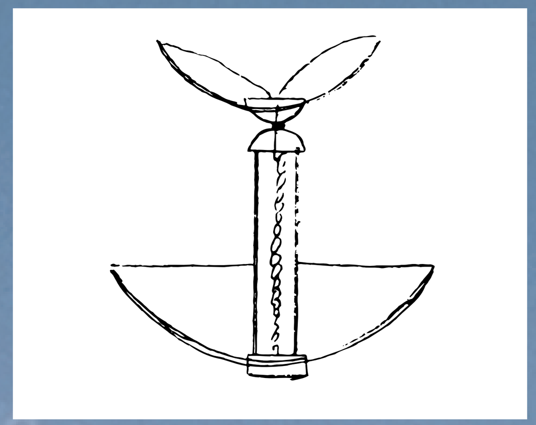
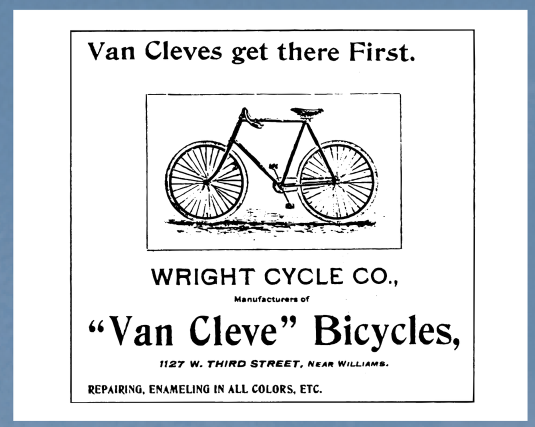
The Wright Way: The Process of Invention

1878



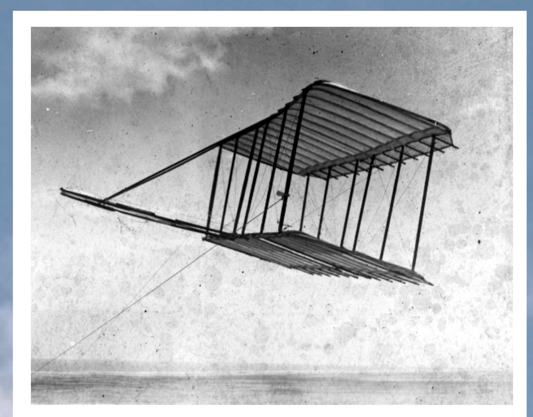
The Flying Toy: A small toy "helicopter"—made of wood with two twisted rubber bands to turn a small propeller—that the Wright brothers played with as small boys.

1892



The Bicycle Business: The Wright brothers opened a bicycle store in 1892. Their experience with bicycles aided them in their investigations of flight.

1900

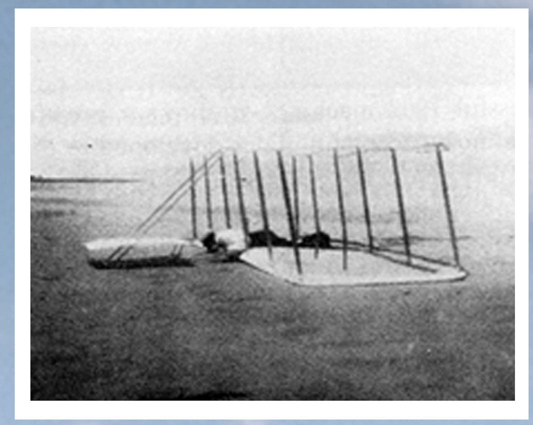


The Search for Control: From their observations of how buzzards kept their balance, the Wright brothers began their aeronautical research in 1899 with a kite/glider. In 1900, they built their first glider designed to carry a pilot.

Wilbur and Orville Wright
Inventors

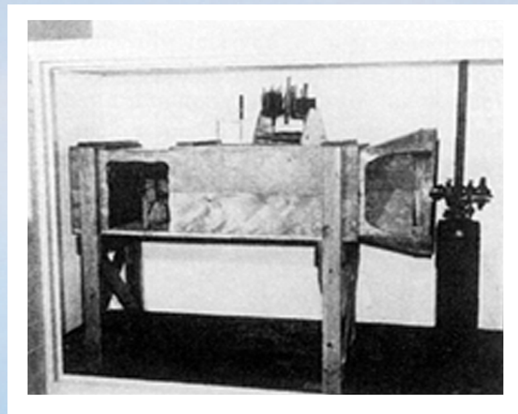
Wilbur and Orville Wright placed their names firmly in the hall of great American inventors with the creation of the world's first successful powered, heavier-than-air machine to achieve controlled, sustained flight with a pilot aboard. The age of powered flight began with the Wright 1903 Flyer on December 17, 1903, at Kill Devil Hills, NC. The Wright brothers began serious experimentation in aeronautics in 1899 and perfected a controllable craft by 1905. In six years, the Wrights had used remarkable creativity and originality to provide technical solutions, practical mechanical design tools, and essential components that resulted in a profitable aircraft. They did much more than simply get a flying machine off the ground. They established the fundamental principles of aircraft design and engineering in place today. In 1908, they demonstrated their flying machine publicly in the United States and Europe. By 1910, the Wright Company was manufacturing airplanes for sale. Despite the Wrights' dramatic jump ahead of the rest of the world aeronautical community, others quickly caught up to Wilbur and Orville Wright and surpassed their designs, which is the nature of science. They accomplished their goals by themselves. They relied on their own questions, hypotheses, experiments, research, observations, inferences, and conclusions. They tested and failed repeatedly. They endured disappointment and hardships to realize their dream of inventing a flying machine, the airplane. The Wright brothers did not just fulfill their goals but they ushered in a new era of air and space exploration.

1901



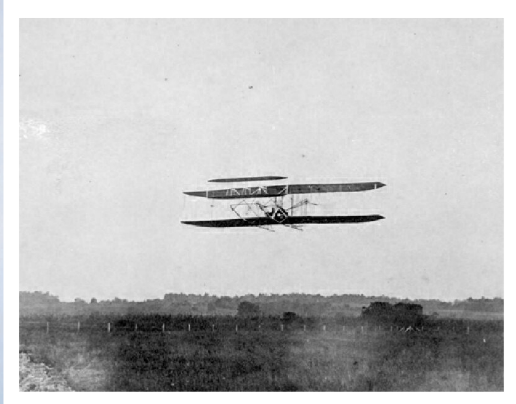
The 1901 Glider: The Wright brothers 1901 Glider enabled them to spend more time in the air and to uncover additional design problems.

1901



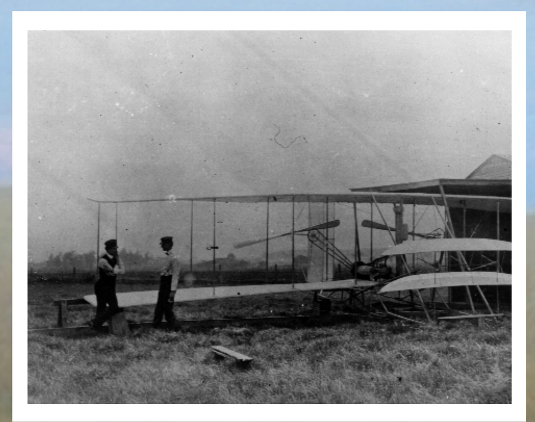
The Wind Tunnel: The Wrights tested small model wings in a wind tunnel that enabled them to calculate the wing shape and size that would be required to lift them into the air.

1905



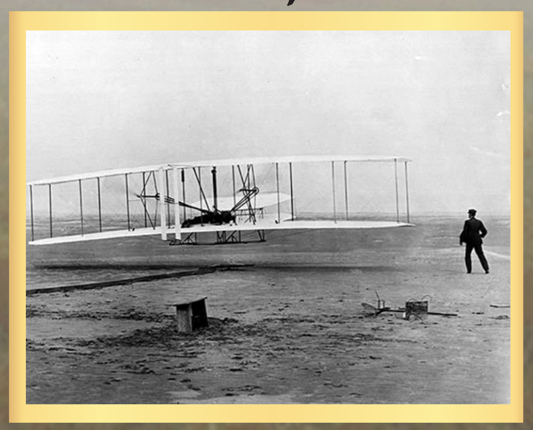
The Wright 1905 Flyer: This Flyer was the world's first practical airplane—a machine that could bank, circle, turn, and fly figure eights.

1904



The Wright 1904 Flyer: The Wrights' second powered airplane, flown at Huffman Prairie, achieved the first circular flight of an airplane. Stability was still a problem.

Dec. 17, 1903



The Solution: At Kill Devil Hills, NC, in the morning, the Wright 1903 Flyer became the first powered, heavier-than-air machine to achieve controlled, sustained flight.

1902

Controlling the Aircraft: The key to solving the control problem was the addition of a rudder to the glider design. This allowed the Wrights to develop a powered aircraft.

Huffman Prairie
Dayton, Ohio

CENTENNIAL OF FLIGHT
1903-2003

100th Anniversary of Powered Flight 1903-2003

Susan and Milton Wright

Celebrating a Century of Powered Flight

The Wright brothers turned their dreams into reality and revolutionized the world.

About The Poster

This poster was designed to honor the accomplishments of the Wright brothers, two brilliant, self-trained engineers from Ohio who designed, built, and flew the first power-driven, heavier-than-air machine in which humans made free, controlled, and sustained flight.

The centennial of powered flight presents a unique opportunity to focus on the historical significance of the aviation-related events leading up to, and following, December 17, 1903. More importantly, the 100th anniversary of flight will inspire a new generation of inventors, innovators, and dreamers. In the span of a single century, the vision, persistence, and ingenuity of many have taken us from the first powered flight on the sand dunes of North Carolina's outer banks to a permanent presence in space.

In honor of the 100th anniversary of flight, the U.S. Congress established the U.S. Centennial of Flight Commission. The Commission will encourage, enable, and amplify the efforts of all the organizations and individuals planning to celebrate the achievements of the Wright brothers and a century of powered flight by serving as a catalyst for activities and a central resource. The Commission is encouraging and promoting national and international participation in the commemoration of the centennial of powered flight by the public; educators and students; Federal, State, and local government officials; members of civic and cultural organizations; and members of the aviation and aerospace industry.

We invite you to visit the U.S. Centennial of Flight Commission's Web site *(www.centennialofflight.gov)* where you will find information about the Commission, the centennial of powered flight, and the history of aviation and aerospace. The site has been designed to be used by educators and their students, aviators, aviation enthusiasts, the media, and all organizations planning to participate in the celebration. The Web site also includes a calendar that provides information about upcoming events related to the centennial of flight, the history of aviation and aerospace, and aviation in general. A "Submit an Event" feature is available for event planners who wish to post information on the U.S. Centennial of Flight Commission's calendar. New information and resources will be added regularly to the site through December 2003.

To The Educator

The purpose of this poster is to help you inspire, educate, and encourage your students to learn about the Wright brothers, the celebration of the 100th anniversary of flight, and the history of aviation and aerospace. The classroom activities are designed to provide hands-on experiences for your students that relate to some of the scientific processes employed by the Wright brothers.

The resources listed throughout this poster will help you and your students locate additional information, educational products, and activities related to the Wright brothers and the history of aviation and aerospace.

A Few Questions to Get Your Students Started

The state motto of Ohio is "The Birthplace of Aviation." Why was that motto chosen? Where did the Wright brothers live? What did they do? When did they become interested in aviation? What did they do to further their knowledge about aviation? Read "The Wright Brothers' Story" on this poster to find out why the pictures on the front of this poster are significant.

Why is the State of North Carolina known as "First in Flight." Why did the Wright brothers travel from Ohio to North Carolina? How did they get there? How often did they go to North Carolina? How long did they stay? Where did they live? Were their machines transported from one State to the other, if so, how?

Although the States of Ohio and North Carolina are well known for early developments in aviation, many people from other States and countries around the world were thinking about flight, building aircraft, and conducting experiments before, during, and after the Wright brothers' involvement in flight. Who were these people? Where did they live? What contributions did they make?

Study your State's aviation and aerospace history. Discuss how the advances in aviation and aerospace during the past 100 years have affected you and your family. Imagine what changes will occur in aviation and aerospace in the next 100 years. Design a poster representing the history of aviation and aerospace in your State. Create a calendar with information about significant people, places, and historical aviation and aerospace events in your State. Share your poster and calendar with others in your school, community, or State. Send an electronic copy of your poster and your calendar to the Centennial of Flight Commission's Web site *(centennialofflightadmin@hq.nasa.gov)*. Plan your own centennial of flight celebration. If your event meets the criteria for inclusion on the Commission's calendar, complete and submit the electronic form found on the Centennial Web site.

History and Nature of Science

What is the nature of science? When do you teach what? What should students be able to understand and do? What is the role of the teacher? How is history important to the understanding of science? Society? Cultures? Technological advances?

Grades K–4

The following guidelines are designed to help students in grades K–4 develop an understanding of science as a human endeavor.

Developing Student Understanding:
Teachers should build on students' natural inclinations to ask questions and investigate their world. Groups of students can conduct investigations that begin with a question and progress toward communicating an answer to the question. Teachers should emphasize investigations and thinking about explanations and not overemphasize memorization of scientific terms and information. Students learn about scientific inquiry and significant people from history.

Fundamental concepts and principles for Science as a Human Endeavor:
Science and technology have been practiced by people for a long time. Men and women have made contributions throughout the history of science and technology. Although men and women using scientific inquiry have learned much about the objects, events, and phenomena in nature, much more remains to be understood. Scientific inquiry will never be finished. Many people choose science as a career and devote their entire lives to pursuing the study of science.

Grades 5–8

The following guidelines are designed to help students in grades 5–8 develop an understanding of science as a human endeavor, the nature of science, and the history of science.

Developing Student Understanding:
Teachers engage students in scientific investigations to provide the background for developing an understanding of the nature of scientific inquiry, and also provide a foundation for appreciating the history of science.

Historical examples are introduced to help students see the scientific enterprise as philosophical, social, and human. Middle-school students are given opportunities to better understand scientific inquiry and the interactions between science and society. Teachers of science can use the actual experiences of student investigations, case studies, and historical vignettes to develop an understanding of the history and nature of science.

Fundamental concepts and principles for Science as a Human Endeavor:
People of various social and ethnic backgrounds engage in the activities of science, engineering, and related fields. Scientists communicate extensively with others. Science requires different abilities, depending on such factors as the field of study and type of inquiry. Science relies upon basic human qualities of reasoning, insight, energy, skill, creativity, intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas.

Fundamental concepts and principles for the Nature of Science:
Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models. Scientists change their ideas about nature when they encounter new experimental evidence that does not match their existing explanations.

In areas of active research it is normal for scientists to differ with one another about the interpretation of the evidence or theory being considered. Scientists acknowledge such conflict and work towards finding evidence that will resolve their disagreement. It is part of scientific inquiry to evaluate the results of scientific investigations, experiments, observations, theoretical models, and the explanations proposed by other scientists. Evaluation includes reviewing the experimental procedures, examining the evidence, and suggesting alternative explanations for the same observations. Scientists agree that questioning, response to criticism, and open communication are integral to the process of science.

Fundamental concepts and principles for the History of Science:
Many individuals have contributed to the traditions of science. Learning something about these individuals can provide further understanding of scientific inquiry, science as a human endeavor, the nature of science, and the relationships between science and society. Science is practiced by a wide variety of individuals in virtually all cultures. World history suggests that scientists and engineers of high achievement are considered to be among the most valued contributors to their culture.

Tracing the history of science can show how difficult it was for scientific innovators to break through the accepted ideas of their time to reach conclusions that we currently take for granted.

Grades 9–12

The following guidelines are designed to help students in grades 9–12 develop an understanding of science as a human endeavor, the nature of scientific knowledge, and historical perspectives.

Developing Student Understanding:
Studying the history of scientific inquiry can be useful in helping students understand how the philosophy of science has developed over time and in various cultures. Effective science lessons may incorporate historical examples that accommodate student interests, while helping develop an understanding of the human dimension of science, the nature of scientific knowledge, and the place of science in society.

Fundamental concepts and principles for Science as a Human Endeavor:
Individuals and teams have contributed and will continue to contribute to the scientific enterprise whether it is as a career or hobby. Doing science or engineering can be as simple as an individual conducting field studies or as complex as hundreds of people working on a major scientific question or technological problem.

Scientists have ethical traditions. Scientists value peer review, truthful reporting about the methods and outcomes of investigations, and making public the results of work.

Fundamental concepts and principles for the Nature of Scientific Knowledge:
Science distinguishes itself from other ways of knowing and from other bodies of knowledge through the use of empirical standards, logical arguments, and skepticism, as scientists strive for the best possible explanations about the natural world.

Scientific explanations must meet certain criteria. They must be consistent with experimental and observational evidence in order to make accurate predictions. They also should be logical, respect the rules of evidence, be open to criticism, report methods and procedures, and report their findings.

All scientific ideas depend on experimental and observational confirmation; all scientific knowledge is, in principle, subject to change, as new evidence becomes available. In situations where information is fragmentary, it is normal for scientific ideas to be incomplete, but this is also where the opportunity for making advances may be greatest.

Fundamental concepts and principles for Historical Perspectives:
Throughout history, diverse cultures have contributed scientific knowledge and inventions. Modern science began to evolve rapidly in Europe several hundred years ago. During the past two centuries, it has contributed significantly to the industrialization of Western and non-Western cultures. Many non-European cultures have developed scientific ideas and solved human problems through technology as well.

Changes in science usually occur as small modifications in extant knowledge. The daily work of science and engineering results in incremental advances in our understanding of the world and our ability to meet human needs and aspirations.

Occasionally, there are advances in science and technology that have important and long-lasting effects on science and society. The historical perspective of scientific explanations demonstrates how scientific knowledge changes by evolving over time, almost always building on earlier knowledge.

References:
National Science Education Standards, National Academy Press, Washington, DC, 1996.

The Process of Invention

Orville and Wilbur Wright were masters of inquiry. Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information; planning investigations; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. The Wright brothers used critical and logical thinking skills when considering alternative theories of aviation.

Students should engage in inquiry as they come to know the natural world and eventually develop the capacity to conduct complete inquiries. Students should develop an understanding of what science is, what science is not, what science can and cannot do, and how science contributes to culture. Students need to become scientifically literate citizens with an understanding of the nature of science and its relationship to mathematics and technology.

"Scientific literacy means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomena. Scientific literacy entails being able to read with understanding articles about science in the press and to engage in social conversation about the validity of the conclusions. Scientific literacy has different degrees and forms; it expands and deepens over a lifetime, not just during the years in school. Attitudes and values established toward science in the early years will shape a person's development of scientific literacy as an adult."

Poster Credits

This poster was developed by the NASA Headquarters' Education Division, Office of Human Resources and Education, Frank C. Owens, Director of Education. Anne Holbrook, NASA Einstein Fellow, created the poster with oversight from Debbie Gallaway, Assistant Director of Programs for the U.S. Centennial of Flight Commission and William E. Anderson, Partnership Manager for Education, Office of Aerospace Technology. The following individuals were consulted during the development of the poster: Linda Hallenbeck, Teacher in Residence for Governor Bob Taft of Ohio, and Karen Garr, Teacher in Residence for Governor Jim Hunt of North Carolina.

Vladimir Herrera and Leslie Lien, two graphic artists in the NASA Headquarters Printing and Design Office, did the poster layout. Their combined creative talents and patience throughout the design process of this project are much appreciated.

The following individuals and organizations provided images and/or information that were used on "The Wright Way: The Process of Invention" poster:

Fred Fisk, author of *The Wright Brothers from Bicycle to Biplane*, provided the image of the "Wright Bros. Cycle" ad from High School Times, April, 1897.

Ted Huetter, at the Dryden Flight Research Center Education office, provided ideas and aircraft images.

The Library of Congress archives provided the Wind Tunnel image.

The National Air and Space Museum, Smithsonian Institution, provided the images A-4189 and A-442710. Special thanks to Kate Igoe, Thomas Crouch, and Peter Jakab for their wealth of knowledge and assistance.

The National Research Council provided their research and publication of the National Science Education Standards, by the National Academy Press.

Wright State Archives, Dayton, Ohio, provided images for the poster. Special thanks to Jane Wildermuth and Dawn Dewey for their dedication.

NASA Student Competition Opportunities!
To find out more information about how students can participate, visit the NASA Student Involvement Program (NSIP) Web site at http://education.nasa.gov/nsip/index.html

Attention High School Students!
The NASA Summer High School Apprenticeship Research Program (SHARP) and SHARP PLUS are research-based mentorship programs. Check them out!
http://education.nasa.gov/stures.html

The Wright Brothers' Story

The Flying Toy

Wilbur (1867-1912) and Orville Wright (1871-1948) were brothers. They lived in Dayton, Ohio, at 7 Hawthorn Street. Their older brothers were Reuchlin and Lorin. Katharine was their younger sister. Their father, Milton, was a bishop in the Church of the United Brethren in Christ. Their mother, Susan, the daughter of a wagon maker, made toys for her children and encouraged their curiosity. One day, Bishop Wright brought home a small toy "helicopter" made of wood with two twisted rubber bands to turn a small propeller. Wilbur and Orville played with it until it broke, then made new copies of the toy themselves. They also sold toys to their friends, including handmade kites. The Wright brothers did things together from the time they were small boys.

The Bicycle Business

The Wright brothers went into the printing business together in 1889. Three years later, they opened their first bicycle shop. Initially, they sold and repaired bicycles. They would replace spokes, fix broken chains, and sell accessories. In 1896, they began to build their own brand of bicycles. The Wright brothers' experiences with bicycles aided them in their investigations of flight. They used the technology they learned from their bicycle business in their airplanes: chains, sprockets, spoke wires, ball bearings, and wheel hubs. Their thoughts on balancing and controlling their aircraft were also rooted in their experience as cyclists.

The Search for Control

Orville and Wilbur Wright were convinced of the need to control an aircraft in three axes of motion. An elevator, or horizontal control surface, in front of the wings on their aircraft, enabled the pilot to control climb and descent (pitch axis). The elevator was controlled by a lever in the pilot's left hand. A "wingwarping" system controlled the aircraft in a roll (roll axis). To initiate a roll, the pilot would shift his hips from side to side in a cradle on the lower wing, "twisting" the wings left or right or restoring them to level flight. Orville and Wilbur developed this idea from observing birds in flight. They observed the buzzards keeping their balance by twisting their wings and sometimes curving one wing more than the other. In 1902, the brothers added a vertical rudder to the rear of their machine to control the left and right motion of the nose of the aircraft (yaw axis).

The Kite/Glider Experiments

The Wright brothers began their aeronautical research in 1899. Their first aircraft was a small kite with a five-foot wingspan that was used to test their notions of aircraft control. In 1900, they built their first machine designed to carry a pilot and chose Kitty Hawk, NC, as a suitable testing ground. With its strong steady winds, open areas, and tall sandy dunes, the area was perfect for their experiments. When their 1900 aircraft produced less lift than expected, the Wright brothers flew it as a kite and gathered information that would enable them to design improved machines. They returned to Kitty Hawk in 1901 with a new glider that did not perform as they expected. While they had learned a great deal with their first two machines, they had also encountered new puzzles and dangers.

The Wind Tunnel

To simulate flight conditions, the Wrights tested small model wings in a wind tunnel they had built. The wind tunnel was a box with a fan at one end that blew a steady stream of air over model wings mounted on a special "balance" inside the tunnel. Using this device, the brothers were able to gather information that could be used to design the wings of the gliders and powered aircraft that would carry them into the air. The wind tunnel provided them with information on the most satisfactory wing shape. It also enabled them to calculate the size of wing that would be required to lift them into the air, the performance of their propellers, and the amount of power that their engine would have to produce. They based the design of their next glider on this information.

Controlling the Aircraft

During the 1901 glider tests, the Wright brothers had discovered that "wingwarping" created unequal drag on the two wings. Key to solving the control problem was the addition of a rudder to the glider design in 1902. They developed a direct linkage between the rudder and warping system. With the success of this system design, the Wrights were ready to move onto a powered aircraft.

The Solution

At Kill Devil Hills, NC, at 10:35 am, the Wright 1903 Flyer took off under its own power with Orville as the pilot. It flew 12 seconds and went a distance of 37 meters. Orville and Wilbur took turns making three more flights that morning. Wilbur was at the controls for the fourth and longest flight, traveling 260 meters in 59 seconds. The Wright 1903 Flyer became the first powered, heavier-than-air machine to achieve controlled, sustained flight with a pilot aboard. Today, this amazing flying invention can be viewed as it is suspended overhead, at the National Air and Space Museum in Washington, DC. (www.nasm.edu/nasm/nasmexh.html)

The Wright 1904 Flyer

Having achieved success in North Carolina, the Wright brothers decided to continue their experiments closer to home. They built and flew their second powered airplane at Huffman Prairie, a pasture eight miles east of Dayton, Ohio. Progress was slow without the strong, steady winds of Kitty Hawk, but the brothers did achieve the first circular flight of an airplane on September 20, 1904. This first complete circle flight lasted only 1 minute 36 seconds and covered 1,244 meters. Stability problems still plagued the Wright brothers' invention. The modifications made during 1904 helped but did not solve the stability problem.

The Wright 1905 Flyer

This Flyer was the world's first practical airplane. During more than 40 flights at Huffman Prairie, the machine was repeatedly banked, turned, circled, and flown in figure eights. On two occasions the flight exceeded half an hour. Wilbur and Orville Wright, brilliant self-trained engineers, had overcome complex technical problems that had barred the way to mechanical flight for centuries. Think about how their invention has changed our world!

Activities for Grades K–12

Objectives: The students will construct a flying model glider and determine its weight and balance.

Teacher background:
On December 17, 1903, Wilbur and Orville Wright became the first humans to fly a controllable, powered airplane. To unravel the mysteries of flight, the brothers built and experimented extensively with model gliders. Gliders are airplanes without motors or a power source. Building and flying model gliders helped the Wright brothers learn and understand the importance of weight and balance in airplanes. If the weight of the airplane is not positioned properly, the airplane will not fly. They also learned that the design of an airplane was very important.

The Wright Flyer was the first plane to complete a controlled takeoff and landing. Airplanes use control surfaces to manage flight direction. Elevators are control surfaces that make the nose of the airplane move up and down. A rudder is used to move the nose of the aircraft left and right. On modern airplanes, ailerons are used to roll the airplane into a turn. The Flyer used a technique called wingwarping to initiate a turn.

In research and development, model aircraft are used to develop new concepts, create new designs, and test ideas in aviation. Some models fly by remote control, others are tested in wind tunnels. Information learned from models is an important part of NASA's aeronautical research program. The goals of research are to make aircraft fly safer, perform better, and become more efficient.

This activity is designed to help students learn about basic aircraft design and to explore the effects of weight and balance on the flight characteristics of a model glider. Students will use science process skills to construct and fly a Styrofoam™ glider. Younger students will need to have the pieces traced and cut out for them. They should only move one surface at a time, and only after they have had an opportunity to "play" with their glider. Older students should also have the opportunity to test their gliders to better understand the control surfaces well enough to set up experimentally designed tests. The data will be shared within the group/class via detailed design drawings and graphs. Students should be encouraged to modify the glider for longer/higher/straighter flights.

Building The Glider

K–3 students will need assistance cutting and constructing the glider. Older students could act as mentors and precut the parts. The parts can also be punched out with a plastic serrated knife, poster pin, or sharp pencil.

Construction and Experimentation

Ask students to name some materials that might be used to build a model glider.

Explain to students that Styrofoam™ is lightweight and strong which makes it an ideal material to construct model gliders.

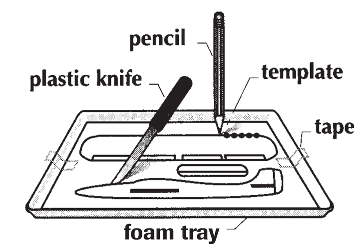
Distribute the materials to each group of students.

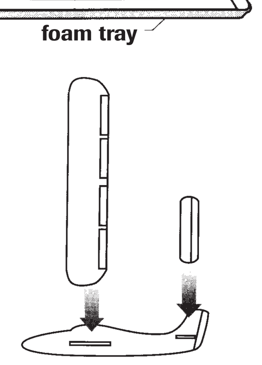
Explain that the template is a guide to cut out the parts for the airplane.

Use sandpaper or an emery board to smooth the edges.

Have the students assemble the glider by inserting the wings and elevator into the fuselage slots.

The students may add personal touches. Civilian aircraft have a letter or letters preceding the aircraft's identification number indicating the country in which it is registered. For example, Mexico uses the letter "X" and the United States is "N." Students may apply N-numbers to their models. Caution the students not to throw gliders toward other students. Eye protection is advisable.





The model glider's weight must be balanced or distributed properly before it will fly well. To demonstrate this, ask a student to launch a glider before adding weight. Have students describe and record the flight characteristics.

Add weight to the model using paper clips, binder clips, or a penny. Attach the paper clip or glue a penny to the nose of the glider. If a binder clip is used, attach it to the bottom of the fuselage. Ask the students to test fly the glider and observe the flight characteristics.

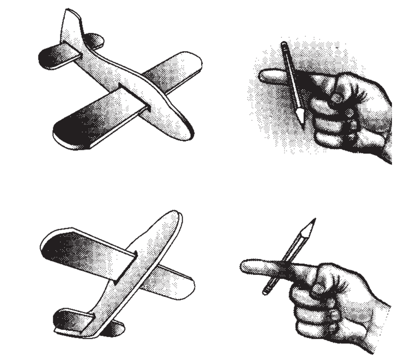
Move the weight forward or backward on the fuselage to determine the best weight and balance for the glider. Try to find the weight and balance combination that allows the glider to fly the greatest distance.

Discussion

Are weight and balance important on "real" aircraft?

(The total weight of the cargo and passengers of any airplane has certain limits and is distributed to keep the plane properly balanced. Flights should not be attempted if an aircraft is overloaded, or if the cargo distribution makes the plane too "nose heavy" or "tail heavy.")

Using the model glider, the students will explain how they determined the weight and balance for their glider.



Hint: The weight of the model glider must be balanced before it will fly successfully. To determine the "Center of Gravity" of the glider, the model can be balanced much like a pencil on their finger (diagram).

Challenge for older students
Carefully cut out the flaps and ailerons along the solid lines. (figures on panel 7)

The Wright brothers used "wingwarping" to turn their airplane to the right or left. Modern aircraft use ailerons to initiate a roll. Ailerons work in opposition to one another. If the left aileron is in the up position, the right aileron must be in the down position and vise versa. Ask your students to experiment with the ailerons by bending them up or down along the dashed lines.

Bend each flap down along the dashed line into the same position below the wing. How are the flight characteristics of the glider affected with the flaps in the down position?

Set up a course for students to demonstrate the flight characteristics of their gliders. The students may cut off 2 cm of each wing, and record a new series of flight testing data. Develop new wing designs. Research wind tunnels and build one to test various wing lengths, shapes, and sizes.

Use these NASA Educator Resources to teach and reinforce flight concepts:

Grades K–12
The Beginner's Guide to Aerodynamics at *http://www.lerc.nasa.gov/WWW/K-12/airplane/bga.htm*

Grades K–4
Aeronautics: An Educator's Guide with Activities in Science, Mathematics, and Technology Education, EG-1998-09-105-HQ.

Grades 5–8
Exploring Aeronautics, a CD-ROM, includes an introduction to aeronautics, fundamentals of flight, a historical timeline, and different types of aircraft. The CD teaches students to use the tools of aeronautics to test aircraft designs. Developed by NASA Ames Research Center, EC-1998-03-002-ARC.

Grades 9-12
FoilSim, developed at the NASA Glenn Research Center, is interactive simulation software that determines the airflow around various shapes of airfoils. Download from: *http://www.lerc.nasa.gov/WWW/K-12/aerosim/*

Extension Activity

Design a space vehicle to transport people and goods to the International Space Station and beyond—applying aeronautical principles for an aircraft design/model and research project.

If the Wright brothers were living today, they might be researching new forms of power and types of structures, conducting experiments, and designing models to develop the new Space Shuttle. The Space Shuttle is the world's first reusable spacecraft, and the first spacecraft in history that can carry large satellites both to and from orbit. The Space Shuttle launches like a rocket, maneuvers in Earth orbit like a spacecraft, and lands like an airplane. Each of the four Space Shuttle orbiters now in operation—*Columbia, Discovery, Atlantis, and Endeavour*—is designed to fly at least 100 missions. NASA is prepared to continue flying the Shuttle for at least the next decade. What will happen then? Engineers and scientists are busy at work now on Advanced Space Transportation Systems to replace the Space Shuttle.

Apply the principles learned from the glider experiences. Take into account current experimental designs, and the Wrights' work in aerodynamics, stability, flight control, power, and structure. Design and build a model of a new aircraft to transport people and goods to the International Space Station and beyond. Keep in mind that NASA believes in developing safe, reliable, and affordable transportation. Present a report describing your investigation.

To learn more, visit the following sites:

Shuttle Basics
http://spaceflight.nasa.gov/shuttle/reference/basics/index.html

NASA Scientific and Technical Information: *http://www.sti.nasa.gov/*

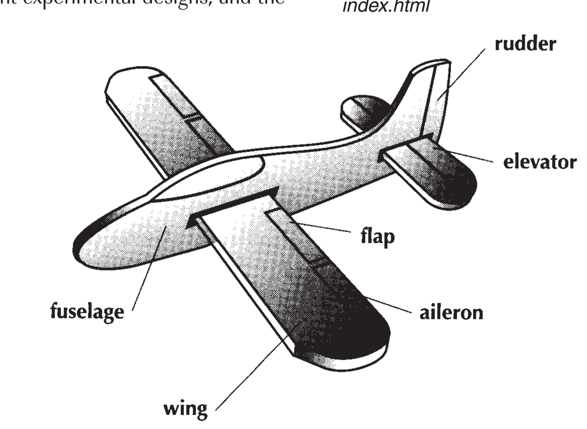
NASA's X-Gliders
http://spacelink.nasa.gov/products/X.Gliders/

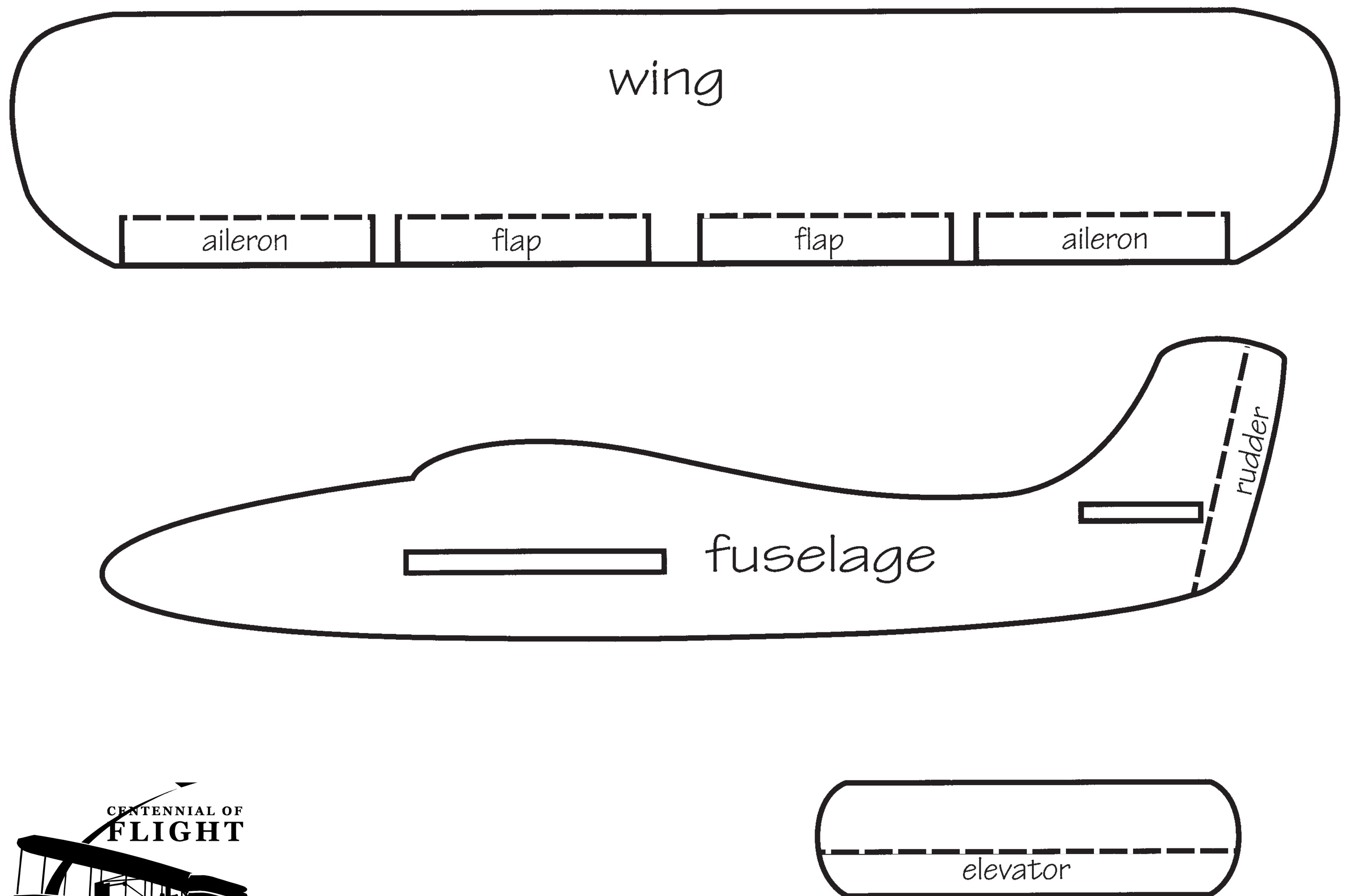
X-38 Home Page
www.dfrc.nasa.gov/projects/X38/intro.html

X-38 Image Gallery
www.dfrc.nasa.gov/gallery/photo/

X-43A Home Page
www.dfrc.nasa.gov/projects/hyperx/x43.html

X-43A Image Gallery
www.dfrc.nasa.gov/gallery/photo/HyperX/index.html





CENTENNIAL OF FLIGHT
1903 • 2003

NASA Resources for Educators

NASA's Central Operation of Resources for Educators (CORE) was established for the national and international distribution of NASA-produced educational materials in audiovisual format. Educators can obtain a catalogue and an order form by one of the following methods:

- NASA CORE
  Lorain County Joint Vocational School
  15181 State Route 58
  Oberlin, OH 44074-9799
- Toll Free Ordering Line: 1-866-776-CORE
- Toll Free FAX Line: 1-866-775-1401
- E-mail: nasaco@leeca.org
- Home Page: http://core.nasa.gov

Educator Resource Center Network (ERCN)
To make additional information available to the education community, NASA has created the NASA Educator Resource Center (ERC) network. Educators may preview, copy, or receive NASA materials at these sites. Phone calls are welcome if you are unable to visit the ERC that serves your geographic area. A list of the centers and the regions they serve includes:

AK, Northern CA, HI, ID, MT, NV, OR, UT, WA, WY
NASA Educator Resource Center
Mail Stop 253-2
NASA Ames Research Center
Moffett Field, CA 94035-1000
Phone: (650) 604-3574

IL, IN, MI, MN, OH, WI
NASA Educator Resource Center
Mail Stop 8-1
NASA Glenn Research Center
21000 Brookpark Road
Cleveland, OH 44135-3191
Phone: (216) 433-2017

CT, DE, DC, ME, MD, MA, NH, NJ, NY, PA, RI, VT
NASA Educator Resource Laboratory
Mail Code 130.3
NASA Goddard Space Flight Center
Greenbelt, MD 20771-0001
Phone: (301) 286-8570

CO, KS, NE, NM, ND, OK, SD, TX
Space Center Houston
NASA Educator Resource Center for
NASA Johnson Space Center
1601 NASA Road One
Houston, TX 77058-3696
Phone: (281) 244-2129

FL, GA, PR, VI
NASA Educator Resource Center
Mail Code ERC
NASA Kennedy Space Center
Kennedy Space Center, FL 32899-0001
Phone: (321) 867-4090

Virginia Air & Space Center
Educator Resource Center for
NASA Langley Research Center
600 Settlers Landing Road
Hampton, VA 23669-4033
Phone: (757) 727-0900 x 757

AL, AR, IA, LA, MO, TN
U.S. Space and Rocket Center
NASA Educator Resource Center for
NASA Marshall Space Flight Center
One Tranquility Base
Huntsville, AL 35812-0001
Phone: (256) 544-5812

MS
NASA Educator Resource Center
Building 1200
NASA Stennis Space Center
Stennis Space Center, MS 39529-6000
Phone: (228) 688-3965

NASA JPL Educator Resource Center
Village at Indian Hill
1460 East Holt Avenue, Suite 20
NASA Jet Propulsion Laboratory
Pomona, CA 91767
Phone: (909) 397-4420

AZ and Southern CA
NASA Educator Resource Center for
NASA Dryden Flight Research Center
45108 N. 3rd Street East
Lancaster, CA 93535
Phone: (661) 948-7347

VA and MD's Eastern Shores
NASA Educator Resource Center
Visitor Center Building J-17
GSFC/Wallops Flight Facility
Wallops Island, VA 23337
Phone: (757) 824-2298

Regional Educator Resource Centers offer more educators access to NASA educational materials. NASA has formed partnerships with universities, museums, and other educational institutions to serve as regional ERCs in many states. A complete list of regional ERCs is available through CORE, or electronically via NASA Spacelink at http://spacelink.nasa.gov/ercn/

NASA's Education Home Page serves as a cyber-gateway to information regarding educational programs and services offered by NASA for the American education community. This high-level directory of information provides specific details and points of contact for all of NASA's educational efforts, Field Center offices, and points of presence within each state. Visit this resource at the following address: *http://education.nasa.gov*

NASA Spacelink is one of NASA's electronic resources specifically developed for the educational community. Spacelink is a "virtual library" in which local files and hundreds of NASA World Wide Web links are arranged in a manner familiar to educators. Using the Spacelink search engine, educators can search this virtual library to find information regardless of its location within NASA. Special events, missions, and intriguing NASA Web sites are featured in Spacelink's "Hot Topics" and "Cool Picks" areas. Spacelink may be accessed at: *http://spacelink.nasa.gov*

NASA Spacelink is the official home to electronic versions of NASA's Educational Products. A complete listing of NASA Educational Products can be found at the following address: *http://spacelink.nasa.gov/products*

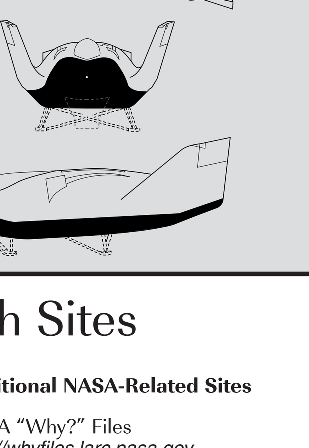
NASA Television (NTV) features Space Shuttle mission coverage, live special events, interactive educational live shows, electronic field trips, aviation and space news, and historical NASA footage. Programming includes a 3-hour block for Video (News) File, NASA Gallery, and Education File. Programming begins at noon Eastern standard time and is repeated five more times throughout the day. Live feeds preempt regularly scheduled programming.

Check the Internet for programs listings at: *http://www.nasa.gov/ntv*

For more information on NTV, contact:
NASA TV
NASA Headquarters
Code P-2
Washington, DC 20546-0001
Phone: (202) 358-3572

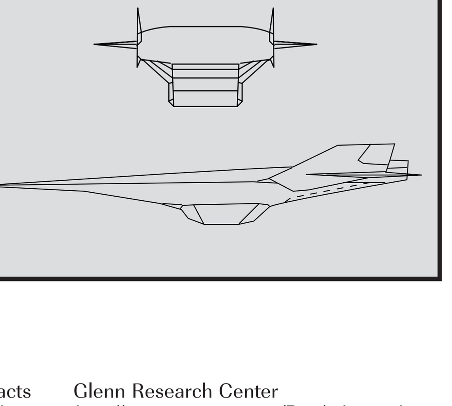
EW-2000-11-133-HQ
The Wright Way: The Process of Invention
Please provide feedback on how this poster has been used.
Complete the survey at
https://ehb2.gsfc.nasa.gov/edcats/educational_wallsheet

NASA X-Planes



X-38

Powerplant: none
Max speed: 230 mph
Range: N/A
Operational ceiling: 50,000 ft (drop from B-52)
Weight: 14,000 lb
Span: 15'
Length: 24'
Height: 12'



X-43A

Powerplant: GASL, Inc. scramjet engine
Max speed: Mach 10
Range: 575 miles
Operational ceiling: 100,000 ft
Weight: Approx. 2,200 lb
Span: 5'
Length: 12'
Height: 2'

Educational Research Sites

National Education Standards

National Research Council Science Content
http://bob.nap.edu/readingroom/books/nses/html#content

NCTM Mathematics Content Standards
http://standardse.nctm.org/1.0/89ces/Table_of_Contents.html

National Geography
http://www.tapr.org/~ird/Nordick/Standards.html

National Standards for Arts Education
http://artsedge.kennedy-center.org/cs/design/standards

The National Educational Technology Standards
http://cnets.iste.org/index.html

Related Site

Centennial of Flight Commission
http://www.centennialofflight.gov

Additional NASA-Related Sites

NASA "Why?" Files
http://whyfiles.larc.nasa.gov

NASA CONNECT Series
http://edu.larc.nasa.gov/connect/

NASA Jobs
http://www.nasajobs.nasa.gov

NASA Headquarters News Releases
http://www.nasa.gov/releases/1999/

NASA Shuttle Missions
http://www.ksc.nasa.gov/shuttle/missions/missions.html

NASA Jet Propulsion Laboratory Mission Status Reports
http://www.jpl.nasa.gov

NASA Technology Success Stories
http://nctn.hq.nasa.gov/success/index.html

NASA QUEST "WEBCASTS," Interactive Events for Students
http://quest.arc.nasa.gov

NASA Field Center Precollege Contacts
http://education.nasa.gov/precoll.html

NASA Educational Workshops for Teachers
http://education.nasa.gov/new

NASA Student Involvement Program
http://education.nasa.gov/nsip

National Coalition for Aviation Education (NCAE)
http://www.aviationeducation.org

Take Our Daughters to Work
http://iita.ivv.nasa.gov/happenings/event_2.html

NASA Field Center Education Home Pages

Ames Research Center
http://www.arc.nasa.gov/kids.html

Dryden Flight Research Center
http://www.dfrc.nasa.gov/trc/

Glenn Research Center
http://www.grc.nasa.gov/Doc/educatn.htm

Goddard Space Flight Center
http://education.gsfc.nasa.gov

Jet Propulsion Laboratory
http://eis.jpl.nasa.gov/eao/

Johnson Space Flight Center
http://spaceflight.nasa.gov/outreach/index.html

Kennedy Space Center
http://www.pao.ksc.nasa.gov/kscpao/educate/educate.htm

Langley Research Center
http://edu.larc.nasa.gov

Marshall Space Flight Center
http://www1.msfc.nasa.gov/EDUCATION/index.html

Stennis Space Center
http://wwwedu.ssc.nasa.gov/