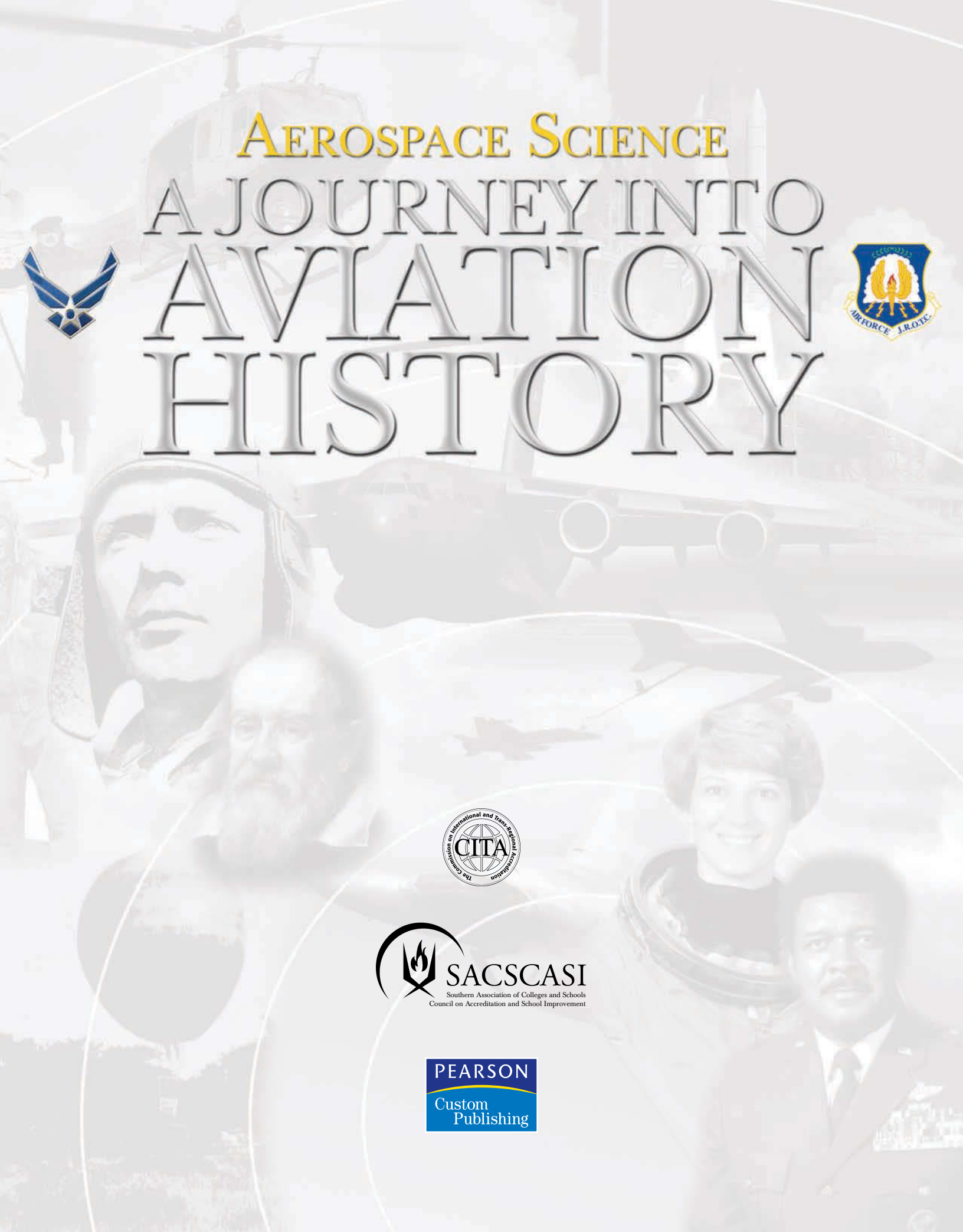
AEROSPACE SCIENCE

A JOURNEY INTO AVIATION HISTORY



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Preface

Aerospace Science: A Journey Into Aviation History is a course about aviation history focusing on the development of flight throughout the centuries. It starts with ancient civilizations, then progresses through time to modern days. It emphasizes civilian and military contributions to aviation, the development and modernization of the United States Air Force, and a brief history of astronomy and space exploration. The present edition is the first major revision of this course in more than two decades.

Our vision for this course is to bring alive the significant events that make up the exciting history of aviation. Along with the events, we focus on those people who accomplished them. This book tells their stories and shows why we are so proud of Air Force heritage—which lays the foundation for the Air Force Junior Reserve Officer Training Corps (AFJROTC) program. As our mission for AFJROTC is to "develop citizens of character dedicated to serving their nation and community," we know this course will meet one of our objectives—to provide instruction in air and space fundamentals.

New features of this book include *Flight Paths*—short profiles of famous people whose lives illustrate aspects of the lesson material; *Skynotes*—which provide brief information about a topic; and *Capsules*—interesting tidbits related to aerospace facts. Throughout the course, there are readings, video clips, hands-on activities, and in-text and student-workbook exercises. A student workbook and an instructor guide with lesson plans and slides supplement the text.

"Unit One: Imagining Flight" covers ancient flight. It includes how people discovered flight and the early days of flight. You'll read how the imaginative thinking of Leonardo da Vinci led people in following centuries to experiment with parachutes and gliders.

"Unit Two: Exploring Flight" deals with pioneers of flight. It begins with the Wright brothers and discusses the development of aircraft and air power in World War I. It continues with lessons on the barnstormers; flight goes mainstream; and commercial flight, air mail, and helicopters. You'll read about the Wright brothers' careful and logical experiments that led to the first controlled, manned, heavier-than-air flight. You'll study how aviation developed rapidly during World War I and how Charles Lindbergh captured imaginations with his trans-Atlantic solo flight.

"Unit Three: Developing Flight" focuses on the early days of the Army Air Corps through air power in World War II. It then goes on to the propeller and jet eras in commercial flight. The discussion of the modern Air Force includes US Air Force beginnings through the Korean War, the Vietnam War, and other military operations and global interventions from 1990. You'll read how brave Allied flyers helped liberate Europe and the Pacific region in World War II, about the birth of the independent US Air Force, and the role air power has played in US global interventions since then.

"Unit Four: Extending Flight" begins with astronomy and space, starting with the solar system and some early astronomers, then turning to rocketry and the space race. It goes on to discuss the space program and the future of air and space power. You'll read about the beginnings of the space program, the first men to reach the moon, the accomplishments and tragedies of the space shuttles, and possibilities of the future of air and space power.

This book is dedicated to everyone who enters the door into our AFJROTC program. We hope that as you go through this course, you will think about the possibilities that lie ahead and the great things that you can experience.

Linda Sackie

Acknowledgements

The subject matter in *Aerospace Science: A Journey Into Aviation History* was based on suggestions received from AFJROTC instructors around the world. The Air Force Officer Accession and Training Schools (AFOATS) Curriculum Division team involved in the production effort was under the direction of Dr. Charles Nath III, Director of Curriculum, at Maxwell Air Force Base, Alabama. His deputy, Major Chris Senkbeil and the Acting Chief of Junior ROTC Curriculum, Roger Ledbetter, completed an exceptional leadership team, resulting in a superb product for the AFJROTC program. Special thanks go to Curriculum's Linda Sackie, an instructional systems specialist and the primary editor, reviewer, and significant contributor for this project. We commend Linda's continued selfless dedication and outstanding efforts to produce the best academic materials possible for our units worldwide.

We are indebted to our academic consultants/reviewers who provided sustained leadership and guidance: Colonel John Gurtcheff (retired), AFJROTC Senior Aerospace Science Instructor at SC-873, Crestwood High School, Sumter, South Carolina, (and a former KC-135 pilot), and Dr. Nath. Special thanks go to Master Sergeant William Chivalette (retired), curator, Air Force Enlisted Heritage Hall, Gunter Annex in Montgomery, Alabama, for his invaluable historical expertise and insight, and to the Airman Memorial Museum in Suitland, Maryland, for their support of this project.

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We would like to express our gratitude to the Pearson Custom Publishing team for all its hard work in publishing this new book. That team consisted of subcontractors at High Stakes Writing, LLC—Lawrence J. Goodrich, W. Dees Stallings, John G. Birdsong, Katherine Dillin, Linda Harteker, and Ruth Walker; from Perspectives, Inc.—Philip G. Graham, Emily G. Haney, and Suzanne M. Perry; Mia Saunders (graphic design and page layout); Paul Lester (McREL standards); and numerous Pearson Custom Publishing personnel, including Christopher Will, Ed Perlmutter, Rich Gomes, Susan Kahn, Liz Faerm, Jennifer Sczerbinski, Sarah Dowden, Christopher O'Brien, and David Gehan.

Through the efforts of all the different team members identified, we believe this course continues our tradition of sustaining a "world-class" academic program.

UNIT ONE

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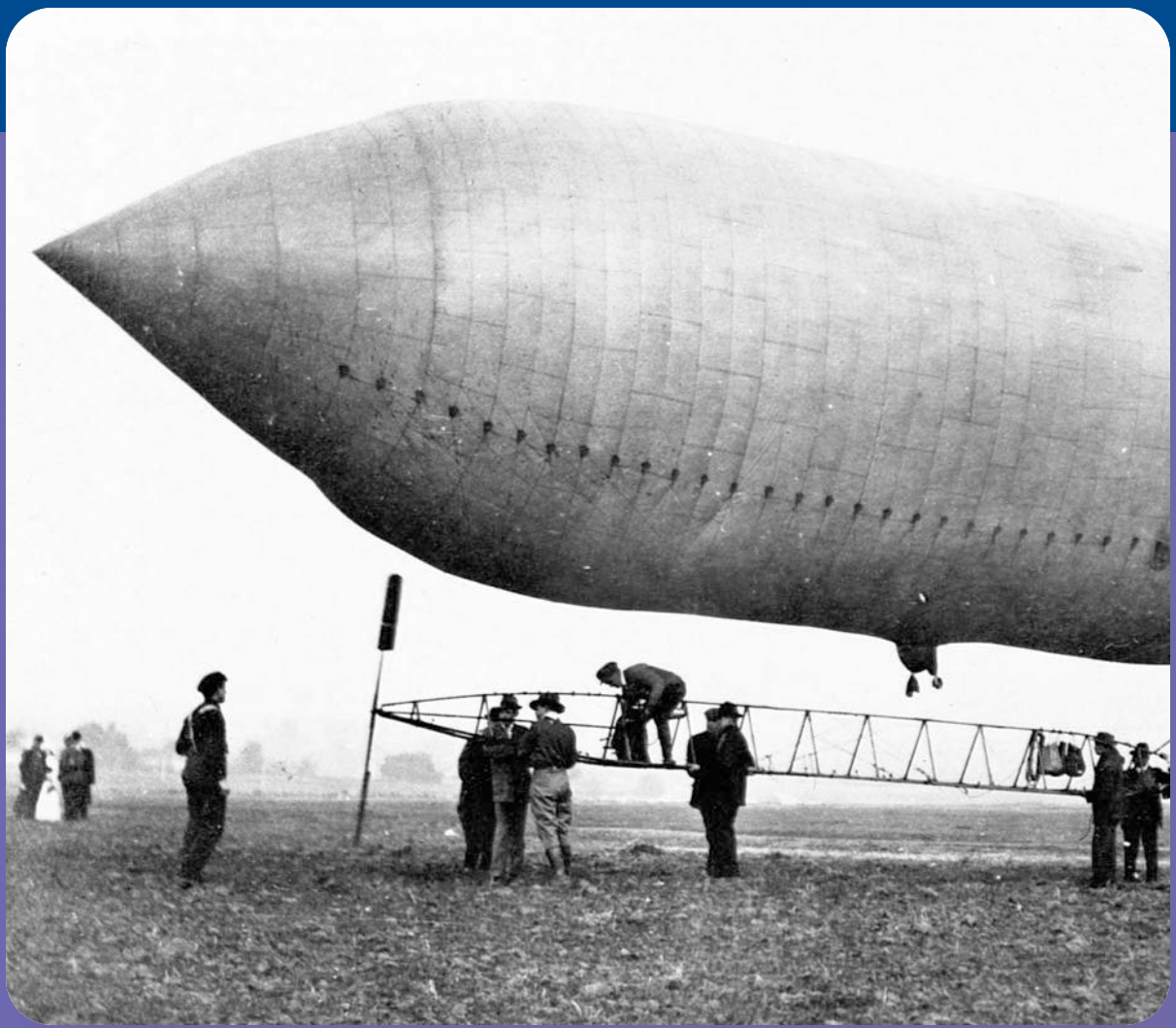


An early German Zeppelin

Courtesy of Corbis Images

inning FLIGHT

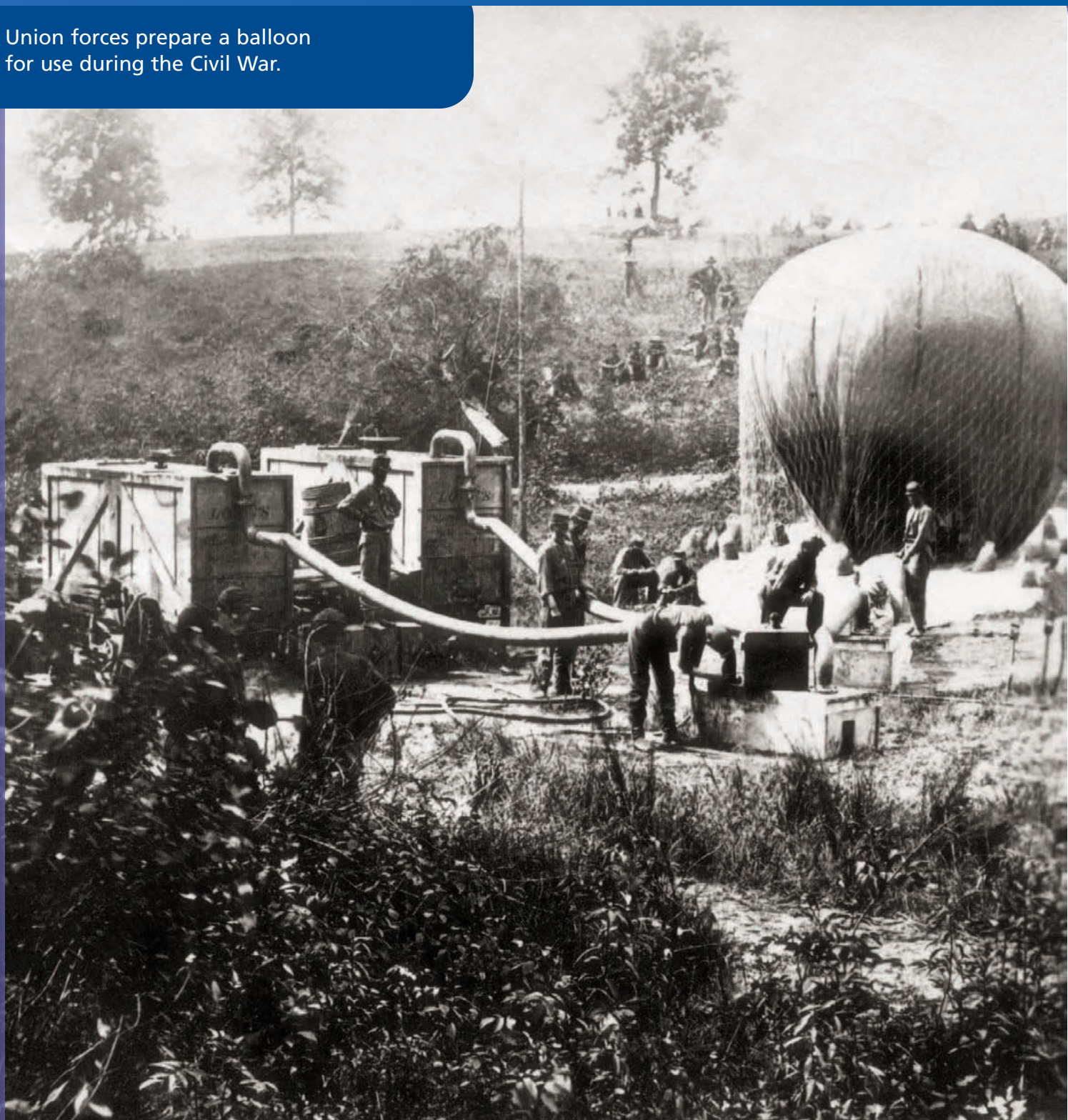
Unit Chapter

CHAPTER 1

Ancient Flight

CHAPTER 1

Union forces prepare a balloon for use during the Civil War.



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Ancient Flight

Chapter Outline

LESSON 1

Discovering Flight

LESSON 2

The Early Days of Flight

"The way in which we experience the irregularities of the wind while gliding through the air cannot be learned in any other way except by being in the air itself. . . ."

OTTO LILIENTHAL,
"The Father of Modern Aviation"

LESSON 1

Discovering Flight

Quick Write

Why do you think the idea of flight is so appealing to people? Does it appeal to you? Why?

Learn About...

- **how humans tried to fly in ancient times**
- **key aviation devices created during ancient times**
- **why machines do not fly the way birds do**

A stiff, 27-mile-an-hour wind roared across the dunes at Kill Devil Hills, North Carolina. Wilbur Wright reached out to steady the wing of his experimental flying machine. His brother, Orville, lay at the controls. For years the brothers had worked for this moment—both in their bicycle shop in Dayton, Ohio, and on these same coastal dunes. They'd tested kites. They'd tested gliders. They'd even built a small wind tunnel and learned how to control their craft in the air.

Now, on 17 December 1903, they were ready to find out: Would their heavier-than-air craft leave the ground and fly on its own?

Orville gunned the engine, and Wilbur let go of a wire that held the plane in place. The *Wright Flyer* rolled down a set of tracks on a trolley, with Wilbur's hand still steadying the wing. Suddenly, it happened: The *Flyer* lifted into the air, dropped the trolley, and flew for 12 seconds. Under Orville's control, it landed 120 feet away from the track's end. The Wright brothers had achieved a milestone: the first controlled, sustained, and powered heavier-than-air flight.

That flight and the three that followed on that raw December day changed the course of human history. After thousands of years of dreaming and trying, humans had mastered flight. But the Wrights' achievement was only the final step in centuries of attempts to learn how to fly. The brothers from Dayton built on the work of hundreds of others before them.

How Humans Tried to Fly in Ancient Times

Vocabulary

- **flight**
- **parachute**
- **kite**
- **gunpowder**
- **rocket**
- **legend**
- **helicopter**
- **streamlining**
- **glider**
- **ornithopter**

Humans have dreamed of taking flight—of escaping gravity to fly "free as a bird"—for thousands of years. People told tales about flight—*the act of passing through the air on wings*—around the fire at night. Parents in early societies handed down these stories to their children.

One of the best known is the Greek story of Daedalus and his son, Icarus, who were imprisoned by King Minos on the island of Crete. To escape, they made wings from bird feathers and attached them to their bodies with beeswax. The wings did carry them off the island. But Icarus enjoyed his new freedom so much that he ignored his father's warning and flew too close to the sun. Its heat melted the wax. Icarus fell into the sea and drowned.

The story of Icarus and Daedalus is a myth. It isn't a true story. But people still tell it today because of what it says about the human quest for freedom—and about sons who disobey their fathers. The story, however, doesn't say much about how to build a good flying machine.

The first true stories of human attempts to fly, though, included things that today seem almost as strange as stick-on wings. Some of these early inventors made devices of lightweight material such as cloth or wood, in imitation of birds' or bats' wings. They strapped the devices onto their arms or legs, or both. Then they would jump from the top of a tower or tall building, hoping to glide or flap their way gently to earth.

Unfortunately, none of the devices succeeded. At best, they slowed their wearers' plunge to earth. These early inventors all made hard landings, resulting in serious injury or death.

History credits a Moor named Armen Firman with the first known human attempt to fly. In the year AD 852, he put on a huge cloak and jumped from a tower in Cordoba, Spain. He hoped the cloak would open wide like a bat's wings to slow him on the way down. But it didn't, and Firman fell to his death. His unfortunate experiment might be described as an early attempt at a jump by parachute—*a device intended to slow free fall from an aircraft or another high point.*

Key Aviation Devices Created During Ancient Times

Chinese Kites

A lot of ancient scientific progress took place in China. The Chinese invented the kite around 1000 BC. A kite *is a light framework covered with paper or cloth, provided with a balancing tail, designed to be flown in the air.* A kite may seem very different from an airplane, but kites were actually among the first man-made devices to take

Skynotes

Using Kites to Spot the Enemy

In 200 BC, a Chinese general named Han Hsin used kites to scout his enemy's position and movements by air. His soldiers attached long measuring ropes to the kites. They got the kites in the air and then let the wind carry them to a position over the enemy camp. By determining how much rope had been let out, the Chinese soldiers could figure how far away the enemy was. They wanted to tunnel under the enemy's walled fortress. The marks on the rope showed them how far they had to dig to reach the fortress.

flight. It's not clear that these early kites actually carried people at first. Evidence suggests, though, that they were quite large and strong. Within a few hundred years, people were using them in warfare.

Around AD 1300 the Italian explorer Marco Polo reportedly saw Chinese sailors attached to kites as "eyes in the sky," observing enemy actions during battle. In the seventeenth century, other Western observers reported seeing Chinese soldiers on kites serving as flying spies.

Chinese Gunpowder and Rockets

In the 800s AD, the Chinese made another important invention: gunpowder—*an explosive powder made of potassium nitrate, charcoal, and sulfur, used to shoot projectiles from guns*. And just 200 years later, the Chinese were using gunpowder to make the first simple rockets. A rocket *is a large, cylindrical object that moves very fast by forcing burning gases out one end of the tube*.

The Chinese used these devices mostly for celebrations, such as holiday fireworks. But they also used their rockets in battle to scare off the enemy.

There's even a Chinese legend, or *unverified story handed down from earlier times,* about a rocket trip into space. This legend says that a man named Wan Hoo fastened 47 rockets to a chair. He hoped his invention would take him to the moon. Not surprisingly, it didn't work. He went up in a ball of fire, and, the legend suggests, perhaps became the Man in the Moon.

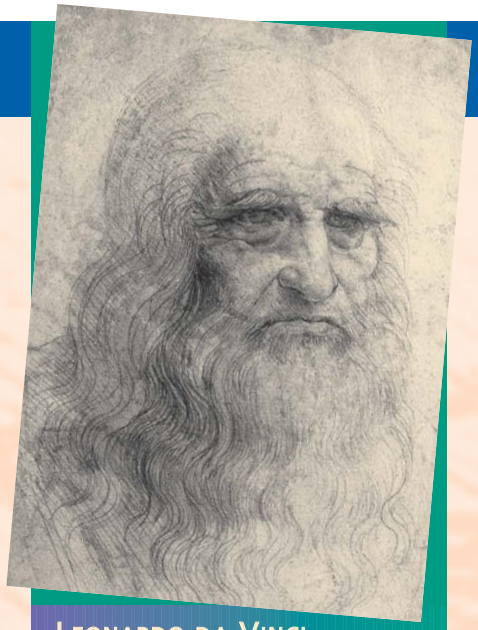
It's obvious that this is just a story. But in a way, the legend foretold history. When the *Apollo* astronauts traveled to the moon in the 1960s and 1970s, they were strapped into special chairs in their spacecraft and then lifted away from Earth by rockets.

A Parachute and a Helicopter

The first person in the history of aviation who was also a real scientist was Leonardo da Vinci (1452–1519). Da Vinci produced the first known designs for a parachute and a helicopter, *an aircraft that gets its lift from spinning blades*. He apparently made models of both and may even have flown one of his helicopters.

Da Vinci's drawing of an "airscrew" looks a lot like a modern helicopter. And in fact, both devices are based on the same principle: a flat screw that, when turned, produces lift. What's more, today's parachutes are based on principles first described by Da Vinci. His invention, he wrote, would allow someone to "throw himself down from any height without sustaining any injury."

Flight Paths



LEONARDO DA VINCI

Courtesy of the Library of Congress

Leonardo da Vinci

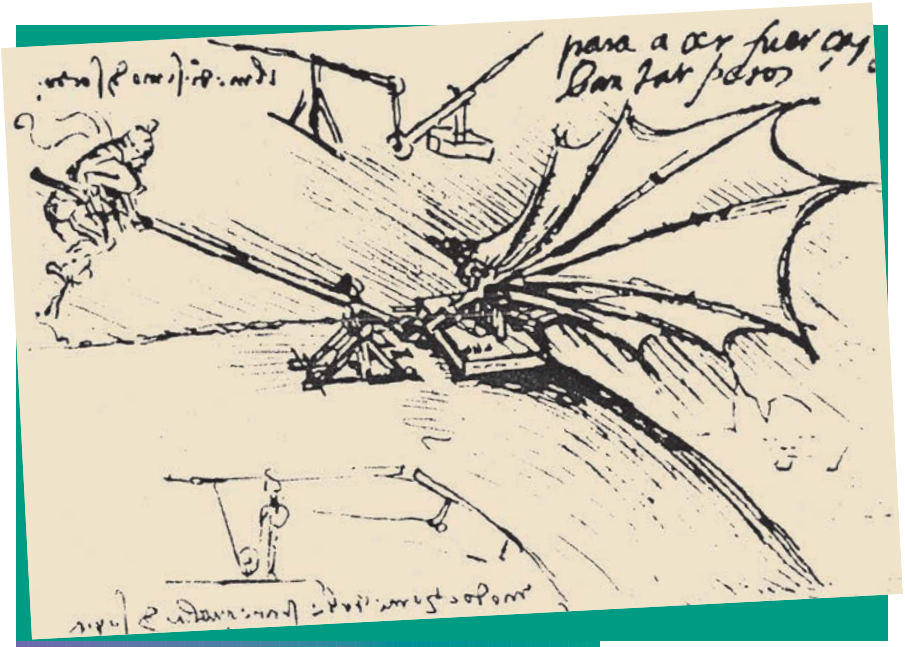
Have you heard the term "Renaissance man?" It refers to someone who has many talents. Leonardo da Vinci was such a man. He's best known today as an artist—for example, he painted the *Mona Lisa*. But he was a scientist, too. He conducted the first scientific experiments in aviation.

Like other scientists, Da Vinci observed the world closely. Also like other scientists, he kept good records. He filled the pages of his notebooks with detailed drawings of things he had actually seen, as well as things he thought up. The notebooks included 160 pages of drawings of his projects for flight. The notebooks show that Da Vinci understood several key concepts in aviation, such as streamlining, *which is designing an aircraft to reduce resistance to motion through the air.*

His orderly way of working did a lot for science. But it could have done much more. Tragically, his notes were lost for about 300 years following his death. He left his drawings and papers in the care of a friend, who never published them. Scientists today wonder how much sooner human flight would have developed had Da Vinci's work been available during those "lost" years.

DA VINCI'S "AIRSCREW" HELICOPTER

Courtesy of Clipart.com



Da Vinci's Ornithopter

Courtesy of The Granger Collection, New York

Gliders

Da Vinci also researched the idea of a glider, *a light aircraft without an engine, designed to glide after being towed aloft or launched from a catapult.* Gliders were the first aircraft that had directional control.

Da Vinci was fascinated with birds, and he experimented with flapping-wing machines. He worked out structures and mechanisms intended to mimic the motions of a bird. These included some designs for ornithopters. An ornithopter *is an aircraft designed to get its support and forward motion from flapping wings.* (*Orni-* comes from a Greek word for bird.)

Da Vinci was a careful observer. But even he didn't understand how complex the movements of a bird's wing are. He also didn't realize that human muscle power could never be powerful enough to keep a person in the air. That realization didn't come until about 150 years after Da Vinci's death. At that time, the Italian biologist Giovanni Alfonso Borelli (1608–1679) concluded that a man's muscle power just wasn't great enough to lift his weight.

You may think of birds as "lightweights," and in many ways, they are. But it's relative proportions that matter. Birds are very powerful for their size. Their large wing muscles and hollow bones make them well suited to flight. Unfortunately, when it comes to being able to fly on their own muscle power, humans have more in common with elephants than with birds!

Why Machines Do Not Fly the Way Birds Do

The Principles of Bird Flight

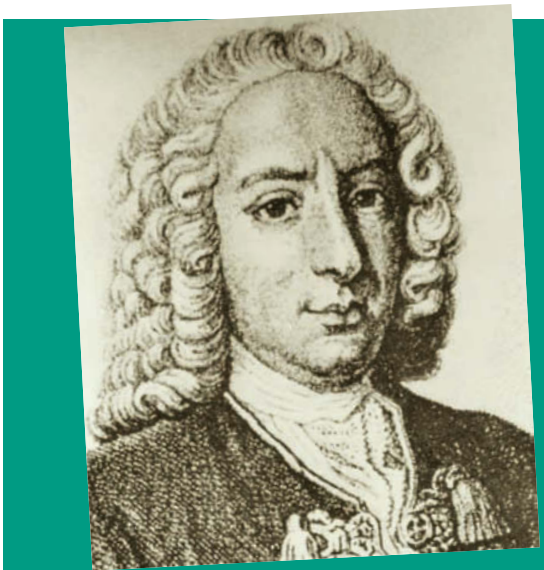
A bird's flight is similar to an airplane's in some ways and different in others. Here's how Dr. Paul Fortin, author of *The Fantasy and Mechanics of Flight*, explains it:

> There are two phases of bird flight—a ground phase and a lift phase. The ground phase allows the bird to get started moving forward in order for the wings to provide the necessary lift. To be lifted by its wings, a bird . . . must be moving forward fast enough to make air pass over its wings. A bird can move forward by flapping its wings. Most of the flapping is done by the outer wing. The flight feathers work like the propeller of a plane: i.e., they push downward and backward, thereby driving the air backward and moving the bird forward. Once the bird's speed is adequate, lift over the wing is generated by the same principle as the flow of air over the wing of an airplane.

Dr. Fortin adds:

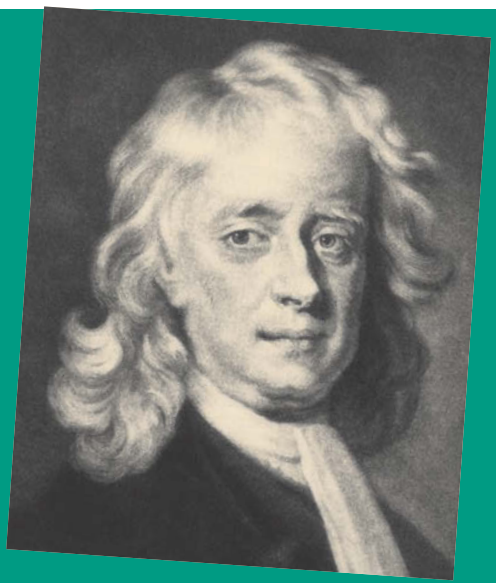
> Slow-motion pictures of birds in flight show that the wings move downward rapidly. The wing tips trace a figure eight as they move though the air. The downward beat of the wings moves the bird forward as the outer tips push against the air. Wing feathers are arranged much like shingles on a roof. They change position when the bird is flapping. On the downbeat of the wing, the feathers are pressed together so little air can pass through them. On the up stroke the feathers open.

Bird flight and the flight of human-made aircraft rely on two kinds of lift, each named for a famous scientist who never flew, but who made significant contributions to aeronautical science: Daniel Bernoulli and Isaac Newton.



DANIEL BERNOULLI

Courtesy of Photo Researchers, Inc.



SIR ISAAC NEWTON

Courtesy of Photo Researchers, Inc.

The Dutch-born scientist Daniel Bernoulli (1700–1782) made an important discovery about the relationship between pressure and fluids (liquids or gases) in motion. A fluid has a constant pressure, he found, but when a fluid starts to move faster, the pressure drops. Wings are designed to make air flow faster over their tops. This makes the pressure drop and the wings move upward, defying the force of gravity. This phenomenon is known as *Bernoullian lift* or *induced lift*.

Sir Isaac Newton, an Englishman who lived from 1643 to 1727, formulated three famous laws of motion. The third law states, "For every action, there is an equal and opposite reaction." This principle comes into play when an airplane is ascending, or flying higher. When a pilot angles the wing of the plane up against the oncoming wind, the action of the wind causes a reaction by the wing. This reaction provides some additional lift, known as *Newtonian* or *dynamic lift*. So with Bernoullian lift pulling from above and Newtonian lift pushing from below, a wing has no choice. It can only go up—whether it's attached to a bird or to an airplane.

By now you're beginning to understand that birds and airplanes don't work exactly alike. Here's another difference: Airplanes are fixed-wing aircraft. They don't flap their wings as birds do. Instead, airplanes rely on their propellers or jet engines to get them off the ground.

Timeline of Aviation History

1000 BC:	**Chinese invent the kite.**
200 BC:	**Chinese General Han Hsin uses kites for military surveillance.**
In the AD 800s:	**Chinese invent gunpowder.**
AD 852:	**In an unsuccessful attempt to fly, Armen Firman dons a huge cloak and jumps from a tower in Cordoba, Spain.**
AD 1100:	**Chinese start using gunpowder to make simple rockets.**
AD 1300:	**Explorer Marco Polo reportedly sees Chinese sailors flying on kites as "eyes in the sky," observing enemy actions during battle.**
1452–1519:	**Life span of Leonardo da Vinci, who pioneered the scientific study of aviation.**
1643–1727:	**Life span of Isaac Newton, who formulated three laws of motion.**
1700–1782:	**Life span of Daniel Bernoulli, who discovered the phenomenon of induced lift.**
17 December 1903:	**Wilbur and Orville Wright make the first controlled, sustained, and powered heavier-than-air flight.**

Why Ancient Inventors Tried to Mimic Bird Flight

At the beginning of aviation history, flapping wings seemed to be what flight was all about. People observed birds, bats, and insects flying this way. As you've now learned, some early inventors thought feathers might possess some lifting power of their own. And even a thinker as brilliant as Da Vinci got stuck on birds as the model for human flight. Some scientists think that if Da Vinci had focused on fixed-wing gliders, instead of ornithopters, he might have done even more for the progress of aviation than he actually did. Only when people stopped trying to fly as birds do did the way open for the Wright brothers' success on the North Carolina dunes.

CHECKPOINTS

Lesson 1 Review

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

1. What milestone did the Wright brothers reach in December 1903?
2. Who were Daedalus and Icarus?
3. Who was Armen Firman, and what was his role in aviation history?
4. What were some early military uses of kites?
5. Who made the first rockets? What were they first used for?
6. What kinds of flight devices did Leonardo da Vinci explore?
7. What are the two phases of bird flight?

Applying Your Learning

8. Flying squirrels don't have wings, but they do have flaps of skin between the legs on each side of their body. These flaps allow them to "fly" from tree to tree or from a tree to the ground. To which flying device would you compare a flying squirrel and why?

LESSON 2

The Early Days of Flight

Quick Write

How could the information the US Army balloonists gathered change the course of the Battle of San Juan Hill? What lesson can you draw from the fact that the Americans could view the battlefield and the Spanish could not?

Learn About...

- developments in lighter-than-air flight from Da Vinci to the Wright brothers
- ways balloons were used during the US Civil War
- ways the balloon contributed to US victory in the Battle of San Juan Hill during the Spanish-American War
- developments in heavier-than-air flight from Da Vinci to the Wright brothers

It had been a tough trip for Lt Col 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 Lt Col 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—Sgt 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, Lt Col 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 not before 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.

Vocabulary

- **lift**
- **aerial reconnaissance**
- **dirigible**
- **rudder**
- **keel**
- **internal-combustion engine**
- **aeronaut**
- **drag**
- **thrust**
- **biplane**
- **patent**
- **monoplane**

Cuba and the US Gulf Coast

Courtesy of Maps.com

The US Army balloon During the Battle of San Juan Hill

Courtesy of the National Archives

CAPSULES

Teddy Roosevelt's Rough Riders

The Rough Riders were a volunteer Army regiment. Theodore Roosevelt organized them to help Cuba win independence from Spain. He didn't have any military experience, so he asked a friend who did to be in charge. With the friend's help, Roosevelt, who would later become the 26th President of the United States, rounded up a group of 1,250 cowboys and Indians, as well as Ivy League athletes and sportsmen, to fight for a free Cuba.

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.

Developments in Lighter-than-Air Flight From Da Vinci to the Wright Brothers

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.

Skynotes

What do printing presses have to do with flying machines? Quite a bit. During the early years of aviation, the cost of printing fell sharply. Books and papers became cheaper. More people could afford to buy them. For the first time, scientists throughout Europe could read about one another's work. The printing presses were a big help in making the dream of flight come true.

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.

Flight Paths

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 MONTGOLFIER BROTHERS' BALLOON

Courtesy of John Lienhard

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. They'd simply observed a principle of physics: Hotter air rises above cooler air.

The Montgolfiers' experiments attracted attention. French King Louis XVI and his 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.

While the Montgolfiers were testing their balloons, the young 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.*

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 1793 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. 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 movable flap or blade attached to the rear of a craft*. 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.

CAPSULES

Steam Engines

Steam engines were the main source of mechanical power in the 19th century—before the invention of the gasoline-powered internal-combustion engine and the electric motor. Water heated by fire (usually fueled by wood or coal) was used to create steam. The steam's force drove a piston or turbine blade that turned a wheel or—as in the case of the Giffard dirigible—a propeller. The discoverer of steam power, James Watt, coined the term *horsepower* as a measurement of mechanical power. One horsepower is 33,000 foot-pounds of work in one minute.

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.

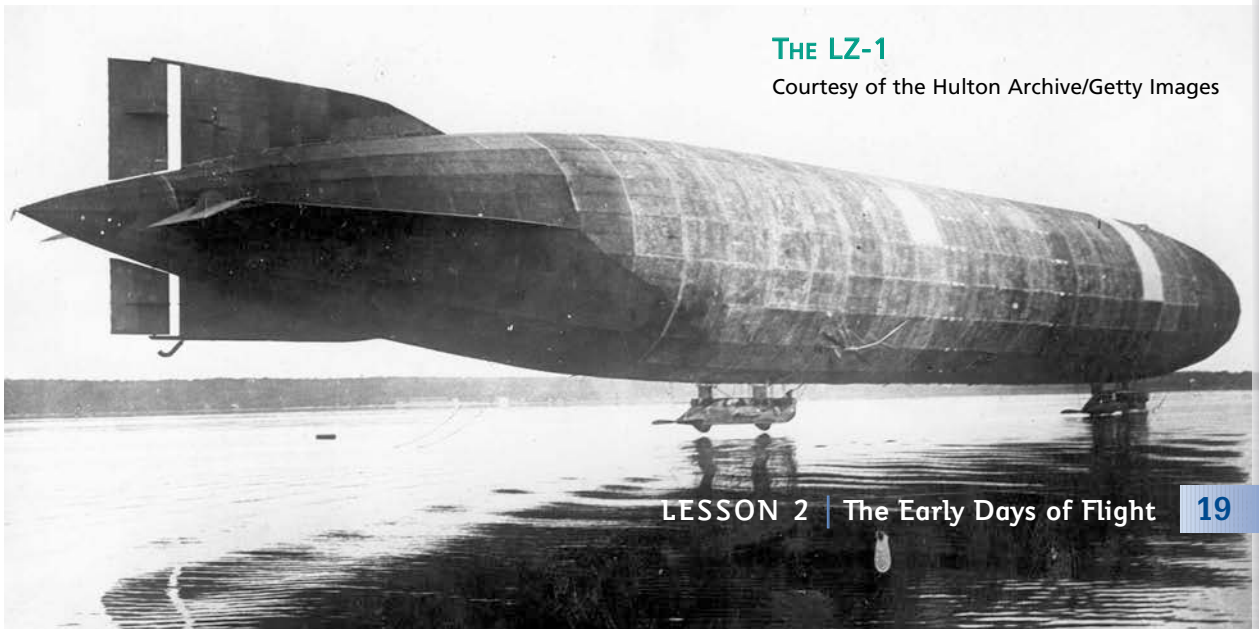
Santos-Dumont, a Brazilian, became famous in 1901. In that year, he flew an airship around the Eiffel Tower. He completed a nine-mile loop in less than half an hour. This won him a big cash prize from a rich oilman named Henri Deutsch. Santos-Dumont gave the money to his own workers and to the poor of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



The LZ-1
Courtesy of the Hulton Archive/Getty Images

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.

Ways Balloons Were Used During 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.

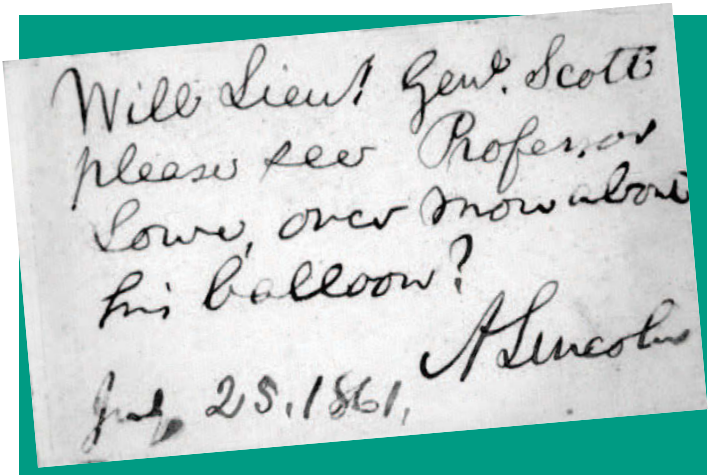
One of these aeronauts was Thaddeus Lowe. He tried to interest Gen Winfield Scott, head of the Union Army, in balloons. But Scott saw no military need for them.

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.



LINCOLN'S NOTE TO GENERAL SCOTT

The Confederates 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.

Ways the Balloon Contributed 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. Brig Gen 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, Lt Col 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.

Developments in Heavier-than-Air Flight From Da Vinci to the Wright Brothers

While balloons and dirigibles were enjoying success, other aviators were making progress with heavier-than-air craft.

Gliders

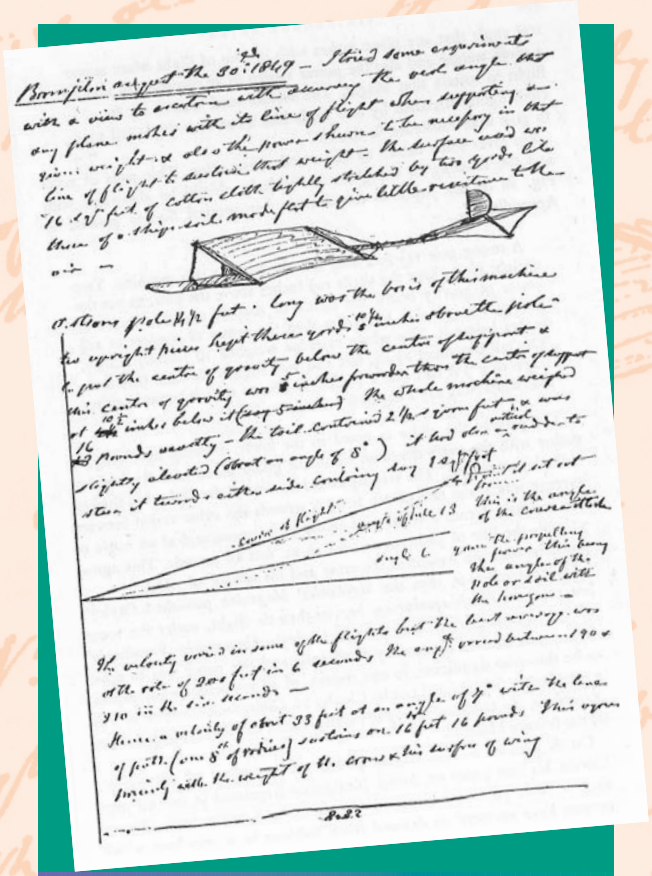
Sir George Cayley (1773–1857) picked up where Leonardo da Vinci left off in developing gliders. This Englishman's gliders resembled today's model gliders. They had the same design as most of today's airplanes, with wings up front and a tail behind.

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.

Flight Paths



Sir George Cayley's Glider

Courtesy of The Granger Collection, New York

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 John J. Montgomery, an American. 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. Sadly, on 18 April 1906, Montgomery's gliders were destroyed in the San Francisco earthquake. He eventually started flying again. But on 31 October 1911, he was killed in a glider accident.

Otto Lilienthal of Germany was another famous aviator. In fact, he's often called the "Father of Modern Aviation." Between 1891 and 1896 he made more than 2,000 glides. He developed a powered biplane, *an aircraft with two main supporting surfaces, usually placed one above the other.* On the eve of the test flight, 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 killed in the fall. But subsequent aviators, including the Wright brothers, made use of his data and experiments.

OTTO LILIENTHAL'S GLIDER

Courtesy of Getty Images

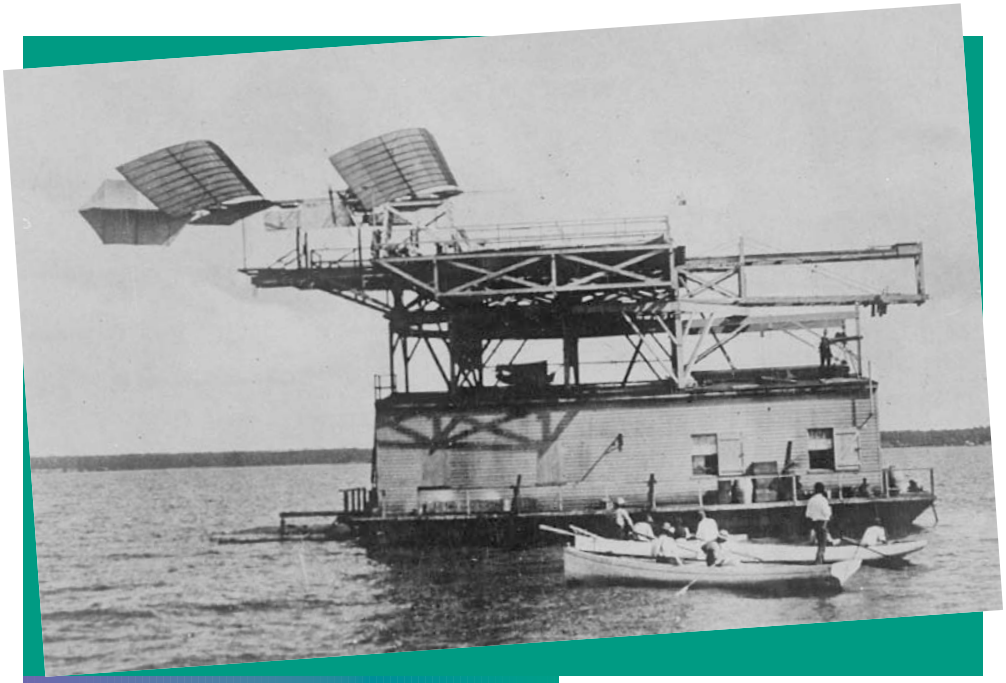
Failed Attempts to Construct an Airplane

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.

JOHN STRINGFELLOW'S FLYING MODEL, 1848

Courtesy of Science Museum/
Science and Society Picture Library



SAMUEL LANGLEY'S AERODROME

Langley's Aerodrome prepares to take off from its launch track, but plunges instantly into the Potomac.

Courtesy of Time Life Pictures/Mansell/Time Life Pictures/Getty Images

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, Bernouillian 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.

CHECKPOINTS

Lesson 2 Review

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

1. What are the two basic types of aircraft?
2. What are the three problems of flight?
3. What is the principle behind a balloon?
4. What did printing presses have to do with the development of flying machines?
5. What kind of engine helped make dirigibles a success?
6. How did a balloon help the US Army win the Battle of San Juan Hill in Cuba?
7. What three important concepts did Sir George Cayley understand?
8. What do historians fault Samuel Langley for?

Applying Your Learning

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