LESSON 3

The Wright Brothers Take Off

Quick Write

The Wright brothers were the first to conduct a manned, controlled, sustained, and powered heavier-than-air flight. Many others had tried unsuccessfully to do this. After reading the paragraphs to the right, list three reasons for the Wrights' success.

Learn About

- the Wright brothers' first flight
- how the principles of airplane flight were applied to the *Wright Flyer*
- the contributions the Wright brothers made to US Army aviation
- how the Wright brothers were the first to succeed in powered flight

IT WAS 14 DECEMBER 1903. Wilbur and Orville Wright stood on the sand dunes of Kill Devil Hills, North Carolina. Beside them was their aircraft, the *Wright Flyer*. It was ready for its first real test. Although their first successful manned flight of this craft would not come until three days later, on 17 December, they had high hopes. The two men had worked for years for this moment. One important question remained: who would fly the craft?

They tossed a coin. Wilbur won. He would pilot the *Flyer* on its first attempt at flight.

Choosing the pilot was a matter of chance. But it wasn't chance that brought the two brothers to this important day. It was years of work and study. Why did they succeed when others had failed?

First, they were intelligent men. They learned from the experiences of others. Second, they were also creative thinkers and great problem solvers. Third, and perhaps most important, they were patient.

A well-known proverb says, "Genius is patience." And the brothers' patience paid off. After making hundreds of flight trials between 1899 and 1903, the Wrights achieved what earlier men had only dreamed of.

The Wright Brothers' First Flight

The *Wright Flyer* that Wilbur and Orville successfully flew in December 1903 was larger than any aircraft the brothers had built earlier. A biplane, it was equipped with an engine and propellers, had a wingspan of 40 feet, 4 inches, and a wing area of 510 square feet. The Flyer was 21 feet, 1 inch long. It stood 9 feet, 4 inches tall. It weighed 605 pounds without a pilot and about 750 with a pilot on board.

The Parts of the Wright Flyer

The *Flyer*'s wings had two main parts—spars and ribs. The spars are *the main, lengthwise pieces of the wing*. Attached to the spars were ribs. The ribs are *the crosswise pieces that give the wings their shape*.

Muslin, a lightweight fabric, covered the wings. It reduced wind resistance and added strength as the wings warped during turns. Struts and bracing between the top and bottom wings further reinforced the plane.

Two propellers sat behind the wings. They rotated in opposite directions and were made of two layers of spruce wood. Their job was to help move the craft forward. The plane also had a front elevator, which was covered by fabric. A rudder at the rear was also wrapped in fabric. The other important part of this plane was, of course, the engine. The *Flyer*'s engine was water cooled like a car engine and fueled by gasoline. The engine and the propellers together weighed about 200 pounds.

Before the *Flyer*, two assistants hand-launched the brothers' gliders. Each assistant would hold a wing and help lift the craft in the air. But the new, powered *Flyer* was too heavy for that. Rather than the wheels that are so common on the airplanes you see today, the brothers used skids—*long, thin runners, like a pair of skis*. Before takeoff, the plane sat on a trolley that rolled along wooden rails.

Vocabulary

- spars
- ribs
- skids
- elevator
- wing warping
- yaw
- airfoil
- center of pressure
- angle of attack
- relative wind
- bid
- strut
- bracing
- lateral
- pitch
- canard configuration
- sateen

The Right Stuff

Orville Wright (1871–1948)

Orville Wright was the scientist of the family. He loved science and technology. He was also quite shy, although he was never timid about playing practical jokes on his family and friends. Later, he wrote about the support he and his siblings found at home:

> We were lucky enough to grow up in an environment where there was always much encouragement to children to pursue intellectual interests; to investigate whatever aroused curiosity. In a different kind of environment, our curiosity might have been nipped long before it could have borne fruit.

Wilbur Wright (1867–1912)

Wilbur, four years older than Orville, was outgoing. He excelled at writing and public speaking. He loved to read. Both Wilbur and Orville liked to tinker as children.

When they had questions about anything mechanical, they would go to their mother, Susan. She was good at inventing. She made toys for her children and basic appliances for herself. Originally, Wilbur hoped to attend Yale University, but he was needed at home to help care for his mother. So he taught himself by reading a lot.

Orville (*left*) and Wilbur Wright

Library of Congress, Prints and Photographs Division, Cole & Co., cph 3a08822

How the Flyer Worked

The brothers controlled their craft through three main means they developed in their glider experiments:

- The forward elevator, *a small moving section attached to a fixed wing to help control up-and-down movement of the aircraft*
- The use of wing warping, *twisting the tips of the wings with a series of cables*
- A single, movable rear rudder

Surprisingly, the pilot did not sit upright. Instead, he lay on his stomach in a padded cradle on the lower wing. Because the engine was somewhat right of center, the pilot was placed slightly left of center to balance the weight.

To the pilot's left was a lever that he used to control the up-and-down movement of the elevator. By moving the lever with his hand, he could climb or descend.

By moving his hips, he pulled on the cables connected to the wings and rudder. This movement could direct the plane left or right.

Before the brothers invented the single, movable rudder, their gliders often slid sideways rather than turned. A *sidewise movement* is called a yaw. With the new, flexible rudder, the plane finally turned in the intended direction. For instance, if the pilot moved his hips so the cable pulled down on the left wing, the plane would veer left. The cables attached to the wings from the cradle twisted one wing down while forcing the other wing up. If the aircraft began to yaw, the rudder corrected this by reacting to pressure from airflow.

To design the propellers, the brothers drew on their bicycle-shop experience. They made the propellers rotate by attaching them to the engine with bicycle chains. To rotate the propellers in opposite directions, they simply twisted one of the two chains into a figure 8.

Before launch, wires tethered the airplane to earth. Only when the engine had fully revved up did the trolley start to move down the tracks. The plane lifted off the trolley as it rose into the air.

How the Principles of Flight Were Applied to the *Wright Flyer*

To get the *Wright Flyer* off the ground, the brothers had to solve the principles of flight: lift, drag, thrust, angle of attack, center of pressure, airfoil, and relative wind. The combination of solutions they found is still used for modern airplanes.

An engine and propellers gave Wilbur and Orville the ability to use not only lift but also thrust to propel their plane through the air. Both these forces are necessary for powered flight. As you learned in Lesson 2, *lift* is an upward force; *thrust* is a forward, or horizontal, force; and *drag* is the slowing effect of air on an aircraft.

When working on their gliders, the Wrights focused most of their attention on the lift exerted on the wings. Now that they had an engine and propellers, they could start to think more about thrust. They considered the propellers as extra wings on their airplane. But unlike wings, which are stable and horizontal, the propeller "wings" rotated and sat vertically. The propellers on the *Flyer* were eight feet in diameter.

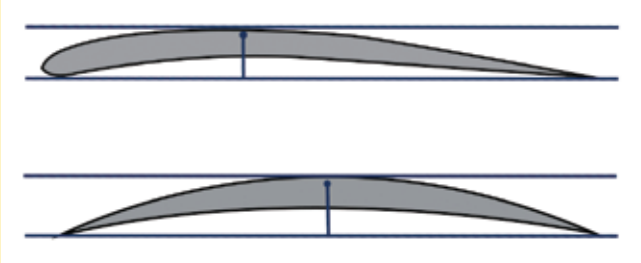


FIGURE 1.1

Airfoil

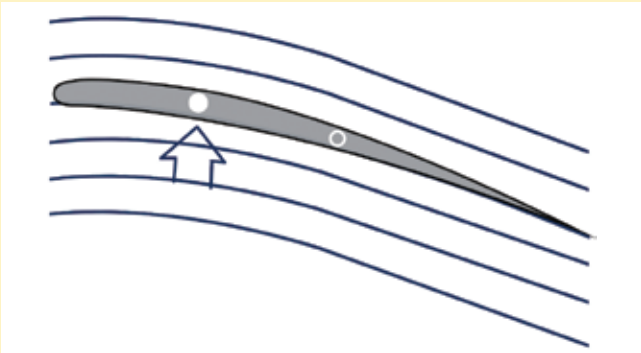


FIGURE 1.2

Center of Pressure

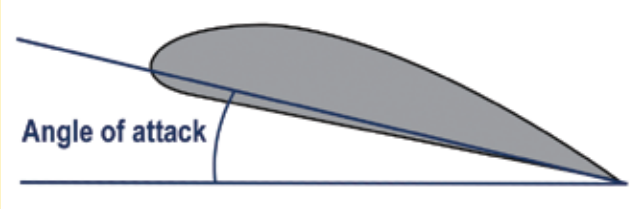


FIGURE 1.3

Angle of Attack

If a horizontal, curved wing reacts to lift, the Wright brothers reasoned, vertically mounted propellers could provide the airflow for thrust. They calculated they needed 90 pounds of thrust to propel the *Wright Flyer.* Their 12-horsepower engine and the large propellers proved equal to the task. The fabric with which they coated the wings, elevator, and rudder helped reduce drag.

Airfoil is *a wing's profile* (Figure 1.1). The Wrights experimented extensively with wing shapes to learn which curve worked best. They had moved the center of pressure, or *the focal point of lift*, further forward on the wing than had earlier experimenters (Figure 1.2). They had also learned that a low angle of attack—*the angle between the* relative wind *(the flow of air) and the airfoil*—provided more stability and control during flight (Figure 1.3). You'll read more about how they came to these conclusions while developing their gliders later in this lesson.

The Contributions the Wright Brothers Made to US Army Aviation

After their first success, the Wright brothers continued refining their airplane. Once they had achieved powered flight, they no longer needed the wind conditions of the North Carolina coastline for their tests. In October 1905 they circled a field in Dayton, Ohio, for 38 minutes and traveled 24 miles. They decided it was time to cash in on their remarkable invention.

They'd already started their marketing effort. Back in January 1905 they contacted their representative in Congress, R. M. Nevin, and asked him to try to interest the US government in buying their airplane. Mr. Nevin passed along their letter to the Board of Ordnance and Fortifications, which made military weapons purchases. The board was leery of wasting government money. It turned down the brothers' offer.

The brothers, patient as always, contacted the secretary of war later that year. Again, their offer was rejected. After all, as Lesson 2 related, the government had already invested $50,000 in Samuel Langley's flight experiments. The secretary didn't want to spend more money when the outcome seemed so uncertain.

Why the US Army Purchased the *Wright Flyer*

Meanwhile, the British and French governments got into the act. They were interested in buying the *Flyer*. Representatives from both countries made offers to the Wrights. But the brothers wanted the US government to have first crack at owning a *Wright Flyer*.

A turning point came on 22 May 1906. On that date, after three years of trying, the brothers received a government patent for their invention. This spurred the Aero Club of America, a group of aviation enthusiasts and scientists, to take action. They sent a clipping about the Wrights to President Theodore Roosevelt. The president ordered the Board of Ordnance and Fortifications to look again into the airplane.

After that, things started to happen. On 23 December 1907, Brigadier General James Allen, chief of the Army Signal Corps, sent out a request for bids to build a plane for the government. A bid is *an offer or a proposal, with a price attached*. The brothers received their copy of General Allen's request on 3 January 1908.

The bid set forth the technical requirements for the craft. These requirements stated that the craft must:

- achieve a speed of 40 miles per hour,
- carry two passengers for a total of 350 pounds,
- have a fuel tank large enough to fly 125 miles nonstop, and
- be able to land without damage.

The government also required that the successful bidder train two Army pilots to fly the craft.

The *Wright Flyer* met these requirements. Orville Wright signed a contract on 10 February 1908 selling the *Flyer* to the US government.

Ways the Wright Brothers Contributed to Army Aviation

With the purchase of the *Wright Flyer*, the Army bought not only the military's first plane but also access to the Wright brothers' inventive minds. In the years that followed, the Wrights continued to improve their aircraft. For instance, they created wheels for the *Flyer*. The wheels enabled it to take off and land in a wider variety of settings.

Orville spent much of 1908 and 1909 improving the *Flyer*. He made more test flights and took up military passengers. One such flight tragically ended in a crash that seriously injured Orville and killed 1st Lieutenant Thomas Selfridge—the first US military aviation casualty. Wilbur was often overseas giving demonstrations during this time.

The brothers switched roles in mid-1909. Wilbur trained two pilots for the Army—1st Lieutenant Frank P. Lahm and 2nd Lieutenant Fredric E. Humphreys. In October 1909 both men made their first solo flights with less than a month's training. These were adventurous men: each had barely three hours' instruction in the air before going it alone.

The Wright brothers' Type A airplane flying at Fort Myer, Virginia, in 1909

Library of Congress, Prints and Photographs Division, Harris & Ewing Collection, hec 06070

A third pilot, 1st Lieutenant Benjamin Foulois, got instruction later that month. One of the men initially picked for pilot training, he was delayed because of business in France. He took the *Wright Flyer* to Fort Sam Houston, Texas, where he continued teaching himself to fly. He corresponded with Wilbur and Orville whenever he had a question. On 2 March 1910 he took his first solo flight. By the time of his retirement a quarter-century later, Foulois had achieved the rank of major general. He was also chief of the Army Air Corps.

It took a while for the Army to decide how to use airplanes during war. At first, the Army thought that airplanes would be useful only for aerial reconnaissance, much as hot air balloons were used during the US Civil War and the Spanish-American War. But World War I brought about a change in strategy: soon, the warring sides were employing planes for bombing missions and to support troops on the ground. Before that could happen, however, airplanes needed improvements to make them faster, sturdier, and more reliable.

How the Wright Brothers Were the First to Succeed in Powered Flight

All pilots face three challenges—they must get up in the air, stay up, and control their craft. The choice of craft was up to the pilot. And pilots had three choices to experiment in flight:

- Manned and powered full-size aircraft
- Models
- Full-size gliders

The Wrights chose a glider as their starting point. By using a glider, they could focus first on balancing and controlling their aircraft. Power—an engine—could come later. This approach explains why they succeeded where Samuel P. Langley, who focused on power, failed.

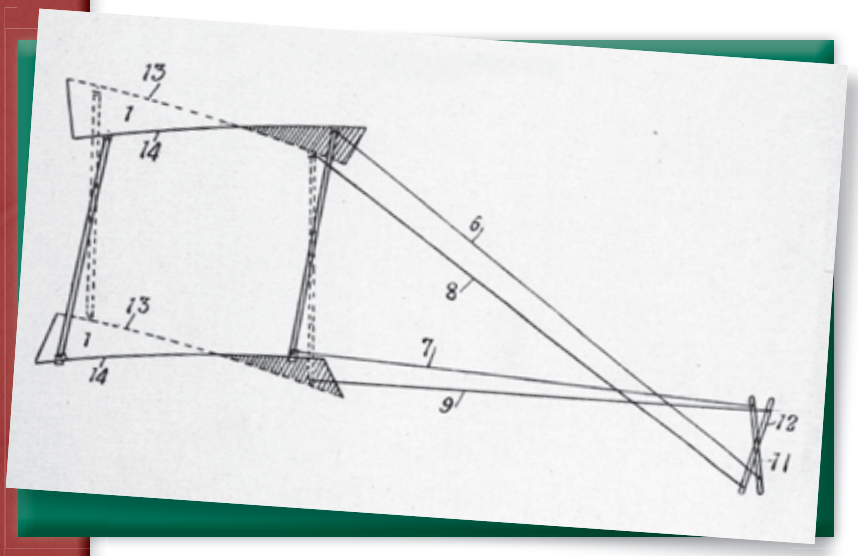
But before they could build a full-size glider, they needed to experiment with other, smaller craft. This was a complicated process. The brothers applied what they learned at each step to make the next one go more smoothly. This step-by-step experimenting was the key to the Wright brothers' success.

Waypoints

Wilbur Writes to the Smithsonian

One reason for the Wright brothers' success was their patience. Another was that they asked lots of questions. They wanted to build on what others had learned. So Wilbur went to the experts. The following is from a letter he wrote to The Smithsonian Institution in Washington, D.C., on 30 May 1899:

> Dear Sirs:
>
> I have been interested in the problem of mechanical and human flight ever since as a boy I constructed a number of bats of various sizes after the style of Cayley's and Penaud's machines. My observations since have only convinced me more firmly that human flight is possible and practicable. It is only a question of knowledge and skill just as in all acrobatic feats.… I believe that simple flight at least is possible to man and that the experiments and investigations of a large number of independent workers will result in the accumulation of information and knowledge and skill which will finally lead to accomplished flight.…
>
> …I wish to obtain such papers as the Smithsonian Institution has published on this subject, and if possible a list of other works in print in the English language. I am an enthusiast, but not a crank in the sense that I have some pet theories as to the proper construction of a flying machine. I wish to avail myself of all that is already known and then if possible add my mite to help on the future worker who will attain final success.…
>
> Yours truly,
>
> Wilbur Wright



Wing warping on the Wrights' 1899 kite

Library of Congress, Manuscript Division, Wilbur and Orville Wright Papers

Step One: An Unmanned Box Kite

The brothers began in July 1899 with an unmanned box kite. The kite had a five- foot wingspan and a biplane structure. It also had struts that connected the upper and lower wings. A strut is *a vertical post*. The kite also had bracing, or *support*, that was *strung diagonally between the struts*. The Wrights used steel for the bracing.

They adapted their bracing design from a manned glider created by Octave Chanute and Augustus Herring in 1896.

The brothers also had a unique approach to controlling the kite. They discovered that they didn't need to tilt an entire wing to turn the craft: They needed to twist only the ends of the wings. They used the process of wing warping. To warp the wings, they removed the bracing between the front and rear struts. They attached four cords to the top and bottom of the front outer struts. Pulling on these ropes turned the craft.

In the summer of 1899, Wilbur successfully tested the kite in a field. The first step in the experiment for aircraft control was a success. The next step: put a person on a glider.

Waypoints

An Absentminded Invention

Wilbur Wright was talking to a customer in the bicycle shop he owned with his brother in Dayton. As he did so, he toyed with a long, empty carton. Twisting the carton this way and that, he made a discovery: the sides of the box retained their shape and strength. Wilbur figured this same principle would apply to the wings of a biplane kite. In other words, the tip could be twisted, but the wing would remain strong. Thus the brothers' groundbreaking wing-warping theory was born.

Step Two: Manned Gliders

The box kite taught Wilbur and Orville Wright how to control lateral—*sideways*—turns. But building a successful manned glider presented other challenges. Between 1900 and 1902, the brothers built three gliders. Before putting a man aboard, they flew each glider like a kite. They wanted to test it for control and lift. Only after doing this would they put a man aboard.

The early glider experiments were successful. They taught the brothers three important things:

- How to control climb and descent
- The best design for the shape of the wing
- How large the wing area had to be to sustain lift

The First Glider (1900)

With a man on board the craft, knowing how to move up and down was essential. Otherwise, a sudden pitch—*a movement up or down*—could be fatal. For example, the German aviator Otto Lilienthal, whom you read about in the previous lesson, died when his craft made a downward pitch and crashed.

The Wrights studied Lilienthal's data. They used it to design a device that gave them greater control of pitch. In their experiments at Kitty Hawk in 1900, they had placed an elevator at the front of the glider.

This was a unique idea: Earlier designers had mounted elevators behind the wings. But the Wrights found it easier to control climb and descent when the elevator was placed forward. This development saved the Wrights' lives on several occasions.

A canard configuration is another name for *an elevator that sits in front of the wings*. (*Canard* is the French word for duck—early observers thought the canard configuration resembled a flying duck.)

Next, the Wrights tackled the challenge of how to shape the glider's wing. This took a couple years to figure out. In 1900 they focused on airfoil. In particular, they zeroed in on the curve of a wing.

The Wrights' 1900 glider

Library of Congress, Prints and Photographs Division, pppr-00556

Wings have a lot to do with lift, which, as you've learned, is the upward force on an aircraft. The Wrights tried to design a wing that shifted the center of pressure toward the front edge of the wing—the wing edge nearest the front of the aircraft. Earlier designers thought that the center of pressure should be in the middle of the wing. The Wrights placed the highest point of the wing's arc closer to the outer edge than to its center. They believed this would create greater stability and control.

Waypoints

A Stitch in Time

A glider's wings need to be strong but not heavy. They need to be stiff but not inflexible. In 1900 Wilbur and Orville Wright hit on a way to get all of this: fabric. They covered the top of the glider's wings with French sateen, *a cotton fabric woven like satin with a glossy surface*. Pieces of the wings' framework slid into "pockets" sewn on the underside of the fabric. These skeleton-like pieces of the wings "floated" inside the pockets.

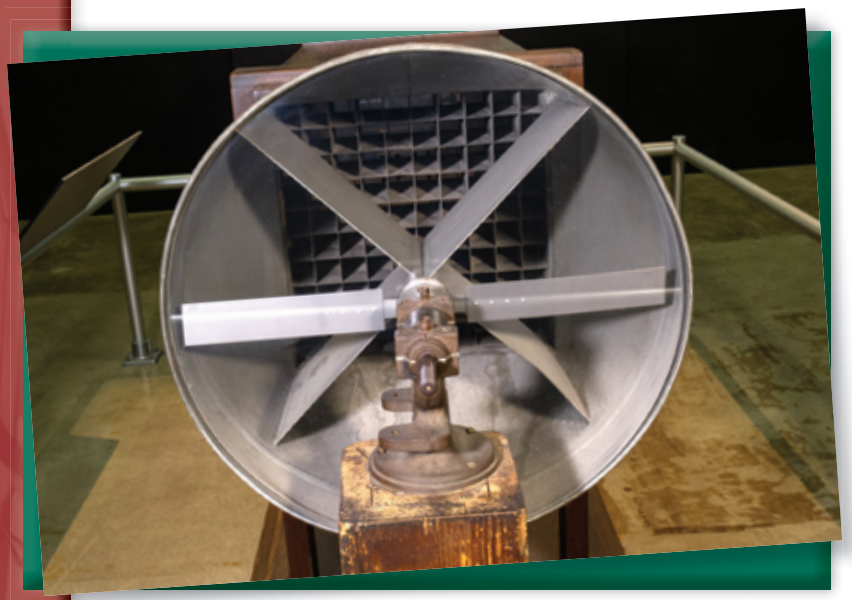
The fabric took the role that heavier wires and bracing would otherwise have taken. The Wrights attached the fabric to the wing's frame on the bias, which is a 45-degree angle. This made the wing stronger.

The brothers test-flew their glider at Kill Devil Hills in 1900. It didn't crash. But clearly improvements were necessary. The Wrights left North Carolina and headed back to Ohio. During the winter, they would tinker with their craft and build the next version of their glider.

The Second Glider (1901)

The Wrights' first glider had a wing area of 165 square feet. That glider didn't have nearly enough lift. So for their 1901 glider, the brothers increased the wing area to 290 square feet. This glider was also a big disappointment. The brothers couldn't control it well when they tested it at Kill Devil Hills. It flew less than 300 feet. Time to return to Dayton.

Wilbur and Orville built a wind tunnel in their bicycle shop in Ohio to test model-size wings. These wings came in many shapes—squares, rectangles, and semicircles. They ranged from perfect curves to arcs with their highest points at the outer edges. The Wrights made them of sheet steel. Over the winter, the brothers cut more than 200 model wings of different shapes.



The Wright Brothers' 1901 wind tunnel

Ken La Rock/Courtesy National Museum of the US Air Force

The Third Glider (1902)

At this point, the brothers could have been tempted to try powered flight. After all, their model-wing tests had answered many questions. But remember—these two men were patient. They didn't want to rush the process. So in preparation for 1902, they applied what they'd learned to build a third glider.

This glider had two fixed, vertical rudders behind the wings. Test flights showed that this resulted in erratic behavior during turns. So the Wrights tried a single, movable, vertical rudder. This improved control. This aircraft, too, had a forward elevator, but it had a more elliptical shape, and longer, skinnier wings. Wing area was 305 square feet. In addition, the glider had a low angle of attack. This also made the glider more stable and easier to control.

This design was a success. The brothers took to the air in the North Carolina dunes more than 700 times in the fall of 1902.

Winter arrived. It was time to head back to Ohio. It was also finally time to put an engine on the glider.

Wilbur Wright and Dan Tate flying the 1902 glider as a kite

Library of Congress, Prints and Photographs Division, ppprs-00631

Wilbur flying the 1902 glider

Library of Congress, Prints and Photographs Division, ppprs-00603

Step Three: A Manned, Powered Aircraft

One key to the Wright brothers' success was their countless test flights. Another was sticking with a core design. Their kites and gliders evolved from a single design into the manned, powered aircraft they eventually flew in 1903. They tinkered with the details, but didn't get distracted. For instance, they didn't attempt powered flight until they'd perfected other elements, such as the wings.

Once they'd resolved questions about control and lift, the brothers set out to fit their plane with an engine. They hoped they might buy one ready made. They sent out queries to a number of firms. But no one met their needs or price. So the brothers had their bicycle mechanic, Charles E. Taylor, build them a four-cylinder, 12-horsepower engine.

In September 1903 they returned to Kitty Hawk and Kill Devil Hills. The aircraft was ready. But they couldn't take to the skies quite yet. They had to build a trolley track to give their powered aircraft a running start. Bad weather also caused delays. So the first test flight of the *Wright Flyer* didn't take place until 14 December.

The brothers tossed a coin. Wilbur won the toss. He took the pilot's seat for the initial powered flight. He rolled down the trolley, launched into the air, and—crashed. That flight lasted only 3.5 seconds. The crash damaged the elevator.

But the brothers were not discouraged. Quite the opposite—in a note to home, Wilbur wrote, "There is now no question of final success."

It took three days to repair the damaged craft. Then, on 17 December, Orville took the controls for this day's first flight. It was 10:35 a.m. The *Flyer* rose into the air.

It stayed aloft for 12 seconds and traveled 120 feet. He had made the first controlled, sustained, heavier-than-air human flight with a powered aircraft.

On that momentous day, the brothers took turns piloting the *Flyer* for three more flights. Each launch was more impressive than the last. The fourth and final launch lasted 59 seconds. The craft traveled 852 feet.

On that day atop the windswept dunes of North Carolina's Outer Banks, the aviation age had begun.

The Wright brothers' first sustained powered flight, Kitty Hawk, North Carolina

Library of Congress, Prints and Photographs Division, pppprs-00626

CHECKPOINTS

Lesson 3 Review

Using complete sentences, answer the following questions on a sheet of paper.

1. What were the two parts of the *Wright Flyer*'s wings?
2. What did the Wright brothers invent in order to control yaw?
3. What are the principles of flight the Wright brothers had to solve?
4. What kind of force did the *Wright Flyer*'s engine and propellers provide?
5. Who was the first US military aviation casualty?
6. Who was Benjamin Foulois?
7. How did the Wright brothers' approach to building an aircraft differ from Samuel Langley's?
8. What three important points did the Wrights learn from their gliders?

APPLYING YOUR LEARNING

9. What lessons can you learn from the Wright brothers about problem solving?