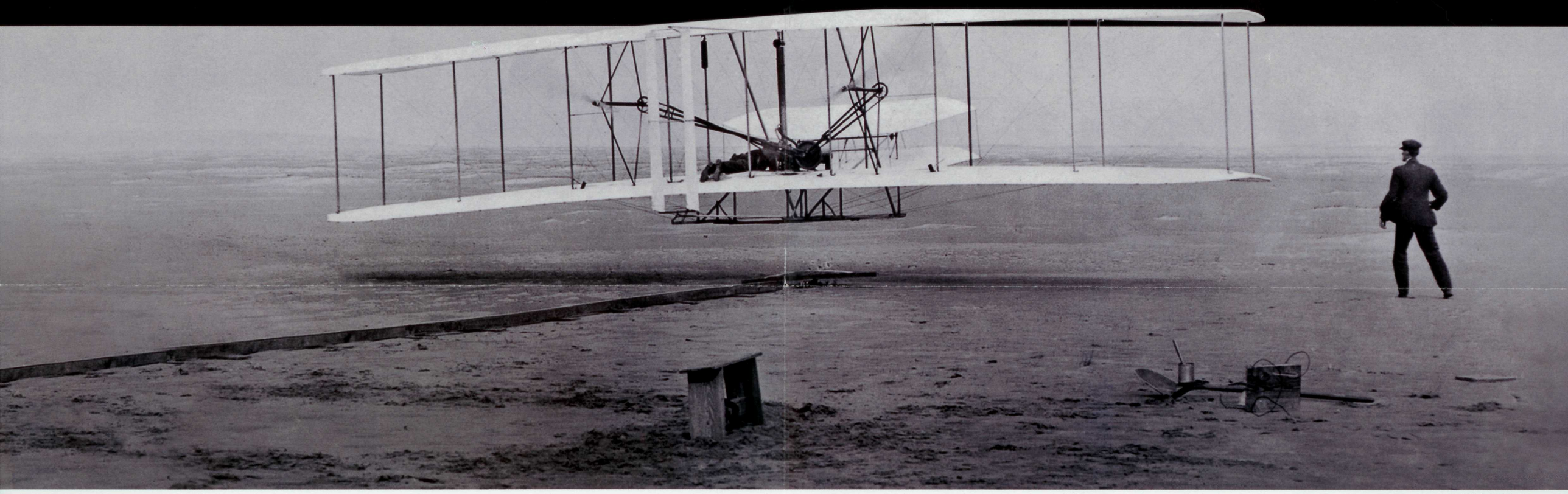
Wright Brothers

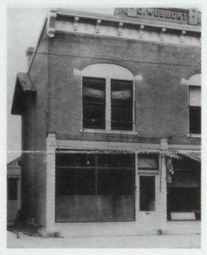
Wright Brothers National Memorial
North Carolina

National Park Service
U.S. Department of the Interior



SMITHSONIAN INSTITUTION

Kill Devil Hills: We Take to the Air



The Wright Cycle Company occupied part of this building in Dayton, Ohio, where Orville *(right)* and friend Ed Sines are shown working in 1897.
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The Wrights learned to fly on a stretch of beach near the Kill Devil Hills. It provided isolation, high dunes, strong winds, and soft landings.
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At their 1902 camp the Wrights shared their living quarters with the glider. They slept aloft in burlap slings hung from the rafters.
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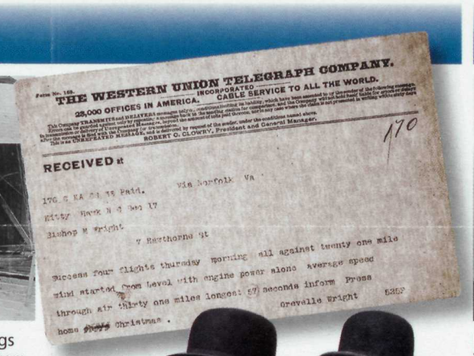

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Bishop M Wright

Succeas four flights thursday morning all against twenty one mile wind started from level with engine power alone Average speed through air thirty one miles longest fifty seconds inform Press home Christmas .

Orevville Wright

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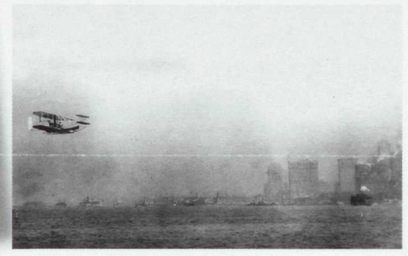
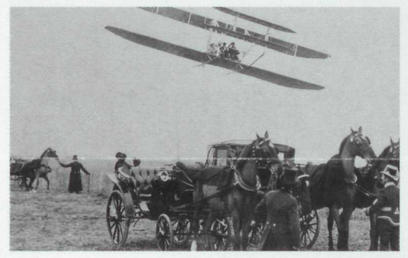


In 1908 and 1909, the Wrights performed for awestruck crowds in America and Europe. Hundreds of thousands of New Yorkers cheered Wilbur's 20-mile circuit from Governors Island up the Hudson to Grant's Tomb and back *(left)*.
SMITHSONIAN INSTITUTION



At Pau, France, *(above)* the 1908 Flyer soars over nervous horses.
SMITHSONIAN INSTITUTION

The Wrights of Dayton

In the early 1890s the Wright brothers had settled into a respectable life as proprietors of a small business in Dayton, Ohio. But the Wright brothers nurtured a dream, which at the time was barely respectable: the possibility of human flight. Wilbur, four years older, was quiet and intense, a dreamer who could lose himself in books. Orville was outgoing, talkative, and an immaculate dresser. Both combined intuitive mechanical ability with analytical intelligence.

In 1892 they opened a bicycle shop. While they prospered in their business, they were restless, especially Wilbur. Their energies focused on two events of 1896: the death of Otto Lilienthal, German glider experimenter, in a flying accident, and the successful unmanned powered model flights of Samuel Langley.

The Wrights' serious work in aeronautics began in 1899 when Wilbur wrote the Smithsonian Institution for literature. Dismayed that so many great minds had made so little progress, the brothers were exhilarated by the realization that they had as much chance as anyone of succeeding. Wilbur took the lead in the early stages of their work, but Orville was soon drawn in as an equal collaborator. They developed their own theories, and for the next four years devoted themselves to the goal of human flight.

The brothers dressed in coats and ties that December morning—a touch of private ceremony for an event that would alter the world. The pools around their camp were icing up, and the break in the weather might be their last chance of the season. Words were impossible over the engine's roar so they shook hands, and Orville positioned himself in the flyer.

On this remote, sandy beach, in 1903, Orville broke our human bond with Earth. He flew. It lasted only 12 seconds, and the distance of the flight was less than the length of an airliner. But for the first time, a manned, heavier-than-air machine left the ground by its own power, moved forward under control without losing speed, and landed on a point as high as that from which it started. Within the next two generations, people flew for routine travel, heard an aircraft break the sound barrier, and watched a man walk on the moon.

The Wrights labored in relative obscurity, while the experiments of Samuel Langley of the Smithsonian Institution were followed in the press and underwritten by the U.S. Department of War. Yet Langley, as others before him, had failed to achieve powered flight. They relied on brute power to keep their theoretically stable machines aloft, sending along a hapless passenger and hoping for the best. It was the Wrights' genius to see that humans would have to fly their machines, that the problems of flight could not be solved from the ground. In Wilbur's words, "It is possible to fly without motors, but not without knowledge and skill." With over a thousand glides from the top of Kill Devil Hill, the Wrights made themselves the first true pilots. These flying skills were a crucial component of their invention. Before they ever attempted powered flight, the Wright brothers were masters of the air.

Orville and Wilbur Wright
WRIGHT STATE UNIVERSITY

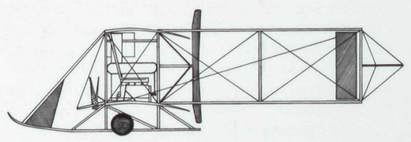
Showing the World

"They have done it! Damned if they ain't flew!" said a witness to the first human flight. But so often had this claim proven hollow that the public was skeptical of yet another, especially after the spectacular failure of Langley's flying machine nine days earlier. Undaunted, the Wrights built an improved flyer and refined their flying skills over a field in Ohio, making 105 flights in 1904. In the 1905 Flyer—the first practical airplane—circling flights of up to 38 minutes became routine. But when the Wrights offered the Flyer to the U.S. Army, that institution, dubious of their achievement, refused to meet with the brothers. Unwilling to show their control system without a contract in hand, the Wrights did not fly for another three years.

Despite the break in progress, the gap between the Wrights and European aviators remained substantial. After 1903, the French built flyers based on the Wright 1902 Glider. But by 1906 none had remained aloft for more than a few seconds of ragged flight. Not until 1907 did a European plane stay in the air as long as the Wrights had in 1903.

But the Wrights' refusal to fly caused even early believers to doubt their success. By 1908 a French pilot had flown for over 20 minutes. That year the Wrights signed a contract with the U.S. Army and France and showed the world what they could do—Wilbur in France, Orville in America. After Wilbur flew a circle under good lateral control and landed gently, no one questioned that the Wrights had truly mastered flight. The French attempts were shaky, barely on the edge of control. What Wilbur had done was effortless, graceful, decisive. In other flights he flew over two hours and reached an altitude of 360 feet, demonstrating the Flyer's reliability and endurance. "We are as children compared with the Wrights," said one French pilot.

By 1910 the rest of the world had caught up. The French introduced refinements to the Wright design: monoplane wings, closed body, front propeller, rear elevator, single stick control, wheels, and ailerons. But the principle behind the Wrights' control system was unchanged. A 1911 Wright Model B *(below)* reflecting some of these changes is the prototype for planes today.



Planning Your Visit

Visitor Center Start at the visitor center for information, exhibits, and a bookstore. Exhibits and interpretive programs tell the Wright brothers' story, and you can see full-scale reproductions of the 1902 glider and the 1903 flying machine. Open daily, except December 25.

Centennial Pavilion The pavilion has films, educational programs, a gift shop, and exhibits on the Outer Banks, the evolution of aviation, and challenges of flight. Open daily, except December 25.

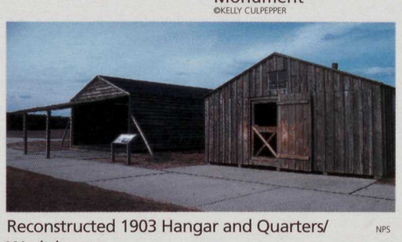
For Your Safety Please use caution. Remember, your safety is your responsibility. Stay on the paths to help protect Kill Devil Hill and to avoid sand spurs and prickly pear cactus. Be aware that Kill Devil Hill is highly exposed to lightning. Bicycles are permitted only on established roads, not on paths, and skateboards are prohibited.

First Flight Airstrip This 3,000-foot paved airstrip accommodates small planes. Parking at the limited tie-down area is restricted to 24 consecutive hours or a total of 48 hours in any 30-day period. Pilots staying longer may tie down at the Dare County Regional Airport; gas and rental cars are available.

Getting Here Wright Brothers National Memorial is on the Outer Banks of North Carolina in the town of Kill Devil Hills, about midway between Kitty Hawk and Nags Head on U.S. 158, between mileposts 7 and 8.

First Flight Boulder
NPS

Wright Brothers Monument
©KELLY CULPEPPER



Reconstructed 1903 Hangar and Quarters/ Workshop
NPS

December 17, 1903 Sculpture
NPS

Touring the Park
First Flight Boulder and *First Flight Markers.* A granite boulder marks the spot where the first plane left the ground on December 17, 1903. Smaller stone markers chart the paths, distances, and landings of the four flights.

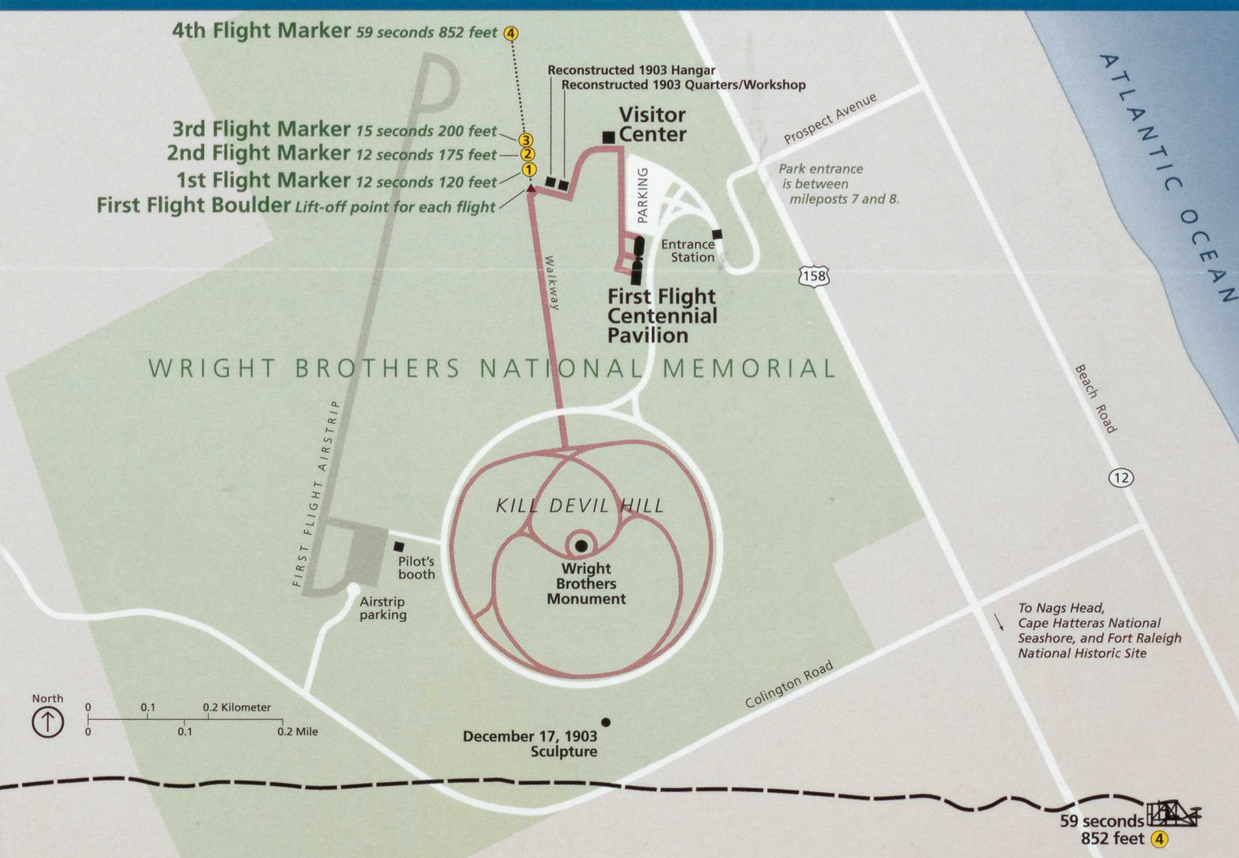
Wright Brothers Monument. The 60-foot monument atop Kill Devil Hill honors the Wright brothers and marks the site of the hundreds of glider flights that preceded the first powered flight. Grass stabilizes the 90-foot sand dune.

Reconstructed 1903 Hangar and Quarters/ Workshop. The building on the left depicts the hangar the Wright brothers used for their 1903 flyer. The building on the right is similar to their workshop and living quarters. It is furnished with items like the Wrights used when they were here.

December 17, 1903 Sculpture. This life-sized artwork by Stephen H. Smith recreates the historic event. The Flyer is made of stainless steel and weighs 10,000 pounds.

More Information
Wright Brothers National Memorial is one of over 390 parks in the National Park System. The National Park Service cares for these special places so that all may experience our heritage. Visit www.nps.gov.

Outer Banks Group
1401 National Park Drive
Manteo, NC 27954
252-473-2111

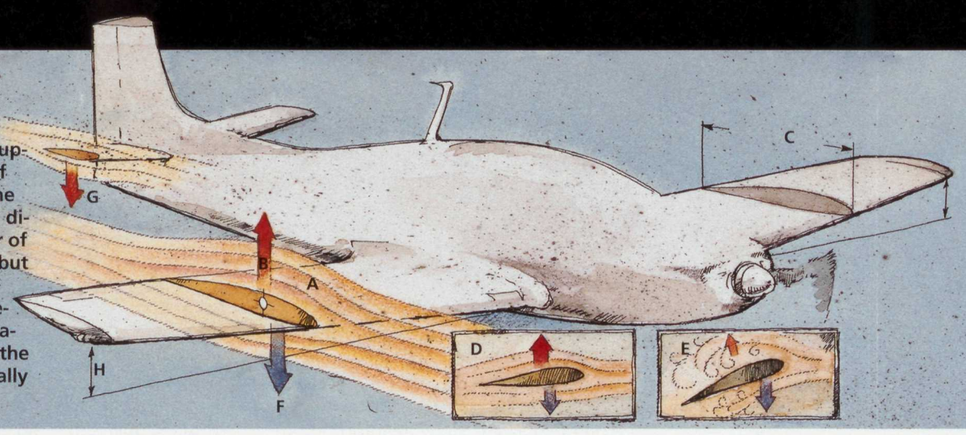


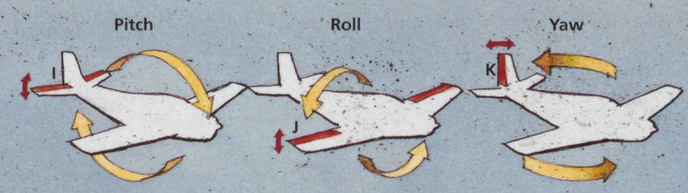
The First Four Flights
12 seconds 120 feet (1)
12 seconds 175 feet (2)
15 seconds 200 feet (3)
59 seconds 852 feet (4)

Solving the Problems of Flight

Principles of Flight

Any aircraft design has to solve three critical problems: lift—generating an upward force greater than the weight of the plane; thrust—propelling the plane forward; and control—stabilizing and directing the plane's flight. Any number of approaches can achieve these results, but natural selection eliminated the early designs that failed to meet the requirements of efficiency, reliability, and durability. The design rapidly evolved into the familiar, basic configuration that virtually all airplanes share.





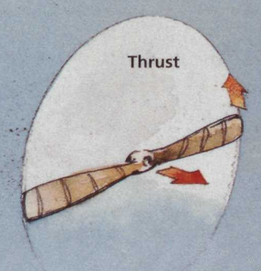


ILLUSTRATION: NPS/RICHARD SCHLECHT

Lift Air passing over the arched, or cambered, upper surface of a wing **(A)** must travel farther than the air passing beneath the wing. So, it has to move faster, making the air pressure drop relative to the pressure under the wing. Upward lift **(B)** is created. The degree of curvature of the upper surface and the ratio of the wing span to its chord (distance from the front to the back of the wing) **(C)** affect lift. The angle of attack—the angle at which the wing meets the air **(D)**—also affects lift. The greater the angle, the greater the lift—up to a point. Past a certain angle, the smooth flow of the air over the wing suddenly becomes turbulent **(E)** and stalling occurs. That is, lift is lost. At higher speeds, less angle is needed to generate the same amount of lift.

Control A wing is inherently unstable fore-and-aft. This is because lift **(B)** is greatest behind the center of gravity **(F)**, making the wing rotate around that point. The nose pitches down, the tail comes up. To counteract this, the horizontal stabilizer **(G)** acts as an inverted wing, creating negative lift to hold the tail down. Lateral stability of the plane is affected by the amount of dihedral **(H)**, the deflection from horizontal built into the wings. Movable control surfaces produce the three movements needed for maintaining control of the aircraft and changing direction. The elevator **(I)** produces ***pitch*** (up and down movement of the nose), for longitudinal control. Ailerons **(J)** produce ***roll*** (rotation of the wings), for lateral control. The rudder **(K)** produces ***yaw*** (right and left movement), for directional control. These movements in combination turn the aircraft.

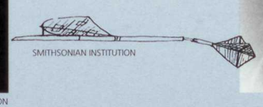
Thrust Just as air flow over the wings generates lift, air flow over the rapidly turning blades of a propeller-driven plane produces thrust, or forward motion. Each blade of the propeller acts as a small airfoil, or wing. As the blade rotates, air flows over its curved surface. The resulting horizontal "lift" propels the aircraft forward. Because the velocity of the blade increases from hub to tip, the blade is twisted, providing the most efficient angle of attack at each point along its length.

Predecessors

George Cayley (1773–1857) was the father of aerodynamics. His 1804 glider model incorporated most design elements of a modern airplane.

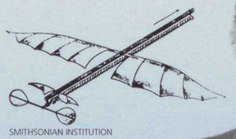
NATIONAL PORTRAIT GALLERY, LONDON

Alphonse Penaud (1850–80) built a rubber band powered "planophore" model. Its 131-foot flight was the first of an inherently stable aircraft.



SMITHSONIAN INSTITUTION

MUSEE DE L'AIR ET DE L'ESPACE



SMITHSONIAN INSTITUTION

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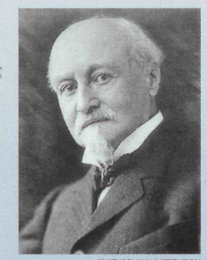
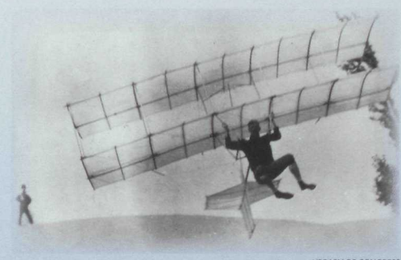
Otto Lilienthal (1848–96) was the first true glider pilot. Inspired, the Wrights took up his quest to get on "intimate terms with the wind."

SMITHSONIAN INSTITUTION



Octave Chanute (1832–1910) gathered and disseminated aeronautical knowledge. He encouraged the Wrights, who used his biplane glider design.



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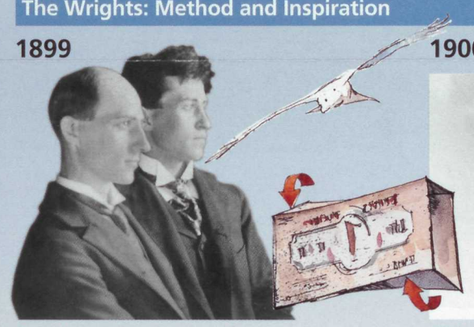
The Wrights: Method and Inspiration

1899



Experiments in wing-warping

The Wrights knew that the solutions to lift and propulsion needed refining, but no one had achieved lateral control. Rejecting the principle of inherent stability—the conventional wisdom—they wanted control to depend on the pilot. Wilbur hit upon the idea of warping the wings—sparked by watching birds and idly twisting a box—to rotate the wings and stabilize flight. They tested wing-warping—the forerunner of ailerons—on a five-foot biplane kite.

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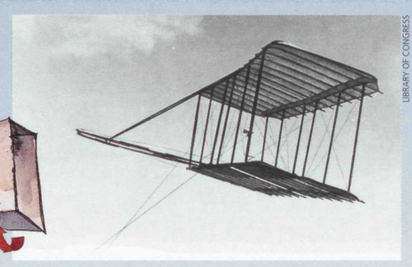
ILLUSTRATION: NPS/RICHARD SCHLECHT

1900



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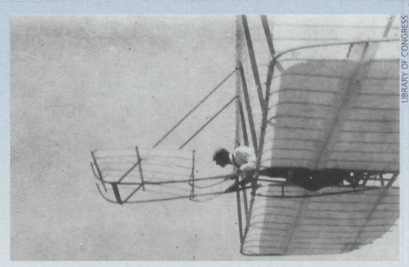
Glider flown like a kite

Confident their design was sound, the Wrights built a 17-foot glider with an unusual forward elevator. They went to Kitty Hawk hoping to gain flying experience, but the wings generated less lift than expected, and they flew the glider mostly as a kite, working the control surfaces from the ground. Wilbur's time aloft in free flight totalled only 10 seconds. They went home somewhat discouraged, but convinced they had achieved lateral and longitudinal control.

1901



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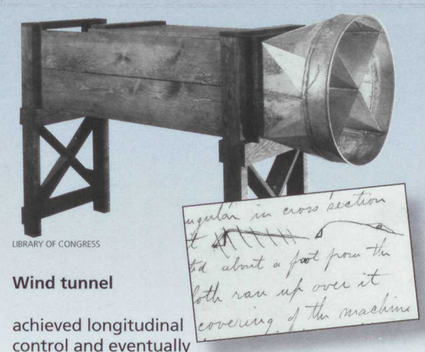
Increased camber and wingspan

This was the year the Wrights sharpened their focus. Trying to overcome the lift problem, they increased the camber of the 1901 Glider. They also lengthened its wingspan to 22 feet, making it the largest glider anyone had attempted to fly. But at their new Kill Devil Hills camp, lift was still only a third of that predicted by the Lilienthal data upon which the wing design was based. And the Glider pitched wildly, climbing into stalls. When they returned to the earlier camber, they achieved longitudinal control and eventually glided 335 feet. But the machine was still unpredictable. When the pilot raised the left wing to initiate the expected right turn, the machine instead tended to slip to the left (adverse yaw). This failure, and the realization that their work had relied on false data, brought them to the point of quitting. Instead they built a wind tunnel and produced their own data.



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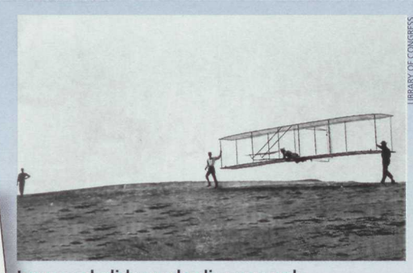
Wind tunnel

1902



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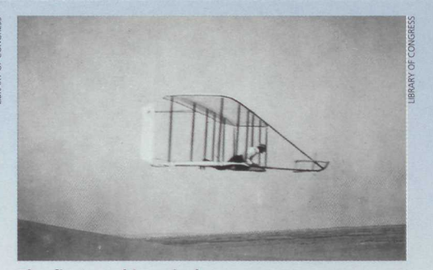
Improved glider embodies research

The 1902 Glider embodied the Wrights' research. They gave it 32-foot wings and added vertical tails to counteract adverse yaw. The pilot moved a hip cradle to warp the wings. Some 400 glides proved the design workable, but still flawed. Sometimes, when the pilot tried to raise the lowered wing to come out of a turn, the machine instead slid sideways toward the wing and spun into the ground. Orville suggested a movable tail to counteract this tendency.



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The first working airplane

After Wilbur thought to link the tail movement to the warping mechanism, the Glider could be turned and stabilized smoothly. If others had thought about steering at all, it was by rudder—a marine analogy unworkable in the air. The Wrights saw that control and stability were related, that a plane turned by rolling. Six hundred more glides that year satisfied them that they had the first working airplane.

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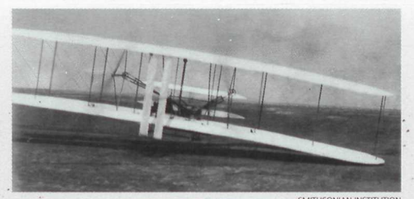
1903

Now the Wrights had to power their aircraft. Gasoline engine technology had recently advanced to where its use in airplanes was feasible. Unable to find a suitable lightweight commercial engine, the brothers designed their own. It was cruder and less powerful than Samuel Langley's, but the Wrights understood that relatively little power was needed with efficient lifting surfaces and propellers. Such propellers were not available, however. Scant relevant data could be derived from marine propeller theory. Using their air tunnel data, they designed the first effective airplane propeller, one of their most original and purely scientific achievements.

Returning to Kill Devil Hills, they mounted the engine on the new 40-foot, 605-pound Flyer with double tails and elevators. The engine drove two pusher propellers with chains, one crossed to make the props rotate in opposite directions to counteract a twisting tendency in flight. A balky engine and broken propeller shafts slowed them, until they were finally ready on December 14. Wilbur won the coin toss, but lost his chance to be the first to fly when he oversteered with the elevator after leaving the launching rail. The Flyer climbed too steeply, stalled, and dove into the sand. The first flight would have to wait for repairs.

SMITHSONIAN INSTITUTION

Propellers
The Wrights dismissed the traditional view of a propeller as an "air screw," seeing it instead as a rotary wing.



SMITHSONIAN INSTITUTION

December 17, 1903

Three days later, they were ready for the second attempt. The 27-mph wind was harder than they preferred, because their predicted cruising speed was only 30 to 35 mph. The headwind would slow their groundspeed to a crawl, but they proceeded anyway. With a sheet they signaled the volunteers from the nearby lifesaving station that they were about to try again. Now it was Orville's turn.

Remembering Wilbur's experience, he positioned himself and tested the controls. The stick that moved the horizontal elevator controlled climb and descent. The cradle that he swung with his hips warped the wings and swung the vertical tails, which in combination turned the machine. A lever controlled the gas flow and airspeed recorder. The controls were simple and few, but Orville knew it would take all his finesse to handle the new and heavier aircraft.

At 10:35 he released the restraining wire. The flyer moved down the rail as Wilbur steadied the wings. As Orville left the ground, John Daniels from the lifesaving station snapped the shutter on a preset camera, capturing the image of the airborne aircraft with Wilbur running alongside. Again the flyer was unruly, pitching up and down as Orville overcompensated with the controls. But he kept it aloft until it hit the sand about 120 feet from the rail. Into the 27-mph wind the ground speed had been 6.8 mph, for a total airspeed of 34 mph. The brothers took turns flying three more times that day, getting a feel for the controls and increasing their distance with each flight. Wilbur's second flight—the fourth and last of the day—was impressive: 852 feet in 59 seconds.

This was the real thing, transcending the powered hops and glides others had achieved. The Wright machine had flown. But it would not fly again, after the last flight it was caught by a gust of wind, rolled over, and damaged beyond easy repair. Their flying season over, the Wrights sent their father a matter-of-fact telegram reporting the modest numbers behind their epochal achievement.

ILLUSTRATION: NPS/RICHARD SCHLECHT