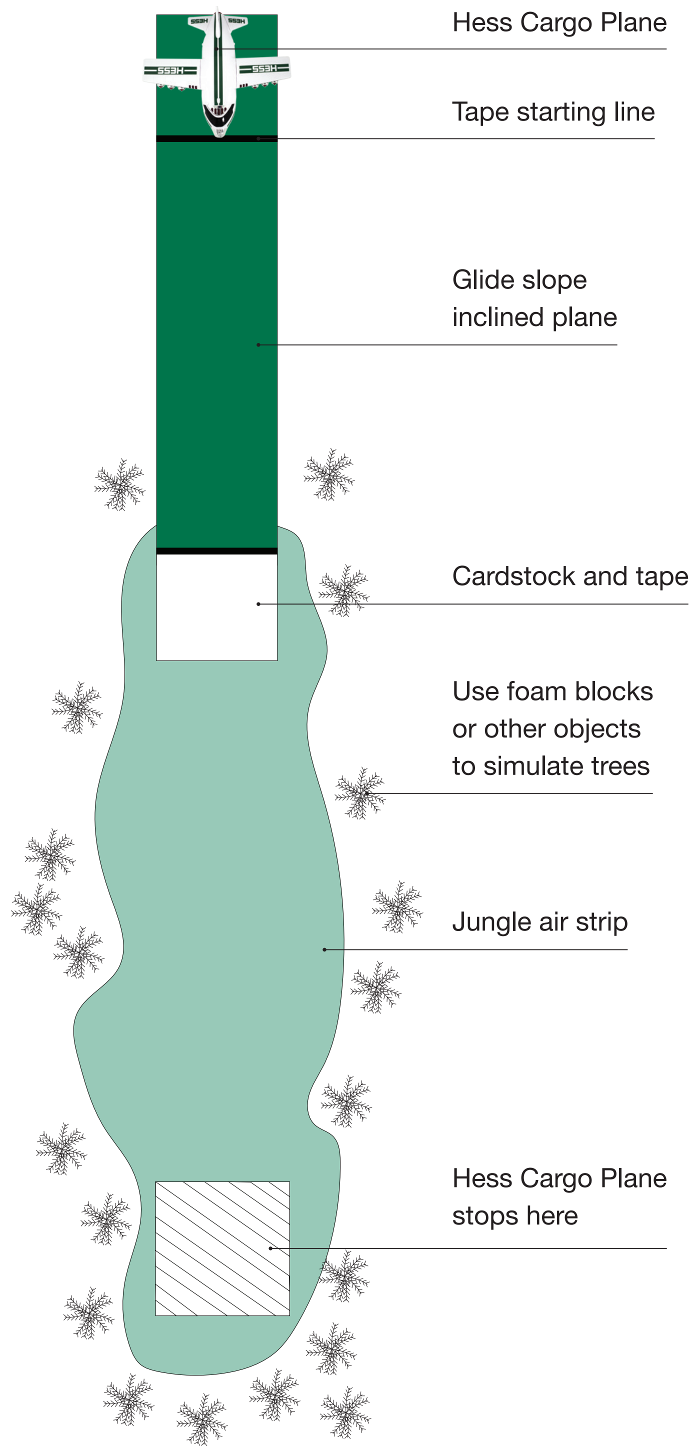
// The Glide Slope Investigation is an approximation of what really happens when cargo planes like the Hess Cargo Plane come in for a landing.

// Simulated Landing Strip

Extensions

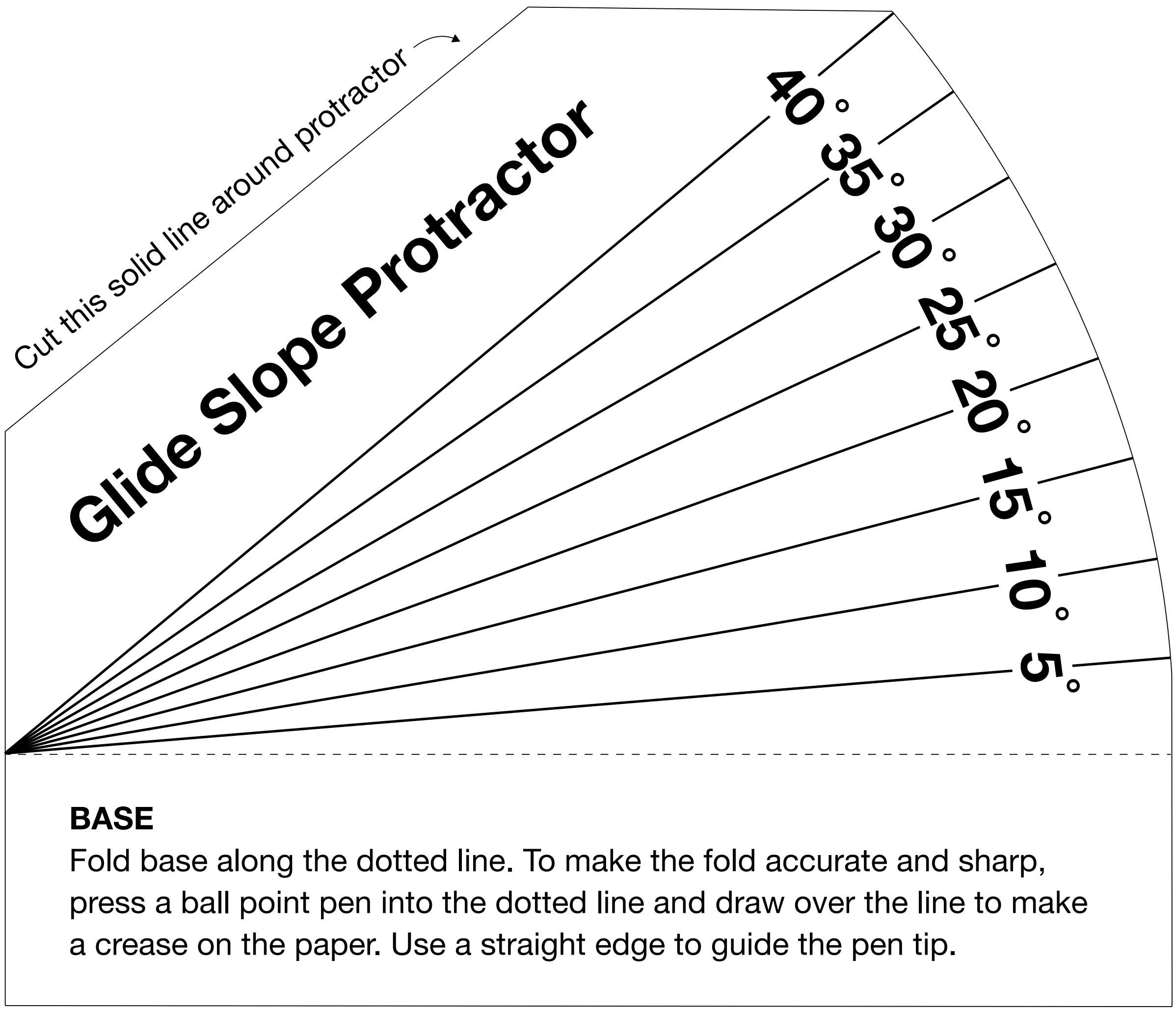
- **Set up a Simulated Remote Landing Strip** (see diagram to the right) by placing small blocks or other objects at the end of the runway. Challenge student teams to use the inclined plane to stop their airplanes in a square placed at the far end of the runway. If the plane rolls beyond that point, it crashes into obstructions. Student teams may have to conduct multiple trials, making adjustments each time, to find the optimal angle of the inclined plane.
- **Repeat the investigation with the Hess Cargo Plane empty of cargo** and compare the landing rollout distance to the plane loaded with cargo. Have students load the cargo bay with the Hess Jet or small weights, such as small plastic bags with metal washers, coins, marbles, etc.
- Short runways require a steeper angle. **Determine the landing rollout distance of the Hess Jet** with different angles of the included plane.





// Glide Slope Protractor Pattern

▸ Print the Glide Slope Protractor on cardstock paper.



// The glide slope angle of the inclined plane determines how fast the Hess Cargo Plane travels at the moment when it rolls on the runway.

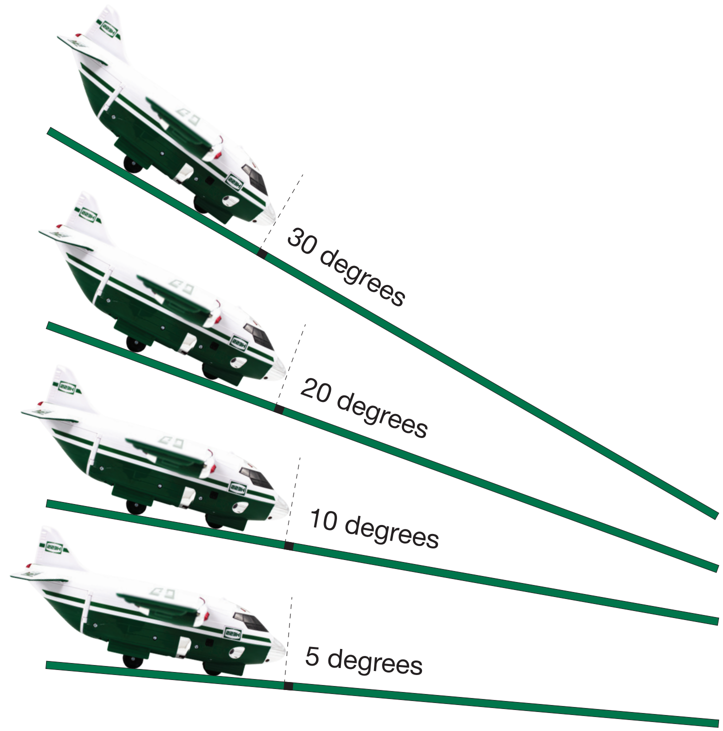
// Glide Slope Investigation

NAME ______________________________ **DATE** ______________________________

Instructions

01 Using the protractor, test the effects of different angles to see how far the Hess Cargo Plane rolls after touchdown.
Special note: To ensure the cargo plane starts at the same point for each test, the teacher can mark a starting point with tape on the upper end of the inclined plane.

02 Use the chart below to record your results.



Record

- Write the test number and inclined plane angle you are testing.
- Measure how far the plane rolled across the floor and write the rollout distance and units of measure.

TEST NUMBER	INCLINED PLANE ANGLE	ROLLOUT DISTANCE	UNITS OF MEASURE

// Glide Slope Investigation

Observations

What did you observe about the relationship of the inclined plane and how far the cargo plane rolled? What else did you observe during the investigations?

▶ Write your observations in the space below.

03

Load Master

Suggested Grades **3–8**

Suggested Grades **3–8**

// **03** Load Master

The Question

How much load by volume can the Hess Cargo Plane carry?

Where's the STEM

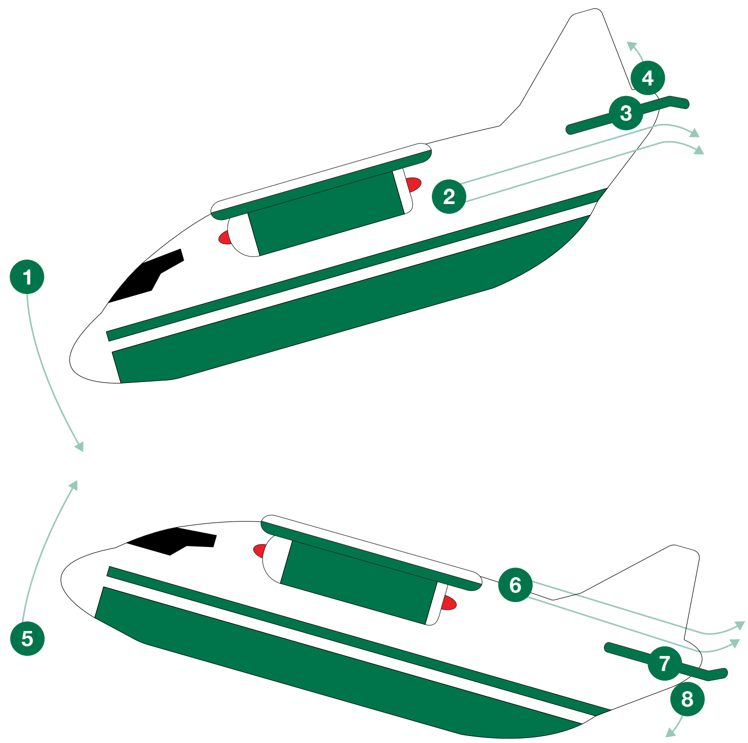
Cargo planes like the Hess Cargo Plane normally carry a crew of three. There are two pilots and one technician, called the Load Master. The pilots have to know and apply the science of flight and all of the technical aspects of the plane's controls, instruments and capabilities.

The Load Master has to understand the science of flight and how to balance heavy loads in the cargo bay. An excessive amount of weight in the front makes the nose of the plane too heavy (nose heavy). In this case, to maintain level flight, the pilots will have to steeply tilt the elevator flaps on the tail upward. Doing so increases drag from the air, which decreases speed and increases fuel use.

An excessive amount of weight in the rear of the cargo bay will cause the rear of the plane to be too heavy (tail heavy). The pilots will have to tilt the elevator flaps steeply downward to maintain level flight. This tail weight increases drag with the accompanying speed reduction and increase fuel use.

The reason the elevator flaps are able to level the plane in flight is explained by referring to Isaac Newton's Third Law of Motion: for every action there is an opposite and equal reaction. Tilting the elevators upward directs air flowing past the airplane's tail upward. This is an upward action force. At the same time an opposite and equal reaction force pushes the tail in the opposite direction—downward. When the flaps are tilted downward, the action force sends air down and the opposite and equal reaction force pushes the tail upward.

It is the job of the Load Master to balance the heavy load in the payload bay. The job requires STEM skills. In addition to the considerations already discussed, **loads should be equally balanced on each side of the aircraft and not be able to shift or move during flight**.



1. Nose down
2. Air flow and action force down
3. Elevators down
4. Reaction force up
5. Nose up
6. Air flow and action force up
7. Elevators up
8. Reaction force down

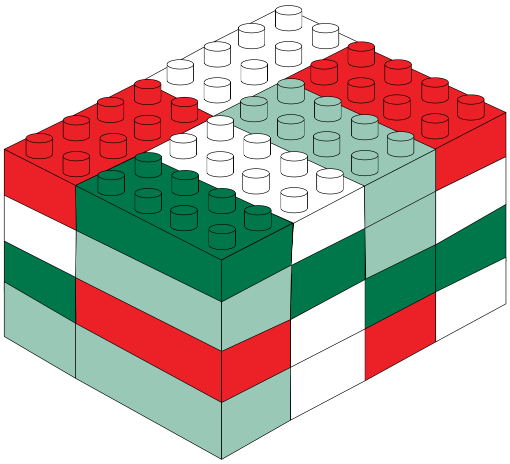
// Loading the Hess Cargo Plane

In this activity, students will take on the role of the Load Master. **They will measure the volume of the cargo bay and determine how many pallets of payload can fit inside for safe and efficient transport**. The payload pallets may be constructed of toys such as plastic toy bricks, small wood or foam building blocks, or cubes made by students. (See the Management Tips section for ideas on constructing cubes.)

Materials

PER STUDENT OR INVESTIGATION TEAM

- Hess Cargo Plane
- Ruler (metric preferred) or cutout ruler printed on cardstock paper (master provided).
- Plastic toy bricks, blocks or other small objects that can be used as cargo. (See image above.)
- Student page



Management Tips

- Metric rulers are easiest to use for calculating volume. Multiplying British units involving fractions is more challenging. Review millimeters and centimeters on the ruler students make.
- **The formula for volume (v) is length (l) x width (w) x height (h)** or v=lwh.
- The interior of the cargo plane is roughly a rectangular box shape. The roof of the cargo bay near its edges is partially curved, as is the floor. This curvature is due to the shape of the plane's fuselage. Have students measure the width of the flat part of the floor and the height straight up to the edges of the flat part of the ceiling. The curved area of the front end should not be measured nor included in the estimates of available space for cargo. (This space is just an accommodation for the nose of the small jet that fits inside.)
- Tell students the cargo they place inside should sit on the flat floor of the bay. It must not touch the curved walls or the ceiling. The payload has to slide easily up the loading ramp and out upon landing. Payload may not be placed in the area surrounded by the curved rear loading doors.
- Plastic toy bricks that snap together are the easiest payload for students to work with. If you have plastic toy bricks, bring them in for students to use. If not, ask for student volunteers to bring some to class. The most useful bricks are rectangular shaped.

Procedure

01 Review the makeup of the crew of the Hess Cargo Plane (2 pilots, 1 technician, called the Load Master). Explain the roll of the Load Master is to balance the heavy load in the cago bay to keep the plane level in flight and to keep the cargo from sliding forward or backwards.

02 Tell the students they will simulate the role of the Load Master and determine how many pallets of payload, or cargo, can fit inside the cargo bay.

03 Provide plastic rulers or have students make card stock rulers from the included master. If necessary, review how to measure in centimeters and millimeters with your students.

04 Explain how to calculate the volume of the payload bay. Students will need to measure the length, width of the flat floor and the height to the top edge of the rear doors. For your convenience, the measurements in centimeters are 15 cm long, 6 cm wide and 4 cm high. Write the volume formula on the board.

- **V=lwh** (volume = length x width x height).

05 Make up some sample numbers and solve for volume. Again, for your convenience, the actual usable storage volume for the Hess Cargo Plane is 15 cm x 6 cm x 4 cm = 360 cubic cm (cm^3).
You may need to explain that each cubic centimeter represents one cube that is 1 cm long on each side. Thus, a volume of 360 cubic cm would fit 360 individual cubes with 1 cm sides.

06 Have students place their plane on a table (Hess Airport Terminal). Distribute student pages so students can work individually or in teams to measure their cargo bays and calculate cargo volume.

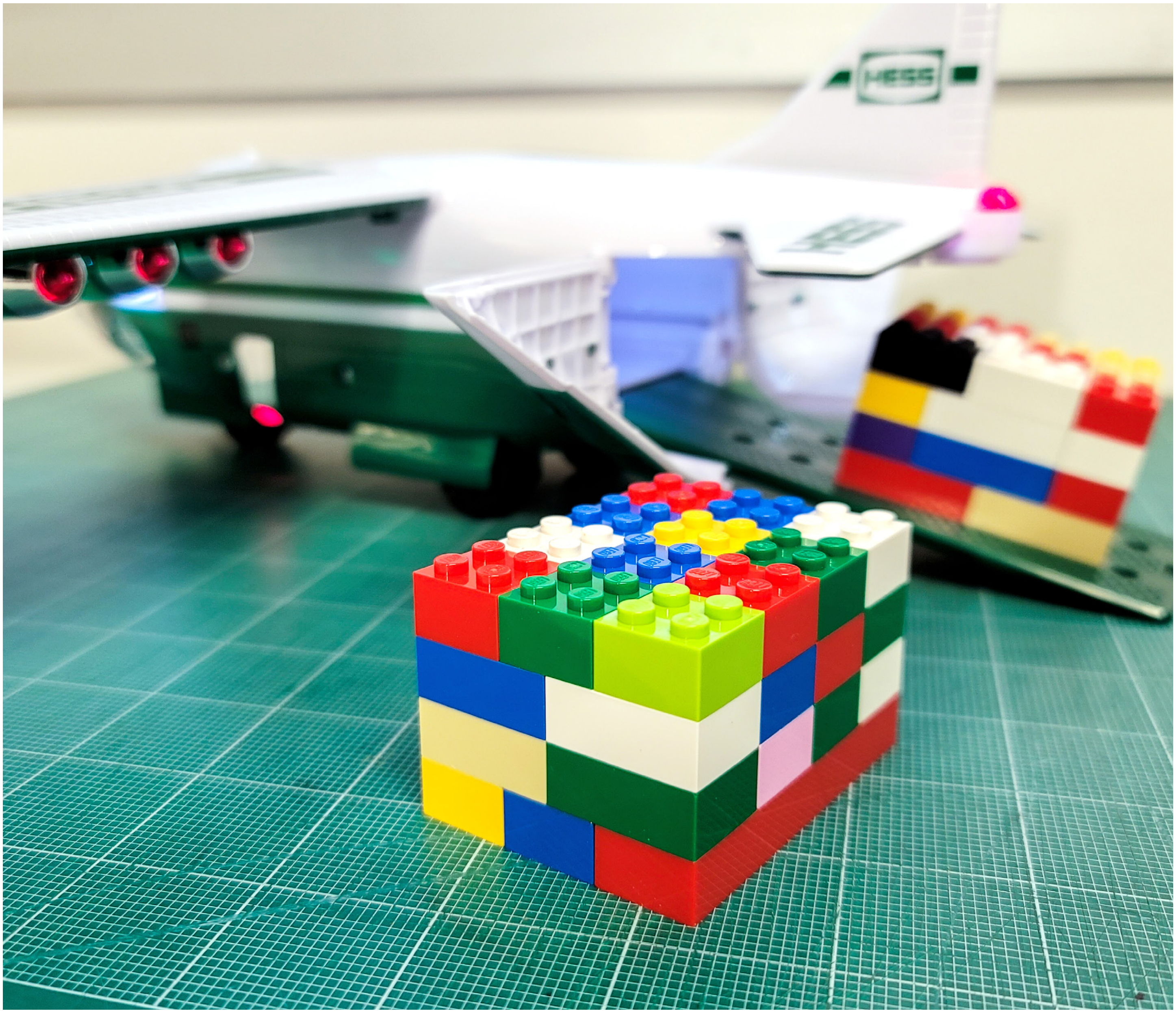
07 Once those measurements are made, students should make the volume calculations. Then, they can start constructing payload pallets based on their calculations.

08 When construction is complete, have students verify if their payloads fit. The loading ramp in the rear of the plane should be pulled down and the payload pallets slide up the ramp. *Do the pallets fit? Do they touch the sidewalls and ceiling? Do they slide in easily? Is there any unused space available?*

Wrap It Up

Have students report on their success and how much payload they were able to fit in the cargo bay.

- Students will note that the width of the floor of the payload bay is not uniform. The floor narrows toward the front of the bay. This makes things a bit more challenging. Share that on actual cargo planes, the payload never completely fills the floor. The Load Master has to be able to walk around the pallets to secure the pallets to the floor, so they don't move during flight. Straps, hooks and cargo nets are used for securing the cargo to attachment points (such as heavy-duty rings or bolts) built into the floor.



// Making Pallet Parachutes and More

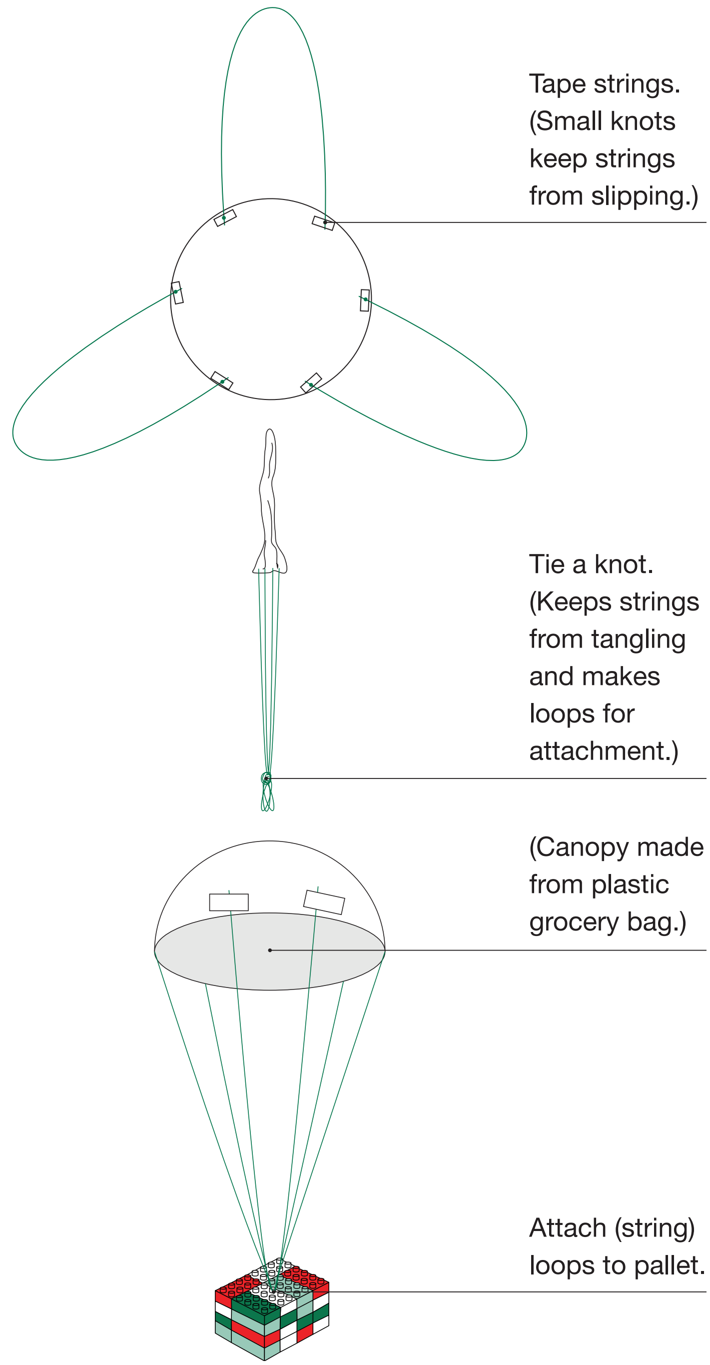
Extensions

PALLET PARACHUTE

When disaster strikes—such as with floods, major storms, earthquakes, volcanic eruptions—cargo planes may be used for transporting emergency supplies to the survivors. In especially remote areas, there may not be any place to land the cargo planes. In that case, parachutes may be used to airdrop supply pallets of water, food, medical supplies and other materials. **Challenge students to make parachutes** for their pallets from plastic grocery bags and string. (See diagram to the right.) To test each parachute, place the pallet with the parachute folded inside the cargo plane. Hold the plane high over the floor and tilt the rear of the plane, with the doors open, downward to test the parachute. Select a carpeted or padded area to conduct the parachute tests.

FULL-SIZE CALCULATIONS

Real cargo planes, of course, are much larger than the Hess Cargo Plane toy. What if a full-size Hess Cargo Plane was constructed? How big would it be? How big would its cargo bay be? How big would the doors of a hanger have to be to allow it to move inside? The C-130J Super Hercules cargo plane, built by the American company Lockheed Martin, is 90 times larger than the toy Hess Cargo Plane. **Have students measure the nose to tail length, wingtip to wingtip length and ground to vertical stabilizer height on the toy and calculate the dimensions of a full-size version of the plane** by multiplying their measurements by 90.



OPERATION RESCUE

Operation Rescue is a related STEM module for students that is based on Super Typhoon Yolanda, which struck the Philippines in 2013. Student teams plan rescue missions and decide what supplies are needed; how much can be carried on a cargo plane similar to the Hess Cargo Plane; and create a flight plan and a flight manifest based on the plane's capabilities. The activity involves science, technology, engineering and mathematics.

Development of the module was funded by the National Institutes of Health. The complete activity is available free through BioEd Online at the following link.

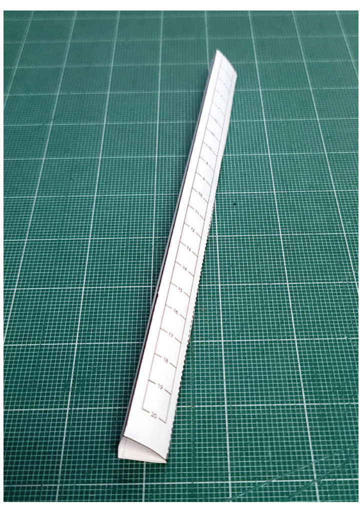
- https://www.bioedonline.org/lessons-and-more/teacher-guides/operation-rescue/.

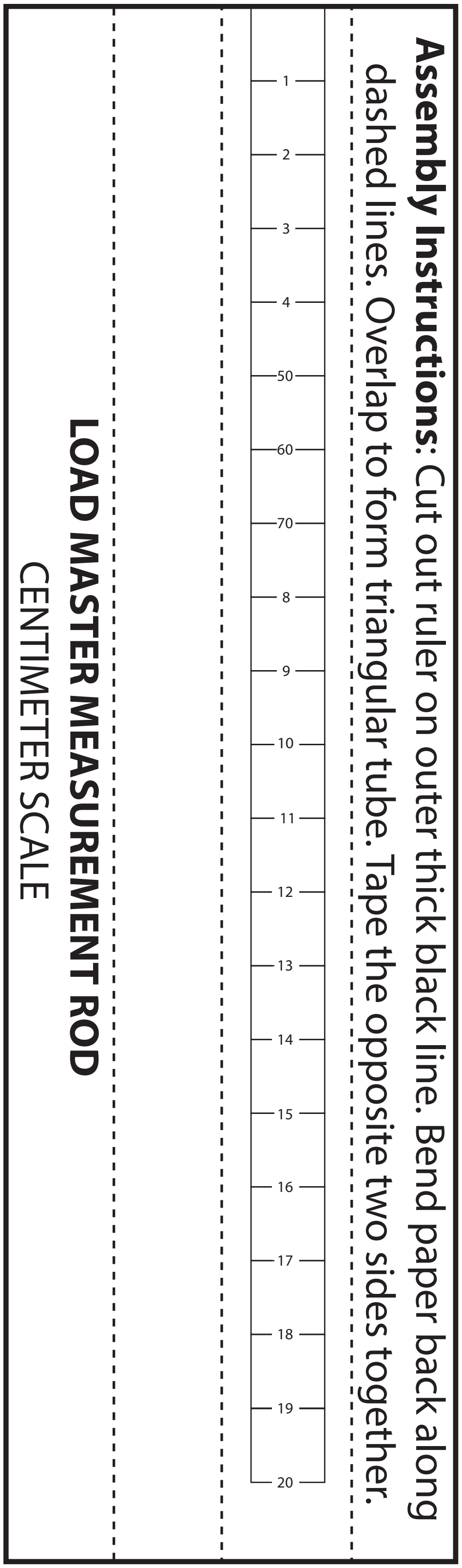
> The Load Master has to understand the science of flight and also how to balance heavy loads in the cargo bay.

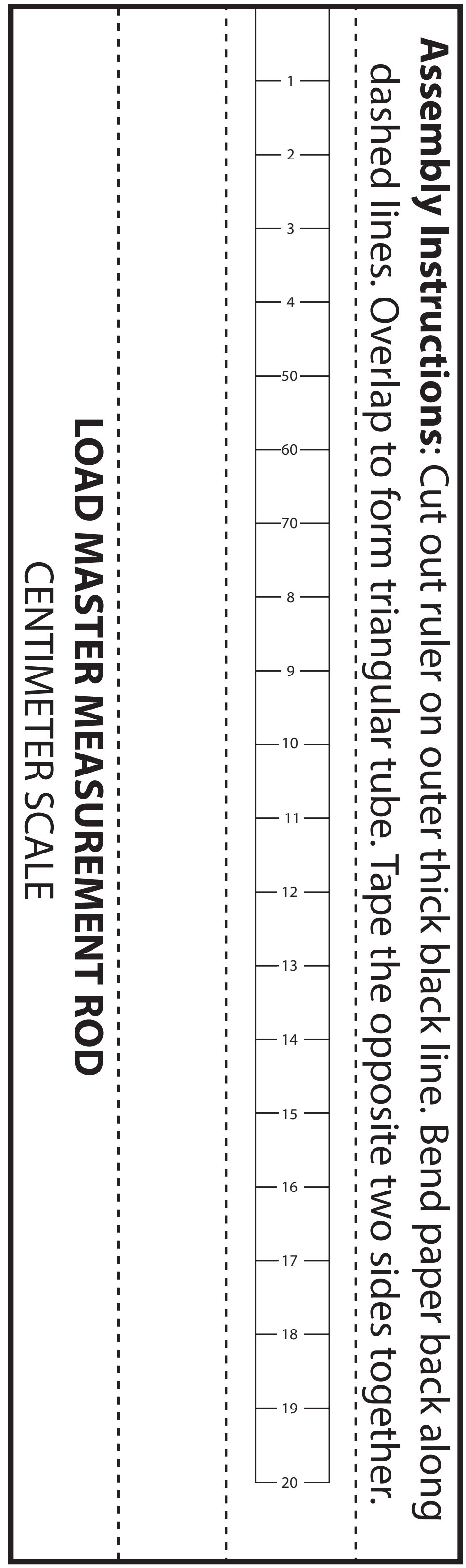
// Load Master Measurement Rod Patterns

Load Master Ruler

- **Important note**: This page should be printed in actual size so the metric measurements are correct. (This step is not necessary if metric rulers are available.)
- Follow the construction instructions on the rulers.
- When folded correctly, the ruler will be a triangular tube with the scale on one long side, the Load Master Measurement Rod title on another and a third side blank. (See image below.)
- Measure the cargo bay to the nearest centimeter. For example: If a measurement is slightly longer than 7 cm, your measurement is 7 cm. If it is almost 8 cm, your measurement is 8 cm.





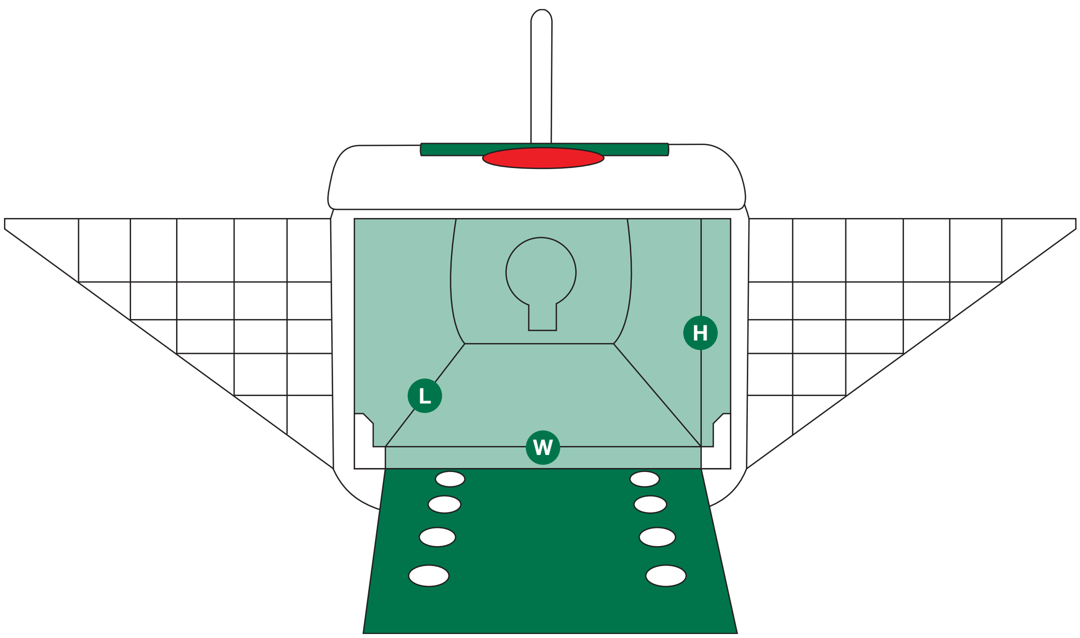


// Load Master Training

NAME ______________________ **DATE** ______________________

Instructions Part 1

- Determine the volume of the cargo plane interior by measuring its length (L), width (W) and height (H). Then, multiply your answers together. (See diagram below.)
- When you have determined the volume, construct cargo pallets to fill the plane. Test the fit of your pallets and answer the four following questions.



01 Length of cargo bay in cm.

02 Width of cargo bay in cm.

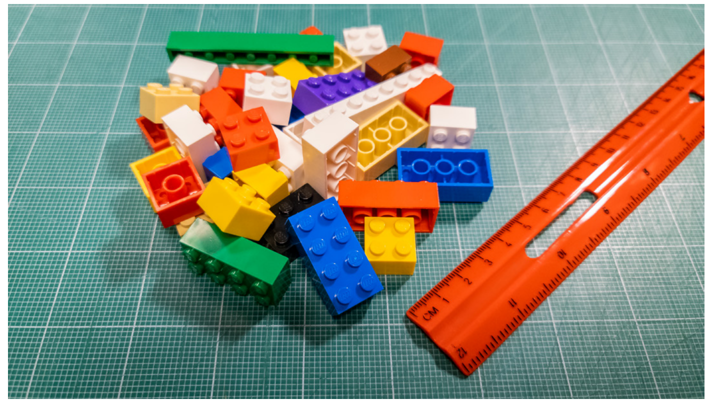
03 Height of cargo bay in cm.

04 Multiply your answers together to arrive at the usable cargo bay volume.

volume = ☐ x ☐ x ☐ = ☐ cubic cm (cm^3)

Instructions Part 2

- Based on your answers, construct cargo pallets to fit inside the cargo bay. Take into consideration that each pallet's size must be no larger than **6.5 cm x 5 cm x 4 cm** in order to fit into the cargo bay. This will enable you, as Load Master, to slide the pallets up the ramp and inside the bay without touching the walls and ceiling.



01 *How many pallets did it take to fill the cargo bay?*

02 *How big are your pallets?* (Length, width and height.)

03 Use the procedure you employed in Part 1 to determine the volume of each of your pallets. (Write your calculations below.)

Pallet 1 ______ cubic cm

Pallet 2 ______ cubic cm

Pallet 3 ______ cubic cm

04 *What is the total volume of all your pallets in cubic centimeters?*

05 *How does your total pallet-volume compare with the volume in Part 1, question 4?*

04

Cargo Comparisons

Suggested Grades **3–8**

Suggested Grades **3–8**

// **04** Cargo Comparisons

The Question

How does the load in the Hess Cargo Plane affect the distance it can travel before it has to land and refuel?

Where's the STEM

Trucks and trains are great ways to move goods from one place to another. But when time is a critical factor, such as during disasters created by storms or earthquakes, cargo planes are the fastest way to bring in emergency supplies.

The Hess Cargo Plane toy is a jet-powered version of cargo planes currently in use around the world. One of these planes is the C-130J manufactured by Lockheed Aircraft. The plane is powered with four turboprop engines. Its cargo bay can hold six large pallets of emergency supplies.

Using a C-130J or other aircraft to transport cargo requires the pilots and the Load Master to understand its flight capability. In particular, **it's important to know the mathematical relationship of the cargo weight vs. the distance the plane can fly before landing to refuel**. The heavier the plane, the more fuel it uses; the shorter its range, and the longer it takes to reach its destination. Below is a list of maximum characteristics of the C-130J airplane.

- Maximum speed: **417 miles per hour**
- Maximum cargo weight: **36,000 pounds**
- Range with no cargo: **5,200 miles**
- Range with 25,000 pounds of cargo: **2,500 miles**
- Range with 36,000 pounds of cargo: **1,960 miles**

The performance numbers above are affected by the flight conditions, the distance the plane can travel and its speed can be increased by tailwinds or reduced by headwinds. Tailwinds move in the same direction as the plane and push it from behind. Headwinds move in the opposite direction as the plane and impede its forward motion. The science of weather is another thing pilots need to understand.

In this activity, students will compare how far the plane rolls to how much it weighs. Doing this investigation is a practical application of Isaac Newton's Second Law of Motion: acceleration equals force divided by mass.

Using a test staging area (large open space), the Hess Cargo Plane will be accelerated across the floor with different cargo weights by a towrope, a string with looped rubber bands attached to a string harness students tie on the plane.

Materials

PER TEAM OF STUDENTS

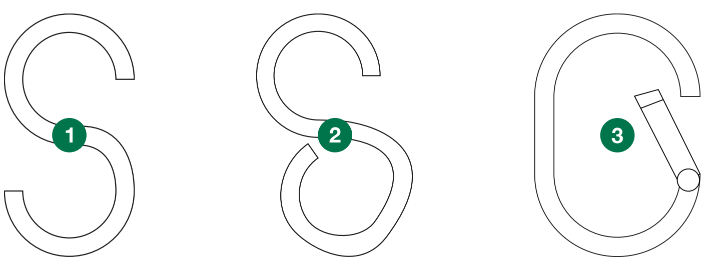
- Hess Cargo Plane
- Hess Jet
- 3 ft (or 1 m) of string
- Student instruction/data sheet

FOR THE CLASS PER TEST STAGING AREA

- 10 heavy rubber bands linked together (size 64 recommended)
- 15 ft (or 5 m) of string
- Hook (see Management Tips for details)
- Tape measure or yard or meter stick
- 1 pound weight (454 grams) that fits cargo bay (see Management Tips on page 32)
- Kitchen scale for measuring weights
- Masking or painter's tape

Management Tips

- Select a clear area for the test staging area. The space should be about 6 feet wide by about 20 feet long. Hard tile floors work best. Consider using a hallway. Set up more than one stand to shorten the time needed by the class for conducting test runs.
- One hook will be needed for each staging area. The hook will be used to attach the long string to a string looped around the cargo plane wings. A small s-hook from a hardware store works best. Use pliers to squeeze one of the curves on the hook to form a loop. The string will attach to the loop end of the hook. You can also use a small carabiner or a hook made out of thin coat hanger wire. (See illustrations below.)



1. S-hook (opened/straight)
2. S-hook (closed/bent)
3. Carabiner

- Prepare a 1-pound weight (454 grams) for students to insert into the cargo bay of their planes. Fill a small, sturdy plastic bag with pennies, metal washers, bolts or similar heavy items. Be sure to tape the bag securely into a bundle so it easily fits the cargo bay. If you have more than one staging area, make one weight for each area. The Jet will serve as another weight students will test.
- For younger students it may be helpful to premeasure and mark the weights. The cargo plane weighs 1 pound 5 ounces (606 grams). The Jet weighs 6.4 ounces (182 grams). The third weight you construct should weigh about 1 pound (454 grams). This represents the maximum load the Hess Cargo Plane could carry.

Procedure

For placement of the testing apparatus, refer to the diagram on page 33.

01 Set up the test staging area.

02 First, loop ten rubber bands together to make one long elastic band.

03 Next, tie the string to one end of the long elastic band.

04 Attach the other end of the long elastic band to a table or chair leg (anchor point) at the far end of the staging area. Be sure the table or chair is heavy enough to anchor the band without moving.

05 Tie the remaining end of the string to a hook. This is the towrope.

06 When the hook, string and elastic are laid out on the floor (without stretching the elastic), the towrope should extend about 12–15 feet from the far end (anchor point).

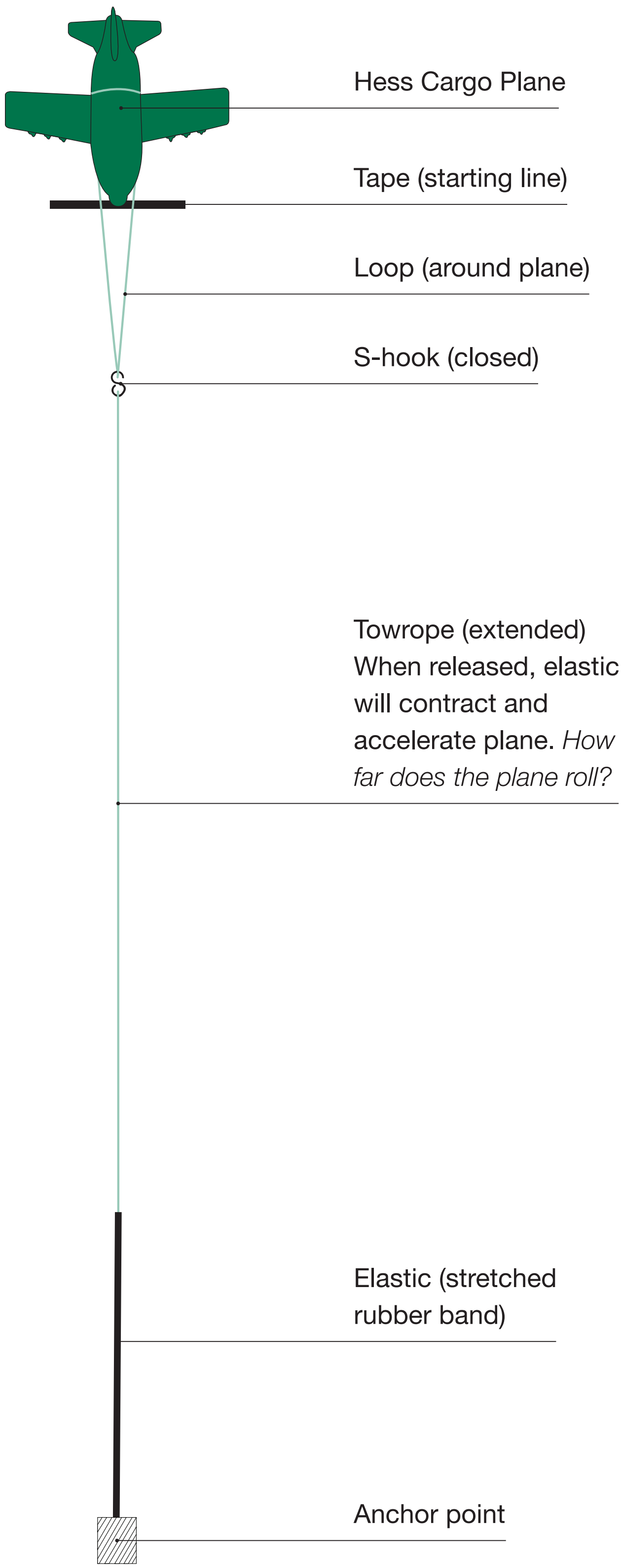
07 Place a strip of masking or painter's tape on the floor perpendicular to the towrope and 3 feet beyond the hook. This becomes the starting line. (Pulling the plane back until its nose is just behind the launch line ensures the same force applied for each test launch —experiment control.)

08 Introduce the activity by discussing how cargo planes are used for transporting emergency supplies during disasters because they are the quickest way of delivering life-saving supplies. Explain how the weight of the aircraft will affect how far it can travel without refueling. Tell them they will test how far the Hess Cargo Plane will go using different cargo loads on the plane.

09 Explain the components of the staging area and how each part will work during the test.

10 For each test, students should start the plane with the nose just behind the taped launch line. Use an unloaded Hess Cargo Plane to demonstrate the correct starting position (landing gear should be down, not retracted).

11 Give teams their instruction and data sheets. Point out the location of the scale and weights to be tested. Remind them that the Hess Jet is one of the cargos they can test.



Wrap It Up

- Have students explain their results on how far the cargo plane traveled with and without cargo, including the impact of using different weights. Allow time for discussion.
- For older students, relate their results to Isaac Newton's Second Law of Motion. The acceleration of the plane depends on the mass of the plane and the amount of force applied. The force comes from the elastic band. Having the same starting line for each test ensures the force is the same every time. The acceleration of the plane is the dependent variable. The independent variable is the mass of the plane and its cargo. **Note**: The investigation does not actually measure acceleration. However, the distance the plane rolls for each test is an indicator of acceleration. The farther the plane rolls, the greater the acceleration. The greater the total mass of the plane and cargo, the less the plane accelerates with the force provided by the elastic. Another variable in this investigation is the friction of the floor with the Hess Cargo Plane's wheels. The wheels of airplane landing gear are designed to reduce friction with the runway during takeoff. During landing, friction of the wheels with the runway helps the pilot stop the plane when brakes are applied. While the Hess Cargo Plane's wheels turn easily, friction with the floor exerts a force to slow the plane. Students can verify this by testing the plane's rollout distance on floors with a different covering, such as carpet.
- Why is understanding the relationship between load and range important? In emergency supply missions, it is important to get supplies to the people in need as quickly as possible. If the distance to the disaster area is within the range of the plane, the plane can be fully loaded. However, if the distance is beyond the range, the pilots will have to find an airport to refuel, which delays the arrival of the supplies. Fewer refueling stops are preferable. A lighter load extends the range of the plane so that it can arrive sooner. Before takeoff, how much cargo to load is one of the important decisions the flight crew must make.

// Creating a Bar Graph and Learning More

Extensions

- **Challenge older students to create a bar graph** showing their results.

C-130J Aircraft | Photo by Airman 1st Class Rhett Isbell | © U.S. Air Force

- **Have students learn more about cargo planes** by going to these sites on the internet.
  - U.S Air Force
    https://www.af.mil/About-Us/Fact-Sheets/Display/Article/1555054/c-130-hercules/
  - Lockheed Martin
    (U.S. manufacturer of several cargo planes)
    https://www.lockheedmartin.com/en-us/products/lm-100j.html
- **Refer to the extension for the Load Master Training** (Activity 03). It describes the Operation Rescue teacher guide that directly relates to this activity, where student teams plan a mission to deliver emergency supplies to the Philippines following a major typhoon. The complete activity is available free to download through BioEd Online at the following link.
  - https://www.bioedonline.org/lessons-and-more/teacher-guides/operation-rescue/

// When time is a critical factor, such as during disasters created by storms or earthquakes, cargo planes are the fastest way to bring in emergency supplies.

Student Page **A**

// Hess Cargo Plane Distance vs. Load Investigation

NAME ______________________________ **DATE** ______________________________

Instructions

01 Prepare your Hess Cargo Plane for the investigation by tying a string loop around the upper fuselage and tie it in front of the forward landing gear. (See Diagram A.)

01 Place your plane on the scale and determine how much it weighs. (Write your answer in the data table on Student Page B. See page 32 for the base weight of the Hess Cargo Plane.)
Special note: Begin your first test with the cargo bay of the plane empty.

02 Take your plane to the test area. Place it on the floor in front of the tape starting line. Attach the tow s-hook to the loop you tied around the plane. Pull the plane by the tail section until the nose is just behind the tape starting line. Do a brief countdown and release the plane. (See Diagram B.)

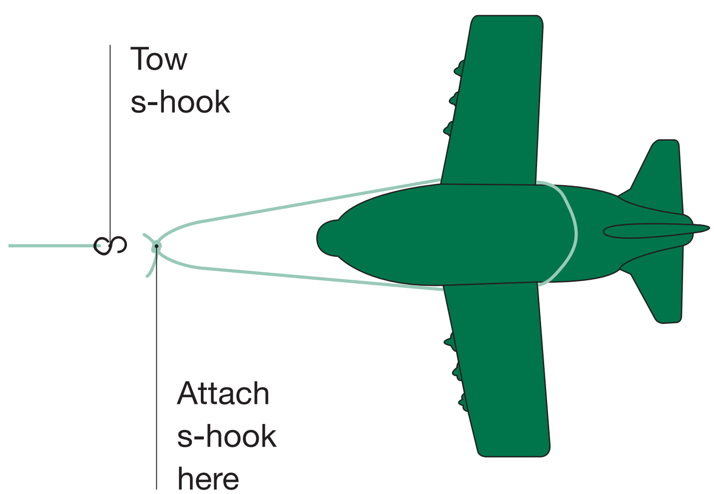
03 Measure how far the plane traveled across the floor, by recording the distance from the nose of the plane back to the starting line. Be sure to report your units of measurement. Enter the distance in the data table below.

04 Repeat the procedure for Test 2. Use the Hess Jet as the cargo. Weigh the jet and write its weight in the data table.

05 Repeat the procedure for Test 3. Use the heavy weight provided by your teacher. Weigh it, record its weight and place it in the payload bay.

Diagram A

Diagram B



Data Log

	WEIGHT OF EMPTY PLANE	WEIGHT OF PAYLOAD	TOTAL WEIGHT PLANE + PAYLOAD	DISTANCE TRAVELED	UNITS OF MEASURE
Test 1					
Test 2					
Test 3					

Observations

What do your results tell you about the relationship of weight of the cargo to how far the plane can carry it before refueling? Why is this important?

▶ Write your observations in the space below.

05

Up, Up and Away

Suggested Grades **3–8**

Suggested Grades **3–8**

// 05 Up, Up and Away

The Question

Will it fly?

Where's the STEM

The 2021 Hess Cargo Plane comes with a sleek, high-performance Jet. The jet fits neatly inside the cargo bay due to its unique engineering design based on the length, width and height of the cargo bay interior. The design includes retractable landing gear. The wings, horizontal tail and vertical tail all fold into the body of the jet to save space.

An aircraft with folding wings is not a new aviation innovation. Military aircraft carriers, which are ships that serve as airbases at sea, can carry many jets because the planes' wings fold to reduce space needed in the below deck hangers.

Because the Hess Jet is a heavy plastic toy without functioning engines, it is unable to fly. However, a full-scale version of the jet, with functioning engines might be capable of flight. How do we know? This is where science and engineering come in.

Airplane designers, called aeronautical engineers, spend extensive time prior to the construction of new aircraft conducting computer simulations to test the forces of flight on their designs. Once they are satisfied their designs could work, technicians construct models of the aircraft for testing in wind tunnels. Wind tunnels are very large tubes that move high-speed air around an object to simulate flying. Engineers can test their designs and make modifications where needed before the full-scale jet is constructed and flown. Some wind tunnels are so big that a full-sized aircraft can fit inside!

In this activity, **students will construct a paper model version of the Hess Jet and test the model to determine whether it will fly**.

Materials

PER STUDENT

- Hess Jet
- Hess Jet Glider Pattern (printed on card stock paper)
- Scissors
- Clear tape
- Pencil
- 1–4 small paperclips (the number as needed by student)
- Eye protection for flight tests

FOR THE TEACHER

- One or more completed paper models for demonstration.
- Airplane vocabulary diagram for projection or drawn on the board. (See the Jet's glossary on page 54.)

Management Tips

- Prior to starting glider construction, discuss the jet vocabulary diagrams at the end of this guide with your students. Construction and test flying the gliders will be easier if everyone uses the same aeronautical terms.
- Encourage students to work with partners to assist each other in making their jet gliders.
- Demonstrate how to curl the wings and fuselage of the jets. Wing curls stiffen the wings and may add some lift to the jets. The upward curl of the fuselage forms a wide v-shape that provides roll stability to the glider. Roll is a circular motion perpendicular to the long axis of the glider (like tipping your head to one side or the other).
- The jets will fly poorly on their initial flights and flop to the floor (crash). After the jets have been tested once, explain the gliders need to have some extra weight on the nose end. Help students attach one or more small paperclips near the nose of the glider to make it fly on a smooth path to the floor.
    - If the weight is too far forward, the glider will dive to the floor (crash).
    - If the weight is too far back, the glider's nose will tip up, lose air speed and fall to the floor (crash).
    - *Where is the "just right" place for the weights?*

- Create a glider to demonstrate what happens to the glider with different placements of the weight. Have older students determine how much weight is needed and where to place the weight for optimum flight performance.

Procedure

01 Compare the Hess Jet with an assembled paper jet glider that you construct. The toy jet and the glider are approximately the same size. The toy won't fly because it is very heavy (182 grams) and its jet engines are non-functional.

02 Explain that the paper glider represents a model of the Hess Toy jet. Tell students they will construct and test fly their own gliders to find out if the aerodynamic design of the jet allows it to fly correctly.

03 Distribute paper Jet Glider Patterns and scissors. Have students carefully cut out their gliders on the outside lines. **Encourage them to not bend or fold the planes as they cut them out**.

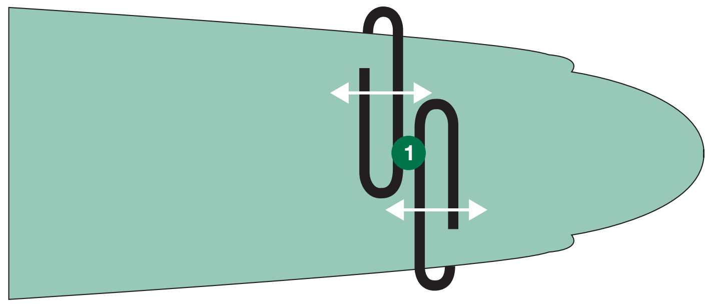
04 Provide clear plastic tape for attaching the vertical stabilizer.

05 Demonstrate how to stiffen the wings and bend the fuselage to form a v-shape. (The card stock paper will retain the curves.)

06 Explain that curling the wings stiffens them and may add some lift to the jets. Also, the upward curl of the fuselage forms a wide v-shape that provides roll stability to the glider. Clarify that roll is a circular motion perpendicular to the long axis of the glide, like tipping your head to one side or the other.

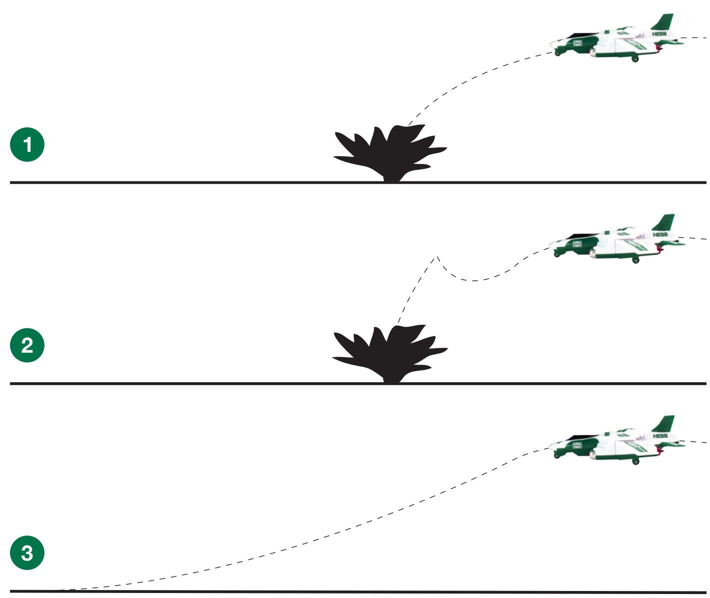
07 Have students test fly their gliders. At first, they will fly very poorly and crash. Explain that the gliders must be balanced to fly correctly. Advise the students to attach one or more small paperclips near the nose of the glider, then test again. **The objective is to have the glider fly a smooth sloping path to the floor**.

08 Tell the students the location of the paperclip will also affect how well the jet flies. Ask them to move the clip(s) forward or backward on the nose to see how the placement affects the flight. (See diagram top right.)



1. Paperclip placement on jet nose. (Move forward or backward as needed.)

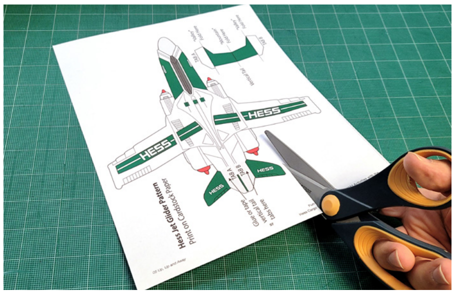
09 For trouble shooting, refer to the following steps.
   - **If glider nose dives and crashes**: Move paperclip back slightly and try again.
   - **If glider nose pitches up and falls to the floor**: Move the paperclip forward and try again. Check the symmetry of the wing bends, the v-shape of the glider and how straight the vertical stabilizer is mounted at the tail. (See diagram below.)



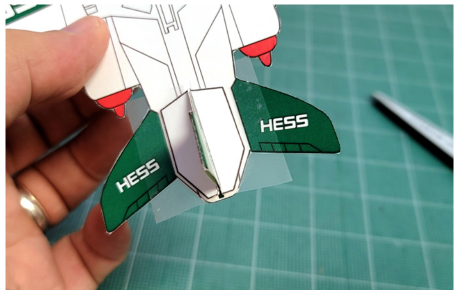
1. Nose heavy: **Jet dives and crashes**.
2. Nose light: **Jet stalls and crashes**.
3. Nose weight just right: **Jet flies smoothly**.

// Hess Jet Glider Preflight Preparation

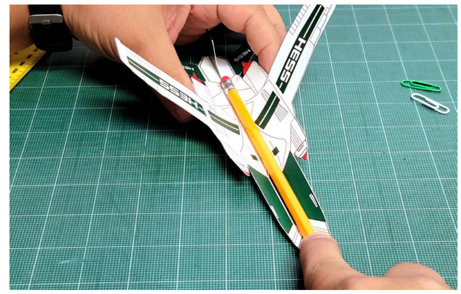
Instructions



1.
Print the Hess Jet Glider pattern on cardstock, then cut out the body and vertical tail.

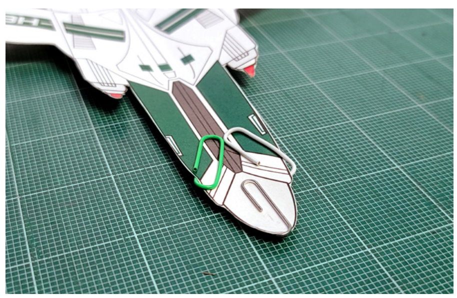


2.
Using clear tape, attach the vertical tail to rear of the glider. Trim off any excess tape.



3.
Curl the fuselage upward along the center of the glider to form a slight V shape, this adds strength and roll stability.

4.
Curl the leading edges of the wings slightly downward to give them an airfoil shape.



5.
Experiment with various combinations of paperclips to add weight to the front of the glider as needed to achieve the best flight performance.

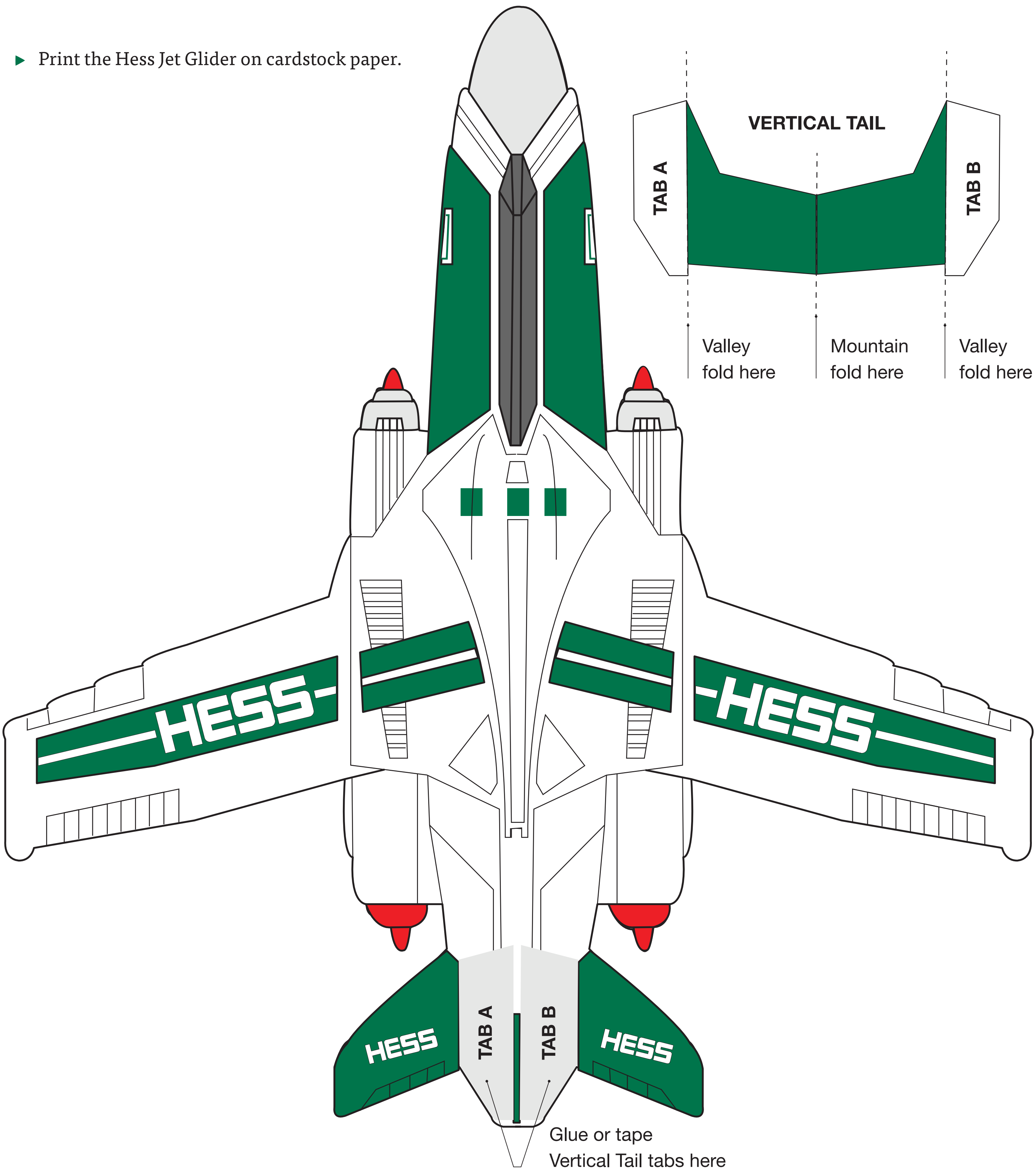
6.
When performing flight tests, find an open space that will allow for long flights such as an empty hallway or gymnasium.

Tips

- On step 3, use something like a pencil to help curl the body and wings.
- On step 6, hold the glider from the front. Throwing it like a dart seems to work well when performing flight tests.
- Wear eye protection for flight tests.

// Hess Jet Glider Pattern

- Print the Hess Jet Glider on cardstock paper.



Wrap It Up

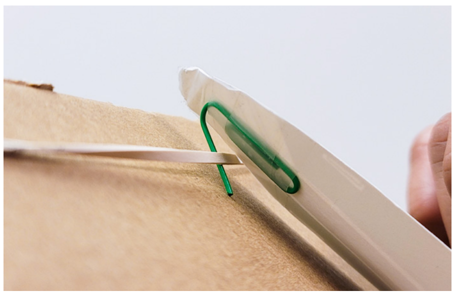
There are four primary forces affecting the flight of airplanes: thrust, drag, lift and weight.

- In a full-size version of the Hess Jet, the jet engines produce the **thrust**, propelling the jet forward. In the glider, thrust is provided by throwing the glider.
- **Drag** (friction) opposes thrust. Drag is caused by friction of the airplane surfaces with air. To fly forward, the force of thrust must be greater than the force of drag.
- **Lift** is the force that elevates an airplane off the ground. As a plane is being pushed forward by engines or a throw, air flows around the airplane, exerting an upward force to raise it and keep it off the ground.
- **Weight** is a downward force caused by gravity. In order to fly, an airplane must produce more upward lifting force than the force of gravity pulling it downward. In horizontal flight, the forces of lift and gravity are balanced.

// A full-scale version of the jet, with functioning engines might be capable of flight. How do we know? This is where science and engineering come in.

// Making a Launcher for the Hess Jet Glider

Extensions

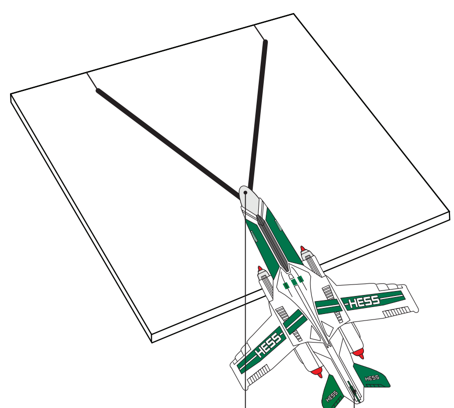


- **Hold a discussion where students can share ideas** about how the jet paper model can be improved. Provide more copies of the cardstock jet so students can test their ideas.
- **Have students make a launcher for their gliders.** (See instructions and diagrams below.)
  - **01** Bend a paperclip into a hook (Diagram A).
  - **02** Rebalance nose paperclip to make a smooth flight.
  - **03** Attach the paperclip(s) to the bottom of the glider near the nose.
  - **04** Make a launcher from a piece of cardboard and a lightweight rubber band. Cut two slots in the cardboard and loop the rubber band through them, so that the glider hook can hook on to the rubber band. Pull back, aim and let go (Diagram B).
  - **05** Hold a Hess Jet Glider flight distance competition. *Whose glider flew the farthest?* Have students investigate why different gliders flew different distances.
- **Build a wind tunnel.** (See the following page.)

DIAGRAM A

Bend this end of the paperclip down at a right angle to form a hook. Then, tape the end to the bottom of the jet near the nose so that the hook hangs downward.

DIAGRAM B



Hold the jet by its tail, pull back, aim and release.

Hook the paperclip taped at the bottom of the jet on to the rubber band.

// Constructing a Rudimentary Wind Tunnel

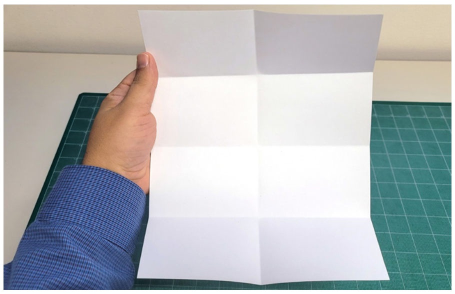
Construct a rudimentary wind tunnel with a desk fan, cardstock, string and the paper jets. Wind tunnels are used to test aerodynamic designs in aviation. In this extension, we will construct a rudimentary wind tunnel to test the flight stability of the Hess Jet Glider. **When stacked and taped together, the partitions are intended to straighten the whirling air flow from the fan**. Test the flight stability of the glider by placing it in front of the fan, both with and without the wind tunnel. Observe the results.

Materials

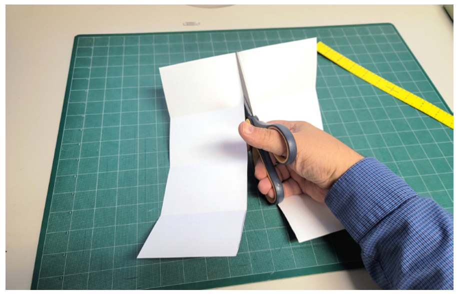
PER CLASSROOM

- 1 desk fan
- 8 sheets of cardstock
- Cardboard (12 x 12 in)
- Clear tape
- Paperclips (assorted sizes)
- Thin string, dental floss or sewing thread

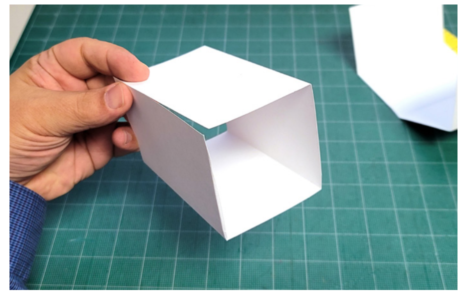
Instructions



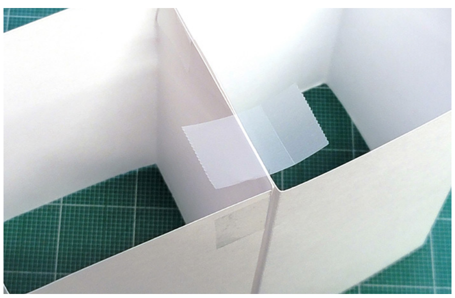
1.
Fold 6 letter-sized sheets of cardstock into 8 segments as shown in the photo above.



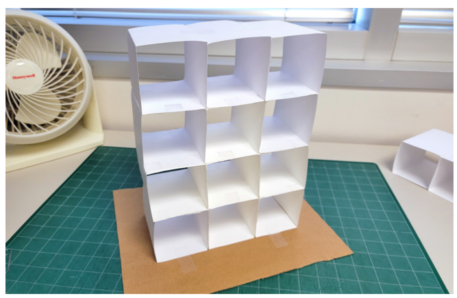
2.
Cut each sheet in half along the vertical seam, creating a pair of tunnel partitions.



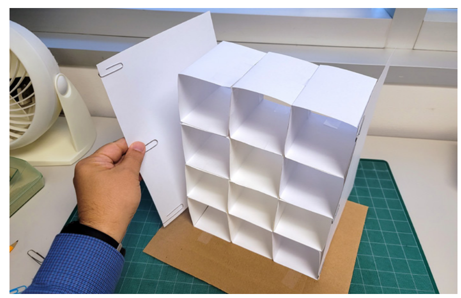
3.
Fold each tunnel partition into a box shape and tape the joining edges together.



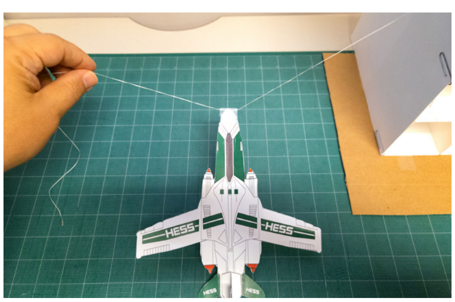
4.
Combine your 12 tunnel partitions into a 3x4 grid using tape to secure them to each other.



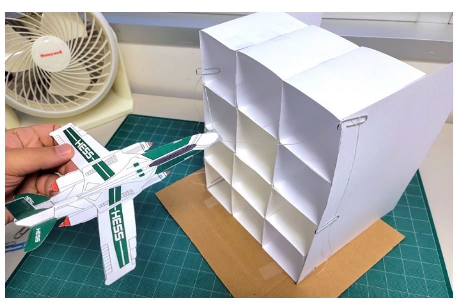
5.
Tape your wind tunnel grid to a large piece of cardboard to use as a base.



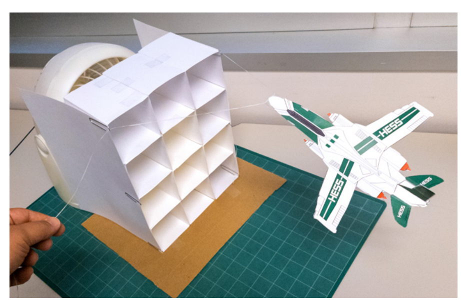
6.
Attach the other 2 pieces of cardstock to each side of the wind tunnel using paperclips.



7.
Find the halfway point of the string and attach it to the front nose of the glider with tape.
Tip: You may need to use 2 pieces of tape for strength.



8.
Attach the ends of the glider string to the 2 top paperclips on each side of the wind tunnel and center the glider to the front.



9.
Place the fan behind the wind tunnel and turn it onto its highest setting.
Tip: Adjust the length of the string on each side of the glider if necessary, to improve flight stability.

06

Thinking Inside the Box

Suggested Grades **3–8**

Suggested Grades **3–8**

// 06 Thinking Inside the Box

The Question

How did the Hess Toy Company get the Hess Cargo Plane and Jet to fit inside the box?

Where's the STEM

The COVID-19 pandemic brought many changes to our daily lives. One of those changes is our new reliance on home delivery of goods. Every imaginable product has been stuffed into boxes, taped shut and shipped all across the country and the world.

Trucks, trains and cargo planes, like the Hess Cargo Plane, move goods from factories to central receiving locations where they are divided, packaged and shipped to customers. Packages get handled, stacked and transported many times before they arrive to their final destination.

All of this handling and shipping can be rough on the goods inside. Crushed boxes can shatter and break items, which then have to be sent back to the manufacturer for a refund of money to the customer. This is an expensive problem for manufacturers and shippers.

Fortunately, STEM skills can solve the problem. The shipping cartons used for the Hess Cargo Plane and Jet are an excellent example of science, technology, engineering and mathematics at work!

Knowing the size of the carton and the proposed size of the Cargo Plane, designers had to come up with unique approaches to the construction of the plane. Because the wings and tail section were too large to fit in the box, the designers made them removable, adding straps to hold them to the plane for easy snap assembly. The landing gear was also designed to fold into the plane. This creative engineering turned the plane into a cylinder shape that slides into the box. A small cardboard tray holds the plane tightly in the box to keep it from rattling around during shipping.

What did they do to get the Jet to fit inside the Cargo Plane? This issue was solved by adding hinged wings, a tail section and landing gear that fold to fit snuggly around the fuselage. A well in the front of the plane's cargo bay, which creates space for the nose of the jet, allowing the entire jet to fit inside.

All of these design innovations required extensive measurements to make everything fit. The result is a streamlined carton made of rugged cardboard, with planes inside protected from rough shipping and handling.

In this activity, **student teams will be presented with the shipping box and the Hess planes and be asked to fit the planes back into the box**. As an extension, students can be challenged to design shipping boxes for other Hess holiday trucks.

Materials

PER TEAM OF STUDENTS

- Hess Cargo Plane and Jet
- Hess Cargo Plane and Jet Shipping Box (and the packing material that came with it)
- Ruler or measuring tape marked in cm. (The ruler students made for Activity 03 can be used.)
- Paper and pencil or markers
- 1–4 small paperclips (as needed by student)
- Student page
- Miscellaneous packing materials found around the school. (See suggested list in Procedure Part 2.)
- Raw small egg inside a small plastic snack bag

Management Tips

- Keep the boxes hidden until the activity begins. Hold up the Cargo Plane, Jet and the Shipping Box and tell students that is their job to make the planes fit inside.
- Have students work in teams of 2–4 individuals for this problem-solving activity.

Procedure Part One

01 Discuss some of the changes in our daily living caused by the COVID-19 pandemic. Examples include having merchandise, such as groceries or home products, shipped to your home. *Has anyone had a bad experience with shipping—for example, crushed or torn boxes, broken or damaged contents or packages left out in the rain*?

02 Have teams place their Hess Cargo Plane and Jet on a tabletop. Show one of the shipping boxes and explain that the two planes were shipped inside the box. *How was that possible*? Pause for discussion or comments.

03 Hand out and read over the student instruction page with students, pass out the boxes the Hess Cargo Plane and Jet came in and then let the teams of students go to work.

04 Students will be calculating the volume of the interior of the shipping box. If needed, remind students about how to measure volume of a rectangular shape.

- **V=lwh** (volume = length x width x height).

05 After they have completed their work, have the teams present their solutions to fitting the Hess Cargo Plane and Jet inside the shipping box.

Procedure Part Two

01 Ask students to imagine themselves as packaging designers. Point out that all packages are intact and clean when they leave the factory. What happens to them during shipping is another matter.

02 Ask students for their ideas about how to protect the contents of a shipping box. List their ideas on the board. Explain that packaging designers need to verify that their designs work. *How could they do that*? (Examples include drop tests, vibration tests, or impact tests, in which something strikes the package.)

03 Challenge teams of students to design a package for a very fragile item, such as a raw egg. Give the teams a day or two to come up with a plan and gather materials to make an actual package for their egg. Remind teams that packages should be as small as possible to accomplish the task of protecting the egg. Large packages increase shipping costs and reduce the number of products that can fit inside a shipping container. The size of the package ideally should be small enough to fit inside the cargo area of the Cargo Plane.

04 Have students bring materials from home and provide materials available in your classroom. Examples of suitable materials include boxes, poster board, rubber bands, tape, cotton balls, foam packing materials and bubble pack.

05 Tell students that the package they create will be dropped from a height of at least 10 ft (3 m) onto a hard floor. A balcony, second floor window or a ladder will work. If using a ladder, invite the school engineer or some other staff member to the class to go up the ladder and conduct the drop tests. As an alternative, the package can be thrown in the air and allowed to fall onto a hard floor.

06 Before giving teams their eggs, place each egg in a plastic snack bag to control the potential mess if an egg breaks.

07 Drop test each team package twice. After testing, have teams open their package and see if their design was successful. Have students discuss which package design elements were most effective in protecting the eggs.

Wrap It Up

Review the reasons packaging is a significant issue for manufacturers, such as the Hess Toy Truck Company.

POTENTIAL ISSUES

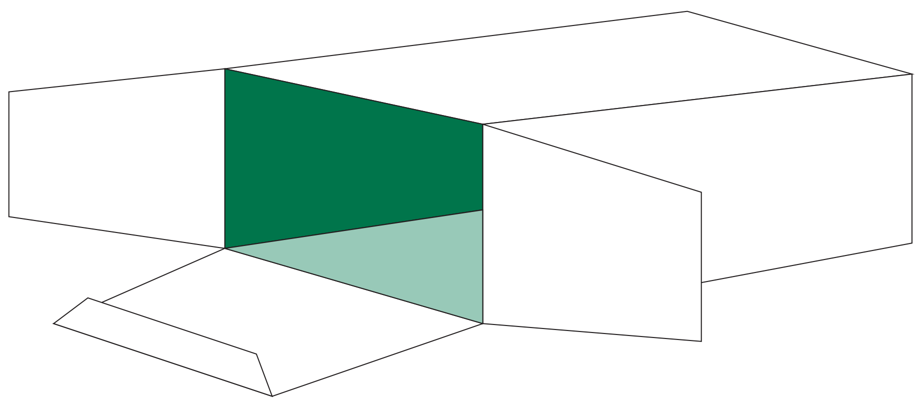
- The product must be protected in shipping. Broken products create extra costs to replace broken parts or provide refunds to customers. Scratches reduce the value of the product.
- Large boxes require more packing material than small boxes, raising the cost of packaging.
- Shippers charge more for large boxes than small boxes.
- Shippers weigh packages and charge more for heavier boxes. Large boxes require more packing material, which increases their weight and cost more to store in warehouses.
- Environmental issues include box size and the kinds of materials used for packing. Larger boxes use more materials. Larger boxes also call for the the use of more pallets and more shipping containers, which require more fuel to ship. Use of more fossil fuels can create more pollutants. Thus, the smaller the box, the better it is for the environment.

> Trucks, trains and cargo planes, like the Hess Cargo Plane, move goods from factories to central receiving locations where they are shipped to customers.

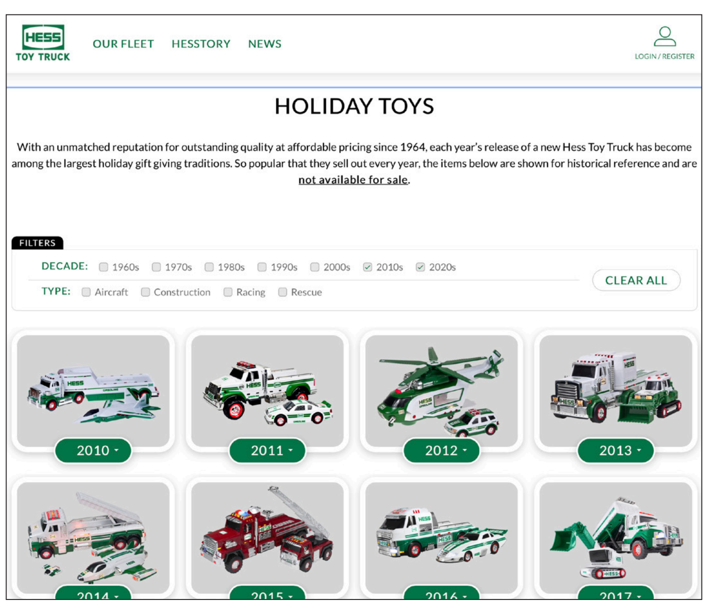
// Engineer a Shipping Box

Extensions

- Every year more than 1 million new Hess Toy Trucks are sold in the United States. The factory that builds the trucks packs a dozen trucks in each master container. The master container is a large cardboard box that provides extra protection for shipping. **Challenge teams to estimate the size of one master container** that would snuggly hold 12 Hess Toy Trucks in their individual boxes.
  - The answer will be approximately 30 by 24 by 15 in (76 x 62 x 38 cm).
- When toys are shipped to customers, they are packed in individual mail order boxes. These boxes are specially designed to protect the green box and the Hess Toy Truck inside. Each box has air buffers at each end to avoid damage from dropping. **Consider having students design individual mail order boxes** to protect an single boxed Hess Truck during shipping.



- **Select another truck model from the Hess website** (https://hesstoytruck.com/holiday-toys/) and decide what you must do to make your chosen truck fit in a Hess Shipping Box. Make sketches of the truck and how you will pack it. Describe your plan.

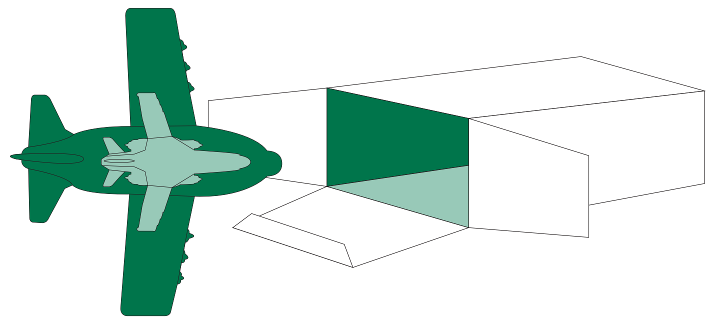


// Box It Up

NAME ______________________ **DATE** ______________________

Instructions

01 Measure the inside of the Hess Box. Include your units of measurement.



- ▶ Length
- ▶ Width
- ▶ Height

02 Calculate the total volume of the box. (Volume = length x width x height.)

- ▶ Volume

03 *Will the Hess Cargo Plane and Jet fit in the box?*

- ▶ Yes
- ▶ No

04 The Hess planes actually fit in the box. Figure out how to pack the planes in the box and then pack them. *What did you have to do to make them fit?*

// Glossary

Terms

ACCELERATION
Acceleration is the rate of change of speed of an object.

AILERON
Flaps found at forward wing tips that move up or down to steer the airplane. The ailerons work opposite to each other—one up and the other down.

CARGO
The cargo is the load of emergency supplies, vehicles and passengers carried by an airplane.

CONTROL SURFACES
Control surfaces is the general name applied to the moveable surfaces on the wings and tail. These include ailerons, elevators, elevons, flaps and rudder.

DRAG
The force of friction on the surface of an airplane that works against its forward motion. Drag works in opposition to thrust.

ELEVATOR
Small flaps on the horizontal stabilizers at the tail of the airplane that move up or down together to enable the plane to climb or descend.

ELEVON
Flaps on the wings of some jet planes that combine the functions of ailerons for steering and elevators for climbing or descending.

FLAP
Flaps are located next to the fuselage of an airplane on the forward wings. They tilt downward during takeoff and landing approach to increase the lift of the airplane at lower speeds.

FUSELAGE
The fuselage is the tubular body of the airplane from its nose to its tail.

GLIDE SLOPE
The glide slope is the angle with the ground when an airplane is coming in for a landing.

HORIZONTAL STABILIZER
The horizontal stabilizer consist of two small horizontal wings at the tail of an airplane. They contain the elevators of the airplane to maintain horizontal flight or to adjust to climb or descend.

LIFT
An upward force that lifts an airplane off the ground and keeps it airborne. Lift works in opposition to weight.

NEWTON'S SECOND LAW OF MOTION
The second law addresses the relationship of force, mass and acceleration. Force equals mass times acceleration.

NEWTON'S THIRD LAW OF MOTION
For every action (force) there is an opposite and equal reaction (force).

PALLET
A platform for holding stacked payload to be loaded on to a cargo plane.

PAYLOAD
Payload refers to the amount of materials, objects or passengers being carried by a vehicle, such as an aircraft. In this Guide, the terms payload, load and cargo are used interchangeably to describe the number, volume or weight of objects that can be held inside the large storage compartment of the Hess Cargo Plane.

PITCH
Pitch is the up or down movement of the nose of an airplane that occurs during climbing or descending. Pitch is initiated by the pilot pulling back or pushing forward on the control stick or yoke.

ROLL
The tilting of the plane to the left or right during turning. Roll is initiated by the pilot adjusting the control stick or yoke.

RUDDER
The rudder is a vertical flap on the vertical stabilizer that controls yaw motions.

STALL
Stalls occur when the plane looses lift and falls from the sky.

STICK
The stick is an upright control that the pilot straddles. It is used for controlling the different motions of an airplane. Sticks are generally used in high-performance airplanes.

THRUST
The forward push on an airplane produced by its engines. Thrust works in opposition to drag.

VERTICAL STABILIZER
The vertical stabilizer is an upright fin at the tail of an airplane that controls yaw motions.

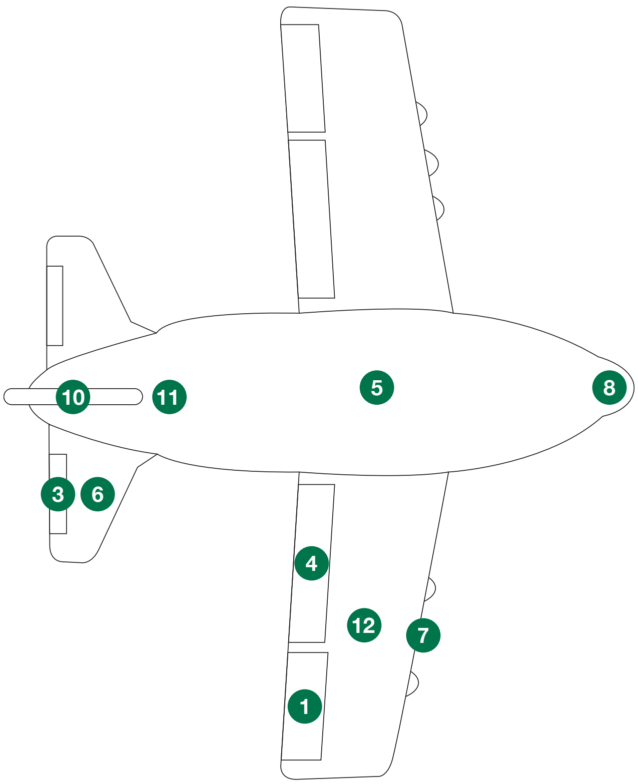
WEIGHT
The total weight of an airplane and its load due to the pull of Earth's gravity. Weight works in opposition to lift.

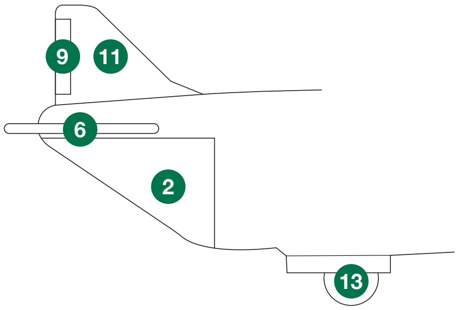
YAW
The sideways movement of the nose and tail of an airplane due to drag and cross winds. Yaw is controlled through small counter movements of the rudder.

YOKE
The yoke is the airplane version of an automobile steering wheel.

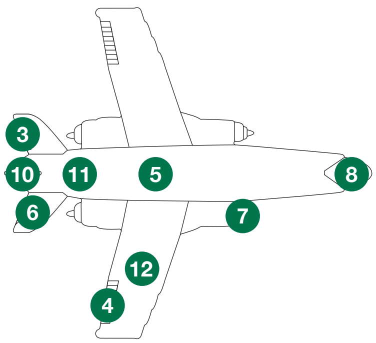
Airplane Parts

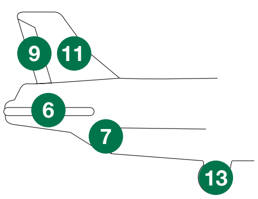
CARGO PLANE





JET





LEGEND

1. Aileron
2. Cargo doors
3. Elevator
4. Flaps
5. Fuselage
6. Horizontal stabilizer
7. Jet engines
8. Nose
9. Rudder
10. Tail
11. Vertical stabilizer
12. Wings
13. Wheels