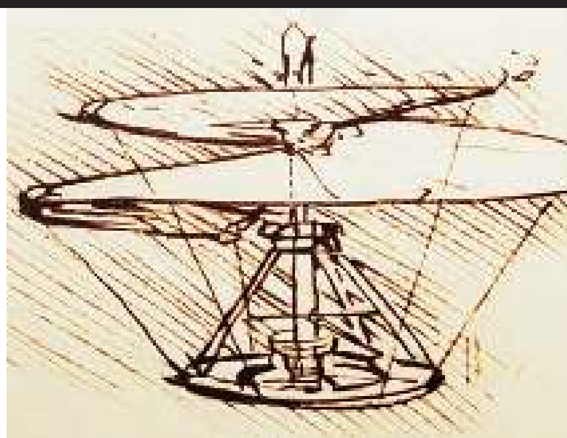
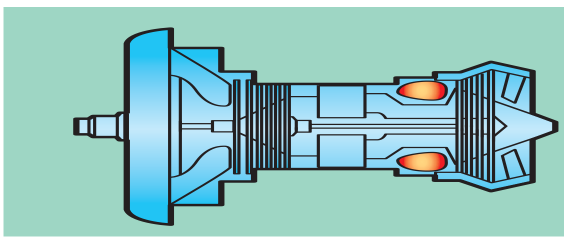
FLIGHT and MOTION

The History and Science of Flying





FLIGHT and MOTION

The History and Science of Flying

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Aerobatics – Balloon

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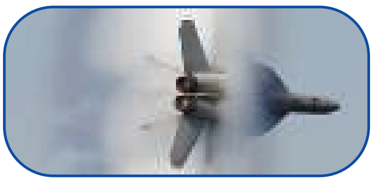
SCIENCE AND TECHNOLOGY

AVIATION AND AIR FLIGHT



SPACE AND SPACEFLIGHT

GENERAL TOPICS

BIOGRAPHY AND PROFILE

INTRODUCTION

The history of flight is a history of progress for humanity. Today, using air and space, we communicate and travel, defend ourselves against various threats, and explore the world around us and the vastness of space beyond. Pessimists can point to alarming increases in the destructive capacity of humans due to atomically armed bombers and intercontinental ballistic missiles. Optimists—such as myself—can point to the tremendous benefits that air and space travel have given us.

Flight is one of the oldest of human aspirations, and it is one that all peoples

have shared. They have incorporated visions of flying deities, spirits, and people in their various cosmologies, theologies, and mythic pasts. Yet for all this global interest, the actual achievement of human flight has greatly exceeded the expectations of those who dreamed what flight would give to humanity. They could hardly have conceived a world in which hundreds of millions of people each year journey from their homes to transportation centers designed for aviation, where they enter specialized aircraft to rise several miles off the ground and travel at speeds of hundreds of miles per hour across their countries and around the globe.

Indeed, those people who dreamed of flight largely did so at a time when they (with the aid of horses) could travel no faster than 6 miles per hour (9.7 kilometers per hour). This rate of mass mobility remained until the early years of the nineteenth century and the introduction of the steam railroad. By the beginning of the twentieth century, the steam locomotive had given people routine mass transportation at 60 miles per hour (97 kilometers per hour).

Then came the airplane, which, by the turn of the twenty-first century, was whisking its passengers over thousands of miles at an average speed of 600 miles per hour (970 kilometers per hour). If current interest in high-speed propulsion continues, it is possible that our descendents will usher in the twenty-second century at a speed of 6,000 miles per hour (9,700 kilometers per hour)—such is the pace of mass mobility in the aerial age.

The achievement of flight has represented the integration of diverse technologies and disciplines: those of flight itself, such as aerodynamics; those of engineering, such as structures and propulsion; and those of related fields, such as electronics and communications. It was this integration process that took the kite, boomerang, turbine, and firework from their first, simple forms to the sophistication of the winged airplane, the helicopter, the jet engine, and the solid-and-liquid-fueled rocket. Even the pioneers (the Wright brothers and rocket scientist Robert Goddard, for example) were masters at blending the various elements into a satisfactory whole.

Human flight was first achieved at the end of the eighteenth century with the invention of hot air and hydrogen-filled balloons. It was only after the invention of the internal combustion engine in the mid-nineteenth century, however, that practical flight became a possibility. Once the airplane and airship had been invented, extraordinarily rapid developments in the field of aviation followed.

At first, several European countries took the lead in the science and technology of flight. The United States, however, was particularly suited to air transportation because of its size. The nation emerged from World War I as the leading industrial power and soon began to dominate the aviation field. By the 1930s, the U.S. aeronautical industry was the largest and most structured in the world. Other nations also produced powerful aeronautical establishments.

This progress in aviation development was demonstrated in the opening months of World War II. Germany's blitzkrieg warfare depended heavily on

a core of powerful air striking forces. Air battles between Britain and Germany in 1940 showed how significant the airplane had become as an instrument of war. The rest of the war that followed, on multiple fronts, revealed the often-surprising power of aircraft in both offensive and defensive combat. In fact, a lack of air power at critical junctures proved to be a more serious disadvantage than any deficits in land or sea power. World War II also highlighted the value of four new technologies that would play a huge role in future aerospace development: radar, the jet engine, the rocket, and the atomic bomb.

In the mid-1900s, flight underwent three remarkable transformations. One was in high-speed aviation, demonstrated by the breaking of the sound barrier in 1947. Another was the application of the drag-reducing swept wing to jet aircraft. This wing design revolutionized both military and civil aviation and led to the rapid global mobility of the present age. The third, in 1957, was the onset of the Space Age, with the launch of the first Earth-orbiting satellite, *Sputnik 1*, by the Soviet Union.

The success of this small sphere hurtling through space overturned the whole aeronautical picture. Today, more than fifty years after that epochal event, it is fair to state that the Sputnik program marked the birth of the Space Age. The product of Sergei Korolev and a team of gifted Soviet designers, Sputnik demonstrated mankind's ability to place a satellite in orbit around Earth. As such, the mission anticipated all subsequent satellites and their varied applications. Weather observation, communication, strategic reconnaissance, warning, navigation, remote sensing—these are all now taken for granted.

Sputnik marked the onset of a brief but intensive rivalry in space between the United States and the Soviet Union. The stakes were, as is now realized, achievement of the first manned flight to the Moon. It was a race that the United States won, but at significant cost. The U.S. space agency NASA then focused on the Space Shuttle project, another major but costly step. Maintaining the Space Shuttle (in great part to support the creation of the complex International Space Station) proved to be a great challenge that has lasted from the 1980s into the 2000s.

Today, the United States is not alone as a space-travel provider. Commercial use and privatization of space is increasing spaceflight greatly. It is a hopeful sign. Individual entrepreneurs, mirroring early aviation pioneers, are willing to invest their own resources in making space access available for many. Only time will tell how successful their various space ventures will be.

Today, the world's goods are largely shipped by air, and the mass mobility of populations depends on air transportation. Aircraft and spacecraft routinely influence the day-to-day activities of humanity. Businesspeople think little of making multiple trips in a single week by air, just as their predecessors relied upon the train. Students and other travelers fly across continents and over seas, carrying the influence of their own culture with them to new places. Science and technology, the environment, and the world in which we live are all dependent on the aerospace industry and the global communications it provides.

For all of these reasons, it is well to have this encyclopedia. Broad in scope and straightforward in explanation, it is designed to meet the needs of students and those seeking to understand the history of flight and its functioning in the modern world. Only through works such as this can the youth of today be adequately prepared to face the wonderful world that awaits them within Earth's atmosphere and the extraordinary discoveries yet to be made far out in the distant reaches of space.

Dr. Richard P. Hallion, 2008

ABOUT THE CONSULTANT

Dr. Richard P. Hallion is the former senior advisor for Air and Space Issues, Directorate for Security, Counterintelligence, and Special Programs Oversight at the Pentagon, in Washington, D.C., and a member of the Senior Executive Service. For more than ten years (1991–2002), he was the historian of the U.S. Air Force. Dr. Hallion is now president of the consultancy group Hallion Associates.

Dr. Hallion has broad experience in science and technology museum development and in research and management analysis. He has served as a consultant to various professional organizations. He also has flown as a mission observer in a wide range of high-performance aircraft.

Dr. Hallion is the author and editor of numerous books, articles, and essays on aerospace technology and military operations. He teaches and lectures widely. His numerous awards include: Citation of Honor, U.S. Air Force Association (1985); Commander's Medal for Public Service, U.S. Army (1988); Louis Bauer Distinguished Lectureship, Aerospace Medical Association (1999); Associate Fellow and Distinguished Lecturer, American Institute of Aeronautics and Astronautics (2005); and the Harry B. Combs Award, National Aviation Hall of Fame (2006).

READERS’ GUIDE

This guide tells you what you will find in the five volumes of *Flight and Motion* and explains how to use the set. There are 135 articles arranged alphabetically in Volumes 1 through 5. They cover science and technology, aviation and air flight, space and spaceflight, general topics, and biographies of notable people. The pages of every article are color-coded according to their main theme (see pages 4–5 for a list of articles by theme). These are the colors used for the different themes:

SCIENCE AND TECHNOLOGY

AVIATION AND AIR FLIGHT

SPACE AND SPACEFLIGHT

GENERAL TOPICS

BIOGRAPHY AND PROFILE

Each volume has its own glossary, which explains terms used in the volume, and an index to help find references to particular subjects within the volume. Volume 5 has a comprehensive glossary and a full index that cover all five volumes. In Volume 5, there are two additional, specific indexes: one for aircraft and spacecraft, and one for people. Volume 5 also contains lists of books and Web sites, places to visit, a measurement conversion chart, and a time line.

A **colored tab** appears at the beginning of each article to indicate its main theme. Color-coding by theme helps readers find articles of interest to them.

Aircraft, Military

Military aircraft are the airplanes and helicopters used by the world’s military forces. They are used for combat and for other military operations, including carrying supplies and troops, reconnaissance, training, and search and rescue.

In the United States all branches of the military (not just the U.S. Air Force) use aircraft. The United States has the world’s most powerful air force, and the U.S. Navy, Army, Marine Corps, and Air National Guard also have their own aircraft. Other major air forces include those of Russia, China, the United Kingdom, and France. Canada does not have a separate air force but has the Canadian Forces Air Command (AIRCOM) within the unified Canadian Forces.

Air Warfare Begins

The first aircraft used in warfare was the tethered balloon. It was used for observation, rising above battlefields so observers could get a view of the action below. The balloon was later developed into the airship, and airships were also used by the military for observation.

The first gasoline-powered military airplanes were known as scouts because reconnaissance (flying on missions to gather information) was their chief purpose. Other uses were soon found for military airplanes. They dropped bombs, fired at enemy ships, and shot down enemy aircraft. Special airplanes, mostly biplanes, were built for these tasks.

An observation balloon rises above the 1862 Battle of Fair Oaks, fought in Virginia during the American Civil War (1861–1865). Balloons such as this one were the first military aircraft.

The first air combat took place during World War I (1914–1918). Pilots shot at one another with pistols, shotguns, and machine guns. The next step was to attach a machine gun, which the pilot aimed at an enemy, to the airplane itself. By 1915 fighter planes had been developed with synchronized machine guns that fired bullets between the whirling propeller blades. Celebrated fighter pilots, known as aces, created successful air fighting tactics.

By the end of World War I, there were two main types of military airplane. Fighters flew at around 125 miles per hour (200 kilometers per hour) at heights of up to 22,000 feet (6,700 meters). Larger, heavier bombers flew more slowly, around 100 miles per hour (160 kilometers per hour), but they could fly for up to 8 hours.

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Captions give information about photographs and diagrams.

The **title** of each article appears at the beginning of the first page of the article and in the running head.

Focus boxes highlight interesting topics, people, or events relevant to the subject of the article.

Tech Talk boxes offer scientific explanations, statistics, and other technical details.

AIRCRAFT, MILITARY

In the 1930s the agile biplane was replaced by the much faster monoplane. This new kind of aircraft had an enclosed cockpit, a streamlined metal body, and a high-performance engine. Fighter planes such as the German Messerschmitt Bf 109 and Curtiss P-40 had a top speed of over 350 miles per hour (563 kilometers per hour). Bombers, such as Boeing's B-17, were slower at around 280 miles per hour (450 kilometers per hour), but they could fly for 2,000 miles (3,220 kilometers). The bombers carried 6,000 pounds (2,725 kilograms) of bombs that could be dropped accurately on city targets.

(From left) An A-10 Thunderbolt II, F-86 Sabre, P-38 Lightning and P-51 Mustang fly in a flight formation during an air show at Langley Air Force Base, Virginia, on May 21, 2004. The formation displayed four generations of U.S. Air Force fighters.

THE VERACRUZ INCIDENT

The first military operation involving U.S. airplanes was during the Veracruz Incident, a dispute between the United States and Mexico that began in April 1914. Five Curtiss flying boats were carried into the Mexican port of Veracruz by U.S. naval ships. The aircraft flew missions to search for mines in the harbor. On May 6, 1914, the airplane flown by Lieutenant Patrick N. L. Bellinger (1885–1962) was shot at from the ground by Mexican forces. This was the first time that a U.S. military plane was hit by enemy fire while on active service. Bellinger survived and went on to become a distinguished admiral.

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Some entries in this encyclopedia have a **colored background.** These are featured entries about special people, inventions, or topics.

TECH TALK

Length: 31 feet (9.45 meters)
Wingspan: 28 feet (8.53 meters)
Weight: 12,250 pounds (5,557 kilograms)
Motor: Reaction Motors XLR-11-RM-3 four-chamber rocket engine
Fuel: Mixture of alcohol and liquid oxygen
Thrust: 6,000 pounds (2,722 kilograms/26,500 newtons)

The Bell X-1 was shaped like a bullet for maximum streamlining. Its wings and tail plane were conventional in design. (In the 1940s, other experimental high-speed aircraft had strange shapes.) The stubby-winged X-1, however, had hidden secrets. Its wings were thin but very strong. A stabilizer, which the pilot could move up and down, improved stability and control. Later supersonic planes were also fitted with stabilizers.

SEE ALSO:
• Bell X-1 • Concorde • Engine • Glider • Jet and Jet Power • Kitty Hawk Flyer • Rocket • Wright, Orville and Wilbur

The **See Also box** at the end of each article lists related articles in this encyclopedia for readers who would like more information. Each article is preceded by a color-coded bullet point to indicate the article's main theme.

Aerobatics

Aerobatics is a form of aviation in which pilots perform by flying in patterns or drawing figures in the sky. Aerobatic stunts include loops, corkscrews, stalls, spins, and rolls. The name *aerobatics* came from the word *acrobatics*. The pilot makes the plane tumble around the sky like an acrobat. Several aircraft flying together in formation make patterns.

How Aerobatics Began

One of the earliest aerobatic maneuvers was looping the loop (flying a complete vertical circle), first performed by a Russian pilot in August 1913. One month later, the French pilot Adolphe Pégoud startled onlookers by flying his Blériot plane upside down. Pégoud had trained for this stunt by having the airplane fixed upside down in a hangar. He strapped himself into the pilot's seat, head down, for twenty minutes.

In the 1920s, pilots known as barnstormers flew stunts that would not be permitted today. Their tricks included skimming under bridges and racing railroad trains. There were also wing-walking displays, with people standing on top of aircraft wings. This stunt is still performed at air shows.

In the 1930s, air force pilots used aerobatic displays to demonstrate tactics used in air combat. They flew in groups that formed patterns, or in formation. Close formation flying included stunts with planes tied together.

The first world championships in aerobatics were held in 1960. In modern-day competitions, there are events for teams and individual pilots. Aerobatic contests are flown at heights from 328 to 3,280 feet (100 to 1,000 meters).

Aerobatics Today

Modern aerobatic aircraft can perform maneuvers impossible for an ordinary airplane, such as torque rolls (rolling and sliding backward at the same time) or *lomcevaks* (tumbling end over end). Aerobatic

The U.S. Navy's Blue Angels, using F/A-18 Hornets, perform aerobatic movements at an air show in 2006.

planes are strong but very light in relation to the power of their engines. Most use piston engines and propellers.

One outstanding aerobatic airplane is the U.S. Pitts Special. The first Pitts flew in 1947, and since then Pitts Specials have dominated aerobatic competitions. The later versions of this little plane remain close to the original design.

Formation teams perform their displays with as many as sixteen aircraft, although a team of nine or ten is more usual. During a per-formance, aircraft change formations a number of times. They split up into smaller groups, following the instructions of the team leader by radio. Pilots often use colored smoke trails to highlight the patterns they are flying.

Famous aerobatic teams include the Blue Angels of the U.S. Navy, the Thunderbirds of the U.S. Air Force, and the Red Arrows of the British Royal Air Force. Unlike other aerobatic performers, military teams usually fly jet planes. These planes fly faster than propeller planes and need more space to display their formations. The Thunderbirds fly the F-16 Fighting Falcon that has a top speed of 1,300 miles per hour (2,092 kilometers per hour).

Accidents are rare, but aerobatics are demanding. Pilots practice constantly to perfect new formations and sequences. They also must keep physically fit to cope with the stress of aerobatics, which subjects their bodies to strong g-forces (acceleration measured as multiples of the force of gravity at Earth's surface).

PATTY WAGSTAFF

Born in 1951 in St. Louis, Missouri, Patty Wagstaff flew with the U.S. aerobatics team from 1985 to 1996. She was the first female U.S. National Aerobatic champion, a title she won three times. Wagstaff was International Aerobatic champion in 1993. In 2004, she was elected to the National Aviation Hall of Fame. The Goodrich Extra 260 plane flown by Patty Wagstaff in the 1990s is displayed at the Smithsonian Institution's National Air and Space Museum. Wagstaff has flown at air shows all over the world and says she likes the precision of aerobatics. "I like flying a perfect loop . . . a perfect maneuver."

SEE ALSO:

- Aerodynamics • Barnstorming
- Gravity

Aerodynamics

Aerodynamics is a branch of science that deals with the behavior of moving gases and how they affect objects passing through them. Designers use their knowledge of aerodynamics to make aircraft and rockets the right shape.

The word *aerodynamics* comes from two Greek words. The first word, *aer*, means "air." The second, *dunamis*, means "force." Aerodynamics, therefore, means "force from air."

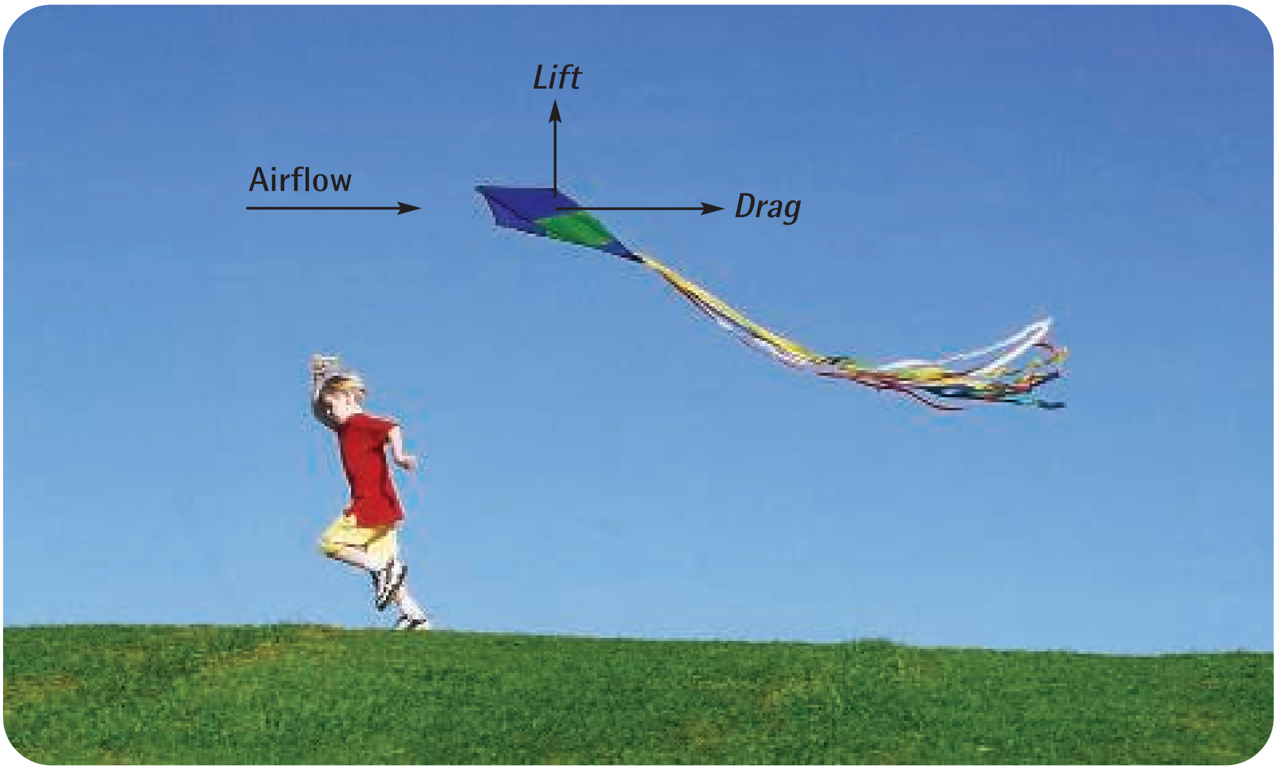
Aerodynamic Force

When an object moves through air, it generates aerodynamic force. The size and direction of the force depend on the size, shape, and speed of the object. The level of force also depends on the physical properties of the air, such as its pressure and temperature.

It does not matter whether it is the object that is moving or the air that is moving. Air flowing around a stationary object generates aerodynamic force, too.

A kite flies because of the force generated by the wind blowing around it. The aerodynamic force that acts on a kite has two parts. These parts are called lift and drag. Lift takes the kite upward, and drag pulls it backward in the direction that the wind is blowing. The kite does not fly away because these forces

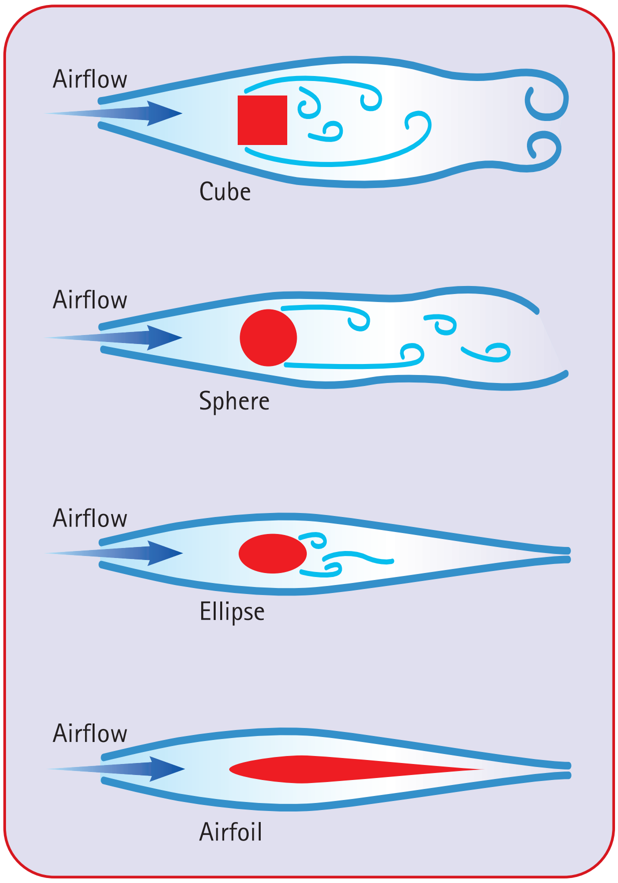
Two aerodynamic forces operate on a kite as it moves through the air. The movement creates lift, which raises the kite up, and drag, which pulls the kite back.



are balanced by the tension in the kite string. Kites often have a long tail. The tail has a purpose—it is there for aerodynamic reasons. The drag it creates keeps the kite facing in the right direction.

Airplanes also generate lift and drag when they move through air. Lift operates at right angles to a plane's direction of flight. When the plane is flying straight and level, the lift generated by its wings acts straight upward. Drag operates in the opposite direction to a plane's motion. When the plane is flying straight and level, therefore, drag pulls backward.

Two other forces act on every powered airplane. First, thrust generated by its engines pushes the plane forward. Second, the plane's weight pulls the plane downward. For an airplane flying straight and level at a steady speed, these forces are perfectly balanced.



Smooth shapes create better airflow than angles and therefore minimize drag. A cube breaks up airflow into turbulent eddies. Air flows more smoothly around a sphere and even better around an ellipse, or oval shape. The airfoil shape used for airplane wings is the most aerodynamic of these shapes.

Aerodynamic Shapes

Some shapes move through air more easily than others. Angular, boxy shapes catch more air. They also break up the smooth flow of the air, making it turbulent and chaotic. Slender, gently curving shapes create less drag than angular shapes, because air can flow around them more smoothly. Objects that air flows around smoothly are described as streamlined.

Airplanes are streamlined. Anything on their surface that might stick out into the air and cause unnecessary drag is smoothed out wherever possible to reduce drag. A plane's metal skin is held in place by fastenings called rivets. Airplanes used to be held together by rivets with round heads. The round heads stuck out and caused some drag. Today, the most streamlined aircraft are held together by rivets with flat heads that do not stick out. A plane's metal skin is also polished or painted to give it a smooth surface that air can flow over easily.

All but the smallest and slowest planes have wheels that fold up inside them after takeoff. Doors close over the wheels to give the plane's body a smooth, streamlined shape. If the wheels stayed down, they would spoil the plane's streamlined shape and create a lot of drag. The doors and windows are also designed to be level with the plane's skin.

The Early Days

The science of aerodynamics was slow to develop compared to other sciences. Long before people began to unravel the secrets of aerodynamics, they could see that birds use their wings to create and control the forces needed for flight. They were unable to see exactly how a bird's wings work, however, because the wings moved too fast to see clearly. Until high-speed photography was developed at the end of the nineteenth century, there was no way to freeze the action of a bird's wing so it could be studied. Without this understanding, early attempts to build flying machines failed.

One person did try to analyze the forces involved in flight more accurately. George Cayley was the first person to study airplane flight scientifically. He experimented with different wing shapes and measured how well they worked. Cayley discovered the four forces that act on an aircraft: lift, drag, thrust, and weight. Other inventors learned from Cayley and expanded upon his work. In time, they learned how to use aerodynamics to create the forces needed to lift and steer flying machines.

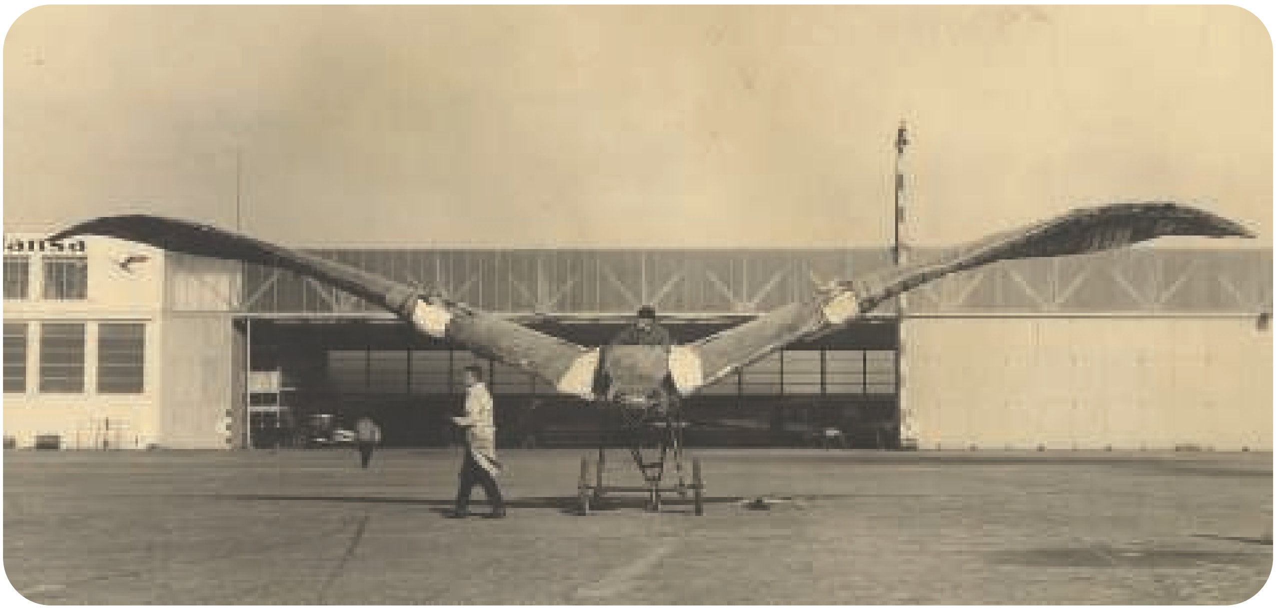
THE FIRST HEAVIER-THAN-AIR FLIGHT

The founder of the science of aerodynamics was the Englishman Sir George Cayley (1773-1857). He worked on a wide variety of engineering projects, but is best known for his aero-dynamic research. By 1804, Cayley was building model gliders with the same layout as a modern airplane—they had fixed wings, a body, and a small tail at the back. He also built gliders capable of carrying people. In the 1840s, Cayley built a small glider that carried a ten-year-old boy. Cayley went on to build a full-size glider. In 1853, it carried his coachman, John Appleby, across a valley on the first heavier-than-air flight by an adult. When the glider landed, the terrified Appleby said, "Please, Sir George, I wish to give notice [quit]. I was hired to drive and not to fly!"

Modern aerodynamics really began with the Wright brothers. Several years of aerodynamic research and experiments with wings, kites, and gliders enabled them to build the first successful powered airplane in 1903.

How Scientists Use Aerodynamics

Scientists who specialize in aerodynamics are known as aerodynamicists.



Hopeful aviators pursued the idea of flapping wings. This aircraft from the 1920s was built by Gustav Lilienthal, brother of aviation pioneer Otto Lilienthal. Gustav Lilienthal worked for years on his own designs, but his aircraft never flew.

They put a lot of time and effort into reducing drag because drag wastes fuel. A plane's engines have to burn fuel to generate the power necessary to overcome drag. Improving a plane's aerodynamics can enable it to fly farther without burning any more fuel. Because drag acts like a brake, reducing drag also enables the fastest airplanes to go even faster. Improving a glider's aerodynamic design enables it to stay aloft longer.

One way to study aerodynamics is to use a wind tunnel. Air is blown through a tunnel with a model aircraft inside. As the air flows around the model, the forces acting on it are measured.

Scientists would like to be able to calculate precisely how a plane will perform in the air instead of having to build models to test every design and every change in a design. Such calculations, however, present a formidable task. That task involves calculating the aerodynamic forces acting on every part of an aircraft as it flies through the air at all angles and speeds. To do this, the air flowing around the aircraft is divided into tiny packets called cells. The forces acting on each and every cell must be calculated to figure out how each cell moves and how it affects the aircraft. Each cell affects all the cells around it. In turn, they affect other cells, which affect yet others, making the problem incredibly complicated.

The method of using computers, numbers, and mathematical equations to figure out how air flows around an object is known as computational fluid dynamics (CFD). Only the fastest supercomputers have the ability to use CFD to tackle complicated aerodynamics.

The F-22 fighter plane can fly at supersonic speeds. It is very maneuverable because it was designed to be less stable than most aircraft.

Stability

Most airplanes are designed to be aerodynamically stable. A stable airplane is one that is steady in the air. If it is rocked by a gust of wind, it steadies itself without the pilot having to do anything. Stability makes an airplane safer and easier to fly, but it also makes it more difficult to maneuver. Stable aircraft are designed to fly straight and level. That stability works well for a plane like an airliner, because passengers want to fly in planes that feel steady and turn gently.

A fighter plane that performed like an airliner, however, would not last long in an air battle. Fighters have to be able to maneuver fast to chase other planes and escape danger. The way to make fighter planes more maneuverable is to make them less stable.

The latest fighters are highly unstable. Sometimes, a pilot needs to make a sudden turn, climb, or dive. A fighter plane's instability enables it to respond quickly to controls and make such a move much faster than a more stable aircraft. In fact, these extraordinary planes are able to fly only with the help of computers that constantly make

FLYING WINGS

Most planes have the same basic layout, with a pair of wings sticking out from a central fuselage (body) and a small tail unit at the back. The B-2 bomber (*below*) is different. It is a type of aircraft called a flying wing. The whole plane is one big wing. There is no tail. A flying wing is very streamlined, but it is also very unstable. If the nose of a flying wing tips up or down even a little, the plane can suddenly flip over. Most planes have a tail unit that prevents this from happening. A flying wing needs a control system to keep it under control in the air.

Flying wing aircraft have been built since the 1930s, but they never became very popular or widespread, because their lack of stability made them difficult to fly. The control systems available then were not able to tame their wild behavior. Control systems developed since the late 1980s work much better. The B-2 bomber, which first flew in 1989, relies on four flight computers to stop it from tumbling out of control. The pilot operates the computers, and the computers fly the plane.

split-second adjustments to keep them under control. Without their flight computers, these planes would be impossible to control.

Scientists know a lot more about aerodynamics today than they did in the early days of aviation, but there is still a lot to learn. The development of new aircraft and faster aircraft, together with the use of new materials, continue to present aerospace engineers with new challenges in aerodynamics.

SEE ALSO:
• Aircraft Design • Bird • Glider • Lift and Drag • Materials and Structures • Wind Tunnel • Wing • Wright, Orville and Wilbur

Aeronautics

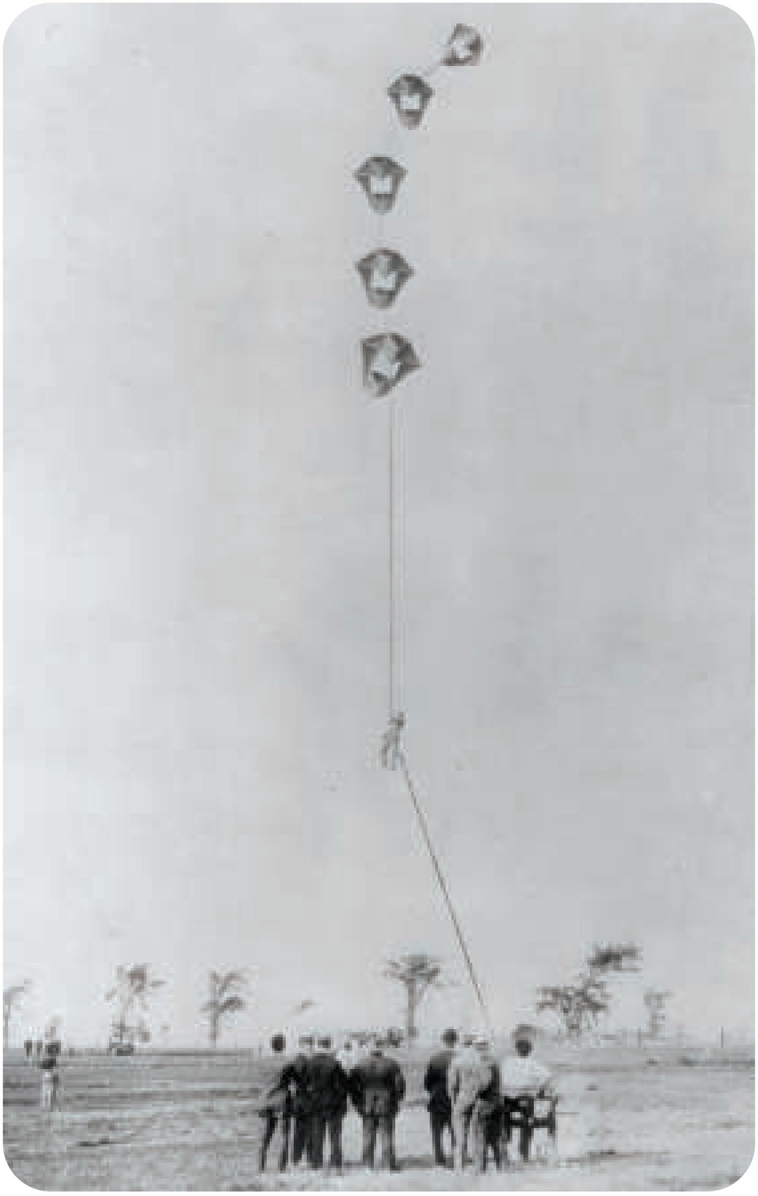
Aeronautics is the science of building and flying aircraft. The term covers scientific study, design, and technology. It also includes the manufacture and operation of all types of aircraft, both lighter than air (such as airships) and heavier than air (such as airplanes).

Aeronautics involves a great variety of scientific and engineering disciplines. Aerodynamics and propulsion are important in aeronautics. So are materials, structures, control systems, and computing.

Early Kites and Wings

The history of aeronautics began long before people understood the principles of flight. The Italian explorer Marco Polo (1254–1324) was one of the first Europeans known to have gone to China. When he returned to Europe in 1295, he told stories of people who flew using giant kites. Kites may have been built in China as long ago as 1000 B.C.E. They are the world's first aerial vehicles.

Even before Marco Polo, there were people who believed they would fly if they strapped a pair of wings to their arms and flapped like a bird. They tested their ideas by jumping from towers and mountains. Without any real understanding of lift, gravity, or the properties of air, they fell to the ground much faster than expected. Injuries and death were common.



Samuel Perkins tested man-lifting kites for observational uses by the U.S. Army during World War I. This 1910 photograph shows five Perkins kites holding a man aloft at Harvard Aviation Field in Atlantic, Massachusetts.

One of the most famous of these early "jumpers" was Abbas Ibn Firnas (810–887 C.E.). He lived in Andalusia, now part of Spain. Firnas was an inventor who studied chemistry, astronomy, and physics. In 875, when he was sixty-five years old, Firnas built a glider. He made a successful flight, which was seen by a large number of people, but he was injured when the glider hit the ground. This happened about 1,000 years before modern aeronautical pioneers started making successful glider flights.

In the year 1010, an English monk named Eilmer tried to fly from the top of a tower with wings fastened to his arms and feet. Eilmer managed to glide for about 650 feet (200 meters), but he landed badly and broke his legs.

Many of the wings used by early fliers copied the wing shape or flapping action of birds' wings. Even the great Italian artist and inventor Leonardo da Vinci (1452–1519), who drew designs for flying machines more than 500 years ago, thought the first successful flying machine would have flapping wings.

Balloons and Airships

Other people thought it might be possible to build flying machines that were lighter than air itself. They believed they would simply float upward like an air bubble floating up through water or smoke rising from a fire.

The first successful manned flights were indeed made in the lighter-than-air craft envisaged by aviation pioneers. The French brothers Jacques-Étienne and Joseph-Michel Montgolfier had the first success with a hot air balloon in 1783. The balloon was able to fly because heated air is lighter than the surrounding air. A sheep, duck, and chicken made a flight and survived! They were the first living creatures to make a balloon flight. Two months later, also in France, Jean-François Pilâtre de Rozier and the Marquis d'Arlandes made the first manned flight in a hot air balloon.

In France the same year, Jacques Charles made the first manned flight in a hydrogen-filled balloon. Hydrogen gas is even lighter than hot air.

The problem with balloons is that they are carried wherever the wind takes them. They cannot be steered. The next goal, therefore, was to make a controlled flight. French engineer Henri Giffard (1825–1882) achieved this in 1852 with a steam-powered hydrogen balloon. The engine was slung under the balloon and drove a propeller. Giffard had invented the airship.

Airships developed further in the following years. In Germany, Ferdinand von Zeppelin (1838–1917) built bigger and bigger airships. They rose without effort into the air, and they were more spacious and comfortable than airplanes. For a time airships seemed to have a promising future.

In 1937, however, the world's biggest airship, the *Hindenburg*, crashed in flames in New Jersey. News and images of the accident traveled around the world, marking the end of the golden age of the airship.

Airships are making a comeback today. Early airships were filled with hydrogen, a gas that catches fire and burns very easily. Modern airships are filled with helium, a gas that cannot catch fire. They are used for tasks, such as filming, which require a stable platform that can stay aloft for long periods.

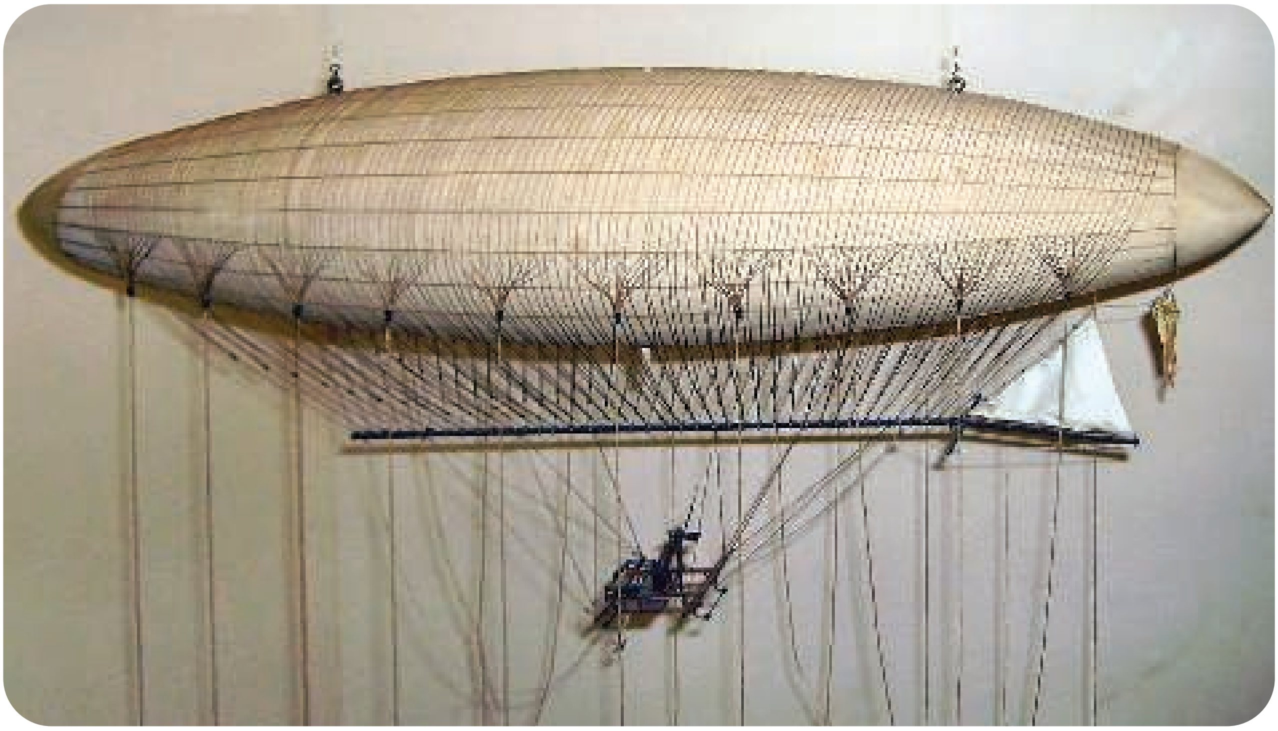
The First Aircraft

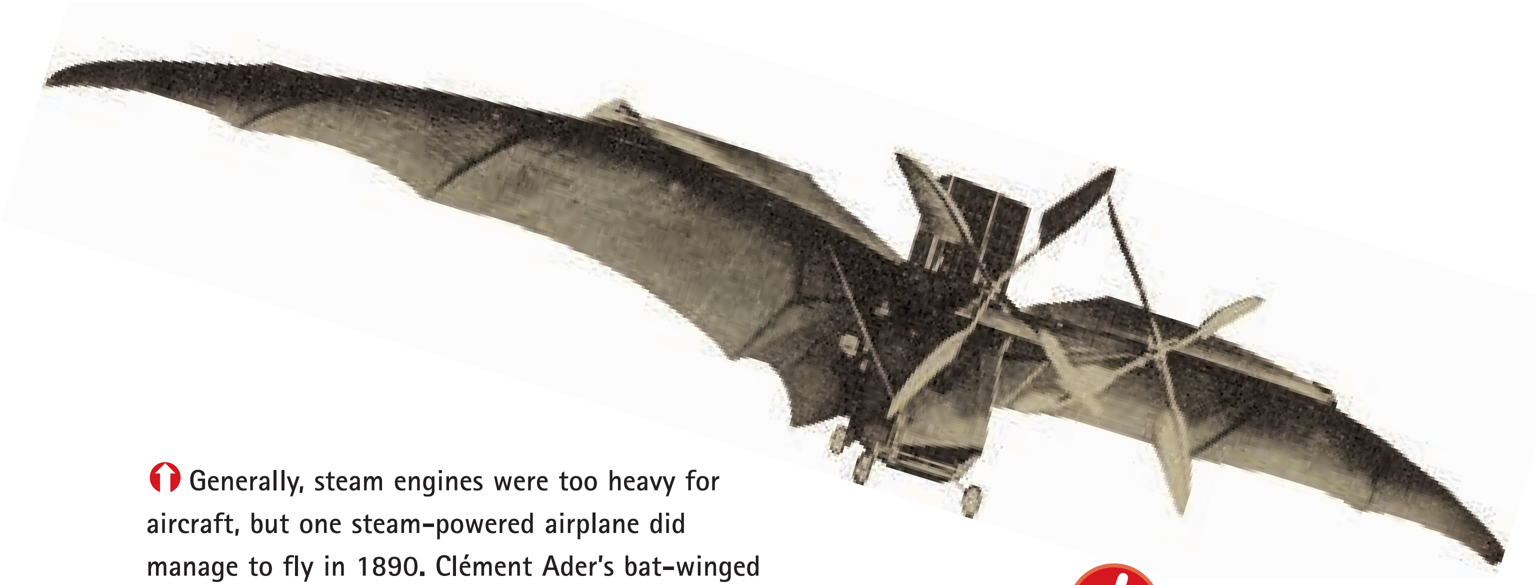
Meanwhile, the airplane took the lead. When Giffard was making the first airship flight in France in 1852, Englishman George Cayley had already begun a scientific study of the forces produced by moving air, or aerodynamics. Cayley was interested in how these forces could be used by heavier-than-air flying machines.

He wrote that the challenge was "to make a surface support a given weight by the application of power to the resistance of air." He was talking about lift and drag, the aerodynamic forces that act on aircraft. Cayley's work resulted in the first manned gliders in the middle of the nineteenth century.

The invention of the steam engine in the nineteenth century awakened interest in developing steam-powered airplanes. The steam engines of the day were too heavy, however. Powered airplanes had to wait until smaller, lighter engines powered by gasoline were developed in the late 1800s. That would

The Giffard steam-powered balloon made the first successful powered flight. The engine, propeller, and platform for the pilot hang beneath the 144-foot (44-meter) hydrogen-filled balloon. This model of Giffard's balloon is now on display at the Science Museum in London, England.





Generally, steam engines were too heavy for aircraft, but one steam-powered airplane did manage to fly in 1890. Clément Ader's bat-winged *Éole* flew 165 feet (50 meters), but only 8 inches (20 centimeters) above ground. Ader later built a larger version, *Avion III* (above), which he claimed flew 984 feet (300 meters) in 1897.

lead to a usable engine for airplanes. Aeronautical pioneers, meanwhile, concentrated on learning to build stable gliders and control them in the air.

The brothers Orville and Wilbur Wright experimented with kites and gliders in a very methodical way. Each time they encountered a problem, they worked at it until they found a solution. They also designed a gasoline engine light enough to power an airplane based on one of their gliders. The brothers were finally ready to fly the world's first successful powered airplane in 1903.

The Wright brothers had developed the airplane and shown that controlled flight was possible. Other engineers and inventors reshaped the airplane and otherwise improved it with their own ideas. The age of modern aeronautics had begun.

RESEARCH INTO AERONAUTICS

Otto Lilienthal (1848–1896) in Germany made more than 2,000 glider flights. Other aeronautical engineers and inventors around the world avidly read Lilienthal's books and essays on aeronautics. The readers included Percy Pilcher in Britain and the Wright brothers and Octave Chanute in the United States. These innovators flew gliders similar to modern hang gliders. They steered by shifting their weight to one side.

Aeronautical research at that time was very risky, and accidents were common. Flimsy aircraft made of wood and fabric could fall apart, or they could spin out of control and plunge to the ground. Lilienthal and Pilcher both died as a result of aircraft crashes.