PART ONE

The Rich History of Air Power

Chapter

1 INTRODUCTION TO AIR POWER

What is unique about the air and space domain? Can you drive or fly faster from home to school? Is it easier to turn around in a plane or a ship? Can you see farther from your car or from a plane? The answer to these questions and many more tell us that the air and space domain is special and unique. That is why we study it.

Objectives

Describe what makes air power unique.
Define air and space power.
Recognize the various legends of flight.
Identify the Chinese invention that solved one of the major problems of air power.
Identify the contributions the Chinese made to advance air and space power.
Identify the significant contributions that advanced air and space power.
Recall the individual scientists and researchers and their experiments.

Speed and Perspective Unique

The ability to move people, cargo and information quickly through air and space is unmatched. For example, what if you want to deliver medicine to a place across the ocean? Would it be faster to take a ship across the ocean, or to fly? What if you had to get to a town hundreds of miles away? Would it be faster to take a car or a plane? The answer to these questions, of course, is to fly.

Another aspect of air and space power that makes it unique is elevation. Not only can you fly over an obstacle that is in your way, you can see over it. Elevation gives you the ability to see objects that are far away.

In this chapter, you will discover why we should care so much about air and space domain. Its very uniqueness and our ability to use it is an interesting story.

At first there were problems that had to be overcome. Learning to fly was a very difficult task. The very first questions that had to be answered are fairly obvious. Just think about it. How would you go about figuring out how to fly? Would you ask a bird? Could you tell a bird how you are able to run or walk? Why are you able to run faster and jump higher than someone else? It isn't as easy as you may think, is it?

Men tried to imitate the flight of birds.

Believe it or not, both subjects are related. Walking and flying have several things in common. For instance, you need some sort of power to get you going. You will also need more power as your load gets heavier. You will also need some place to store that power. This only adds to your problem because when you add a storage container you also add weight.

Air does not flow freely over a surface without some sort of reaction. Are there road signs in the sky? How do those airline pilots know where they are going? This is getting complicated and we haven't even started talking about the more advanced problems such as lift and navigation.

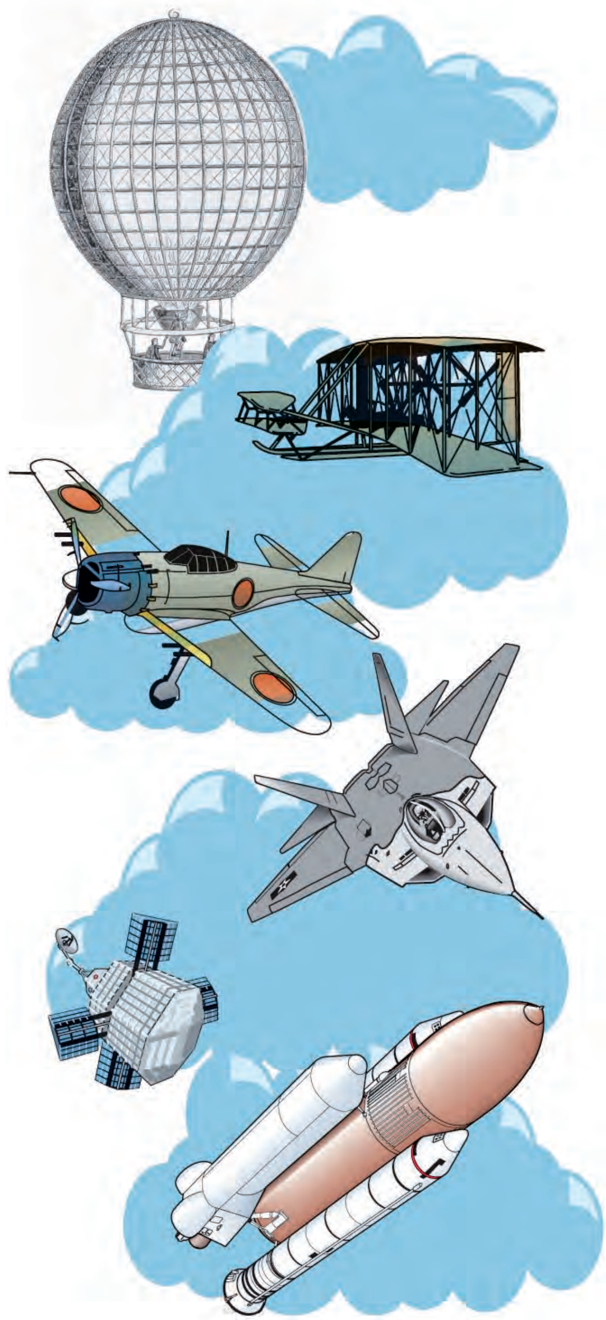
Virtually Unlimited Possibilities

Just think. In the last 100 years we have gone from gliders, to rotary aircraft, to jets. We have gone from traveling just a few miles to traveling unlimited distances. We have gone from building our planes from wood to building them from stealthy, man-made composite materials. We have gone from moving a few miles per hour to flying at multiples of the speed of sound and beyond.

The uses of air and space power have expanded as well. We have gone from using balloons to see a few miles ahead, to using satellites to monitor weather patterns from space. We have gone from carrying one or two people, to moving hundreds. We have gone from small loads to cargo loads large enough to carry a helicopter, tank or even another plane. We have gone from navigating by sight, to relying totally on instruments to tell us where we are going. The result of all this success is even higher expectations for bigger and better things in the future.

However, before we examine the future of air and space power, we should examine how we got to where we are today. The lessons learned developing air and space power are very interesting. More importantly these lessons should be examined so that we do not repeat the mistakes of the past. This will let us expand our horizons and reach out even farther, faster and better than we do today.

In the following chapter, we will look at the lessons learned and the development of air and space power. What is air and space power? It is the ability to take advantage of air and space to do many things. We can move people, cargo and information farther, faster and cheaper than ever before. We can now move all the information in the Library of Congress from Washington DC to Los Angeles faster than a blink of an eye. We can do this because of our satellites in space.



The Growth of Air Power from Balloons to Rockets

Our ability to use air and space did not come easy. Many lessons were learned the hard way, and they cost many lives along the way. Mistakes were made while we experimented with new engines, wings and life support systems. We don't want to repeat costly mistakes. We want to build on what we learned from them so we can get even better. The following chapter looks at many of the major developments in the history of air and space power. Additionally, the chapter points out why these are important to the continuing development of our air and space power.

The Heritage of Flight

Long before people appeared on this planet, other forms of life, which included birds, mammals (bats) and reptiles (pterodactyls) learned to travel through the air. Some imaginative people even believe that, many centuries ago, life from other planets may have traveled through space.

For people here on Earth, however, air and space travel is a very recent occurrence. Only within the last century have we been able to fly. In another sense, however, people have probably traveled through air and space for as long as they have been on Earth—at least, in their imagination they have.

Legends About Flight

Among the earliest recorded stories of man in flight is the Chinese legend of Emperor Shun. According to this legend, nearly 4,000 years ago, Emperor Shun escaped from prison by "donning the work clothes of a bird."

The Chinese have always been particularly enchanted by flight. Legends tell us that Kei Kung, the Chinese god of thunder and lightning, flew using the wings of a bat. Also, 1,800 years before Christ, legend has it that Ki-Kung-Shi built a flying chariot that had no visible means of support.

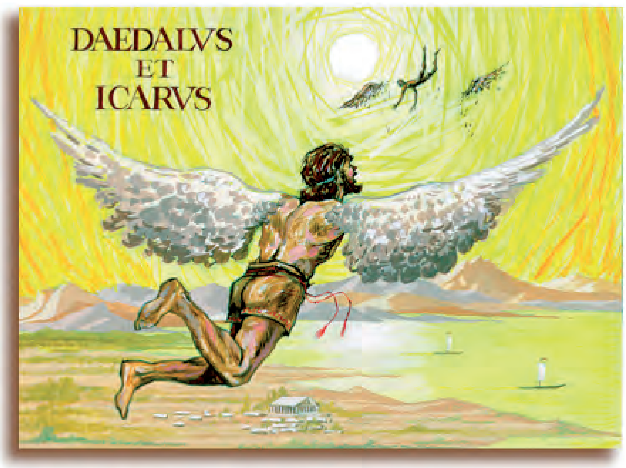
Wan Hoo

Although we don't know how truthful these legends are, we do know that the Chinese built the first devices that enabled us to fly. About 100 BC, the Chinese invented the kite. Some of the kites were very large and may have carried man aloft. We are fairly certain the Chinese used man-carrying kites to watch enemy troops in the seventeenth century.

About 900 AD, the Chinese invented gunpowder, and by 1100 AD, they were using gunpowder to build simple rockets. These early rockets were used for celebrations and in warfare. There is at least one Chinese legend of manned flight using rocket power. According to this legend, a Chinese official named Wan Hoo attempted a flight to the Moon using a large wicker chair to which were fastened 47 large rockets. When the rockets were ignited, Wan Hoo disappeared in a large ball of smoke and fire—never to be seen again. The Chinese legend concludes that maybe Wan Hoo is the man in the Moon.

It is from ancient Greece and Rome (800 BC—527 AD), however, that we get our most familiar legends and art showing flight. The Greek god Hermes and the Roman god Mercury traveled on winged sandals. Eros and his Roman counterpart, Cupid, are both pictured as winged children. The Greeks also gave us Pegasus, the winged horse.

Of course, the most famous myth of all is that of Icarus and Daedalus. According to this myth, Daedalus (an architect and mechanic) and his son, Icarus, were imprisoned by King Minos of Crete. Determined to escape, Daedalus made a large set of wings for himself and his son. The wings were made of feathers. They attached them to their bodies with wax. With these wings, they glided away from the island prison. Despite his father's warning, Icarus flew too close to the Sun. The wax melted, and Icarus fell to his death into the sea.



Daedalus and Icarus

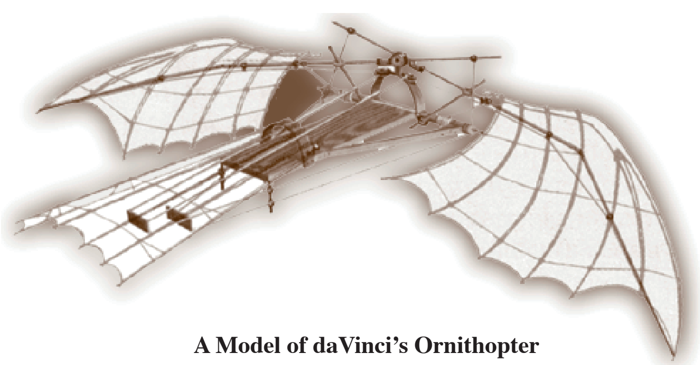
One of the earliest illustrations of flight is found on a seal from Babylonia that was made in about 3500 BC. This seal pictures King Etena flying to heaven on the back of an eagle.

Another example is from 1500 BC. The Persian King, Kai Kawus, was supposed to have had a flying throne that was carried aloft by four eagles. In addition, Alexander the Great, King of Macedon in 336 BC, is said to have ridden in a cage drawn by winged griffins (a mythical animal—half eagle and half lion).

In tracing the history of flight, there are two trends that appear over and over in all parts of the world. First, it seems that people have always had the desire to fly. Second, since they did not have the natural ability to fly like the birds, flight depended on their ability to build machines to carry them aloft. The history of flight is really a history of people's ability to invent and perfect these machines.

Early Scientific Research

Leonardo da Vinci, (1452 – 1519), the great Italian artist, architect and man of science made the first scientific experiments in the field of aviation. He devoted many years of his life to understanding the mysteries of flight and left the world 160 pages of descriptions and sketches of flying machines. Among these descriptions and pictures are the world's first known designs of the parachute and the helicopter.


A Model of daVinci's Ornithopter

He understood and wrote about the importance of the center of gravity, center of pressure and streamlining. These principles are vital in designing and building modern aircraft and spacecraft.

It seems certain that if da Vinci had concentrated his research only in these areas, he could have constructed a workable manned glider 400 years before the first one was actually built and flown. However, like so many before and since, he was obsessed with the idea of man flying like a bird.

He described, sketched and built models of many types of *ornithopters* (flying machines that are kept aloft and propelled by flapping wings). He left detailed sketches of wing mechanisms that used levers and pulleys to allow human muscle power to flap the artificial wings.

It is important to note that Leonardo da Vinci was a brilliant scientist whose work could have changed the entire history of flight—except for one tragic fact. It was 300 years after his death before his manuscripts were published and made known to the world. As a result, this knowledge was temporarily lost to the world and likely delayed the progress of manned flight.

Leonardo da Vinci

Basic Scientific Research

Beginning in the late 1500s and through the 1700s, there were many stories and books written about flight. Some were partially based on scientific principles. In the 1600s, a great deal of scientific research took place that was not directly related to flight. This research provided knowledge that would be used later to accomplish flight.

Three European scientists (Torricelli from Italy, Von Guericke from Germany and a Frenchman named Pascal) performed scientific studies of the atmosphere. They learned that the atmosphere is a fluid and that atmospheric pressure decreases the higher you climb. They invented the barometer, which measures the pressure of the atmosphere, and the air pump, which allowed them to study vacuums. This knowledge eventually led to successful lighter-than-air flight.

Francesco de Lana's Aerial Ship

In 1670, a Jesuit priest, Francesco de Lana, a professor of mathematics, wrote about an "aerial ship." This airship would be carried aloft by four large spheres from which all air had been removed to make them lighter than the surrounding air. He proposed to make the spheres out of very thin copper. The principle was sound but the spheres would have been immediately crushed by the pressure of the surrounding air. Francesco de Lana's writings are the first scientific records of a "vacuum balloon."

He also discussed the need for ballast (a heavy substance) for controlling ascent and the need to let air enter the spheres gradually to control descent. Francesco de Lana also wrote about military uses for balloons.

Several developments made the first successful lighter-than-air flight possible. None were more important than the developments that reduced the cost of printing, which made the wide distribution of books and other written documents possible. For the first time, scientists throughout Europe could compare notes, and benefit from the work done by each other.

Another Jesuit priest, Laurenco de Gusmao, is credited with inventing the hot-air balloon. In 1709, he demonstrated a small hot air balloon for the King of Portugal. Records of this demonstration were printed and widely read throughout Europe.

In 1766, an English chemist named Henry Cavendish made an important contribution to flight when he discovered a gas, which he called “flammable air.” Later named hydrogen, this gas is important because it is lighter than air. Cavendish himself didn’t recognize its importance to flight.

However, Dr. Joseph Black, Professor of Chemistry at Glasgow University, did. He realized that if this light gas were enclosed in a thin bladder, it would weigh less than the surrounding air and would therefore rise. Dr. Black’s records show that he intended to experiment with this idea, but dropped it due to his heavy teaching schedule.

Finally, two brothers, who were papermakers in Annonay, France, achieved manned flight. Joseph and Etienne Montgolfier were well-educated eighteenth century gentlemen who enjoyed researching science and flight. They read all about the work of English scientist Joseph Priestley. Priestly discovered oxygen and had written scientific papers on the properties of air.

Montgolfier’s Hot Air Balloon

In 1782, Joseph Montgolfier was watching a fire in his fireplace and noticed an example of Priestley’s work. He saw a force cause the sparks and smoke in the fireplace to rise. He then made a small bag out of fine silk and lit a fire under the opening at the bottom. The bag swelled and rose to the ceiling of the room. The Montgolfiers soon moved their experiments outdoors, building and flying larger and larger bags made of paper and linen.

In June 1783, the Montgolfier brothers were ready for a public demonstration using a paper-lined linen bag 38 feet in diameter. On June 5, in the marketplace, they built a fire of straw and wood under their balloon. The balloon rose to an altitude of 6,000 feet and traveled over a mile before landing.

The Montgolfiers had no idea that their balloon rose because it contained heated air that was lighter than the surrounding air. They thought a lighter-than-air gas that was created by the burning fuel caused the balloon’s ascent. They called this gas “Montgolfier gas.”

An account of this demonstration was sent to the Academy of Science in Paris. This led to an invitation for the Montgolfiers to demonstrate their balloon. Once again, the demonstration was a success.

They were then asked to demonstrate their balloon before King Louis XVI and Marie Antoinette on September 19, 1783. For this demonstration, the Montgolfiers attached a cage to their balloon and the first living passengers—a sheep, a rooster and a duck—were carried aloft and returned safely to Earth.

The first men to fly in a lighter-than-air craft rode a Montgolfier balloon into the air over Paris on November 21, 1783. These two men were Pilatre de Rozier, a young physician, and the Marquis d’Arlandes, a young infantry officer. The flight lasted 25 minutes and covered a little more than 5 miles.

After centuries of dreaming, flight had become a reality. However, we were still a long way from mastering air and space power.

The problem with these hot air balloons was that they only stayed aloft as long as a fire continued to heat the trapped air. This made them very dangerous. It also limited the duration of the flight because a great deal of wood and straw had to be carried as fuel.

Later, the Montgolfiers hired a young scientist, J. A. C. Charles, to carry out further research on balloons. Charles was familiar with the "flammable air" isolated by Cavendish. He also realized that whatever "Montgolfier gas" was, it was not as light as hydrogen.

Charles was aware of the difficulties in containing hydrogen; therefore, for his balloon he developed a small globe of rubberized silk. On August 23, 1783, the globe was inflated with hydrogen and rose into the air.

One of the spectators at this event was Benjamin Franklin. He was so impressed that he immediately wrote to scientists in the United States stressing the military importance of this new invention. On December 1, 1783, Charles and another passenger made the first manned flight in a hydrogen balloon. This flight lasted over 2 hours and covered more than 27 miles.

Following these early flights, ballooning became very popular in Europe. Between 1783 and 1790, 76 flights were recorded in France alone. In 1793, the French government formed an air arm to their Army, and used balloons for reconnaissance during the French Revolution.

Andre-Jacques Garnerin's first parachute jump from a balloon.

In 1797, Andre-Jacques Garnerin made the first parachute jump from a balloon flying at an altitude of 3,000 feet.

During this time period, the hydrogen balloon became much more popular than the hot air balloon. In fact, by the end of the 1700s, the hot air balloon disappeared and its popularity would not return until the advent of modern-day sport balloons.

On January 7, 1785, a French aeronaut (balloonist), Jean Pierre Blanchard, and an American passenger, Dr. John Jeffries, made the first balloon flight from one nation to another. They flew across the English Channel from England to France. The flight covered about 20 miles and required almost two hours to complete.

It was not until 1799 that a woman flew alone in a balloon. That flight was made in a hydrogen balloon piloted by Madam Jeanne-Genevieve Garnerin.

The first woman to make ballooning a career was Jean Blanchard's wife, Madeleine Sophie Blanchard. From 1805-1819, she performed exhibitions of ballooning throughout Europe. Madame Blanchard was also the first woman to be killed in a ballooning accident (1819, in Paris).

The first balloon flight in the United States took place in Philadelphia, Pennsylvania, on January 9, 1793. The "pilot" was the same Jean Pierre Blanchard who had flown across the English Channel. President George Washington and thousands of spectators witnessed the flight. The balloon lifted off at 10 o'clock in the morning and landed safely near Woodbury, New Jersey, about 46 minutes later.

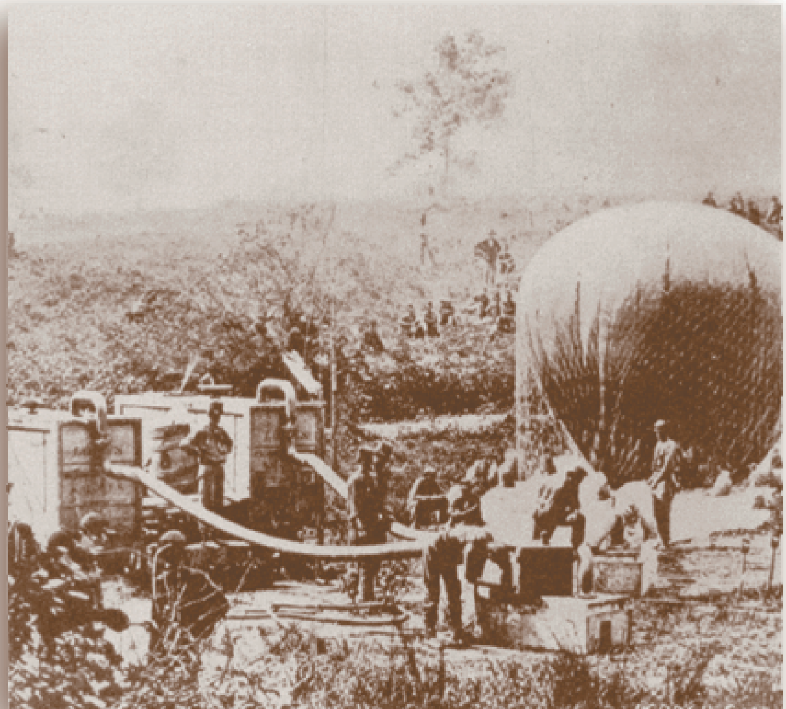
The first use of balloons by the United States military occurred during the Civil War. Several professional aeronauts, including Thaddeus S. C. Lowe, volunteered their services to the Union Army.

Lowe was unable to convince General Scott, of the Union Army, that there was a real military need for balloons. He told his friend Joseph Henry, first Secretary of the Smithsonian Institution, of his disappointment at the General's reaction. Henry made an appointment with President Abraham Lincoln and went with Lowe to tell the President of the advantages of aerial observation.

To show how well aerial reporting could work, Lowe went up in his balloon from the Smithsonian grounds. He used a telegraph wire that extended from his balloon basket to the White House to describe the scene to President Lincoln. After the dramatic show and the discussion with Lowe and Henry, President Lincoln sent General Scott a note asking him to seriously consider Lowe's offer.

Lowe was finally allowed to organize the Balloon Signal Service of the Union Army. He and a few other Army aeronauts served in the balloon corps for the first 2 years of the war. The aeronauts furnished valuable information to Union forces during several battles.

The aerial observers also had some frustrating experiences. They had to struggle to get their salaries, supplies, ground and maintenance crews. They even had to get permission to make aerial ascents. Lowe headed the corps, but he was never given an official title. He often had to pay for his own ballooning supplies. He eventually resigned from the corps. Later, the balloon corps was disbanded due to the lack of manpower and money for upkeep.



An Observation Balloon in the American Civil War

The South was well aware of the value of the aeronauts' services to the Union and wanted to start a Confederate balloon force. They made their first balloon of varnished, polished cotton and raised it with air heated over a fire of turpentine and pine knots. The second Confederate balloon had to be made from silk dresses donated by Southern women. Each day the crew filled this patchwork balloon at the Richmond, Virginia, gas plant. They took it by rail to the battle lines east of the city. Once, they mounted the balloon on a James River steamer, but the steamer ran aground. When the Union troops spotted the helpless vessel, they captured the balloon and ended Confederate hopes for a balloon corps.

The next advance in ballooning came in the form of gas. The use of hydrogen gas overcame the major disadvantage of the hot air balloon. Carrying fire and fuel aloft to keep the air heated was difficult and dangerous.

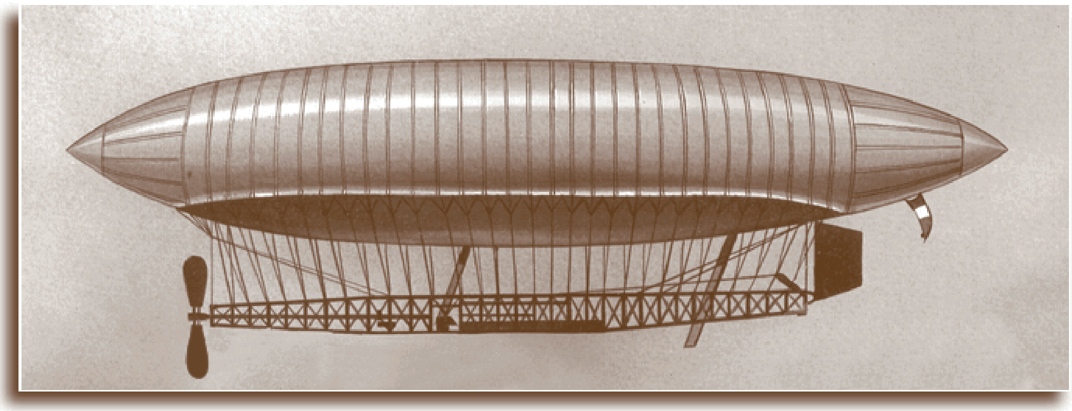
However, hydrogen also had a serious disadvantage—it was highly flammable and many people were killed before a safer gas (helium) came into use.

In either case, the balloon's real major problem was steering it. The problem of changing a free balloon into a *dirigible* (a lighter-than-air craft that can be propelled and steered) would stump scientific minds for almost a century.

In 1785, a French general, Jean Baptiste Meusnier, made several suggestions that eventually led to successful *dirigibles*. First, he suggested changing the shape of a balloon from a sphere to the shape of a football. This would reduce air resistance and also establish a front and rear for the balloon.

He also suggested an envelope (container for the gas) made of several compartments and a passenger car shaped like a boat attached to the bottom of the dirigible by a system of ropes. The one problem Meusnier did not solve was how to power the dirigible. He suggested a large propeller turned by 80 men!

The next breakthrough came in 1852 by another Frenchman, Henri Giffard. He built a cigar-shaped *dirigible* 114 feet long and 39 feet in diameter. The *dirigible* was powered by a 3- horsepower steam engine that pushed it at a speed of about 5 mph. This *dirigible* is generally credited as being the first successful one in the world.



Renard's *Dirigible*

Another *dirigible*, which is sometimes credited as being the first successful one, was the LaFrance, built by Charles Renard and A. C. Krebs in 1884. This airship was powered by electric motors. It was the first *dirigible* to be steered back to its takeoff point.

However, there was a problem with the electric motors being too heavy. They limited the range of the *dirigible*. It was not until the invention of the internal combustion engine that *dirigibles* became a real success.

A German engineer, Paul Haenlein, built the first *dirigible* powered by an internal combustion engine in 1872. This engine used coal gas taken from the balloon envelope as its fuel. The big problem with this was the longer the *dirigible* flew, the less lift it had because the engine was using the gas from the balloon.

These early *dirigibles* were nonrigid, which meant that only the pressure of the gas inside maintained the shape of the envelope. If the airship exceeded a certain speed, or if the pressure of the gas went down below a certain point, the balloon envelope would buckle or become distorted.

As balloon technology improved, an internal rigid keel (a long, reinforcing piece on the bottom of the balloon) stiffened the envelope. This keel extended along the length of the airship and carried the load of the engines and the passenger compartment. These were known as semi-rigid airships.

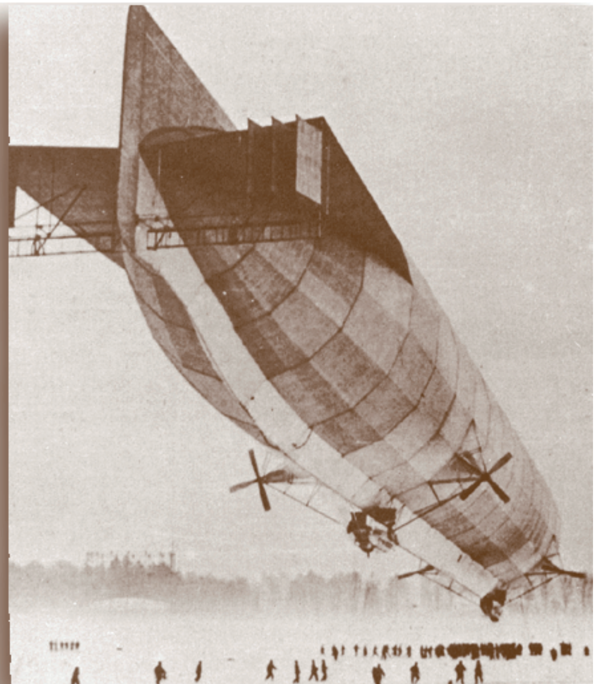
As a practical flying machine, the *dirigible* made its most noteworthy advances with the contributions of Alberto Santos-Dumont, a Brazilian, and Count Ferdinand von Zeppelin, a German. Both men successfully used internal combustion engines to power lighter-than-air crafts.

It was Santos-Dumont who ushered in the era of the powered gasbag. His first non-rigid airship was a small vessel 82 feet long driven by a 3-horsepower gasoline motor. On its first flight, it reached a height of 1,300 feet and was steered by movements of its rudder.

During the period between 1898 and 1907, Santos-Dumont constructed and flew 14 gasoline-powered, non-rigid airships. On his largest airship of 157 feet, he used a 20-horsepower engine.

Santos-Dumont became the idol of Paris in 1901, when he piloted an airship driven by a 12-horsepower motor, around the Eiffel Tower, a distance of nine miles. Despite a side wind of 12 to 13 mph, he developed a speed of 19 mph and covered the distance in less than 1/2 hour. For this accomplishment, Dumont won a 100,000 franc award put up by Henri Deutsch, a French petroleum magnate.

In July 1900, Ferdinand von Zeppelin built and flew the world's first successful rigid *dirigible*, the *LZ*-1. This began a long period of German domination of this type of aircraft. In fact, Germany so dominated the development of rigid airships, they became known as Zeppelins. These were rigid-type airships with an internal framework of steel or aluminum girders to support the *dirigible* and give it its shape.



The *LZ*-1 was built by Ferdinand von Zeppelin in 1900.

Zeppelin built many large rigid airships for the German government. On June 22, 1910, the *Deutschland* (*LZ*-7) became the world's first commercial airship. Between 1910 and the beginning of World War I in 1914, German *Zeppelins* flew 107,208 miles and carried 34,028 passengers and crew—entirely without injury.

Developing the Airplane

The developments that finally led to the airplane of today were not easy. There were many basic problems of flight to be solved by both lighter-than-air and heavier-than-air fliers. First, they had to develop the lift necessary to get into the air. Second, they had to figure a way to sustain that lift. Third, they had to develop a way to control the aircraft once it was flying.

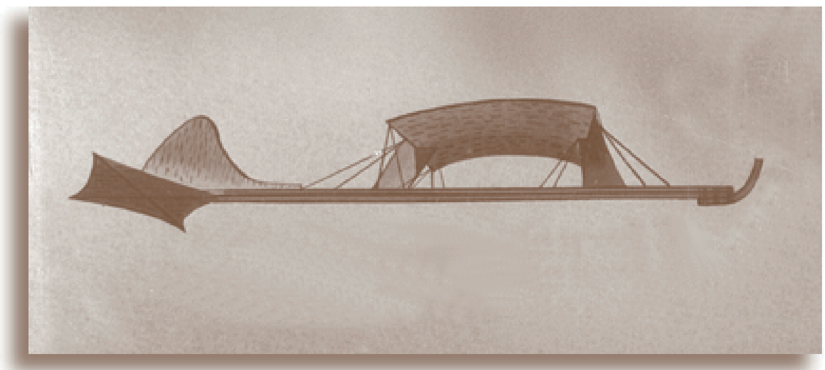
The balloonists overcame the first two problems by building their aircraft lighter than air. They kept them lighter than air by either dumping ballast or maintaining a fire to heat the trapped air. Therefore, they were faced only with the problem of control. Since the airplane would not have the balloon to keep it aloft, pioneers of the airplane had to struggle with all three problems.

The first airplane pioneer in the nineteenth century was a young Englishman named George Cayley. He was 9 years old when the Montgolfiers made their first flight. It was then that he began experimenting with small paper balloons.

His interest in flight continued into his teens, and he built small model helicopters. He applied what is called the "airscrew" concept to his models. Like Leonardo da Vinci, Cayley also studied the flight of birds. In 1804, he constructed a whirling-arm device. He used it to test the behavior of air pressure on various types of wings. He later built and flew small model gliders.

In 1809, he published the conclusions of his research in a scientific paper.The most important part of his paper was stated in one single sentence, which laid the whole foundation for modern aeronautics. It said, "The whole problem is confined within these limits, namely, to make a surface support a given weight by the application of power to the resistance of air."

Cayley identified the forces of lift, drag and thrust. He developed the cambered (curved) upper surface on a wing to increase lift. He also worked on propellers and power plants, and developed the concept of biwinged and triwinged aircraft. In 1850, he built the first successful full-sized, manned glider.



Sir George Cayley's Glider

Other Europeans, particularly the French, tried to unlock the secrets of the airplane in the nineteenth century. In 1871, Frenchman Alphonse Penaud developed a twisted rubber band to power workable helicopter models and to fly his planaphore. It was a 20-inch model airplane that flew 131 feet in 11 seconds. The planaphore contained Penaud's greatest contribution to aviation. It had automatic longitudinal (front to back) stability. To do this, he placed a small tail wing well behind the main wings. Penaud ranks close to Cayley as one of the most significant nineteenth century aeronautical thinkers.

Toward the end of the century, Clement Ader built the first manned aircraft to take off from level ground under its own power (1890). The craft looked like a huge bat and was powered by a 20-horsepower engine. Although it rose to a height of 8 inches and traveled through the air some 165 feet, it was not able to sustain flight. Seven years later he built a better model, which he called the *Avion* III. Unfortunately, it never got off the ground.

During the second half of the nineteenth century, flying became very popular and many people tried designing gliders and airplanes. Most of the gliders were unsuccessful, but from these failures came a lot of knowledge that would later contribute to the success of aviation.

For example, Francis H. Wenham had little practical success with his own gliders, but he became the first person to build a wind tunnel to test various wing shapes (1871). In time, both his invention and his glider work would become useful to Octave Chanute and the Wright brothers. During this period, three men made significant contributions to real gliding: an American, John J. Montgomery; a German, Otto Lilienthal; and a French-born American, Octave Chanute. These men all conducted very successful gliding experiments.

In 1884, 26-year-old John Montgomery, secretly built a 440-pound, man-carrying glider with wings like a sea gull. To avoid the ridicule of neighbors, he and his brother chose to try their first flight in the dead of night.

They had to wait until dawn before a breeze came in from the sea. To take off, Montgomery faced the wing surface of the glider into the 12 mph breeze, with his brother along side carrying a rope that was attached to the glider. The glider then carried Montgomery's 130 pounds aloft 600 feet before easing to Earth again.

Montgomery made several flights in his glider before it was wrecked in an accident. He built two other gliders: one with flat wings and one with wings that pivoted to the rear. Neither flew as well as his first.

From 1886 through 1892, Montgomery made thousands of experiments and studies of the wings of soaring birds. He gave every moment he could spare from his job, as professor of physics at Santa Clara College in California, to conduct these experiments.

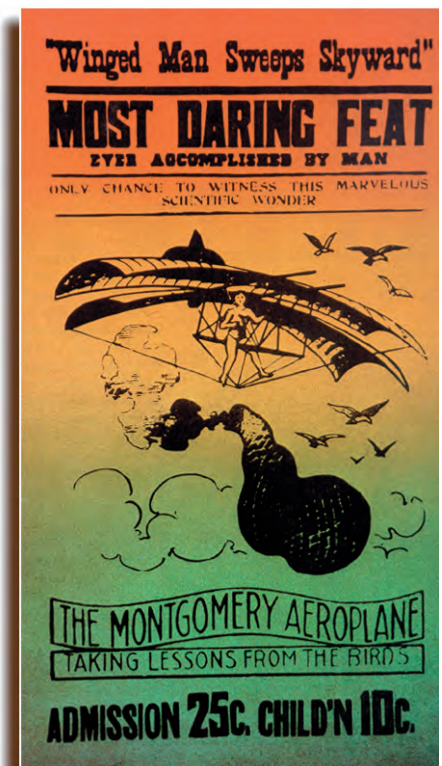
By 1893, Montgomery had done enough research to design a glider that he thought would be successful. Yet, he had to wait 9 years before he had the time and money to turn the plans into a real flying craft.

In 1905, he unveiled his glider to the public. Fifteen thousand people gathered at Santa Clara, California, to watch Daniel Maloney, known for his parachute jumps from hot air balloons at county fairs, pilot Montgomery's craft.

Montgomery left and Maloney standing beside glider *Santa Clara*.

Maloney climbed aboard the glider, which Montgomery had hitched to a hot-air balloon. After the balloon was cut loose, it rose to 4,000 feet where Maloney cut the glider loose. Twenty minutes and 8 air miles later, Maloney brought the ship down to a pre-selected spot, 3/4 of a mile from where the ascent had started.

During the flight, he had whipped the craft into sharp dives and turns and had reached speeds estimated at 68 mph. Everyone in attendance was thrilled with Montgomery's successful glider.

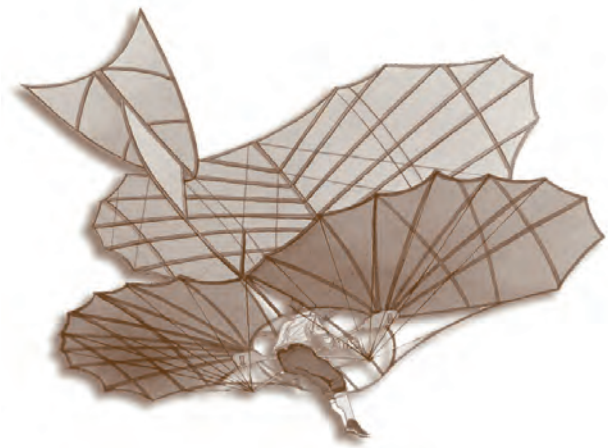


Poster Advertising Aerial Exhibition

During the next year, Montgomery exhibited his glider throughout California, raising funds for additional experiments. He built five more gliders and trained men to pilot them. These craft were all extremely maneuverable and capable of all sorts of twists, turns and somersaults. Then on April 18, 1906, his 20 years of labor were demolished in an earthquake. It was the same earthquake that destroyed San Francisco.

Montgomery was unable to resume his experiments until 1911. On October 31, 1911, his lifelong devotion to gliding and aviation ended. As he was landing his glider, a gust of wind flipped it and hurled him to his death.

The next pioneer, Otto Lilienthal, has been called the "Father of Modern Aviation." This German engineer was the first practical aviator. He built many single- and two-winged gliders, which he flew by running downhill until sufficient speed was built up to allow them to fly. His gliders had cambered (curved) wings and fixed-tail surfaces. Between 1891 and 1896, he made over 2,000 glides, many of which covered over 700 feet.



Lilienthal's Glider

In 1896, Lilienthal explored powered flight. He chose to use a biplane patterned after a double-winged glider he had flown successfully the year before.

He built an engine to link to the wingtips, which were hinged for flapping. He built a pilot control system into both the old and the new biplane for elevating the surfaces of the tail plane. The pilot's head worked the controls by a headband and rope that connected him to the tail. When the pilot lowered his chin, the plane rose, and when he lifted his chin, the plane dropped.

Before trying his powered biplane, Lilienthal flew the older biplane glider one last time to practice with the new elevating controls. He took off in a gusty wind. At 50 feet, his glider stalled and suddenly dropped like a rock. The fall broke Lilienthal's back, and he died the next day.

Lilienthal's book on flying informed and inspired pioneers in many countries. The development of photography allowed pictures to accompany his writings. The photos of his aircraft were seen throughout the world and helped create a great deal of interest in aviation.

One of the people who read Lilienthal's works was an American civil engineer, Octave Chanute. By 1896, Chanute was performing gliding experiments on the sand dunes around Lake Michigan.

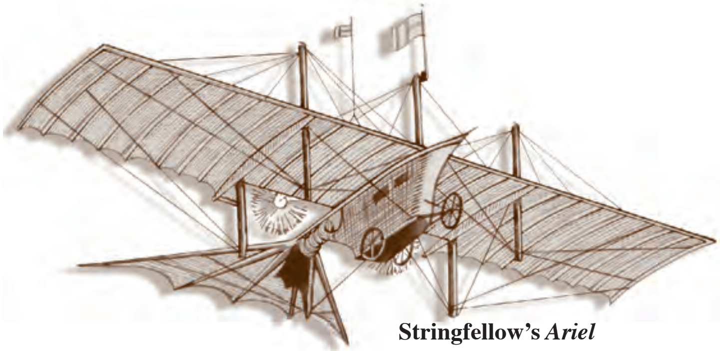
Chanute was in his sixties when he became interested in flight. Because of his age, he did no flying himself. He designed the gliders, which were flown by another engineer named A. M. Herring. Chanute is not noted for any outstanding advancement in aeronautics, although he did improve on Lilienthal's work. Chanute is noted for his careful study of aviation history and collection and distribution of aviation information.

Two Englishmen made additional contributions to the development of heavier-than-air flight. They read the works of Cayley which were published and widely read by scientists and aviation enthusiasts throughout the world. The two Englishmen were W. S. Henson, an inventor, and John Stringfellow, a skilled engineer. In 1843, they drew up plans and received a patent for a man-carrying powered aircraft. This aircraft, named the *Ariel,* was to be a monoplane with a 150-foot wingspan. It was powered by a steam engine, which drove two six-bladed propellers. This aircraft was never built, but the plans were masterpieces of aviation engineering.

Octave Chanute

The plans for the wing structure showed a front and a rear spar with connecting ribs. This same type structure is used for making aircraft wings today.

A small model of the *Ariel* was built and tested, but it failed to fly. Later, Stringfellow built a steam-driven model which did fly (1848). This was the first successful powered flight of a heavier-than-air craft.



Stringfellow's *Ariel*

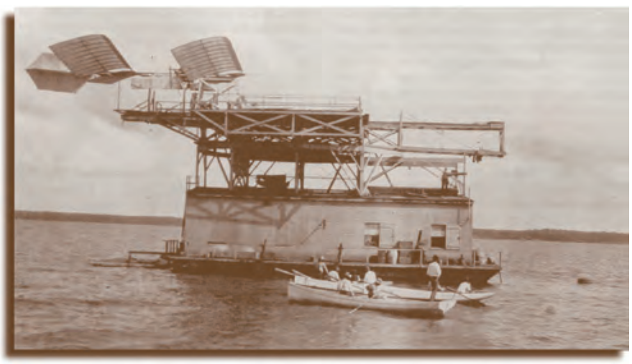
Another American who entered the field of aviation at this time was Samuel Pierpont Langley. Langley was an astronomer and the director of the Smithsonian Institution in Washington, D.C. His major contributions to flight involved attempts at adding power to a glider.

In 1896, he successfully built a steam-powered model that flew for 3/4 of a mile before it ran out of fuel. He then set out to build a full-size, man carrying aircraft. He received a $50,000 grant from Congress to build it.

One problem Langley encountered was the extremely heavy weight of steam engines. He was convinced that the internal combustion gasoline engine held the greatest promise for a lightweight, powerful engine for aircraft.

Charles M. Manly, Langley's assistant, designed such an engine. It was a 5-cylinder, radial engine that weighed only 125 pounds, but produced an amazing 53-horsepower. By October 1903, the engine had been placed in a full-size copy of his successful model, and Langley was ready for flight-testing.

The *Aerodrome,* as Langley called his aircraft, was to be launched by catapult from a barge anchored in the Potomac River .



Langley's *Aerodrome* speeds from its launch track atop a houseboat, only to plunge instantly into the Potomac.

The first flight was conducted on October 7, with Manly at the controls. The *Aerodrome* left the catapult; however, it did not fly and fell into the Potomac.

The test was repeated on December 8, with exactly the same results. Unfortunately, both attempts were well attended by the press. The reporters' critical writings caused the government to withdraw its support and Langley gave up his project.

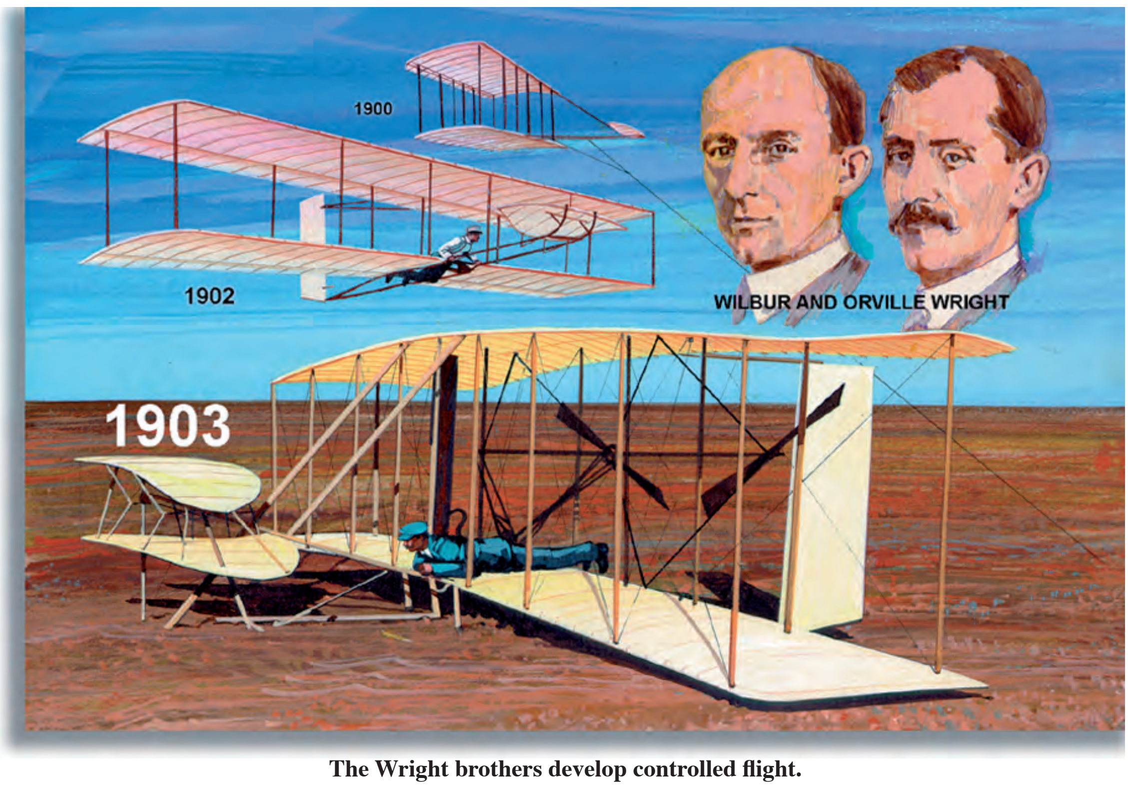
Langley made some important contributions to flight. However, he spent far too much time on the power plant and too little time on how to control the aircraft once it was flying. Just 9 days after

Langley's last failure, two brothers succeeded. They had approached the problem from the opposite direction (control first and then power) and succeeded with powered flight on the sand dunes of North Carolina.

The Wright Brothers

A combination of factors helped Orville and Wilbur Wright achieve success in controlled, sustained and powered flight. First, they had access to the knowledge about flight gained by the others before them. The lessons learned by their predecessors contributed greatly to the success of the Wright brothers.

Secondly, they lived at a time when the first practical power plant (the gasoline engine) had been developed. Finally, they were patient in their approach to solving problems. They possessed a combination of attitudes and skills that allowed them to bring the work of their predecessors together and combine it into a successful product.



The Wright brothers develop controlled flight.

The Wright brothers' approach to flight was to first develop an aircraft that would fly and could be controlled in flight, and then to add a power plant. Their observations led them to believe that birds maneuvered in flight chiefly by twisting their wings. Using this information, they built a large box kite with four cords attached to the wingtips. They found by pulling these cords, and thus twisting (warping) the wings, they could maneuver the kite from the ground.

Following these successful kite flights, the brothers realized that the next step must be to get into the air themselves to further test their "wing-warping technique." Before beginning their glider tests, they requested information from the Weather Bureau to determine a site for conducting their tests. They needed a location that would have steady winds and plenty of open space. They were advised to try the beaches just south of Kitty Hawk, North Carolina.

They selected Kill Devil Hills, North Carolina, for their tests. In October 1900, their first glider was ready. This glider was a biplane with a horizontal elevator in front, no tail and cords attached to the wingtips for warping them. To reduce wind resistance, the pilot rode lying down between the wings.

They made a few successful glides during that first winter, but the winds were generally too light for manned flights. For the most part, this first aircraft was flown as a kite.

The following July, they returned with their second glider which had much larger wings. They also had fastened the wing-warping cables to a cradle in which the pilot lay. The aircraft was controlled by shifting this cradle with the hips, thus tightening the cables and causing the wings to warp.

The Wright brothers' crowded shack, at Kill Devil Hills, N .C., that sheltered the 1901 glider.

The cables were arranged so that as the rear of one wingtip was warped downward, the wingtip on the opposite side was warped upward. This caused the aircraft to turn. This was the first of two great contributions the Wright brothers made toward controlling flight.

The Wrights had so many problems with the control of their second glider, that after only 1 month, they stopped their tests and returned home to Dayton, Ohio.

During the winter of 1901, they built a small wind tunnel and tested many different shapes of wings. These tests gave them the knowledge they needed to overcome the control problems of their second glider.

By September 1902, they built a third glider and returned to North Carolina. This aircraft was almost the same as the first two. The only difference was the addition of two fixed vertical fins at the rear. It performed well except for its turns.

This is the Wright brothers' workshop at Dayton, Ohio, which was reconstructed at the Henry Ford Museum in Dearborn, Michigan. Their wind tunnel stands between an aircraft engine (far right) and a workbench cluttered with wing ribs. The overhead shaft was turned by an engine that the brothers built. It also ran the shop machinery.

The wing, which was warped downward, would tend to drag and the aircraft would begin to slide sideways through the air. This was corrected by changing the two fixed vertical fins to a single moveable rudder that was connected with the wing-warping cables. This allowed the rudder to be turned so that the air pressure against it would cause the body of the airplane to pivot toward the downward wing. The pivoting action caused the airplane to enter turning flight more quickly and smoothly, putting an end to the sliding sideways action. This was the second great contribution they made toward controlling flight.

By the time the Wright brothers returned to Dayton, Ohio, in October, they had performed over 1,000 successful flights and had solved all the major problems of control in the air. Now, all that remained was to add a suitable power plant.

On their quest for powered flight, the Wrights found no suitable lightweight engines that would meet their needs. Although they had no experience in power plants, they designed and built a four cylinder, water-cooled gasoline engine that produced about 12 horsepower.

Next, they designed and built the two propellers that would be turned by the engine. The propellers were connected to the engine by two bicycle chains and turned in opposite directions.

By September 1903, the engine had been installed and the Wrights returned to North Carolina with their powered aircraft, which they named the *Flyer.* The *Flyer* had no wheels, but landed in the sand on a pair of skids.

For takeoff, they constructed a long wooden rail upon which ran a small trolley. The skids were set on the trolley, and a wire held the trolley until the aircraft's engine was running at full power. When the wire was released, the aircraft and trolley ran smoothly down the track until the aircraft lifted off, leaving the trolley behind.

Their first attempt to fly was on December 14, 1903, with Wilbur at the controls. The *Flyer* became airborne but stalled and fell back into the sand. It was slightly damaged.

Three days later the damage was repaired. The wind was blowing at over 20 mph. It was Orville's turn, so he fitted himself into the cradle. The engine was started, turned up to full power, and the wire was released.

The *Flyer* began picking up speed as it moved down the track with Wilbur running alongside. As the *Flyer* neared the end of the track, it rose into the air and flew for 12 seconds. One hundred and twenty feet from the end of the track, it slowly settled back onto the sand. It was 10:35 a.m., December 17, 1903.

Three more times that day the *Flyer* left the Earth. The final flight with Wilbur at the controls lasted 59 seconds and covered 852 feet.

Following the last flight, a gust of wind tipped the Flyer and badly damaged it. This small, flimsy, wood and cloth airplane made a place in history, but it never flew again. Its total useful lifetime was 1 day.

Prior to the Wright brothers' success with the *Flyer,* Stringfellow had flown a powered model airplane, but he was not aboard to control it. Lilienthal created controlled flight with his glider, but it was not sustained flight because it was not powered. Clement Ader created a manned craft that flew under its own power, but it was not controllable, nor could it sustain flight. With the flight of the *Wright Flyer*, mankind's age-old dream of controlled, sustained and powered heavier-than-air flight was finally a reality.

Summary

This chapter has pointed out the major milestones in the development of flight and the significant accomplishments of the men and women around the world who helped make the flight of the *Wright Flyer* possible. With the *Wright Flyer*, controlled, sustained, and powered heavier-than-air flight was finally achieved. Real flight was born.

However, it would be a number of years before the powered airplane would be developed to the point of being accepted as a practical, useful tool. In the next chapter, we will examine how the flying machine continued to evolve.

Key Terms and Concepts

- kite
- lighter-than-air
- gunpowder
- hot air balloon
- hydrogen gas
- helium gas
- aerial observation
- Balloon Signal Service
- aeronaut
- *dirigible*
- *Zepplin*
- rocket
- glider
- lift
- drag
- thrust
- helicopter
- wind tunnel
- airplane
- powered flight

? Test Your Knowledge ?

SELECT THE CORRECT ANSWER

1. *According to legend,* **(Wan Hoo / Daedalus)** *built two sets of wings so he and his son could escape imprisonment.*
2. *The* **(Greeks / Chinese)** *invented gunpowder.*
3. *The* **(Chinese / Persians)** *may have used man-carrying kites to spy on their enemies.*

MATCHING

4. *Developed first known principles of flight.*
5. *Invented the hot air balloon.*
6. *First human passengers flew on their balloon.*
7. *Organized Balloon Signal Service of the Union Army.*
8. *First successful rigid dirigible.*
9. *"Father of Modern Aviation."*
10. *First success in controlled, powered and sustained flight.*

a. **Otto Lilienthal**
b. **Thaddeus S. C. Lowe**
c. **Laurenco deGusmano**
d. **Wright brothers**
e. **Montgolfier brothers**
f. **Leonardo da Vinci**
g. **Ferdinand von Zepplin**

TRUE OR FALSE

11. *The* dirigible *was an important improvement over the balloon because it could be steered.*
12. *Hydrogen, as a lifting gas in balloons, was a major advancement in ballooning because of its safety.*
13. *Three European scientists – Toricelli, von Guericke, and Pascal – learned that atmospheric pressure decreases the higher you climb.*
14. *The three basic problems of flight are (1) developing necessary lift, (2) sustaining that lift and (3) controlling the aircraft once it is flying.*
15. *George Caley laid the foundation for modern aeronautics when he wrote, "The whole problem is confined within these limits; namely, to make a surface support a given weight by the application of power to the resistance of air."*
16. *Alphonse Penaud's greatest contribution to aviation was the development of the cambered wing.*
17. *John Montgomery was known as "The Father of Modern Aviation."*
18. *Wings having a front and a rear spar, with connecting ribs, were developed by John Stringfellow.*
19. *Samuel Pierpont Langley's aircraft* Aerodrome *was the first airplane to successfully fly after being launched from a catapult.*
20. *The Wright brothers solved the three basic problems of flight when their* Flyer *flew on December 17, 1903.*