



National Aeronautics and
Space Administration

Educational Product

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AERONAUTICS

An Educator's Guide with Activities in Science,
Mathematics, and Technology Education





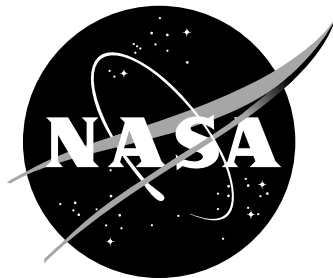
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Aeronautics

An Educator's Guide with Activities in Science, Mathematics, and Technology Education

What pilot, astronaut, or aeronautical engineer
didn't start out with a toy glider?



National Aeronautics and Space Administration

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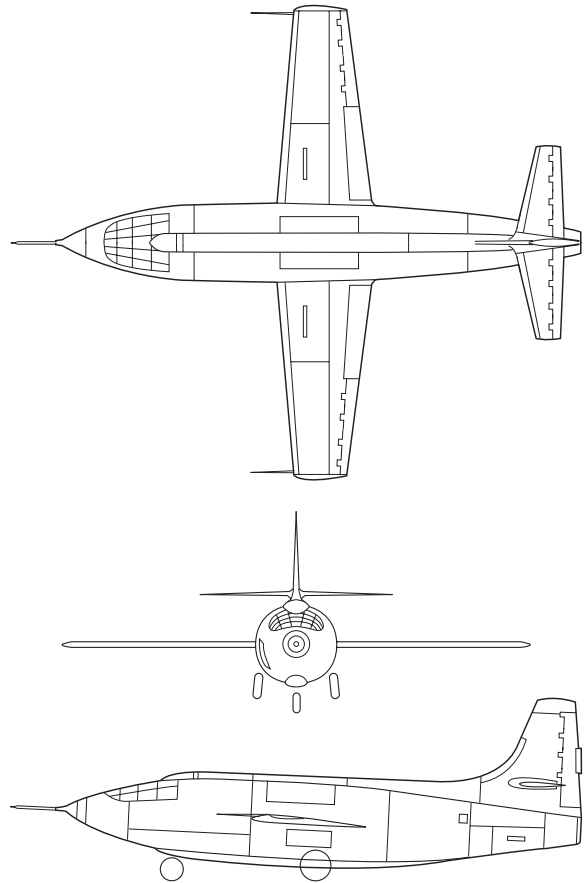
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**NACA X-1 Research Aircraft
1946**

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Preface

Welcome to the exciting world of aeronautics. The term aeronautics originated in France, and was derived from the Greek words for “air” and “to sail.” It is the study of flight and the operation of aircraft. This educator guide explains basic aeronautical concepts, provides a background in the history of aviation, and sets them within the context of the flight environment (atmosphere, airports, and navigation).

The activities in this guide are designed to be uncomplicated and fun. They have been developed by NASA Aerospace Education Services Program specialists, who have successfully used them in countless workshops and student programs around the United States. The activities encourage students to explore the nature of flight, and experience some real-life applications of mathematics, science, and technology.

The subject of flight has a wonderful power to inspire learning.

How to Use This Guide

This guide begins with education standards and skills matrices for the classroom activities, a description of the NASA aeronautics mission, and a brief history of aeronautics. The activities are divided into three chapters:

Air
Flight
We Can Fly, You and I

The activities are written for the educator. Each activity begins with (1) objectives, (2) education standards and skills, and (3) background material for the subject matter in the activity. The activity continues with by step-by-step instructions (and associated graphics) to help the educator guide students through the activity in the classroom. Each activity includes “student pages,” easily identified by this icon:



The student pages are as simple as a graphic of the activity, and as advanced as a work sheet. They are meant to supplement the educator’s presentation, serve as reminders, and inspire students to explore their own creativity. Activities requiring step-by-step assembly include student pages that present the project in a way that can be understood by pre-literate students.

Each chapter ends with a section listing suggested interdisciplinary activities.

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Activity Matrix

Problem Solving
 Communication
 Reasoning
 Connections
 Measurement
 Verifying and Interpreting Results
 Estimation
 Prediction
 Graphs

Air Engines
 Dunked Napkin
 Paper Bag Mask
 Wind in Your Socks
 Bag Balloons
 Sled Kite
 Right Flight
 Delta Wing Glider
 Rotor Motor
 Making Time Fly
 Where is North?
 Let's Build a Table Top Airport
 Plan to Fly There

●				●					
					●				
●		●		●					
						●			
			●	●		●			
●		●		●			●		
●				●					
●	●								
			●		●		●		
●	●	●							
●	●		●						

Mathematics Standards



Activity Matrix

	Observing	Communication	Measuring	Collecting Data	Predicting	Making Graphics	Investigating	Interpreting Data	Inferring	Controlling Variables	Making Models
Air Engines	●				●	●	●				
Dunked Napkin	●						●				
Paper Bag Mask			●		●			●			●
Wind in Your Socks	●		●								●
Bag Balloons	●		●								●
Sled Kite	●		●		●						
Right Flight	●		●	●	●			●	●	●	
Delta Wing Glider						●	●				●
Rotor Motor	●								●	●	
Making Time Fly		●		●			●				
Where is North?	●							●			●
Let's Build a Table Top Airport		●	●				●				●
Plan to Fly There		●	●				●				

Science Process Skills



Aerospace Technology Enterprise

The NASA Aerospace Technology Enterprise's charter is to pioneer advanced technologies that will meet the challenges facing air and space transportation, maintain U.S. national security and pre-eminence in aerospace technology, and extend the benefit of our innovations throughout our society.

To benefit fully from the revolution in communication and information technology, we also need a revolution in mobility. To open the space frontier to new levels of exploration and commercial endeavor, we must reduce cost and increase the reliability and safety of space transportation. Both the economy and our quality of life depend on a safe, environmentally friendly air transportation system that continues to meet the demand for rapid, reliable, and affordable movement of people and goods.

Working with our partners in industry, Government, and academia, we have developed four bold goals to sustain future U.S. leadership in civil aeronautics and space transportation. These goals are as follows:

- revolutionize aviation;
- advance space transportation;
- pioneer technology innovation; and
- commercialize technology.

Revolutionize Aviation

NASA's goal to revolutionize aviation will enable the safe, environmentally friendly expansion of aviation in the following areas:

- Increase safety—Make a safe air transportation system even safer by reducing the aircraft accident rate by a factor of 5 within 10 years and by a factor of 10 within 25 years.
- Reduce emissions—Protect local air quality and our global climate.
- Reduce NO_x emissions of future aircraft by 70 percent within 10 years and by 80 percent within 25 years (from the 1996 ICAO Standard for NO_x as the baseline).
- Reduce CO₂ emissions of future aircraft by 25 percent and by 50 percent, respectively, in the same timeframes (from 1997 subsonic aircraft technology as the baseline).
- Reduce noise—Lower the perceived noise levels of future aircraft by a factor of 2 (10 decibels) within 10 years, and by a factor of 4 (20 decibels) within 25 years. The baseline is 1997 subsonic aircraft technology. The word “perceived” is key to the intended interpretation of this noise reduction goal. In subjective acoustics, a 10-dB reduction is perceived as “half” as loud, hence, the stated interpretation of the goal.
- Increase capacity—Enable the movement of more air passengers with fewer delays.
- Double the aviation system capacity within 10 years and triple it within 25 years. The baseline is 1997 levels.
- Increase mobility—Enable people to travel faster and farther, anywhere, anytime.
- Reduce intercity door-to-door transportation time by half in 10 years and by two-thirds in 25 years.
- Reduce long-haul transcontinental travel time by half within 25 years.

Advance Space Transportation

NASA's goal to advance space transportation is to create a safe, affordable highway through the air and into space.

- Mission safety—Radically improve the safety and reliability of space launch systems. Reduce the incidence of crew loss to less than 1 in 10,000 missions (a factor of 40) by 2010 and to less than 1 in 1,000,000 missions (a factor of 100) by 2025.
- Mission affordability—Create an economical highway to space.
- Reduce the cost of delivering a payload to low-Earth orbit (LEO) to \$1,000 per pound (a factor of 10) by 2010 and to \$100 per pound (an additional factor of 10) by 2025.
- Reduce the cost of interorbital transfer by a factor of 10 within 15 years and by an additional factor of 10 by 2025.
- Mission reach—Extend our reach in space with faster travel. Reduce the time for planetary missions by a factor of 2 within 15 years and by a factor of 10 within 25 years.

Pioneer Technology Innovation

NASA's goal to pioneer technology innovation is to enable a revolution in aerospace systems.

- Engineering innovation—Enable rapid, high-confidence, and cost-efficient design of revolutionary systems.
- Within 10 years, demonstrate advanced, full-life-cycle design and simulation tools, processes, and virtual environments in critical NASA engineering applications.
- Within 25 years, demonstrate an integrated, high-confidence engineering environment that fully simulates advanced aerospace systems, their environments, and their missions.
- Technology innovation—Enable fundamentally new aerospace system capabilities and missions.
- Within 10 years, integrate revolutionary technologies to explore fundamentally new aerospace system capabilities and missions.
- Within 25 years, demonstrate new aerospace capabilities and new mission concepts in flight.

Commercialize Technology

The NASA Commercial Technology Program enables the transfer of NASA technologies to the private sector to create jobs, improve productivity, and increase U.S. competitiveness. NASA provides assistance to a wide variety of companies, with special emphasis on small businesses.



Aeronautics

Background for Educators

“Birds fly, so why can’t I?” That question was probably first asked by cave dwellers watching a bird swoop through the air. Perhaps even then, people understood the advantages of human flight. The desire to defy gravity and experience the freedom of flight compelled early attempts to unravel the mysterious technique the birds had mastered proficiently.

Piloted flight and the mobility it offered to humankind would have to wait many centuries. The more immediate goal of the cave dwellers was survival. The discovery of fire by early inhabitants helped assure a permanent place on Earth for descendants. While a small spark eventually produced the light and heat of fire, the spark for flight was imagination. Ironically, the discovery of fire would play a major role in our first flight. Fire and flight forever changed the way we lived.

The writings and voices of past civilizations provide a record of an obsession with flight. The aerial dreams of early writers are revealed in Roman and Greek mythology. The mythical father and son team of Daedalus and Icarus used artificial wings of wax and bird feathers to escape from Crete. In Greek mythology, Pegasus was a winged horse. Some writings contributed significantly to the emerging science. From the early 1480’s until his death in 1519, the Florentine artist, engineer, and scientist, Leonardo da Vinci, dreamed of flight and produced the first drawings for an airplane, helicopter, *ornithopter*, and parachute.

In the early 17th century, serious aeronautical research was conducted by so-called “birdmen” and “wing flappers.” These early experimenters were erroneously convinced that wings strapped to a human body and muscle power were the answer to flight. Their daring and often dangerous experiments made scant contributions to aeronautical knowledge or progress. By the mid-17th century, serious-minded experimenters had correctly decided that

humans would never duplicate bird flight. They turned their attention to finding a device that would lift them into the air.

Two French paper makers, Joseph and Etienne Montgolfier, noting the way smoke from a fire lifted pieces of charred paper into the air, began experimenting with paper bags. They held paper bags, open end downward, over a fire for a while and then released them. The smoke-filled bags promptly ascended upward. Smoke, the brothers deduced, created a lifting force for would-be flyers. Scientists would later explain that when air is heated, it becomes less dense, thus creating a buoyant or lifting force in the surrounding cool air.

On September 19, 1783, a sheep, a rooster, and a duck were suspended in a basket beneath a Montgolfier balloon. The cloth and paper balloon was 17 meters high, and 12 meters in diameter. A fire was lit, and minutes later the balloon was filled with hot air; it rose majestically to a height of more than 500 meters. The farm animals survived the ordeal and became the first living creatures carried aloft in a human-made device. The dream of flight was now the reality of flight. Two months later on November 21, 1793, two volunteers stepped into the basket and flew for eight kilometers over Paris, thereby becoming the world’s first aeronauts. Flying became practical in lighter-than-air devices, and balloon mania set in.

Throughout the 19th century, *aeronauts* experimented with hydrogen gas-filled balloons and struggled to devise a method to control them. After another century of experimenting, the balloon had become elongated and fitted with propulsion and steering gear. Ballooning had become a fashionable sport for the rich, a platform for daring circus acts, and provided valuable observation posts for the military. Yet none of this was flying the way birds fly – fast, exciting, darting, diving, and soaring with no more than an effortless flick of wings. To escape the limitations of a floating craft, early researchers began the search for another, more exciting form of lift.

A small but dedicated handful of pioneers were convinced that the future of human flight depended



more on wings and less on smoke and hot air. One of these early pioneers had an intense interest in the flight of birds and became obsessed with ways its principles might be adapted by humans. As early as 1796, Englishman George Cayley conducted basic research on *aerodynamics* by attaching bird feathers to a rotating shaft, thereby building and flying a model helicopter. In 1804, he built and flew the world's first fixed-wing flyable model glider. This pioneering model used a paper kite wing mounted on a slender wooden pole. A tail was supported at the rear of the pole providing horizontal and vertical control. It was the first true airplane-like device in history.

In 1849, after years of extensive and persistent research, Cayley constructed his "boy glider." This full-sized heavier-than-air craft lifted a 10 year old boy a few meters off the ground during two test runs. Four years later, Sir George Cayley persuaded his faithful coachman to climb aboard another glider and make the world's first piloted flight in a fixed-wing glider.

In Germany, Otto Lilienthal believed that arched or curved wings held the secret to the art of flight. In his Berlin workshop, Lilienthal built test equipment to measure the amount of lift that various shapes of wings produced. His work clearly demonstrated the superior lifting quality of the curved wing. By 1894, Lilienthal's unpowered flying machines were achieving spectacular glides of over 300 meters in distance. Lilienthal built a 2 1/2 horsepower carbonic acid gas engine weighing 90 pounds. He was ready to begin powered glider experiments. Unfortunately, Lilienthal was killed in an 1896 glider mishap before he could test his power-driven airplane.

Otto Lilienthal left behind an inspiration and a warning. If his life's work proved that we could fly, then his death was a somber warning. Humans would have to master the aerodynamics of wings before flight like the birds could be accomplished with confidence and safety. His extensive research and experiments in aviation brought the world closer to realizing the age-old dream of human flight.

Lilienthal's work was carried forward by one of his students, a Scotsman named Percy Pilcher. Like Lilienthal, Pilcher built his own four-horsepower engine in hopes of achieving powered flight. Ironically, before he could conduct any experiments with powered flight, Pilcher was killed in a glider accident during 1899.

As the 19th century drew to a close, aviation pioneers continued to probe the mystery surrounding mechanical flight. Octave Chanute, Samuel Langley, and others experimented to produce further understanding of aeronautical principles and knowledge, yet controlled, powered flight was not realized. In 1900, the world waited for a lightweight power source and a method to control flight.

On May 30, 1899 Wilbur Wright wrote to the Smithsonian Institution in Washington, D.C. requesting information about published materials on aeronautics. By early summer of that year, Wilbur and his brother Orville had read everything they could find on the subject. The Wright brothers began a systematic study of the problem of flight by conducting research on the methods tried by previous experimenters. They conducted hundreds of wind tunnel experiments, engine and propeller tests, and glider flights to gain the knowledge and skill needed to fly.

On December 17, 1903, four years after beginning their research, the world was forever changed. A fragile cloth and wood airplane rose into the air from a windswept beach at Kitty Hawk, North Carolina, and flew a distance of 36 meters. The brothers provided the world with a powered flying machine controlled by the person it carried aloft. Ingenuity, persistence, and inventiveness had finally paid a big dividend—the Wright Flyer was successful. This 12-second event marked the beginning of tangible progress in the development of human-carrying, power-driven airplanes.

By 1905, an improved Wright Flyer could fly more than 32 kilometers and stay aloft almost 40 minutes. Five years later, the first international air meet in the United States was held in Los Angeles, California. Glenn Curtiss set a new world's speed record of 88



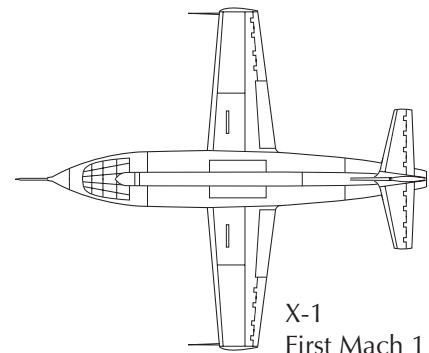
kilometers per hour and Frenchman Louis Paulhan set an altitude record of 1250 meters. At the outbreak of World War I, the airplane could fly at speeds of over 200 kilometers per hour and reach altitudes of 7500 meters.

The Congress of the United States recognized that a new era in transportation was beginning and the changes would have significant impact on human interchange, commerce, foreign relations, and military strategy. Flight research in the United States got a significant boost in 1915. The National Advisory Committee for Aeronautics (NACA) was formed by the United States Congress “to supervise and direct the scientific study of the problems of flight, with a view to their practical solutions.”

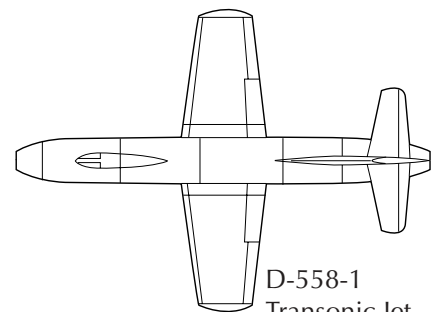
By the 1930’s, NACA wind tunnels and flight test investigations led to improvements in aircraft performance and safety. Research produced new *airfoil* or wing shapes and propeller designs that increased the safety and efficiency of airplanes. New engine cowlings and aerodynamic streamlining reduced drag and increased aircraft speed.

Today NACA’s successor, the National Aeronautics and Space Administration (NASA), has a much broader mission. As its name implies, NASA continues research to keep aviation on the cutting edge of technology for airfoils, materials, construction techniques, engines, propellers, air traffic control, agriculture development, electronics, efficiency, and safety. NASA is striving to make airplanes ecologically safe by lessening the sonic boom for aircraft traveling at *supersonic* speeds and developing propulsion systems that use pollutant-free fuel.

On August 17, 1978 near Paris, France, a hot air balloon descended from the sky and landed in a cornfield. Thousands of onlookers watched and cheered as the three crew members stepped down from the Double Eagle II. They had just completed the first nonstop crossing of the Atlantic Ocean in a balloon. Almost two hundred years earlier in 1783, Parisians cheered the Montgolfier brothers as they launched the first hot air balloon. The time span between the two events is filled with flight milestones that have taken humankind from the dream of flight to landing on the moon.

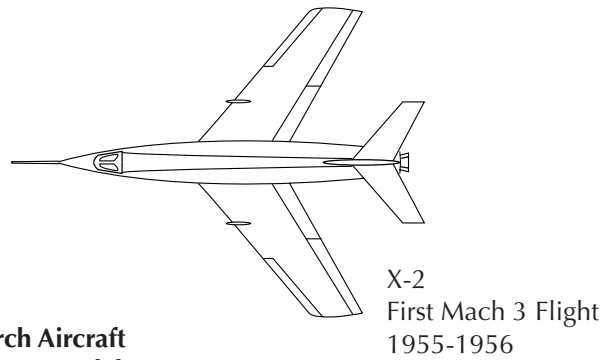
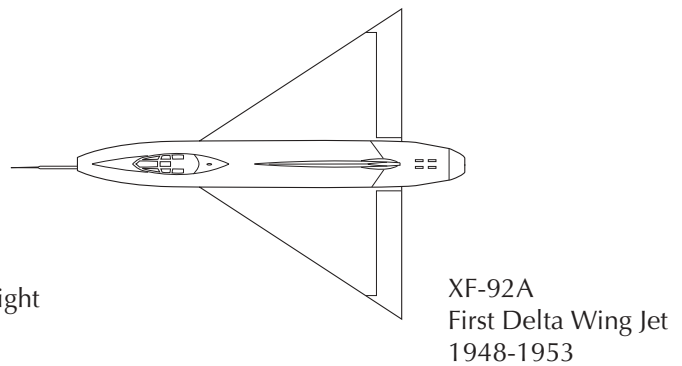
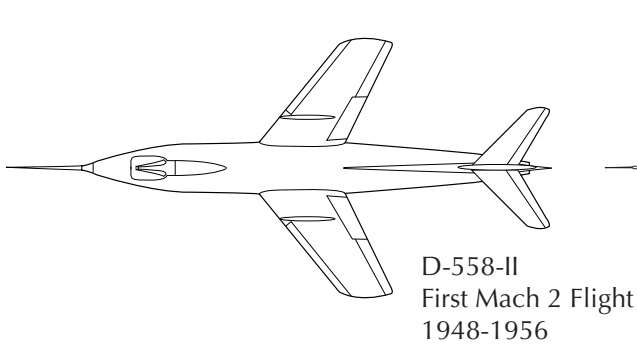
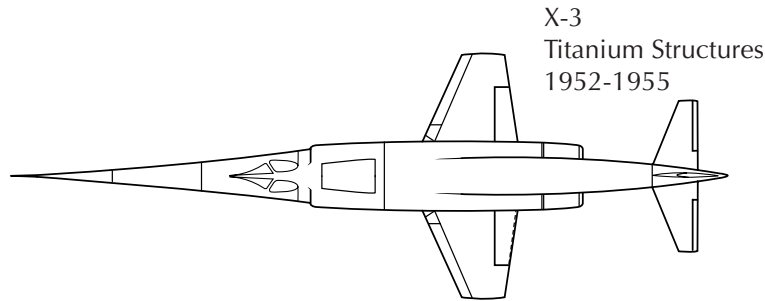
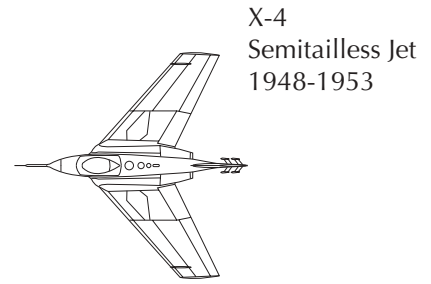


X-1
First Mach 1 Flight
1946-1951



D-558-1
Transonic Jet
1947-1953

Exploring Supersonic Flight



The NACA Experimental Research Aircraft Program which began in the 1940's took human flight to previously unexplored speeds and altitudes.

