MODULE 2

TOPIC 1

THE MYTH OF DAEDALUS AND ICARUS

The myth of **Daedalus and Icarus** is one of the most known and fascinating Greek Myths, as it consists of both historical and mythical details.

While in Crete Daedalus created the plan for the Minoan Palace of Knossos, one of the most important archaeological sites in Crete and Greece today. It was a magnificent architectural design and building, of 1,300 rooms, decorated with stunning frescoes and artifacts, saved until today. The sculpture of Ariadne in Knossos and many others in Elounda and Karia are also his.

King Minos and Daedalus had great understanding at first, but their relationships started deteriorating at some point; there are several versions explaining this sudden change, although the most common one is that Daedalus was the one who advised Princess Ariadne to give Theseus the thread that helped him come out from the infamous Labyrinth, after killing the Minotaur.

The Labyrinth was a maze built by Daedalus; King Minos wanted a building suitable to imprison the mythical monster Minotaur, and according to the myth, he used to imprison his enemies in the labyrinth, making sure that they would be killed by the monster.

Minos was infuriated when found out about the betrayal and imprisoned Daedalus and his son Icarus in the Labyrinth.

The Flight Of Daedalus And Icarus

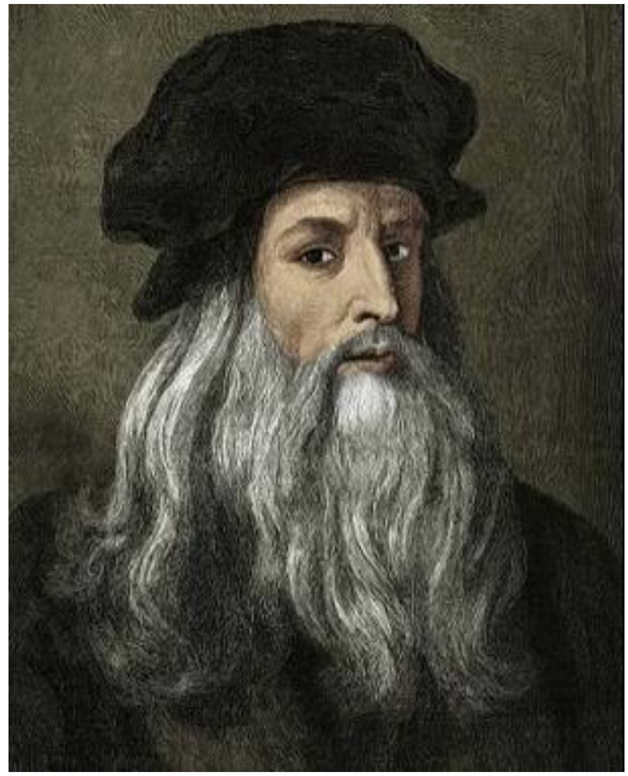
Icarus was the young son of Daedalus and Nafsicrate, one of King Minos' servants. Daedalus was way too smart and inventive, thus, he started thinking how he and Icarus would escape the Labyrinth. Knowing that his architectural creation was too complicated, he figured out that they could not come out on foot. He also knew that the shores of Crete were perfectly guarded, thus, they would not be able to escape by sea either. The only way left was the air.

Daedalus managed to create gigantic wings, using branches of osier and connected them with wax. He taught Icarus how to fly, but told him to keep away from the sun because the heat would make the wax melt, destroying the wings. Daedalus and Icarus managed to escape the Labyrinth and flew to the sky, free. The flight of Daedalus and Icarus was the first time that man managed to fight the laws of nature and beat gravity.

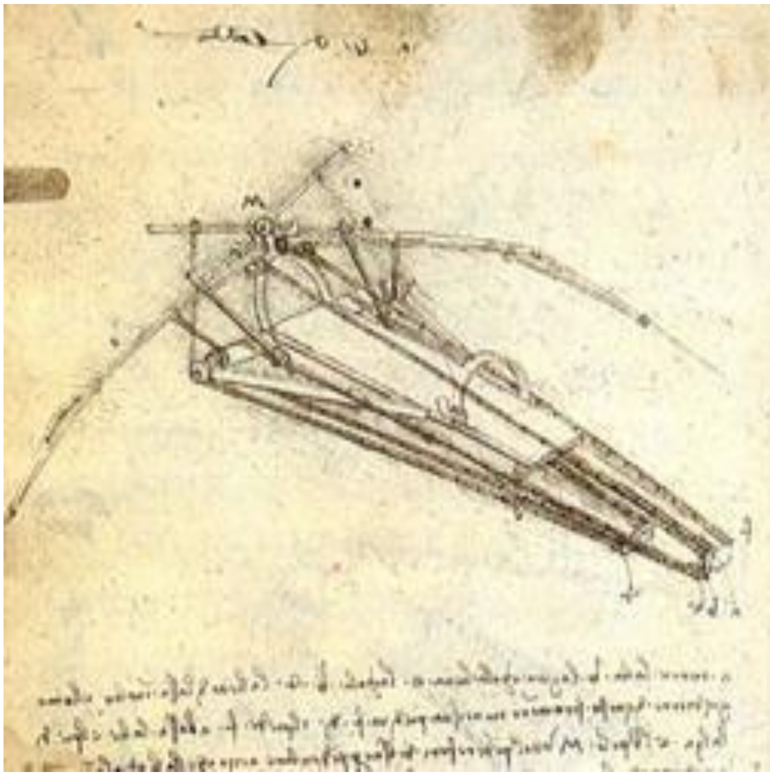
Icarus Death

Although he was warned, Icarus was too young and too enthusiastic about flying. He got excited by the thrill of flying and carried away by the amazing feeling of freedom and started flying high to salute the sun, diving low to the sea, and then up high again. His father Daedalus was trying in vain to make young Icarus to understand that his behavior was dangerous, and Icarus soon saw his wings melting. Icarus fell into the sea and drowned. The Icarian Sea, where he fell, was named after him and there is also a nearby small island called Icaria.

Flying Machine



Of Leonardo da Vinci's many areas of study, perhaps this Renaissance man's favorite was the area of aviation. Da Vinci seemed truly excited by the possibility of people soaring through the skies like birds. One of da Vinci's most famous inventions, the flying machine (also known as the "ornithopter") ideally displays his powers of observation and imagination, as well as his enthusiasm for the potential of flight. The design for this invention is clearly inspired by the flight of winged animals, which da Vinci hoped to replicate. In fact, in his notes, he mentions bats, kites and birds as sources of inspiration. Perhaps the inspiration of the bat shines through the most, as the two wings of the device feature pointed ends commonly associated with the winged creature. Leonardo da Vinci's flying machine had a wingspan that exceeded 33 feet, and the frame was to be made of pine covered in raw silk to create a light but sturdy membrane. The pilot would lie face down in the center of the invention on a board. To power the wings, the pilot would pedal a crank connected to a rod-and-pulley system. The machine also had a hand crank for increased energy output, and a head piece for steering. As the busy pilot spins cranks with his hands and feet, the wings of the machine flap. The inspiration of nature in the invention is apparent in the way the wings were designed to twist as they flapped. Unfortunately, as da Vinci himself might have realized, while the flying machine may have flown once it was in the air, a person could never have created enough power to get the device off the ground.

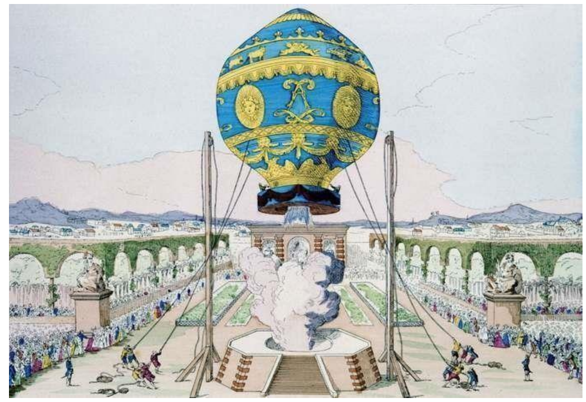


Montgolfier Brothers

Joseph-Michel and Jacques-Étienne Montgolfier, also called the **Montgolfier brothers**, (respectively, born Aug. 26, 1740, Annonay, France—died June 26, 1810, Balarucles-Bains; born Jan. 6, 1745, Annonay, France— died Aug. 2, 1799, enroute from Lyon to Annonay), French brothers who were pioneer developers of the hot-air balloon and who conducted the first untethered flights. Modifications and improvements of the basic Montgolfier design were incorporated in the construction of larger balloons that, in later years, opened the way to exploration of the upper atmosphere.

Joseph and Étienne were 2 of the 16 children of Pierre Montgolfier, whose prosperous paper factories in the small town of Vidalon, near Annonay, in southern France, ensured the financial support of their balloon experiments. While carrying on their father's paper business, they maintained their interest in scientific experimentation.

In 1782 they discovered that heated air, when collected inside a large lightweight paper or fabric bag, caused the bag to rise into the air. The Montgolfiers made the first public demonstration of this discovery on June 4, 1783, at the marketplace in Annonay. They filled their balloon with heated air by burning straw and wool under the opening at the bottom of the bag. The balloon rose into the air about 3,000 feet (1,000 metres), remained there some 10 minutes, and then settled to the ground more than a mile and a half from where it rose. The Montgolfiers traveled to Paris and then to Versailles, where they repeated the experiment with a larger balloon on Sept. 19, 1783, sending a sheep, a rooster, and a duck aloft as passengers. The balloon floated for about 8 minutes and landed safely about 2 miles (3.2 kilometres) from the launch site. On Nov. 21, 1783, the first manned untethered flight took place in a Montgolfier balloon with Pilatre de Rozier and François Laurent, marquis d'Arlandes, as passengers. The balloon sailed over Paris for 5.5 miles (9 kilometres) in about 25 minutes.



Montgolfier balloon JeanFrançois Pilâtre de Rozier and François Laurent, marquis d'Arlandes, ascending in a Montgolfier balloon at the Château de la Muette, Paris, November 21,

1783. © Photos.com/Jupiterimages

The two brothers were honoured by the French Académie des Sciences. They published books on aeronautics and continued their scientific careers. Joseph invented a calorimeter and the hydraulic ram, and Étienne developed a process for manufacturing vellum.

Jacques Charles

Jacques-Alexandre-César Charles was a mathematician and physicist remembered for his pioneering work with gases and hydrogen balloon flights. Charles was born on November 12, 1746, in Beaugency, Loiret, France; his first occupation was as a clerk at the Ministry of Finance in Paris. However, his interests eventually turned to science. In the late 1700s ballooning became a major preoccupation of France and other industrialized nations. In early June 1783 the Montgolfier brothers launched the first successful hot-air balloon in Paris. Charles, who was interested in aeronautics, understood the concept of buoyancy and also was aware of Henry Cavendish's discovery of hydrogen, an element some fourteen times lighter than air, seventeen years earlier. On August 27, 1783, Charles launched the first hydrogen-filled balloon using gas produced by the reaction of sulfuric acid on iron filings. Among the 50,000 witnesses of this event was Benjamin Franklin, then residing in Paris as the U.S. ambassador to France. When the balloon returned to Earth in the French countryside, it was reportedly attacked with axes and pitchforks by terrified peasants who believed it to be a monster from the skies. On November 21 of that same year the Montgolfier brothers launched the first hotair balloon with humans aboard, managing an altitude of less than 30 meters (98 feet). Charles, with the aid of brothers Nicholas and Aine Jean Robert, became the first human to ascend in a hydrogen balloon just ten days later. A far greater height of almost 3,000 meters (9,843 feet) was attained thanks to the superior lift of the hydrogen balloon Charles had designed and helped build.Charles is best known for his studies on how the volume of gases changes with temperature. The English scientist Robert Boyle had many years earlier determined the inverse relationship between the volume V and pressure P of a gas when temperature T is held constant. In 1662 he published the results that would later come to be known as Boyle's law (V α1/ P at constant T). During the winter of 1787 Charles studied oxygen, nitrogen, hydrogen, and carbon dioxide and

found that the volume of all these gases increased identically with higher temperature when pressure was held constant ($V \alpha T$ at constant P). Charles did not publish the results of his work at the time, but another
French scientist,

Joseph-Louis Gay-Lussac, eventually learned of them. When Gay-Lussac did more extensive and precise experiments and published his similar findings in 1802 (as did the English scientist John Dalton), he acknowledged Charles's original work. Thus, the law governing the thermal expansion of gases, although sometimes called Gay-Lussac's law, is more commonly known as Charles's law.

While most of Charles's papers were on mathematics, he was ultimately an avid scientist and inventor. He duplicated a number of experiments that Franklin and others had completed on electricity and designed several instruments, including a new type of hydrometer for measuring densities and a reflecting goniometer for measuring the angles of crystals. Charles was elected to France's Academy of Sciences in 1785 and later became professor of physics at the Conservatoire des Arts et Métiers. He died in Paris on April 7, 1823.

Sir George Cayley, The Father of Aeronautics

SIR GEORGE CAYLEY'S GOVERNABLE PARACHUTES.

Fig. 2.

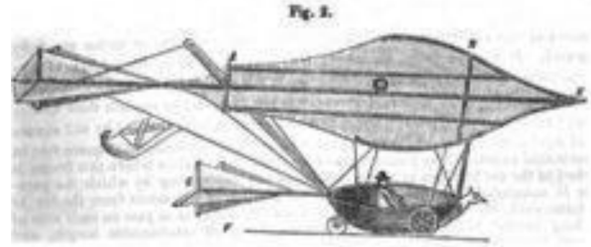
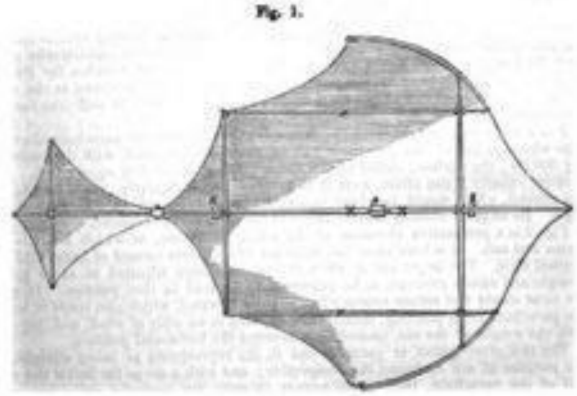


Fig. 1.



According to the account of Cayley's granddaughter, the somewhat reluctant pilotpassenger was a coachman, John Appleby. He took his place in a little boat-like carriage slung under the wings; the glider was duly launched, drawn by a galloping horse, and in a flight that must have only taken seconds, yet doubtless felt like hours to the terrified coachman, the machine flew 900 feet across the valley. It was the first recorded flight of a fixedwing aircraft carrying an adult.

After its brief and successful flight, the glider crashed. The coachman survived. His words on landing have not been recorded. However, in a very short space of time he was greeting his employer with a heartfelt request: "Please, Sir George, I wish to give notice. I was hired to drive, not to fly!" Sir George Cayley's glider had proved a lot more unpredictable than a four-in-hand.

The coachman's airborne journey across Brompton Dale was the culmination of Sir George

Cayley's lifetime of devotion to understanding the principles of flight. In fact, if it hadn't been for the fact that Cayley was nearly 80, he would probably have taken the coachman's place himself.

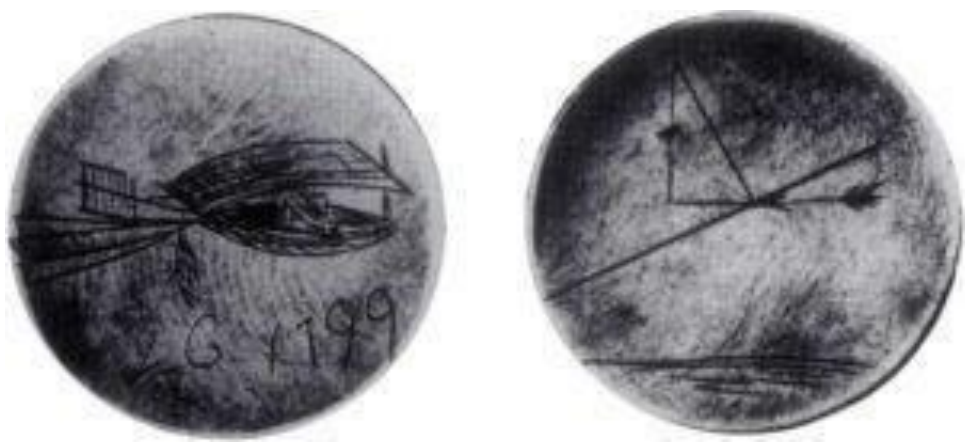
Born in 1773, Cayley was the 6th holder of the Cayley baronetcy. He lived at Brompton Hall and was a local landowner of substance, having inherited several estates on the death of his father. He was interested in a phenomenal range of subjects, mostly related to engineering. An imaginative inventor as well as a talented engineer, Cayley is best known for his research into the principles and mechanics of flying, as well as the practical projects he developed later from his early theoretical work.

Cayley's contribution to the history of manned flight is so important that he is recognized by many as "The Father of Aeronautics". As early as 1799, he had grasped the basic issue of heavier than air flight, that lift should balance weight and thrust must overcome drag, which should be minimised. His summary was presented in his treatise on flight, *On Aerial Navigation*, published in the early years of the 19th century: "*the whole problem is confined within these limits, viz, to make a surface support a given weight by the application of power to the air*."

Cayley had identified and defined the four forces acting on an aeroplane in flight: lift, weight, thrust and drag. Recent research, from 2007, suggests that sketches from his schoolboy days might indicate he was already aware of the principles of a lift-generating plane by 1792.

His conclusions were based on observations and calculations of the forces required to keep those true flying machines, birds, aloft. From these investigations, he was able to set out a design for an aero plane that had all the elements that are recognizable in modern planes, including fixed wings, and lift, propulsion and control systems.

Cayley’s 1799 Coin



In order to record his ideas, in 1799 Cayley engraved an image of his aircraft design on a small disc of silver. The disc, which is now in The Science Museum in London, shows a recognizable aircraft with fixed wings, an underslung carriage like a boat, flappers for propulsion and a cross-shaped tail. On this side, Cayley also engraved his initials. On the other side, he recorded a diagram of the four forces acting on the aircraft while flying in a direct line.

Cayley worked on models of his ideas, successfully hand-launching one of them and flying it in 1804. This was recognised by one aeronautical historian, C. H. Gibbs-Smith, as the first “true aeroplane flight” in history. The wing surface was about 5 square feet, and kite-shaped. At the rear the glider had an adjustable tail with stabilisers and a vertical fin.

In parallel with his interest in fixed-wing aircraft, Cayley was also, like several other inventors of his day, interested in the principles of the ornithopter, based on the idea of flapping to create flight. In

France, Launoy and Beinvenu had created a twin counter-rotation model using turkey feathers. Apparently independently, Cayley developed a rotor helicopter model in the

1790s, calling it his “Aerial Carriage”.

Model of Sir George Caley’s “Aerial Carriage”, 1843. Licensed under the Creative Commons Attribution-Share Alike 3.0 Unported license.

From 1810 onwards, Cayley was publishing his threepart series *On Aerial Navigation.* It was also at this point that Cayley’s visionary side began to show. He knew by then that manpower alone would never be sufficient to successfully fly an aircraft. However much the “make a big set of wings and flap them like hell” school of flying, as portrayed by Jacob Degen (who cheated with a hydrogen balloon) believed (or pretended to believe), that flapping was the answer, Cayley knew otherwise. He turned his attention to the issue of power for fixedwing aircraft that were heavier then air.

Here, he was genuinely too far ahead of his time. Lighter-than-air machines such as balloons were, of course flying successfully. Heavier-than-air machines required power, and the only power available at that point was that produced by the emerging technology of steam. He did give some consideration to using a Boulton and Watt steam engine for powering an aircraft.

More significantly, with remarkable prescience Cayley foresaw and even described the principles of the internal combustion engine. He made attempts to invent hot air engines, using various power sources including gunpowder. Had there been a lightweight engine available to him,

Cayley would almost undoubtedly have created the first manned and powered aircraft.

At the same time as his aeronautical investigations, his enquiring and practical mind led him to devise or develop lightweight tension-spoke wheels, a type of caterpillar tractor, automatic signals for railway crossings and many other items that we take for granted today. He was also interested in architecture, land drainage and improvement, optics and electricity.

Cayley also gave consideration to balloon flight, coming up with streamlined designs that were essentially prototype airships powered by steam. He also had the idea of using separate gas bags on airships as a safety feature to reduce gas loss through damage. Thus, his ideas prefigured airships by many years.

The famous flight that took his employee aloft in 1853 was preceded by one in 1849 with a ten-year-old boy on board. His glider designs were based on the model he had created so many years before, in 1799.

There is some discussion about who was actually involved in the flights – some accounts say it was his grandson who participated in the 1853 flight, not his coachman, which seems a bit of a profligate way to behave with one's relatives, even in the cause of science. Cayley undoubtedly had the true scientific spirit, for he was a founder member of both the Yorkshire Philosophical Society and the Scarborough Philosophical Society and also helped to found and promote the British Association for the Advancement of Science in 1831.

In fact, Cayley felt it was a "national disgrace" that there was no aeronautical society and attempted to to set one up several times. He wanted to claim for Britain "*the glory of being the first to establish the dry navigation of the universal ocean of the terrestrial atmosphere*". In describing his own machines, Cayley could be lyrical as well as scientific. He wrote of his glider design: "*It was beautiful to see this noble white bird sailing majestically from the top of a hill to any given point of the plain below it with perfect steadiness and safety*."

Cayley lived in a great age for engineers, both in Britain and abroad. He may have had more financial resources than the Stephensons of north east England, James Watt, the lighthouse Stevensons of Scotland or many other famous names of the time. However, what comes through clearly in the work of all the memorable pioneers of this period is their egalitarian scientific spirit as well as their commercially competitive ambition. Individuals like Cayley understood these were experiments to which everyone should have access and made sure that his research was publicly available.

His contribution was acknowledged, too. As Wilbur Wright commented in 1909: "*About 100 years ago, an Englishman, Sir George Cayley, carried the science of flight to a point which it had never reached before and which it scarcely reached again during the last century*."

When not taking his seat in parliament as the Whig member for Brompton from 1832 to 1835, some of the most turbulent years in British political history, Cayley spent most of his time at Brompton, involved in his various experiments and research interests. He died there on December 15th 1857. After his death, his colleague the Duke of Argyll finally enabled Cayley's dream of a society dedicated to aeronautical research to come true, with the foundation of the Aeronautical Society of Great Britain.

Lilienthal Glider

The most significant pre-Wright brother's aeronautical experimenter was the German glider pioneer, Otto Lilienthal. Lilienthal was trained in the highly regarded German technical education system and earned his living as a professional engineer. He began research in aeronautics with his brother Gustave in the late 1860s, investigating the mechanics and aerodynamics of bird flight. In the 1870s he conducted a series of experiments on wing shapes and gathered air pressure data using a whirling arm and in the natural wind. The research produced the best and most complete body of aerodynamic data of the day. Lilienthal also established definitively the widely held belief that a curved wing section, as opposed to a flat wing surface, was the optimum shape for generating lift. In 1889 he published his findings in a path breaking book called Der Vogelflug als Grundlage der Fliegekunst (Birdflight as the Basis of Aviation).

Lilienthal was not satisfied to restrict his work to the exploration of aerodynamic theory. Between 1891 and 1896, he put his research into practice in the form of a series of highly successful full-size glider trials. During this period Lilienthal made close to 2,000 brief flights in 16 different glider designs based on his aerodynamic investigations. Most were monoplanes with stabilizing tail surfaces mounted at the rear. He also tried a few biplane and folding wing designs, but the original monoplane glider, or Normal Segelapparat (standard sailing machine) as he called it, produced the best results. Lilienthal built at least eight gliders of this type.

The gliders had split willow frames covered with cotton twill fabric sealed with collodion to make the surface as airtight as possible. Collodion is a viscous solution of nitrated cellulose in a mixture of alcohol and ether that dries to form a tough elastic film. The wings ranged in area from 9 to 25 m2 (100 to 280 ft2), and could be folded to the rear for easier transport and storage. Control was achieved by shifting body weight, similar to modern hang glider practice. The pilot cradled himself vertically in a harness suspended below an elliptical opening between the wings. Swinging his legs from side to side and fore and aft, the pilot could adjust the center of gravity and thereby maintain equilibrium.

Lilienthal did most of his gliding from a manmade hill he had constructed near his home at Gross Lichterfelde, and from the hills surrounding the small village of Rhinow, about fifty miles from Berlin. His best efforts with these gliders covered more than 300 m (985 ft) and were 12 to 15 seconds in duration.

In the summer of 1896, Lilienthal's aeronautical experiments came to an abrupt and tragic end. On August 9, while soaring in one of his standard monoplane gliders, a strong gust of wind caused the craft to nose up sharply, stall, and crash from an altitude of 15 m (50 ft). Lilienthal suffered a broken spine and died the following day in a Berlin hospital.

As successful as they were, Lilienthal's glider designs had some inherent limitations that he would have had to confront had he lived and continued his work. The principal problem was his means of controlling the craft. Lilienthal's technique of shifting body weight to maintain equilibrium did place him ahead of other
experimenters in that he recognized the need for a control system and gave attention to developing one. But, as revealed in his fatal crash, the control response of his method was very limited. Even more significant, shifting body weight as a means of control placed a severe restriction on the size of the aircraft. Because control was achieved by altering the aircraft's center of gravity as a result of repositioning the pilot's body weight, the weight of the aircraft had to be kept comparatively low. This presented a great problem in the design of a powered airplane. Any aircraft capable of lifting an engine and pilot, much less any sort of a payload, would be of a size so large that shifting body weight would be totally ineffectual.

Further, the airfoil of Lilienthal's gliders, although extensively tested and documented during his earlier aerodynamic research, was very inefficient in actual practice. Lilienthal always preferred a perfect arc for the shape of his glider wings with a very deep camber of 1 in 12. His investigations demonstrated that a curved surface was the most efficient shape, but he never abandoned the perfect arc in his gliders to experiment with parabolic airfoils, which later proved to be superior. The deeply cambered perfect arcs of Lilienthal's glider wings resulted in aerodynamic efficiency and stability problems.

Despite these unresolved issues, the impact of Lilienthal's aeronautical work upon the next generation of experimenters, the generation that would finally achieve heavier-than-air powered flight, was highly influential. With his pioneering aerodynamic research and his success in the air, Lilienthal had established a new starting point for anyone entering the field. Beyond his technical contributions, he sparked aeronautical advancement from a psychological point of view as well. He demonstrated unquestionably that gliding flight was possible. Granted, he was flying for only seconds at a time, but he was truly flying. Lilienthal's tentative trips through the air made headlines everywhere. Dramatic photographs showing Lilienthal soaring gracefully over hillsides appeared in newspapers and magazines the world over. The publicity made him quite a sensation in an age when, for most, human flight still seemed a distant possibility at best. This exposure and visible proof that a human being could actually fly contributed as much to spurring other experimenters forward as did Lilienthal's ground breaking aerodynamic research. He was a great inspiration to the Wright brothers in particular. They adopted his approach of glider experimentation and used his aerodynamic data as a starting point in their own research.

The Lilienthal glider in the NASM collection was built by the German experimenter in late 1895, early 1896. It was purchased from Lilienthal by the American newspaper magnate William Randolph Hearst in the spring of 1896. Hearst sponsored test flights of the glider on a Long Island estate in April and May 1896 in an effort to create publicity and boost the circulation of his newspaper, the New York Journal. Harry Bodine, a New Jersey athlete, made most of the flights, although Journal reporters and other spectators were also allowed to test their skill. Flights as long as 115 m (375 ft) at altitudes of up to 15 m (50 ft) were made with the glider.

Further flight testing, however, ceased after Lilienthal's death in August. Hearst then gave the glider to John
Brisben Walker, editor of Cosmopolitan magazine, who displayed it at a New York Aero Club show in January 1906. Alexander Graham Bell suggested to

Walker that the Smithsonian Institution likely would be interested in pursuing acquisition of the Lilienthal glider.
After the Smithsonian approached Walker on the matter, he presented it to the Smithsonian on February 2, 1906. Minor refurbishing was done in 1906 and 1928, and in 1967 the glider was completely restored. The horizontal tail is not original. The NASM Lilienthal glider is one of five remaining in the world.

Wright brothers

Wright brothers, American brothers, inventors, and aviation pioneers who achieved the first powered, sustained, and controlled airplane flight (1903). Wilbur Wright (April 16, 1867, near Millville, Indiana, U.S.—May 30, 1912, Dayton, Ohio) and his brother Orville Wright (August 19, 1871, Dayton—January 30, 1948, Dayton) also built and flew the first fully practical airplane (1905)

Early Glider Experiments

The ability of the Wright brothers to analyze a mechanical problem and move toward a solution was apparent from the outset of their work in aeronautics. The brothers realized that a successful airplane would require wings to generate lift, a propulsion system to move it through the air, and a system to control the craft in flight. Lilienthal, they reasoned, had built wings capable of carrying him in flight, while the builders of self-propelled vehicles were developing lighter and more powerful internal-combustion engines. The final problem to be solved, they concluded, was that of control.

Most aeronautical experimenters up to that time had sought to develop flying machines incorporating a measure of inherent stability, so that the aircraft would tend to fly a straight and level course unless the pilot intervened to change altitude or direction. As experienced cyclists, the Wrights preferred to place complete control of their machine in the hands of the operator.

Moreover, aware of the dangers of weight-shifting control (a means of controlling the aircraft by shifting the position of the pilot), the brothers were determined to control their machine through a precise manipulation of the centre of pressure on the wings. After considering various mechanical schemes for obtaining such control, they decided to try to induce a helical twist across the wings in either direction. The resulting increase in lift on one side and decrease on the other would enable the pilot to raise or lower either wing tip at will.

Their first experiments with "wing warping," as the system would be called, were made with a small biplane kite flown in Dayton in the summer of 1899. Discovering that they could cause the kite to climb, dive, and bank to the right or left at will, the brothers began to design their first full-scale glider using Lilienthal's data to calculate the amount of wing surface area required to lift the estimated weight of the machine and pilot in a wind of given velocity.

Realizing that Dayton, with its relatively low winds and flat terrain, was not the ideal place to conduct aeronautical experiments, the Wrights requested of the U.S. Weather Bureau (later the National Weather Service) a list of more suitable areas. They selected Kitty Hawk, an isolated village on the Outer Banks of North Carolina, which offered high average winds, tall dunes from which to glide, and soft sand for landings.

Tested in October 1900, the first Wright glider was a biplane featuring 165 square feet (15 square metres) of wing area and a forward elevator for pitch control. The glider developed less lift than expected, however, and very few free flights were made with a pilot on board. The brothers flew the glider as a kite, gathering information on the performance of the machine that would be critically important in the design of future aircraft.

Eager to improve on the disappointing performance of their 1900 glider, the Wrights increased the wing area of their next machine to 290 square feet (26 square metres). Establishing their camp at the foot of the Kill Devil Hills, 4 miles (6.5 km) south of Kitty Hawk, the brothers completed 50 to 100 glides in July and August of 1901. As in 1900, Wilbur made all the glides, the best of which covered nearly 400 feet (120 metres). The 1901 Wright aircraft was an improvement over its predecessor, but it still did not perform as well as their calculations had predicted. Moreover, the experience of 1901 suggested that the problems of control were not fully resolved.

Discouraged, but determined to preserve a record of their aeronautical work to date, Wilbur accepted Chanute's invitation to address the prestigious Western Society of Engineers. Wilbur's talk was delivered in Chicago on September 18, 1901, and was published as "Some Aeronautical Experiments" in the journal of the society. It indicated the extent to which the Wright brothers, in spite of their disappointments, had already moved beyond other flying machine experimenters.

Solving The Problems of Lift and Control

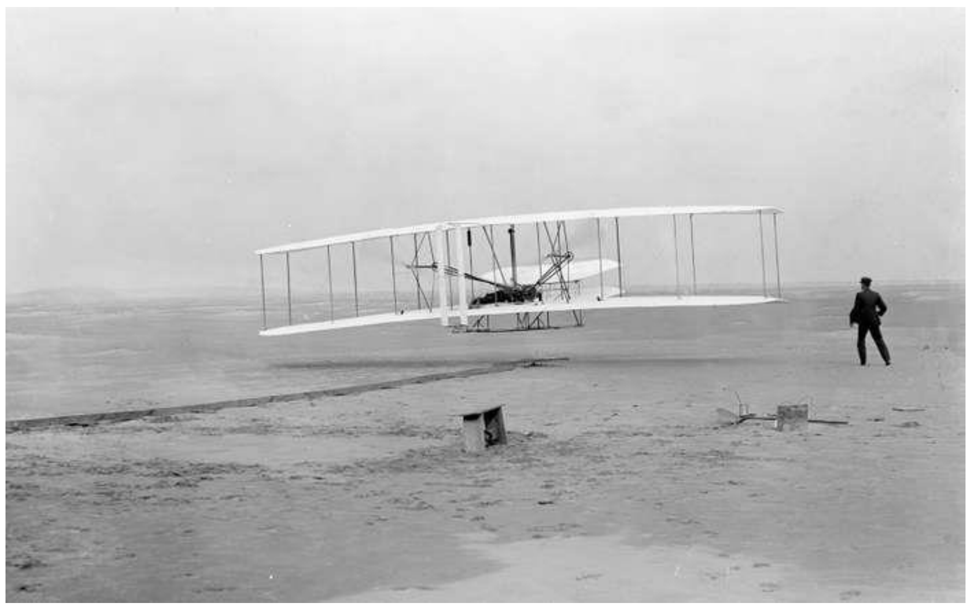
Realizing that the failure of their gliders to match calculated performance was the result of errors in the experimental data published by their predecessors, the Wrights constructed a small wind tunnel with which to gather their own information on the behaviour in an airstream of model wings of various shapes and sizes. The brilliance of the Wright brothers, their ability to visualize the behaviour of a machine that had yet to be constructed, was seldom more apparent than in the design of their wind-tunnel balances, the instruments mounted inside the tunnel that actually measured the forces operating on the model wings. During the fall and early winter of 1901 the Wrights tested between 100 and 200 wing designs in their wind tunnel, gathering information on the relative efficiencies of various airfoils and determining the effect of different wing shapes, tip designs, and gap sizes between the two wings of a biplane.

With the results of the wind-tunnel tests in hand, the brothers began work on their third full-scale glider. They tested the machine at the Kill Devil Hills camp in September and October of 1902. It performed exactly as the design calculations predicted. For the first time, the brothers shared the flying duties, completing 700–1,000 flights, covering distances up to 622.5 feet (189.75 metres), and remaining in the air for as long as 26 seconds. In addition to gaining significant experience in the air, the Wrights were able to complete their control system by adding a movable rudder linked to the wing-warping system.

Wright glider Side view of Wilbur Wright gliding in level flight in Kitty Hawk, North Carolina, on October 10, 1902. **Wright glider** Wilbur Wright executes a banking turn to the right in the Wright brothers' first fully controllable glider, at the Kill Devil Hills, North Carolina, October 24, 1902.

Powered, Sustained Flight

With the major aerodynamic and control problems behind them, the brothers pressed forward with the design and construction of their first powered machine. They designed and built a four-cylinder internal-combustion engine with the assistance of Charles Taylor, a machinist whom they employed in the bicycle shop. Recognizing that propeller blades could be understood as rotary wings, the Wrights were able to design twin pusher propellers on the basis of their windtunnel data. The brothers returned to their camp near the Kill Devil Hills in September 1903. They spent the next seven weeks assembling, testing, and repairing their powered machine and conducting new flight tests with the 1902 glider. Wilbur made the first attempt at powered flight on December 14, but he stalled the aircraft on take-off and damaged the forward section of the machine. Three days were spent making repairs and waiting for the return of good weather. Then, at about 10:35 on the morning of December 17, 1903, Orville made the first successful flight, covering 120 feet (36 metres) through the air in 12 seconds. Wilbur flew 175 feet (53 metres) in 12 seconds on his first attempt, followed by Orville's second effort of 200 feet (60 metres) in 15 seconds. During the fourth and final flight of the day, Wilbur flew 852 feet (259 metres) over the sand in 59 seconds. The four flights were witnessed by five local citizens. For the first time in history, a heavier-thanair machine had demonstrated powered and sustained flight under the complete control of the pilot.



Orville Wright in first controlled flight, 1903Orville Wright beginning the first successful controlled flight in history, at Kill Devil Hills, North Carolina, December 17, 1903. Determined to move from the marginal success of 1903 to a practical airplane, the Wrights in 1904 and 1905 built and flew two more aircraft from Huffman Prairie, a pasture near Dayton. They continued to improve the design of their machine during these years, gaining skill and confidence in the air. By October 1905 the brothers could remain aloft for up to 39 minutes at a time, performing circles and other maneuvers. Then, no longer able to hide the extent of their success from the press, and concerned that the essential features of their machine would be understood and copied by knowledgeable observers, the Wrights decided to cease flying and remain on the ground until their invention was protected by patents and they had negotiated a contract for its sale. (Their most successful machine to that date is described in the entry Wright flyer of 1905.)

SUMMARY OF AVIATION HISTORY

-The myth of Daedalus and Icarus tells the story of a father and a son who used wings to escape from the island of Crete. Icarus has become better-known as the flyer who fell from the sky when the wax that joined his wings was melted by the heat of the sun.

-Leonardo da Vinci was a Renaissance painter, sculptor, architect, inventor, military engineer and draftsman — the epitome of a true Renaissance man. Gifted with a curious mind and a brilliant intellect, da Vinci studied the laws of science and nature, which greatly informed his work. His drawings, paintings and other works have influenced countless artists and engineers over the centuries

-The Montgolfier hot-air balloon floats over Paris on November 21, 1783. For the first time in history, a human being is lifted and carried through the air for a sustained period.

- A red-letter date in the progress of aeronautics is 1799. ln that year, Sir George Cayley in England engraves on a silver disk his concept of a fuselage, a fixed wing, and horizontal and vertical tails. He is the first person to propose separate mechanisms for the generation of lift and propulsion. He is the grandparent of the concept of the modern airplane.

-Otto Lilienthal designs the first fully successful gliders in history. During the period of time 1891 to 1896. he achieves more than 2000 successful glider flights. If he had not been killed in a glider Crash in 1896, Lilienthal might have achieved powered flight before the Wright brothers.

-Samuel Pierpont Langley, secretary of the Smithsonian Institution, achieves the first sustained heavier-than-air, *unmanned,* powered flight in history with his small scale

-*Aerodrome* in 1896. However, his attempts at manned flight are unsuccessful, the last one failing on December 8, 1903-just nine days before the Wright brothers' stunning success. Another red-letter date in the history of aeronautics, indeed in the history of humanity, is December 17, 1903. On that day, at Kill Devil Hills in North Carolina, Orville and Wilbur Wright achieve the first controlled, sustained, powered, heavier-than- the air, manned flight in history. This flight is to revolutionize life during the 20 century.

- The development of aeronautics takes off exponentially after the Wright brothers' public demonstrations in Europe and the United States in 1908. The ongoing work of Glenn Curtiss and the

Wrights and the continued influence of Langley's early work form an important aeronautical triangle in the development of aeronautics before World War I.