Science

Pioneers of Spaceflight

GRADES 9-12
Two Class Lesson Plan

STEP 1 LEARN (First class session: 20-25 minutes)

Objectives

- Students will be able to identify the pioneers of spaceflight and their contributions to science and technology.
- Students will experience what it is like to be a pioneer of spaceflight while building and launching an Estes model rocket.

Materials

1. Generic E2X®, Alpha III® or UP Aerospace™ SpaceLoft ™ Rocket Lab Pack™ (12 pack) - 2 or more
2. Rocket Engine Lab Pack™ (24 pack) - 1 or more
3. Electron Beam® Launch Controller - 1 or more
4. Porta-Pad® II Launch Pad - 1 or more
5. Paper, pencil, white or carpenter's glue or plastic cement, scissors, modeling knife, ruler and masking tape for each student
6. History of Rockets PowerPoint

Time

Two class sessions

Background

History of Rockets (Slide 1)

Where It All Began

(Slide 2) The origins of modern rocketry can be traced back to Greece and China. One of the first devices to utilize the principles of rocket flight was a wooden bird. Aulus Gellius, a Roman, told the story of a Greek named Archytas from Tarentum, an area that is now part of southern Italy. Around 400 B.C., Archytas entertained the townspeople by flying a wooden pigeon. The bird was suspended on wires and was propelled by escaping steam (action-reaction principle).

NATIONAL STANDARD

Standard G
History and Nature of Science

Standard 13
Understands the scientific enterprise

Benchmark 1
Knows that, throughout history, diverse cultures have developed scientific ideas and solved human problems through technology.

Benchmark 2
Understands that individuals and teams contribute to science and engineering at different levels of complexity.

Around three hundred years after the pigeon, another Greek, Hero of Alexandria, built a similar rocket-like object called an aeolipile which used steam for propulsion. After attaching a sphere on top of a water kettle, a fire was built below the kettle to heat the water and turn it into steam. The steam would travel through pipes to the sphere and pass through two L-shaped tubes on either side of the sphere causing it to turn around. Today, we call this a Hero Engine.

(Slide 3) The historical records of various cultures show that rocket-like devices appeared from time to time. It is unclear when the first real rockets were developed and, in fact, the first true rockets might have been accidents. In the first century A.D., the Chinese often used a simple form of gunpowder for religious and other festive celebrations. They filled bamboo tubes with the gunpowder mixture and tossed them into fires to create explosions. Some of the tubes didn't explode and jumped out of the fires. They were pushed by the sparks and gases produced from the burning gunpowder. The Chinese started experimenting with the gunpowder-filled tubes and eventually attached these bamboo tubes to arrows and launched them with their bows. Later they found out that these tubes could launch themselves by the power created from the escaping gas. The modern rockets' ancestor was born.

In 1232, the Chinese began using their rockets in a war against the Mongols. In the battle of Kai-Keng, they drove back the Mongols with a barrage of arrows of flying fire. The fire-arrows were a simple form of a solid-propellant rocket. The rocket was a tube that was attached to a long stick and was capped at one end and filled with gunpowder, leaving the opposite end open. The powder was ignited and the quickly burning powder produced fire, smoke and gas that escaped out of the open end producing thrust. The stick became a simple guidance system that provided stability for and kept it going in one direction in the air. While these fire arrows may have inflicted little physical damage, they had to have imposed much psychological damage on the Mongols.

(Slide 4) After the battle of Kai-Keng, the Mongols made rockets of their own and might have been the people responsible for spreading rockets to Europe. There are many records that describe rocket experiments from the 13th to the 15th centuries. During this period in England, Roger Bacon, a monk, worked on improved forms of gunpowder that increased the range of rockets. In France, Jean Froissart launched rockets through tubes to increase the accuracy of the flights. Froissart's design was the forerunner of the modern bazooka. In Italy, Joanes de Fontana used a surface-running, rocket-powered torpedo to set enemy ships on fire.

In the 16th century, rockets weren't commonly used as weapons of war because of their inaccuracy. Instead, rockets were used for fireworks displays. A German fireworks innovator, Johann Schmidlap, designed the step rocket. The step rocket was a multi-staged rocket that propelled rockets to higher altitudes. A large sky rocket (first stage) carried a smaller sky rocket (second stage). When the larger rocket burned out, the smaller one continued to a higher altitude before it showered the sky with glowing cinders. This idea is basic to all rockets today that go into outer space.

(Slide 5) Up to this time, rockets were used for fireworks or warfare. An old Chinese legend shows that rockets were used for transportation. According to this legend, a lesser-known Chinese official named Wan-Hu and his assistants made a rocket-powered flying chair by attaching two large kites and 47 fire-arrow rockets. On flight day, Wan-Hu sat in the chair and signaled 47 assistants to light the rockets. All the assistants, each with a torch, rushed forward to light the fuses at once. A loud roar and huge billowing clouds of smoke filled the air. When the smoked cleared, Wan-Hu and his chair were nowhere to be found. No one knows for sure what happened to Wan-Hu. If this really happened, Wan-Hu and his chair probably didn't survive the explosion.

The Science of Rocketry

(Slide 6) The foundations for modern rocketry were established in the late 17th century by the English scientist Sir Isaac Newton (1642-1727). He organized physical motion into three scientific laws (Newton's Laws of Motion). These laws explain how rockets work both in Earth's atmosphere and in the vacuum of outer space.

Newton's laws soon began to influence many rocket designs. In 1720 a Dutch professor, William Gravesande, built model cars propelled by jets of steam. Rocket experimenters in Russia and Germany worked with rockets with a mass of more than 45 kilograms. Some of these rockets were so powerful that the escaping gases from them left deep holes in the ground even before liftoff.

Congreve Rockets

(Slide 7) Rockets experienced a short revival as weapons of war in the late 18th century and early 19th century. Indian rocket barrages against the British in 1792 and 1799 were so successful that an artillery expert, Colonel William Congreve, began designing rockets for the British military to use. The Congreve rockets were very successful in battle. These rockets were fired from British ships to pound Fort McHenry in the war of 1812. **(Slide 8)** This inspired Francis Scott Key to include "the rockets' red glare" in his poem that later became *The Star-Spangled Banner.*

Even with the Congreve rockets, rockets were not very accurate. Many researchers around the world worked on improving accuracy. In England, William Hale developed a technique called spin stabilization. The escaping exhaust gases struck small vanes at the bottom of the rocket, causing it to spin like a bullet does in flight. Many rockets still use variations of this method today.

Pioneers of Modern Rocketry

Konstantin Tsiolkovsky

(Slide 9) In 1898, Konstantin Tsiolkovsky (1857-1935), a Russian teacher, proposed space exploration by using rockets. In 1903, Tsiolkovsky suggested the use of liquid propellants to help rockets have a greater range. He stated that only the exhaust velocity of escaping gases limited the speed and range of a rocket. Because of his research and ideas, Tsiolkovksy has been called the Father of Modern Astronautics.

Robert H. Goddard

(Slide 10) In the early 20th century, Robert H. Goddard (1882-1945), an American from Worcester, MA conducted experiments in rocketry. He was interested in ways of achieving higher altitudes. He published a pamphlet in 1919 called *A Method of Reaching Extreme Altitudes*. Today we call this mathematical analysis the meteorological sounding rocket. In his booklet, Goddard made several conclusions important to rocketry. One is that a rocket operates with greater efficiency in a vacuum than in air. He also said that multi-stage rockets were the best way to achieve high altitudes and that the velocity needed to escape Earth's gravity could be achieved in this way.

Goddard's first experiments were with solid-propellant rockets. He began to try various types of solid fuels and to measure the exhaust velocities of the burning gases in 1915. While working on solid-propellants, he concluded that a rocket could be propelled better by liquid fuel. Until this time, no one had built a successful liquid-propellant rocket. It was much harder to build liquid-propellant rockets because fuel and oxygen tanks, turbines and combustion chambers are needed. On March 16, 1926, Goddard conducted the first successful liquid-propellant rocket flight. It was fueled by liquid oxygen and gasoline. The rocket flew for only 2.5 seconds, climbed 12.5 meters and landed 56 meters away in a cabbage patch. Not too impressive, but this rocket became the forerunner of a new era in rocket flight.

Robert Goddard experimented with liquid-propellant rockets for many years. His rockets grew bigger and flew higher. He built a gyroscope system for flight

control and a payload section for scientific instruments. He also had parachute recovery systems that returned his rockets and instruments safely to the ground. We call Robert Goddard the Father of Modern Rocketry because of all his achievements in rocketry.

Hermann Oberth

(Slide 11) Hermann Oberth (1894-1989) is another great space pioneer. In 1923, he published a book, *The Rocket Into Planetary Space*, about rocket travel into outer space. This book contained rocketry theories similar to those of Goddard. It included speculation on the effects of space flight on the human body. Oberth covered proven theories that a rocket could travel faster than its exhaust and could operate in a vacuum. He also speculated on the theory of putting satellites in space. His writings were important because they inspired the formation of many small rocket societies around the world. In Germany, the formation of one rocket society, the Verein fur Raumschiffahrt (Society for Space Travel) led to the development of the V-2 rocket. **(Slide 12)** The Germans used the V-2 against London during World War II. The V-2 is a result of German engineers and scientists, including Oberth, meeting in 1937 in Peenemunde on the shores of the Baltic Sea. Under the leadership of Wernher von Braun, the scientists and engineers built and launched the most advanced rocket of its time.

Modern Rocketry

Wernher von Braun

Compared to today's standards, the V-2 rocket (in Germany called the A-4) was small. It achieved its thrust by burning a mixture of liquid oxygen and alcohol at a rate of about one ton every seven seconds. When launched, the V-2 was an effective weapon that could devastate entire city blocks. Fortunately for the Allied Forces and London, this rocket came too late in the war to change the outcome. However, by the end of the war, German rocket scientists had plans for advanced missiles capable of spanning the Atlantic Ocean and landing in the United States. These missiles would have had a winged upper stage with small payload areas. When Germany fell, the Allies acquired many unused V-2 rockets and components. **(Slide 13)** Many German rocket scientists, including Wernher von Braun, came to the United States. Other German rocket scientists went to the Soviet Union. The German scientists were surprised with all the progress Robert Goddard had made with rocketry.

After World War II, the United States and the Soviet Union acknowledged the potential of rockets as military weapons and began experimental rocketry programs. The United States began working on a Goddard idea, high-altitude

atmospheric sounding rockets. The U.S. also developed a variety of medium-range and long-range intercontinental ballistic missiles. These missiles were the starting point of the U.S. space program. Missiles from the program (Redstone, Atlas, Titan) were used to launch astronauts into space.

On October 4, 1957, the Soviet Union surprised the world by launching an Earth-orbiting artificial satellite. This satellite, Sputnik I, was the first successful entry in the race for space between the two nations. It orbited the earth every 96 minutes 17 seconds. Less than a month after Sputnik I, the Soviets launched a satellite, Sputnik II, carrying a dog named Laika. Laika's real name was Kudryabka which means little curly. This mission was not designed to return to earth. Documents after the Cold War revealed Laika died when the life support system couldn't keep the temperature in her cabin below 40 degrees C. She survived in space for seven days.

On January 31, 1958, the United States launched Explorer I. In October 1958, the U.S. created the National Aeronautics and Space Administration (NASA). NASA became a civilian agency with the goal of peaceful exploration of space for the benefit of all humankind.

In 1960, von Braun was given the task of developing the giant Saturn rockets. He became the chief architect of the Saturn V launch vehicle that propelled American astronauts to the moon. He became one of the most prominent spokesmen of space exploration for the United States.

Rockets have launched many people and machines into space. Astronauts orbited the Earth and landed on the Moon. Robot spacecraft have traveled to other planets like Mars. Space opened up to exploration and commercial exploitation. Satellites helped scientists to learn more about our world, forecast the weather and communicate around the globe. Because there was such a demand for more and larger payloads, a large array of versatile and powerful rockets have been developed. Scientific exploration of space with robotic spacecraft continues at a fast pace.

KEY WORDS

aeolipile
diversity
guidance system
gyroscope
multi-staged
NASA
Newton's Laws of Motion
payload
propellant
propulsion
satellites
sphere
spin stabilization
vacuum
velocity

Interesting Fact

Each pioneer of spaceflight, Konstantin Tsiolkovsky, Hermann Oberth, Robert Goddard and Wernher von Braun, all trace their interest in space and rockets to author Jules Verne as their original inspiration.

Activity

1. Ask students to identify the pioneers of spaceflight.
2. Use the History of Rockets PowerPoint to explain the pioneers of spaceflight and the rockets they created.
3. During your PowerPoint review, students can take notes in an outline form.

STEP 2. BUILD (First class session: 35 - 40 minutes)

Activity

1. When students make and launch their rocket they will be able to experience how it felt to be a pioneer of spaceflight.
2. Build the Alpha III®, Generic E2X® or UP Aerospace™ SpaceLoft™ together with students, using step-by-step procedures. E2X® rocket kits contain parts that are colored and easy to assemble. Glue the parts together as per the instructions, apply the self-stick decals, attach the recovery system and you are ready to launch.

STEP 3. LAUNCH (Second class period)

Activity

1. Assign and post launch jobs for students. Launch jobs are in the *Estes Educator Guide for Teachers & Youth Group Leaders.*
2. Prepare rockets for launching in your classroom before going outside to launch. Follow the Engine Preparation steps located in the rocket instructions.
3. Launch rockets outside at a soccer field, football field, baseball field, green grass area or blacktop area.

Wrap Up - Touch Down & Recovery

1. Discuss with students the cultural diversity of the early pioneers of space-flight emphasizing the various areas of the world and how they used the early rockets.

2. Students will write a summary of the people who are considered the pioneers of spaceflight, their rockets and how their discoveries contributed to spaceflight today. Students should also consider how the events (choices) in a person's life have lead them to their individual accomplishments. They should conclude their summary by reflecting on the rocket building process and their rocket launch.

Extensions

1. Students can work in groups to research one of the pioneers - Tsiolkovsky, Oberth, Goddard, Verne or von Braun. Based on their research, they will write and present to the class a skit about a significant spaceflight accomplishment in their life.
2. Hermann Oberth and Wernher von Braun both supported the NAZI war machine and did employ concentration camp slaves at places like Peenemunde. It is said that Von Braun surrendered to the allies for selfish reasons, not out of pure scientific altruism. Students will do a web quest or library research to find out the truth about their ties with the NAZIs, why and what they did in the U.S.

Evaluation/Assessment

- Students will take notes in outline form of the History of Rockets PowerPoint presentation.
- Students will write a summary about the pioneers of spaceflight and how their discoveries contributed to spaceflight.
- Students will assemble and launch a model rocket.

References

- *Estes Educator™ - Guide for Teachers and Youth Group Leaders*
- Estes Educator™ Website – www.esteseducator.com
- Civil Air Patrol – *Model Rocketry Book*
- NASA – *Rockets-A Teacher's Guide with Activities in Science, Mathematics, and Technology*