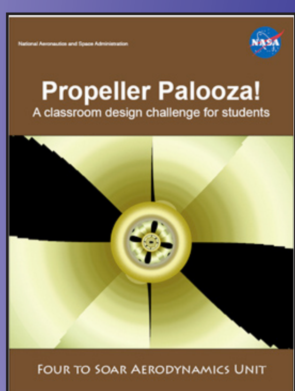
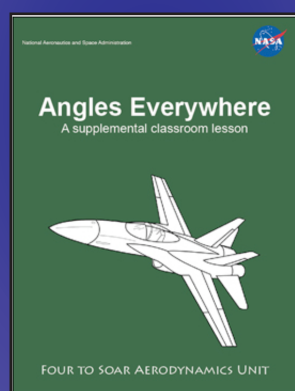
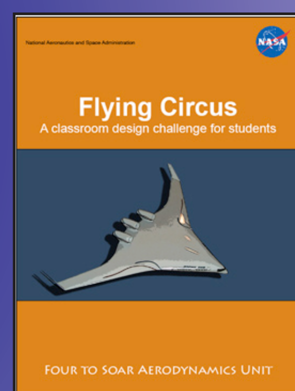
National Aeronautics and Space Administration

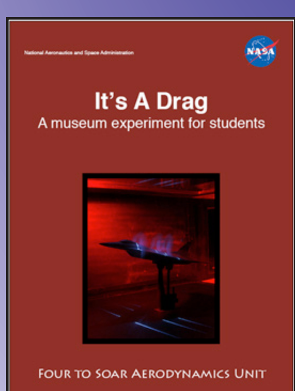
Four to Soar

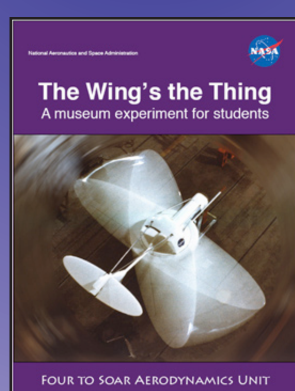
Aeronautics Field Trip Resources for Museums and Science Centers











Acknowledgements

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Four to Soar

Overview

Four to Soar is an aerodynamics unit designed to be integrated with a field trip to an aviation museum or science center. It is composed of five major activities intended for classroom and/or museum use:

- ***Propeller Palooza*** (pre-visit classroom design challenge)
- ***It's a Drag*** (museum inquiry activity)
- ***The Wing's the Thing*** (museum inquiry activity)
- ***In Thrust We Trust*** (museum inquiry activity)
- ***Flying Circus*** (post-visit classroom design challenge)

A sixth activity, ***Angles Everywhere*** (optional classroom lesson), provides a basic understanding of angles and angle measurement for students who have not yet used a protractor to measure angles.

Four to Soar was developed in partnership by the Hiller Aviation Museum in San Carlos, California and the NASA Ames Research Center at Moffett Field, California. Its purpose is to promote student understanding of and excitement about aeronautics, inquiry, engineering design, and the many career opportunities that use science, math, and engineering skills.

The classroom-based pre- and post-visit activities provide students with open-ended engineering challenges that have multiple solutions. These challenges are specifically designed to engage students in hands-on, constructivist design in a creative, non-linear fashion—in the same way that real engineers design their solutions. Students are provided with a variety of materials to try out and are given time to work with a team of classmates to build, test, and revise a number of solutions. In the process, they learn from failure and develop persistence and creativity as they apply scientific concepts to a real-world problem.

The museum activities focus on the scientific inquiry process. Each concentrates on one of the four forces of aeronautics as students conduct experiments to measure how changing a variable affects the force in question. Students learn to control variables, improve accuracy by conducting multiple tests, and draw conclusions from their collected data. These conclusions are then applied to their final classroom design challenge.

Although designed as a unit, the individual activities in ***Four to Soar*** may be presented as stand-alone experiences, and the museum activities may be implemented in a traditional classroom setting. Regardless of the setting and context, ***Four to Soar*** uses aviation to provide a springboard into math and science learning.

Structure

Lesson	Location	Main Concepts	Objectives
Propeller Palooza	Classroom Pre-Visit	• Engineers must make tradeoffs when designing aircraft to overcome weight and drag. • NASA researchers use the engineering and the scientific design and experimentation processes when creating new aircraft technologies. • Unbalanced forces are required to change an object's motion.	Students will understand: • how to apply the engineering design process. • the importance of reproducibility and reliability. • that experimentation often involves non-successful trials and that useful information is learned from these trials. • that different materials and the shapes and sizes of propellers affect the distance (or amount of thrust) of an aircraft. • that unbalanced forces cause an object's motion to change.
Angles Everywhere *(optional)*	Classroom Pre-Visit	• An angle is formed by two lines sharing a common endpoint. The opening between these two lines is measured in degrees using a protractor.	Students will: • know the components of an angle. • identify angles. • measure angles with a protractor.
It's a Drag	Museum	• Scientific progress is made by asking meaningful questions and conducting careful investigations. • A force has both direction and magnitude.	Students will understand: • how the extension of landing gear affects drag.
The Wing's the Thing	Museum	• Scientific progress is made by asking meaningful questions and conducting careful investigations. • A force has both direction and magnitude.	Students will understand: • how an airfoil generates lift. • how the angle of attack of an airfoil affects lift.

Lesson	Location	Main Concepts	Objectives
In Thrust We Trust	Museum	• Scientific progress is made by asking meaningful questions and conducting careful investigations. • A force has both direction and magnitude.	Students will understand: • how the angle of a propeller blade affects thrust.
Flying Circus	Classroom Post-Visit	• Engineers use the engineering and the scientific design and experimentation processes when creating new aircraft technologies.	Students will demonstrate mastery of: • application of the four forces of flight to aircraft design. • how to apply the engineering design process. • the importance of reproducibility and reliability. • experimentation as a means of learning from non-successful trials.

Educational Standards

This unit was designed with both NASA's national audience and Hiller Aviation Museum's California audience in mind. Therefore, the lessons meet both the national education standards and the California state education standards.

Education Standards for All Lessons Except "Angles Everywhere"	
California Science Content Standards	*National Science Education Standards*
Grade 5 • Investigation and Experimentation: 6e, 6f, 6g, 6h Grade 6 • Investigation and Experimentation: 6b Grade 7 • Investigation and Experimentation: 7a Grade 8 • Forces: 2a, 2c, 2d, 2e • Investigation and Experimentation: 9a, 9b, 9c, 9e, 9f	Grades 5–8 Science and Technology, Content Standard E • Abilities of Technological Design: a, b, c, d, e • Understanding About Science and Technology: d, e Physical Science, Content Standard B • Motions and Forces: b, c

Education Standards for "Angles Everywhere"	
California Math Content Standards	*National Math Education Standards*
Grade 5: Algebra and Functions: 1.1 Grade 5: Measurement and Geometry: 2.1 Grade 6: Measurement and Geometry: 2.1 Grade 7: Measurement and Geometry: 3.1	Grades 6-8: Measurement: c Grades 6-8: Geometry: b

Information for Museum Educators

Four to Soar is intended as a series of design and inquiry activities that begin and end in the classroom but that build from key exploratory activities provided during a field trip at a local aviation museum or science center. The museum/science center activities make the four forces vividly concrete and facilitate future classroom exploration after the conclusion of the field trip. The ideal sequence is as follows:

- ***Propeller Palooza*** pre-visit classroom design activity (with *optional* ***Angles Everywhere*** pre-lesson)

- Field Trip Experience, to include:
  - ***It's a Drag*** inquiry activity
  - ***The Wing's the Thing*** inquiry activity
  - ***In Thrust We Trust*** inquiry activity
  - Museum-specific tours or programs related to flight

- ***Flying Circus*** post-visit classroom design activity

Each activity can stand alone in either the classroom or museum environment, but when presented in sequence they provide a solid introduction to the forces of flight and their application in aviation.

Most field trips will not expose every child to every inquiry activity. Instead, the children are divided into two or more groups and each group investigates one force of flight. A typical schedule might be as follows:

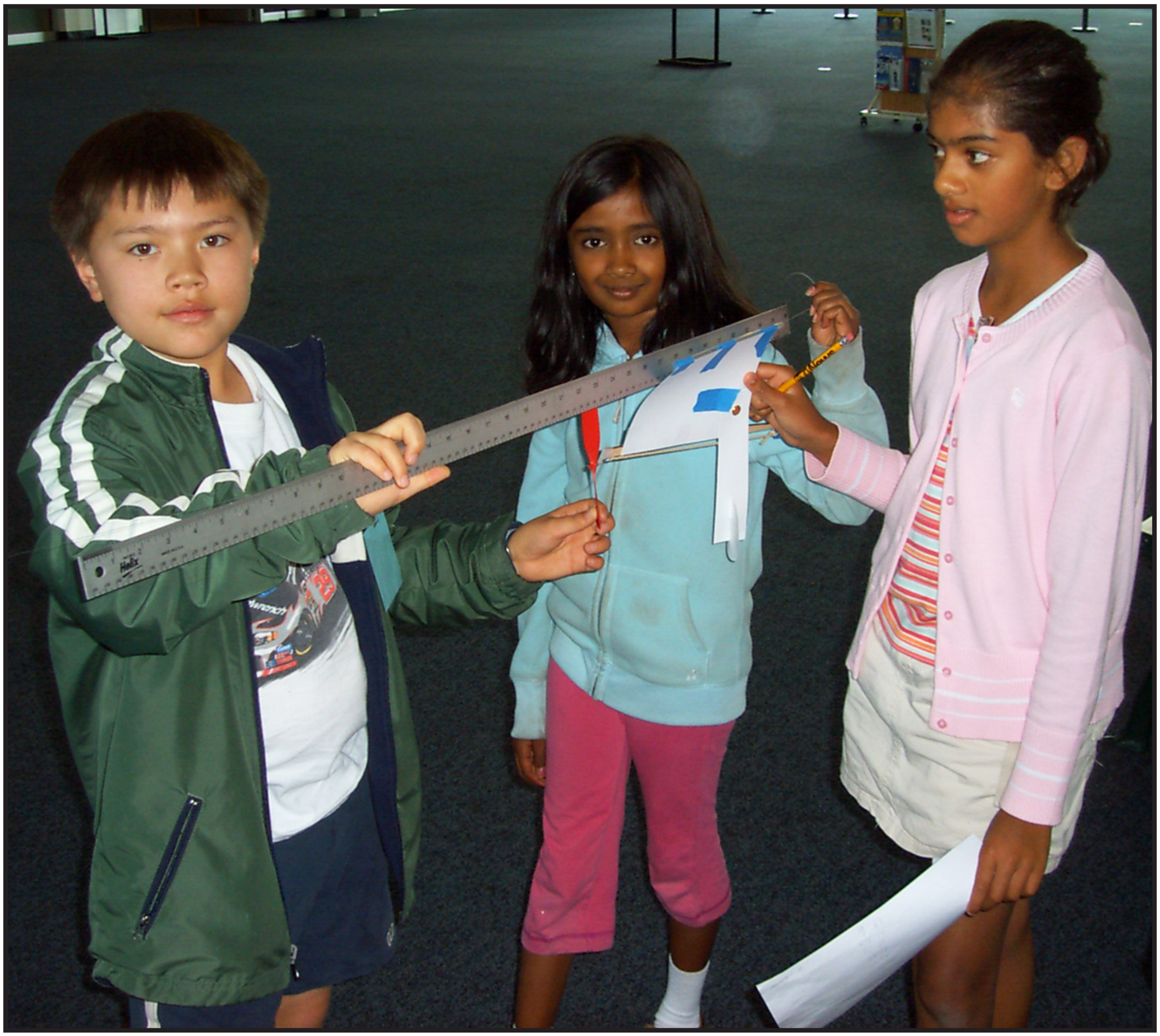
15 minutes	Arrival and orientation
15 minutes	Introduction to the Four Forces
45 minutes	Inquiry activity
15 minutes	Idea sharing
45 minutes	Gallery tour or other museum-specific experience
2 hours 15 min	Total program time

Anywhere from one to three inquiry activities may occur at one time, and at least one teacher or teaching docent is required for each. Additional docents (provided by the facility) and/or chaperones (provided by the visiting group) are extremely desirable due to the hands-on nature of the activities.

At most facilities, a tour of exhibit galleries can be tailored to reinforce the learning experience. Tours may be docent-led or self-guided and will be specific to the resources the host facility has available. Some facilities may also be able to provide other related activities such as large-format film presentations or auditorium-based demonstrations. ***Four to Soar*** can be matched with many of these experiences to provide a field trip that draws on the unique resources of each host facility while also delivering consistent inquiry activities.

Equipment for the drag, lift, and thrust activities must be purchased, procured, and/or fabricated prior to implementation. The batteries used to power the thrust car must be periodically replaced, and lab sheets for data collection are required. Materials lists and lab setup instructions should be reviewed well in advance to ensure that all necessary items are available and ready prior to use.

Gallery tours used in conjunction with this program can be enhanced by integrating concepts and key words from the inquiry activities into each school group's tour and by posing questions to the students during the tour. Tour leaders should be advised of the inquiry activities scheduled for each group, whether those activities were completed before the tour or will follow after, and also whether or not the group completed the school-based pre-visit activity. This will help ensure the best possible experience for each group.



Information for Classroom Teachers

Four to Soar is intended as a series of design and inquiry activities that begin and end in the classroom but that build from key exploratory activities that take place at a local aviation museum or science center. The museum/science center activities make the four forces vividly concrete and facilitate future classroom exploration after the field trip. The ideal sequence includes:

- ***Propeller Palooza*** – a pre-visit classroom design challenge focused on the engineering design process and introduction to forces. This activity promotes student excitement about aeronautics by providing a real-world engineering problem to tackle along with some knowledge to build on at the museum/ science center.
- ***Angles Everywhere*** – an optional pre-visit classroom lesson about using protractors to measure angles. (Students will use protractors in all the museum activities, so engaging them in this lesson will ensure that their field trip learning experience is maximized).
- Field Trip Experience, to include up to three inquiry activities in which students use the inquiry process and learn more about the four forces and how to maximize or minimize their strength for optimal flight:
    - ***It's a Drag*** inquiry activity
    - ***The Wing's the Thing*** inquiry activity
    - ***In Thrust We Trust*** inquiry activity
    - Museum-specific tours or programs related to flight allowing students to immediately apply some of their new knowledge
- ***Flying Circus*** – a post-visit classroom design challenge assessment with an optional culmination for an Air Show Family Night. This activity asks students to apply all of the inquiry and engineering design skills and aeronautics concepts they learned in the other activities to demonstrate their learning for each other and for their families.

Each activity can stand alone in either the classroom or museum environment, but when presented in sequence and in their entirety, they provide a solid introduction to the forces of flight and their application in aviation. The optional culminating air show is a powerful way to increase family engagement in their children's learning and to increase student confidence as they share what they have learned.

Each activity requires specialized equipment that is easily constructed from kits or readily-available items. Instruction for the construction of each device is included in the individual activity plans.

Aeronautics Background Information

This section provides detailed background on the main aeronautics concepts covered in this unit and provides the overall context for the educators teaching it. Some information is repeated in the Background sections of the actual lessons in which these concepts are taught. This section also includes information on NASA's role in aeronautics that can be shared with students.

The Principles of Flight

Look at the picture below. The combined weight of the space shuttle and the modified 747 is over 500,000 kilograms (over 1,100,000 pounds)! A passenger 747 can easily fly from California to Florida on one tank of fuel, but with the shuttle flying piggyback, it takes two stops on the way! How can something so enormous fly? For an airplane to fly, four basic forces are at work: weight, lift, thrust, and drag.

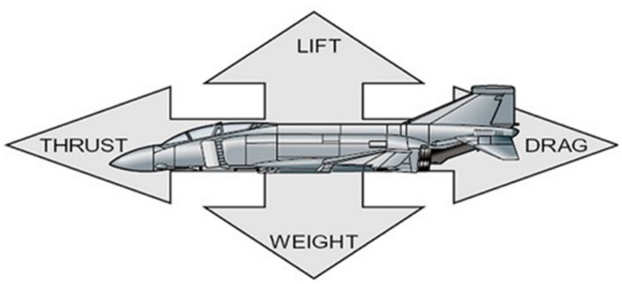
NASA Dryden Flight Research Center Photo Collection
http://www.dfrc.nasa.gov/gallery/photo/index.html
NASA Photo: EC02-0131-10 Date: June 28, 2002 Photo by: Jim Ross
The Space Shuttle Endeavour, mounted securely atop one of NASA's modified Boeing 747 Shuttle Carrier Aircraft, left NASA's Dryden Flight Research Center at Edwards Air Force Base in Southern California at sunrise on Friday, June 28.

The First "A" in NASA

Many forget that the first "A" in NASA stands for "Aeronautics"! The National Aeronautics and Space Administration (NASA) is well known for its exploration of space; however, NASA also plays a significant role in designing new technologies that benefit air travel.

The following aeronautics information and images were adapted from the NASA *Virtual Skies* Aeronautics section. Additional information can be found on this web site at http://virtualskies.arc.nasa.gov.

The Four Forces



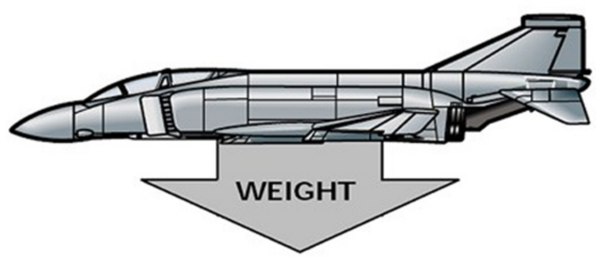
A **force** is most simply defined as a push or a pull. There are two components (parts) to a force: magnitude (or the amount of force applied) and direction. Thus we say, "a force of a certain magnitude is applied in a particular direction."

There are four primary forces that act on an airplane in flight: **weight, lift, thrust, and drag**. It is the interplay between these four forces that result in an airplane's motion.

Weight

All objects in the universe exert an attractive force on each other that is called **gravity**. The magnitude of this force is dependent on the mass of the object. In our day-to-day lives, this attractive force is noticeable only for objects with enormous mass, such as the Earth.

Weight is the word we use to define the attractive force between a planet like Earth and objects that are on or near its surface. People, airplanes, and helicopters all have weight that can be measured. The magnitude of Earth's gravity weakens as objects move farther away from it, but for objects *on* or *close to* the Earth's surface (even the highest airplanes fly at altitudes close to the Earth) their weight can be considered constant.

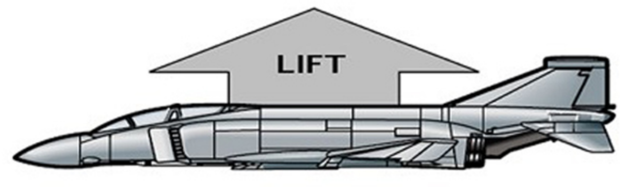


- All objects in the universe exert an attractive force on each other.
- The greater the mass, the greater the attraction.
- On Earth, gravity is the attraction between Earth and an object.
- Weight is how we measure the force of gravity.

Lift

Weight is the force resulting from Earth's gravity pulling on the airplane's mass.

Weight = Mass x gravitational acceleration



- Lift is a force that opposes weight.
- Lift is a force that pulls an airplane into the air.
- Lift is created by air flowing over the wings.

For objects on Earth, this equation becomes:

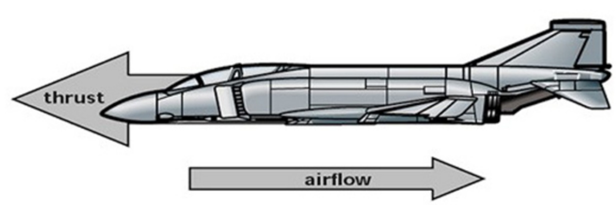
Weight = Mass x 9.8 meters per second per second

or

Weight = Mass x 32.2 feet per second per second

In order for an airplane to rise into the air, an upward force must be generated that is stronger than the weight. And, in order for an airplane to fly at a constant altitude, the upward force must balance the weight. This upward force is called **lift**. The lift force is generated by air flowing over the airplane. The direction of the lift force is roughly perpendicular to the direction the air is flowing. As an airplane flies, air flows over its wing, from the front (or leading edge) to the back (or trailing edge). This generates a lift force perpendicular to the direction of the airflow (in most cases, *up*). It is easy to understand that the shape of the wing will have a direct influence on *how* the air flows from front to back. In turn, *how* the air flows will have a direct influence on how much lift the wing can generate. As an airplane moves forward, its nose is pitched slightly upward into the oncoming airflow, forcing the wings to meet the air at an angle. The angle an airplane's wings make with the oncoming air is called the **angle of attack**. The angle of attack can be changed by pitching (moving) the airplane's nose up or down. This angle of attack has a direct influence on how much lift the airplane can generate.

Thrust

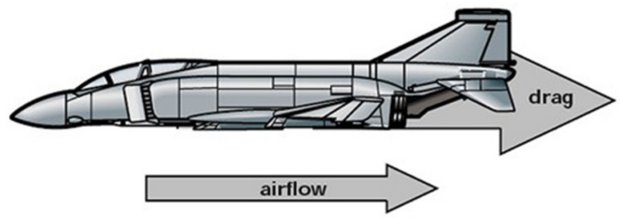


When an airplane is sitting on the ground and the weather is calm, there is no air flowing past the airplane and so no lift is created. Another force is needed to get the airplane moving through the air so that the airflow can do its job of creating lift. This needed force is called **thrust**. Thrust propels an object in a particular direction. The arm of a baseball pitcher generates thrust and applies it to a baseball by throwing it towards a batter. Likewise, a jet engine generates thrust, which is applied to the airplane. So, as the engines thrust the airplane forward, air flows over and under the wings and generates lift. If enough lift is generated, the airplane will fly.

- Thrust is a force that is generated by an airplane's engines.
- The direction of the thrust force is based on where the engines are pointed.
- Thrust is aligned with the direction of flight.
- Thrust is opposite to the direction of the airflow.

Drag

The fourth primary force is **drag**. Drag is the force that resists the motion of any object. The drag on an airplane is the result of the energy needed to move the air out of the way of the airplane and from the wing's creation of lift. Drag is hard at work when a massive object like an airplane flies through a fluid like air. Any motion or movement by the airplane will always be resisted by a drag force, and the faster the airplane moves the greater its drag will be. The direction of the drag force is opposite to the direction of flight.



Reducing drag is one of the main concerns of aeronautical engineers at NASA when they are designing aircraft. Drag has a domino effect on other important aspects of flight. An airplane with less drag can fly faster than one with more drag or can instead fly at the same speed using less fuel. If drag is reduced, then engines can be lighter and less powerful, using less fuel. Lighter aircraft, in turn, need less lift and can be more maneuverable. Reducing drag can reduce the cost to build and fly an airplane in many ways.

- Drag is a force that opposes thrust.
- Drag is a force that resists the movement of objects.
- Drag is generated by air not flowing smoothly across the surface of the aircraft.
- Drag is aligned with the direction of the airflow.

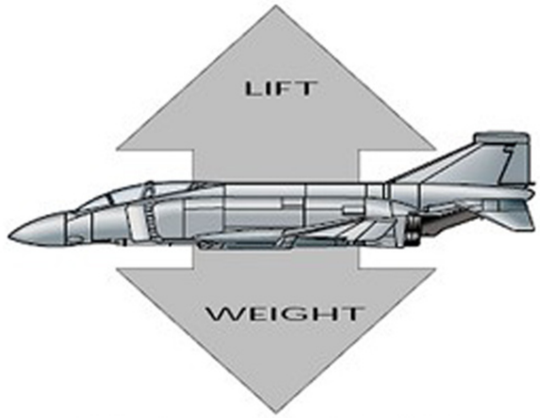
A Simple Model of Flight

A discussion of these four forces can get complicated. For grade levels 5–8, a simplified model of the four forces is best. This model does not take into account all the myriad of directions that an airplane can fly. For example, airplanes can climb, descend, turn and roll. Our model will make the assumption that the airplane is flying straight and level. That is, the thrust of the engines is propelling the airplane forward. Drag is resisting the thrust (forward push) and trying to slow the airplane down. Lift is lifting (pushing) the airplane up into the sky. Weight is trying to pull the airplane down toward the ground.

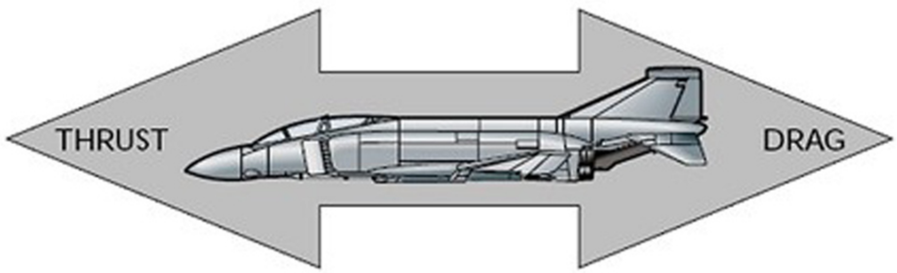
In this simplified model we say that thrust and drag are opposing forces (working against each other) and that lift and weight are opposing forces. Further, in this simplified model, we say that if lift is greater than or equal to weight and thrust is greater than or equal to drag, then an airplane will remain in flight.

The Four Forces in Balance

Let us look more closely at the interplay between the four forces. Recall that in our model, the four forces work in pairs: lift versus weight and thrust versus drag. When forces are in balance (their magnitudes are the same and their directions are opposite), the speed and direction of the object will not change.



Lift and Weight must be balanced
to maintain the same altitude.



Thrust and Drag must be balanced
to maintain the same speed.

Imagine an airplane flying along at its cruising speed and altitude. The wings create enough lift to counteract the weight of the aircraft and keep it at its cruising altitude. The engines create enough thrust to counteract the drag of the aircraft and keep it at its cruising speed.

Imagine that the lift force is increased. Now there is an imbalance between lift force and weight force, and the airplane will rise. Conversely if the lift force is decreased or if the weight of the aircraft is increased, then the lift force and the weight force will not be balanced and the airplane will descend.

In the same way, if the thrust force is increased, an imbalance is created and the airplane will increase its speed in the direction the thrust is directed. Similarly, if the thrust is decreased or if the drag is increased (say the flaps on the wings are extended), then the airplane's speed will decrease.

Thus, the task of a pilot is to manage the balance between these four forces – we call this flying!