IT HAD BEEN A TOUGH TRIP for Lieutenant Colonel Joseph E. Maxfield of the US Army Signal Corps. The year was 1898. The United States was at war with Spain.

Six years earlier, the Signal Corps had formed a balloon section. For the first time since the Civil War, the Army was back in the business of spying from the sky.

Now Colonel Maxfield was in charge of a single balloon. It was the only one the Army had.

Maxfield traveled alone with the balloon from New York to Florida. Then with troops and some equipment, he sailed for Cuba. That country, then a Spanish colony, was one of the major theaters of the Spanish-American War.

Maxfield’s party included three officers and 24 enlisted men. Only one man had ballooning experience—Sergeant Will Ivy Baldwin, who had once worked as a stunt balloonist and had built a balloon with his wife the previous year. None of the others, including Maxfield, had ever even seen a balloon go up.

The party sailed into Santiago harbor 22 June. Because they lacked supplies, they would be able to inflate the balloon just once. They wouldn’t be able to reinflate it.

The terrain was rugged. It took them a whole day to get from the harbor to their headquarters. And once they unpacked their balloon, they found that parts of it had stuck together in the heat. Other parts had disintegrated.

But somehow, they managed to inflate the balloon using hydrogen cylinders. And they got it into the air several times.

On 1 July 1898 during the Battle of San Juan Hill, Soldiers went aloft to scout the enemy position. They made an initial ascent at some distance from the battle. The leader of the Soldiers, Lieutenant Colonel George M. Derby,
then ordered the balloon forward. He got it to within 650 yards of the Spanish infantry trenches. Maxfield feared this was too close to the enemy.

In a way, he was right. By the end of the day, the balloon had been hit by so many enemy bullets that it was useless. But before that, it gave observers aboard a totally different view of the battle. Because of what they’d seen, the balloonists suggested new ways to direct American troops advancing against the Spanish. They also identified new artillery targets.

The battle was a big US victory. Teddy Roosevelt’s Rough Riders made a name for themselves in it. The “buffalo Soldiers,” members of an all-African-American regiment, got to show what they were made of.

The Battle of San Juan Hill was a milestone in military aviation. The spies in the sky may have decided the battle.

It was a good day for Maxfield’s balloon.
Aviation developments in the 19th century followed two lines: lighter-than-air craft and heavier-than-air craft. Lighter-than-air craft include balloons and dirigibles. The story you’ve just read shows how far these craft had come by the end of the 19th century. Heavier-than-air machines include gliders, and later, airplanes and jets.

Whether their craft are lighter or heavier than air, all aviators face the same three problems:

- How to get up into the air
- How to stay up in the air
- How to control where they’re going, including getting safely back to earth

**Principles of Balloon Flight**

A balloon operates on the principle of buoyancy. If the air or gas inside a balloon is lighter than the air around it, it will float. Hot air takes care of the first challenge of flight—getting up into the air.

A Jesuit priest, Laurenço de Gusmão, gets credit for inventing the hot-air balloon. In 1709 he demonstrated his invention before the King of Portugal. Word soon spread across Europe.

Several people tried out balloons during the 18th century. The work of the Montgolfier brothers, Joseph and Étienne, led to the first balloon flight with humans aboard. On 21 November 1783, Pilatre de Rozier and François d’Arlandes made a historic 25-minute flight over Paris in a Montgolfier hot-air balloon.
The Montgolfiers’ achievement was impressive. But there was still work to do. The brothers hadn’t figured out how to achieve the second principle of flight—to keep the balloon up in the air. To do that, you need to keep the air inside the balloon hot. This meant having a fire under the balloon. That was dangerous. It also meant that balloons needed to carry fuel, and fuel was heavy.

While the Montgolfiers were testing their balloons, the young French scientist J.A.C. Charles experimented with hydrogen. This gas is lighter than air. It provided much more lift than hot air, and the balloonists didn’t need to carry a fire and fuel aloft to keep the air heated. Lift is the upward force on an aircraft against gravity.

**A Big Idea Sparked in Front of the Fireplace**

Joseph and Étienne Montgolfier were the first to achieve manned flight. The brothers were papermakers and amateur scientists in Annonay, France. They kept up with the work of other scientists around Europe.

One day in 1782 Joseph Montgolfier was sitting in front of his fireplace when he happened to notice the sparks and smoke rising.

This got him thinking—and experimenting. He made a small bag out of silk and held the bag upside down. Then he lit a fire under the opening at the bottom. The bag swelled and rose to the ceiling. Soon Joseph and his brother moved their experiments outdoors. They built and flew larger bags made of paper and linen.

The brothers thought they’d discovered a new gas. They even gave it a name: “Montgolfier gas.” Today we know that they hadn’t discovered a new gas at all. They’d simply observed a principle of physics: Hotter air rises above cooler air.

The Montgolfiers’ experiments attracted attention. French King Louis XVI and Queen Marie Antoinette asked to see one of the balloons in action. Eventually this led to the first manned balloon flight on 21 November 1783.

The Montgolfiers achieved a milestone in the history of flight. But Joseph Montgolfier’s observation in front of the fire also has a lesson for creative thinkers of all kinds: You never know where you’ll find a good idea. It may come as you sit in front of your fireplace.
But hydrogen could be risky, too, because it is very flammable—it catches fire easily. Many people were killed before a safer gas, helium, came into use. (Helium isn’t as flammable as hydrogen.)

Despite the risks, Charles and a passenger made the first manned hydrogen balloon flight on 1 December 1783. Their flight lasted more than two hours and covered more than 27 miles.

In the years that followed, ballooning attracted interest across Europe. Benjamin Franklin, then an American diplomat in France, saw one of Charles’s balloons in 1783. He immediately wrote home, stressing the military importance of the new invention. In 1783 the French Army started using balloons for *aerial reconnaissance*—looking over battlefields from the sky.

**Dirigibles**

Once balloonists started using lighter-than-air gases, they had solved two of the three problems of flight: getting up into the sky, and staying there. The days of bringing their flying fireplaces along with them were past. But the third problem of flight—control of the craft—was still a problem. It was, that is, until inventors came up with the **dirigible**—a steerable airship.

A balloon in the sky is like an inner tube floating along a river. The inner tube follows the river currents, and a balloon follows the air currents. The balloon rides high or low, depending on how much gas it holds. You can’t steer it.

The new dirigible airships had two things that helped pilots steer them. First, they had rudders. A **rudder** is *a vertically hinged airfoil used for controlling horizontal movement of an aircraft*. Pilots could use the rudder to turn the craft left or right. Second, like steamships or motorboats, the new airships had power sources that drove propellers. Equipped with propellers, the craft could move through the air much as ships move through water.

Scientists also thought an airship with pointed ends would fly better than a round balloon. In 1852 Henri Giffard of France built a cigar-shaped dirigible. It was 114 feet long and 39 feet in diameter. A three-horsepower steam engine pushed it through the sky at about five miles an hour. Most historians give Giffard credit for inventing the first successful dirigible.

Development of dirigibles continued. Some inventors tried out internal keels to improve these aircraft. A **keel** is *a structure that extends along the center of a craft from the front to the back*. A keel helps keep the craft rigid and fully extended. It also streamlines it.
A rigid craft has a frame that contains several balloons to provide lift. A non-rigid ship, on the other hand, holds its shape through gas pressure alone.

The next breakthrough came in 1872, when German engineer Paul Haenlein built a dirigible with an **internal-combustion engine**, *an engine in which the fuel is burned inside, rather than in an external furnace*. (A gas-burning car engine is an internal combustion engine.) Two men made their names with these engines: Alberto Santos-Dumont and Count Ferdinand von Zeppelin.

**Alberto Santos-Dumont**

Santos-Dumont’s first dirigible was 82 feet long. A three-horsepower gasoline motor (about half the power of a small lawn mower) powered it. It could reach an altitude of 1,300 feet. A pilot steered it with a rudder. Between 1898 and 1907 Santos-Dumont built and flew 14 of these non-rigid airships.

Santos-Dumont, a Brazilian, became famous in 1901. In that year, he flew an airship around the Eiffel Tower. He completed a nine-mile loop in less than half an hour. This won him a big cash prize from a rich oilman named Henri Deutsch. Santos-Dumont gave the money to his own workers and to the poor of Paris.

Santos-Dumont became a familiar sight in his frequent flights over the rooftops of the French capital. His generous and adventurous spirit won over the French people. He helped spark interest in aviation worldwide.

**Count von Zeppelin**

Zeppelin’s machines were rigid dirigibles. In July 1900 this German inventor built and flew the first successful rigid dirigible, the LZ-1.

This led to the world’s first commercial airships. The **Zeppelins**, as they were known, were luxurious. They had roomy, wood-paneled cabins. They carried 20 or more passengers. They flew at speeds exceeding 40 miles an hour. For a few years, they had a good safety record.

But the days of airships were numbered. The first airplanes were beginning to hop off the ground. Within a few decades, airplanes would crowd airships almost completely out of the skies.
Early Military Contributions of Lighter-Than-Air Flight

Balloons in the US Civil War

The US armed forces first used balloons during the Civil War. But it took President Abraham Lincoln to make it happen.

After the Civil War began, many *aeronauts*—people who travel in airships or balloons—volunteered their services for the Union cause. They thought it would be a good idea to use balloons for aerial reconnaissance. After all, the French had done this more than half a century earlier.

One of these aeronauts was Thaddeus Lowe. He tried to interest General Winfield Scott, head of the Union Army, in balloons. But Scott saw no military need for them.

Lowe didn’t give up, however. He was a friend of Joseph Henry, the head of the Smithsonian Institution. And Henry knew President Lincoln. Henry convinced the president to let Lowe demonstrate what a balloon could do.

Lowe launched a balloon from the National Mall, a short distance from the White House. A telegraph wire ran from the balloon, up into the sky, and down to the White House, where Lincoln could receive messages over it. From his balloon, the pilot described what he saw to the President. This demonstration made Lincoln realize how useful balloons could be for keeping an eye on Confederate forces. Lincoln sent General Scott a note asking him to reconsider Lowe’s offer.

Lowe was finally allowed to organize the Balloon Corps of the Union Army, the first air arm of the United States military. The balloonists provided valuable information to Union forces during several battles.

But it was a struggle. Lowe often had to pay for staff and supplies out of his own pocket. It was sometimes hard to get permission to send the balloon aloft. Despite some success, the Army disbanded the balloon service in 1863, before the war ended.
The Confederate Army also tried to start a balloon force. Southern women even donated silk dresses to build a balloon. But the Southern balloon effort never really got off the ground.

**The Balloon’s Contribution to US Victory in the Battle of San Juan Hill**

On 1 October 1890 the US Congress gave the Signal Corps the duty of collecting and transmitting information for the Army. At that point, the military had not conducted balloon operations for nearly 30 years. But several other countries—Britain, France, Germany, Italy, Japan, and Russia—had established balloon corps as part of their armed forces. Brigadier General Adolphus V. Greely, the chief signal officer, interpreted his assignment to include aerial navigation. In 1892 he established a balloon section in the Signal Corps.

A few years later, the United States was at war with Spain. The Battle of San Juan Hill gave the Army a chance to see what a balloon could do.

As shown in the story at the beginning of this lesson, Lieutenant Colonel George M. Derby insisted on bringing the Army’s single spy balloon as close to the action as possible during the Battle of San Juan Hill on 1 July 1898.

From that position, observers on board could see a new trail leading to the Spanish forces. This let US commanders divide their Soldiers into two forces to advance against the enemy. This relieved congestion on a main road where the Americans were more vulnerable to Spanish attack. The observers also suggested directing artillery fire from El Pozo Hill against the San Juan Hill trenches.

Historians say these actions may have turned the battle into a US victory.
While balloons and dirigibles were enjoying success, other aviators were making progress with heavier-than-air craft.

**Giders**

Sir George Cayley (1773–1857) picked up where Leonardo da Vinci left off in developing gliders. This Englishman’s gliders resembled today’s model gliders. They had the same design as most of today’s airplanes, with wings up front and a tail behind.

Cayley also came up with the idea of using a fixed wing for lift and a separate system for propulsion. The fixed-wing idea seems simple now. But it was quite new at a time when many people still had flapping birds’ wings as their model for flight.

Cayley identified three important forces in connection with aviation. The first force was lift. The second was **drag**, the pull, or slowing effect, of air on an aircraft. The third was **thrust**, the forward force driving an aircraft. In 1850 Cayley built the first successful full-size manned glider.

Cayley also recognized that a flying machine would need the right kind of engine to propel it. Steam engines were too heavy.

**The Right Stuff**

**Sir George Cayley**

Sir George Cayley was nine years old when the Montgolfiers made their first balloon flight. But even at that young age, he started experimenting with small paper balloons. Later he built model helicopters using Leonardo da Vinci’s “airscrew” concept. In 1809 Cayley summarized his research in a scientific paper. It contained one sentence that laid the whole foundation for modern aeronautics. That sentence read: “The whole problem is confined within these limits, namely, to make a surface support a given weight by the application of power to the resistance of air.” In other words, the problem was how to provide lift using wind resistance.
Work on gliders continued, even after the Wright brothers’ flights in 1903. Two men were especially important.

The first was Otto Lilienthal of Germany, a famous aviator. In fact, he’s often called the “Father of Modern Aviation.” Between 1891 and 1896 he made more than 2,000 glides. His abilities as an engineer and mathematician helped with the development of powered flight. Altogether, Lilienthal constructed 18 types of gliders—15 monoplanes and three biplanes. (A biplane is an aircraft with two main supporting surfaces, usually placed one above the other.)

On 9 August 1896, he decided to fly his glider one more time. He took off in a gusty wind. His glider stalled at 50 feet up and dropped like a rock. Sadly, Lilienthal was severely injured in the crash and died the next day. But subsequent aviators, including the Wright brothers, made use of his data and experiments.

The second was John J. Montgomery, an American. After witnessing a glider flight in 1869, he began his own aerial experiments in August of 1881. After 20 years of experiments, he unveiled his glider to the public in 1905. He thrilled people by performing sharp dives and turns in the air. His glider reached speeds of 68 miles an hour. Unfortunately, on 18 April 1906, Montgomery’s gliders were destroyed in the San Francisco earthquake. He eventually restarted his work in 1911 with new glider called the Evergreen. Sadly, on 31 October 1911, while flying at an altitude of less than 20 feet the Evergreen glider stalled, came down on the right wing, and Montgomery was killed.

### Failed Attempts to Construct an Airplane

In 1843, two Englishmen designed an aircraft theoretically capable of carrying a man. They were W. S. Henson, an inventor, and John Stringfellow, an engineer. The two received a patent—a legal document protecting the rights of an inventor—for their design. Their aircraft, the Ariel, was to be a monoplane—an airplane with one set of wings. It would have a 150-foot wingspan. It would be powered by a steam engine driving two six-bladed propellers. As it turned out, however, the Ariel was never built. But the plans were engineering masterpieces.
In 1848 Stringfellow built a steam-driven model that did fly. This was the first successful powered flight of a heavier-than-air craft.

**The Contributions and Failures of Samuel Langley**

Dr. Samuel Pierpont Langley was one of the first Americans to try to build a flying machine with a motor. He started experimenting with aerodynamics in 1885. Rubber bands powered his first models. In 1898 the US government gave him a $50,000 grant to continue his work.

On 7 October 1903 his aircraft, the *Aerodrome*, was ready for a test flight. Langley planned to launch it from a catapult on a barge on the Potomac River. The plane’s engine worked well, but the aircraft caught on the launching car on takeoff. It fell into the river.

Two months later, Langley tried—and failed—again. His efforts got a lot of press coverage in Washington. Government officials read about them and withdrew their support. So Langley gave up his project. He donated his *Aerodrome* to the Smithsonian Institution.

Despite his failures, Langley made important contributions to aviation. For example, he explained how birds can soar in the sky with no apparent movement of their wings. (As you read in the last lesson, Bernoullian lift pulls the wings up from above, while Newtonian lift pushes them up from below.) Historians fault Langley for spending too much time on how to power his aircraft and not enough on how to control it. Even so, for his contributions to aviation, Langley Air Force Base in southeastern Virginia is named after him.
Lesson 2 Review

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

1. What are the two lines of aviation development followed in the nineteenth century?
2. What are the three problems of flight all aviators face?
3. How did inventors solve the problem of steering lighter-than-air craft?
4. Who was Thaddeus Lowe, and what group did he organize during the Civil War?
5. When the US Army Signal Corps established a balloon section, which other countries had already been using balloons as part of their armed forces?
6. How did a balloon help the US Army win the Battle of San Juan Hill in Cuba?
7. Which three important forces did Sir George Cayley identify?
8. Which two men did important work using gliders?
9. What do historians fault Samuel Langley for?

APPLYING YOUR LEARNING

10. Are dirigibles still in use today? What are they called? What are they used for?