LESSON 2

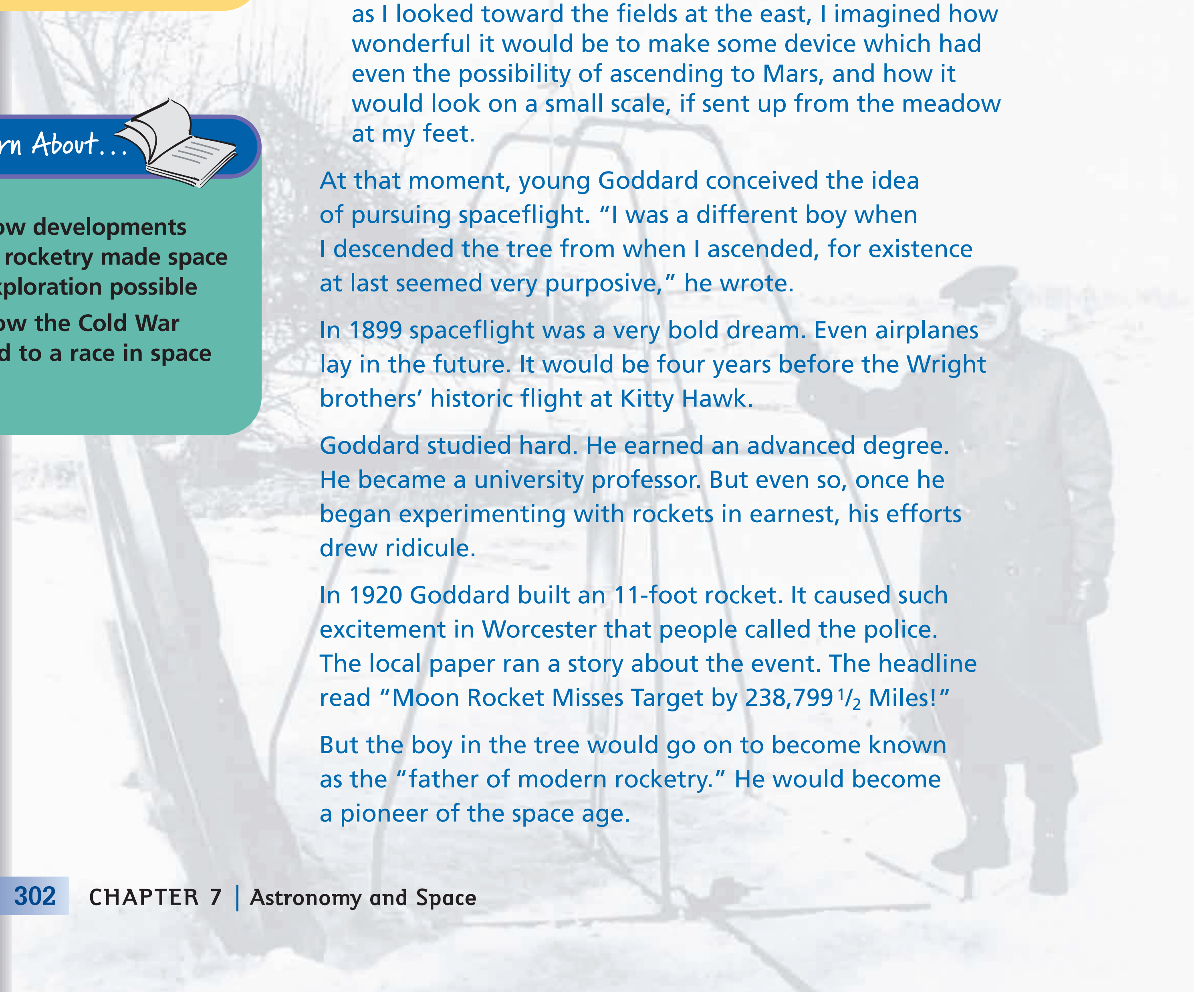
Rocketry and the Space Race

Quick Write

What did Robert Goddard do to pursue his dream of spaceflight?

Learn About...

- how developments in rocketry made space exploration possible
- how the Cold War led to a race in space



On 19 October 1899 Robert H. Goddard, 17 years old, climbed into a cherry tree in the backyard of his home in Worcester, Mass. He'd been asked to prune off its dead limbs.

Using a saw and hatchet, he started to work. But not for long. Perched in the tree, he began to daydream—and not for the first time.

Here's what he later wrote about the experience:

> It was one of the quiet, colorful afternoons of sheer beauty which we have in October in New England, and as I looked toward the fields at the east, I imagined how wonderful it would be to make some device which had even the possibility of ascending to Mars, and how it would look on a small scale, if sent up from the meadow at my feet.

At that moment, young Goddard conceived the idea of pursuing spaceflight. "I was a different boy when I descended the tree from when I ascended, for existence at last seemed very purposive," he wrote.

In 1899 spaceflight was a very bold dream. Even airplanes lay in the future. It would be four years before the Wright brothers' historic flight at Kitty Hawk.

Goddard studied hard. He earned an advanced degree. He became a university professor. But even so, once he began experimenting with rockets in earnest, his efforts drew ridicule.

In 1920 Goddard built an 11-foot rocket. It caused such excitement in Worcester that people called the police. The local paper ran a story about the event. The headline read "Moon Rocket Misses Target by 238,799 $\frac{1}{2}$ Miles!"

But the boy in the tree would go on to become known as the "father of modern rocketry." He would become a pioneer of the space age.

How Developments in Rocketry Made Space Exploration Possible

Vocabulary

- speculative
- payload
- component
- inertia
- totalitarianism

Before people could explore space, they needed a way to get there. The rocket proved to be the vehicle that broke Earth's bounds.

People have built rockets for centuries. And armies have long used them in battle.

Rockets were always hard to control, however. Military engineers found other kinds of weapons, such as cannons, more reliable. But when big thinkers like Robert Goddard began to dream of spaceflight, they turned again to rockets.

Rocketry Before the 20th Century

The first rockets had nothing to do with space exploration.

The Chinese had rockets by around 1000. They used them in the battle of Kai-feng Fu in 1232. They called them "fire arrows." In 1405 a German engineer, Konrad Kyeser von Eichstadt, made a rocket propelled by gunpowder.

The French used rockets against the British in 1429 and 1449, during the Hundred Years' War (1337–1453). During the Thirty Years' War (1618–1648) armies fired rockets weighing up to 100 pounds. They sent small pieces of metal flying everywhere.

In India, rockets were fired on the British during the battles of Seringapatam (1792 and 1799). That action caught the attention of Col William Congreve, a British artillery expert. He started experimenting with rockets. He standardized the kinds of gunpowder used in them. He added guide sticks to hold them steady in flight. He built the first launching pad. With these improvements, Congreve extended the range of British rockets from 300 yards to several thousand yards.

Soon the British had a rocket brigade. It fought in the Napoleonic Wars in Europe and in the United States during the War of 1812. You may recall that our national anthem mentions "the rockets' red glare." That's a reference to those British rockets, which were named after Congreve.

But even with these improvements, rockets weren't used much in war. They were too hard to aim well.

The Contributions of Robert Goddard

During the early years of the 20th century, scientists began to think of another use for rockets: spaceflight.

In 1903 a Russian scientist made the first computations for rocket flights into space. He was Konstantin Eduardovich Tsiolkovsky. He never built a rocket, but he designed several. He also calculated how a rocket engine could escape from and reenter Earth's atmosphere.

DR. ROBERT H. GODDARD

The work of two men—Robert H. Goddard in the United States and Hermann Oberth in Germany—sparked new interest in rocketry. Both men had studied science at an advanced level.

For the next 20 years Goddard continued to do pioneering research on liquid-fuel rockets. He also developed ways to steer rockets.

Goddard was a hands-on scientist. He didn't just crunch the numbers. He built the hardware. He worked systematically, step by step. And he created the foundation on which the space age was built.

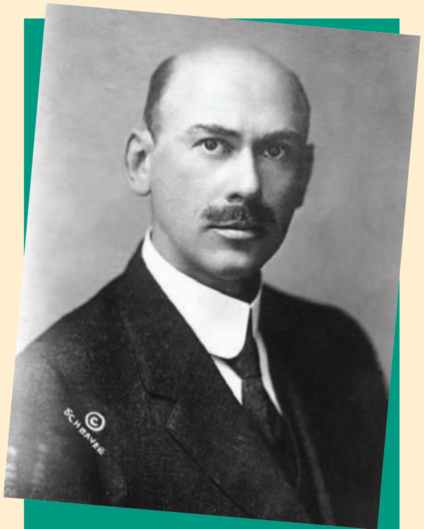
Dr. Robert H. Goddard with the first successful liquid-fuel chemical rocket, launched 16 March 1926

Courtesy of NASA Marshall Space Flight Center

Flight Paths

Robert H. Goddard: The Father of Modern Rocketry

Robert H. Goddard (1882–1945) was born in Worcester, Mass. He did his undergraduate studies at Worcester Polytechnic Institute. He did graduate studies and earned his doctoral degree from what's now Clark University, also in Worcester. He became a professor.



DR. ROBERT H. GODDARD

Courtesy of the Library of Congress/ Photo Researchers, Inc.

Goddard had an ambitious goal: to build a rocket that could travel to the moon.

In 1919 the Smithsonian Institution published his paper, "A Method of Reaching Extreme Altitudes." In this report he described a solid-propellant rocket that would go the moon.

During the 1920s Goddard began experimenting with liquid instead of solid propellants. He also developed a theory of multistage rockets. Perhaps that's what was needed, he thought, to get all the way to the moon.

During World War II Goddard helped the US Navy develop rocket motors. He also worked on jet-assisted takeoff devices for aircraft.

Goddard died in 1945. He didn't live long enough to see some of his biggest dreams realized. NASA's spaceflight center in Greenville, Md., is named in his honor.

Herman Oberth

Hermann Oberth (1894–1989) was another rocket pioneer of the 20th century. He was a German born in Romania.

As an 11-year-old, he read the Jules Verne novel, *From the Earth to the Moon*. In this science fiction book, a capsule containing three men and two dogs is blasted out of a huge cannon to the moon.

The book fascinated Oberth. It sparked a lifelong interest in spaceflight and travel to other planets.

As a student at the University of Heidelberg, Oberth wrote a dissertation on rocket-powered flight. If his professors didn't accept his paper, he would not get his degree. The professors rejected the paper in 1922. They called his work "too speculative," or *not practical or based on facts*.

But Oberth didn't give up. The following year he published the paper under the title "By Rocket to Space." It became a popular classic. It explained the math behind rocket science. It even discussed space stations and human travel to other planets.

The German V-1 and V-2 Rockets

As you read in Chapter 6, Lesson 2, the German V-1 rocket was the first guided missile used in war. The Germans introduced it near the end of World War II. It was a small, pilotless craft similar to today's cruise missiles. It didn't have much of a guidance system, but it carried a large warhead.

The V-1s first hit London 13 June 1944. The Germans launched them across the English Channel from France and the Netherlands. Later they launched them from the air. The Germans also used V-1s against Antwerp, in Belgium.

The Germans were already on the defensive when they introduced the V-1s. The "V" stood for "vengeance" (*Vergeltung*, in German). But the British called them "flying bombs," "buzz bombs," or "doodlebugs."

V-1s weren't very accurate, and they didn't turn the tide of the war. But they were effective terror weapons. They killed thousands of people. And they forced the Allies to devote large amounts of time and resources against them.

Allied pilots eventually learned to shoot down V-1s. But then came the V-2. And there was no defense against it.

The V-2 was the world's first ballistic missile. Recall that a *ballistic missile is one that free-falls after a self-powered flight*.

The V-2 was the largest, most complex missile in the German arsenal. It could deliver a ton of explosives 150 miles down range in five minutes. It traveled like a modern rocket ship. It moved faster than the speed of sound.

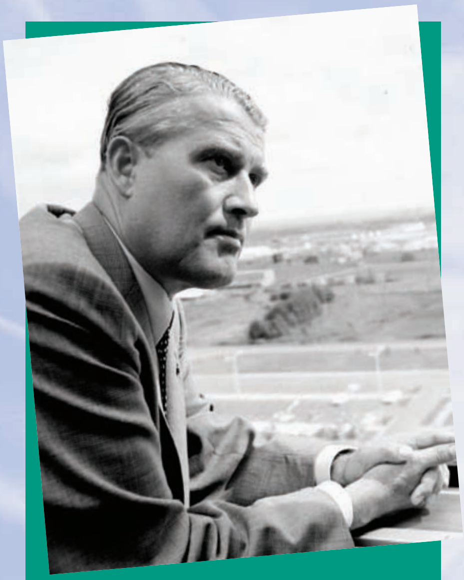
The V-2 was guided by radio signals from the ground or by onboard gyroscopes and a device that measured the rocket's acceleration. Germany fired almost 3,000 V-2s on England, France, and Belgium.

Wernher von Braun

Wernher von Braun (1912–1977) was one of the most important champions of space exploration of the 20th century. He had a lead role in developing missiles for Nazi Germany, the US enemy in World War II. After the war he came to the United States and worked in missile programs. Later he helped the United States in the space race with the Soviet Union, another of Germany's former foes.

As a youth Von Braun read the science fiction novels of Jules Verne and H. G. Wells. He also read Hermann Oberth's 1923 study "By Rocket to Space." Von Braun wanted to understand the physics of rockets. And so he mastered calculus and trigonometry. He earned a doctoral degree in physics at age 22.

Von Braun led the team that developed the V-2 ballistic missile for the German Army during World War II. The rockets were made at a forced-labor factory in Germany.



Dr. Wernher von Braun

Courtesy of NASA

Historians are still assessing Von Braun's relationship with the Nazi regime. It is certain, however, that he ultimately made a major contribution to the US missile and space programs. He worked with the US Army to adapt the V-2 for an American missile program.

Later, for the US Army, Von Braun helped get *Explorer 1*, the first successful US satellite, into orbit. This landmark event occurred just months after the Soviet Union stunned the world with the launch of *Sputnik 1* in October 1957.

In 1960 Von Braun's rocket-development center moved to NASA. His new job was to build the giant Saturn rockets. He became director of NASA's Marshall Space Flight Center. He was also the chief architect of the Saturn V launch vehicle. This device propelled Americans to the moon.

Von Braun retired from NASA in 1972.

The V-2 had a longer range and greater payload than the V-1. A payload *is what a rocket carries that is necessary to its mission*. The payload may include astronauts or a satellite. With the V-2, the payload was explosives. The Allies had no way to stop a V-2, or even to see this deadly missile coming.

The V-2 rocket was the model for rockets that the United States and the Soviet Union would later use in their space-exploration programs.

Wernher von Braun

The V-2 was the brainchild of Dr. Wernher von Braun. He was an engineer the German Army recruited to work on its missile program. He became the program's technical director. He headed the team that developed the V-2.

The team did not have to start from scratch. The German Army had been working on long-range rockets since the 1930s. The Germans first flew the liquid-propellant V-2 successfully in October 1942.

At the end of the war, before the Allies could capture his lab, Von Braun made a deal with them. He engineered the surrender of 500 of his top scientists, along with their plans and test vehicles.

The Allies brought V-2s, whole or in pieces, home for study. For 15 years Von Braun worked with the US Army to develop ballistic missiles.

At first Von Braun's group was based at Fort Bliss, Texas. The US Army had brought V-2 parts to the White Sands Proving Ground in nearby New Mexico. There General Electric was managing a missile-development program called Project Hermes. Von Braun and his team advised GE on how to reassemble the missiles. As the design improved, American components, or *parts*, replaced the German ones.

The Principles of Rocketry

Certain laws of physics govern rocket propulsion, flight, and control. Galileo (1564–1642) and Sir Isaac Newton (1643–1727) discovered these laws.

Rocketry is based on the propelling of a vehicle by a reactive force. The action of the rocket's exhaust gases produces a reaction. This forces the rocket to move in the opposite direction.

A rocket engine, or motor, is a reaction engine. So are jet engines, which power most airliners.

A rocket engine differs from a jet engine in one important way. A jet engine burns a mix of air and fuel. A rocket engine needs no air. It carries within itself all it needs to create a reactive force. This is why rockets work in space, where there is no air, as well as in Earth's atmosphere.

Newton's Laws of Motion

1. A body in a state of rest and a body in motion tend to remain at rest or in uniform motion unless acted upon by some outside force.
2. The rate of change in the momentum of a body is proportional to the force acting upon the body and is in the direction of the force.
3. For every action, there is an equal and opposite reaction.

Rockets and Newton's Laws

Sir Isaac Newton is well known for his three laws of motion. Each of these laws applies to an aspect of rocketry.

The first law concerns overcoming inertia—*the tendency for a body at rest to stay at rest until some force acts on it*. To get a rocket off a launch pad, the force (thrust) in pounds must be greater than the weight of the rocket.

The Saturn V rockets that launched the Apollo spacecraft that took US astronauts to the moon weighed 6 million pounds apiece. That's a lot of inertia to overcome. So the Saturn engines needed to produce more than 6 million pounds of thrust. In fact, they produced 7.5 million pounds.

Newton's second law of motion says that the amount of force needed to make an object move depends on its mass. The more mass a body has, the more force is needed to make it move.

You've probably seen an illustration of this if you've ever watched a film of a rocket launch. At the moment of liftoff, the rocket barely moves. That's because it's so heavy. But second by second, propellant burns off. So second by second, the mass of the rocket is less. Thrust, though, remains constant. The engines keep burning. As the load lightens, the rocket picks up speed. Eventually it disappears from view.

Newton's third law is essential to making rockets go. This law states that for every action there is an equal and opposite reaction.

If you've ever blown up a balloon, then released it and watched it zip across the room, you've experienced this law in action. The force of the air escaping from one end of the balloon pushes it in the opposite direction.

A rocket engine is more complex than a balloon. But the physics of motion are the same. The combustion, or burning, of fuel within a chamber generates exhaust gases. These gases are like the air you blow into a balloon that you then hold pinched shut.

But the rocket engine includes a nozzle and throat that are made of sturdier material than a balloon is. So the escape of exhaust from a rocket can be engineered with greater precision.

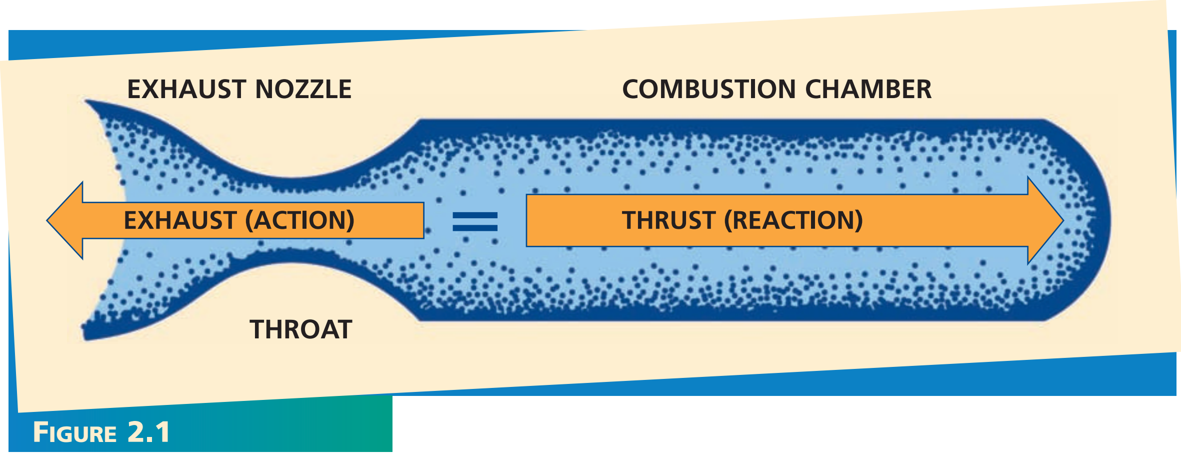


FIGURE 2.1

A basic rocket engine

In designing a rocket engine, an aerospace engineer wants two things:

1. pressure as high as possible in the combustion chamber
2. as much acceleration as possible of exhaust particles through the throat and nozzle.

Both contribute to acceleration of a rocket.

Today's military space rockets are made up of four major systems:

1. airframe
2. propulsion
3. guidance
4. control.

These systems are there to deliver the rocket's payload.

Airframe

The airframe contains the other three systems and provides the streamlined shape. An airframe has to stand up to heat, stress, and vibration. But it also has to be as light as possible.

The Atlas rocket is a good example of airframe design. Its skin serves as the wall of the propellant tank. There's no need for separate internal tanks. This saves weight. The skin of the Atlas is thinner than a dime. In fact, when Atlas has no fuel aboard, it has to be pressurized to keep it from collapsing.

ATLAS ROCKET

Courtesy of Lockheed Martin/
Duffin McGee/AP Photo

Extending Flight

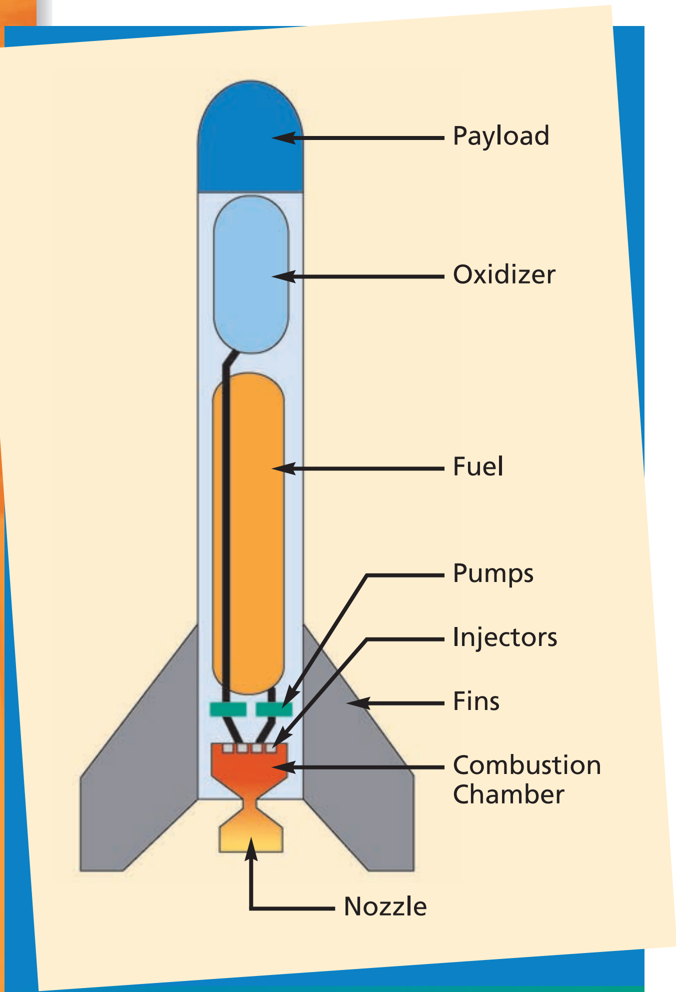


FIGURE 2.2

Liquid fuel–propulsion system

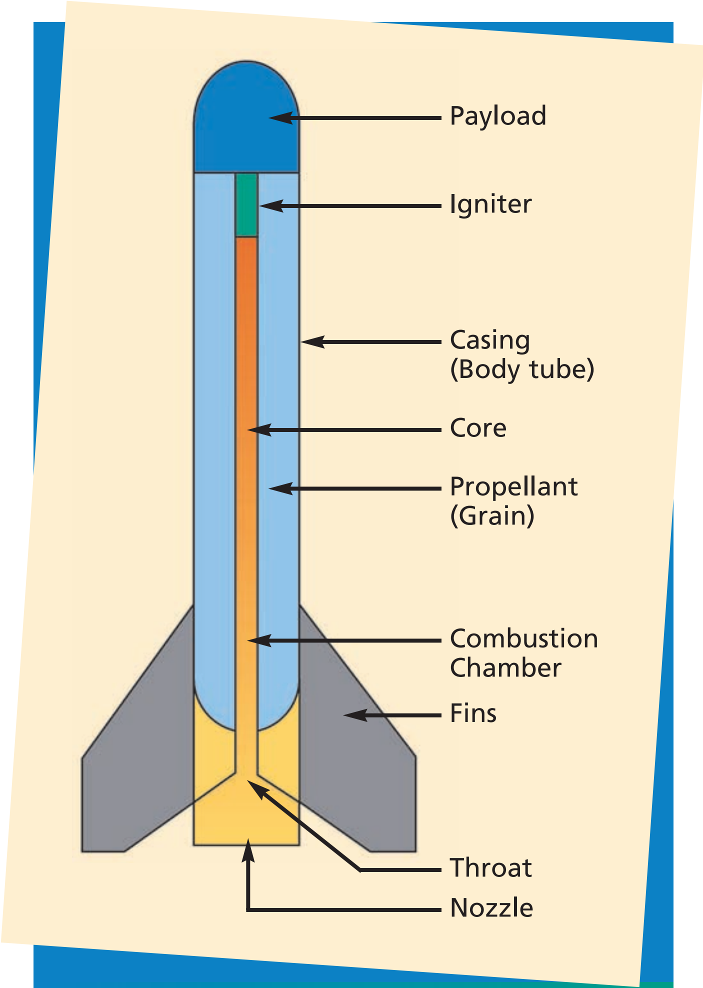


FIGURE 2.3

Solid fuel–propulsion system

Propulsion

The propulsion system includes propellant, containers for the propellant, the plumbing needed to get the propellant from the containers to the engine, and the rocket engine itself. *Propellant* is the fuel that gives the rocket its thrust.

A rocket may have a liquid or solid propellant. A liquid propellant is carried in a separate compartment. A solid propellant is carried in the combustion chamber. Each type of propellant requires a different engine structure.

Guidance

A large rocket's guidance system is its "brain." It includes a computer and an inertial platform—a collection of sensing devices. It may also include a star-tracking system for space navigation.

The computer holds instructions for the rocket's course. The rocket also has a radio link in case the onboard systems fail and ground controllers have to take over.

The guidance systems in today's rockets are quite small. Like cell phones and computers, they have benefited from miniaturization.

Control

The control system's job is to carry out the orders of the guidance system.

Some elements of a rocket's control system are like those of an airplane. They function while the rocket is within Earth's atmosphere. But once a rocket gets up into space, where the air is thin, it needs other ways of steering.

One way to change a rocket's flight path is to redirect its exhaust stream. Another way is to fire up small rockets attached to the airframe. These methods can be used in combination. They work inside Earth's atmosphere as well as in space.

How the Cold War Led to a Race in Space

The United States and the Soviet Union fought together against the Axis Powers during World War II. But after the war, differences between these two former allies became clear.

As you read in Chapter 6, the two countries entered a long period known as the Cold War. It wasn't a shooting war, like World War II. But each side knew who the enemy was.

The two countries faced off in a global power struggle—American democracy versus Soviet totalitarianism. Totalitarianism *is a form of government under which the people are completely under the control of a state authority that oppresses all opposition.*

President Eisenhower said in 1958, "What makes the Soviet threat unique in history is its all-inclusiveness. Every human activity is pressed into service as a weapon of expansion. Trade, economic development, military power, arts, science, education, the whole world of ideas. . . . The Soviets are, in short, waging total cold war."

In the Cold War, space was a crucial arena of competition.

How the Space Race Started

Many people think the space race began on Friday, 4 October 1957, when the Soviets launched *Sputnik 1*. But the Soviets were off and running in this race before the Americans had even heard the starting gun.

The period 1957–1958 had been set as the International Geophysical Year. The United States and the Soviet Union pledged to work together to send satellites into space.

A US effort to launch a tiny satellite called *Vanguard* was in the works. But work was behind schedule. Meanwhile, the Soviets were working on a satellite of their own. Americans hoped they were behind, too.

That Friday evening, the Soviet Embassy in Washington, D.C., gave a reception for space scientists from many countries. The party came at the end of a six-day scientific conference.

At the conference, the Soviets hinted that their satellite wasn't just on schedule—it was ahead of schedule. American scientists wondered: how close to a launch might the Soviets be?

They soon found out.

During the party, a *New York Times* reporter got a phone call from his boss. Big news: TASS, the Soviet news agency, had just announced the launch of *Sputnik 1*. It was the first Earth-orbiting artificial satellite. ("Sputnik" is the Russian word for satellite.)

Word spread around the gathering: "It's up!"

The chief American delegate to the conference was known for his diplomacy. He announced the news and congratulated his Soviet hosts. But the American scientific team was crushed.

And many ordinary Americans, caught in the tensions of the time, felt as if their country were reliving the 1941 attack on Pearl Harbor. *Sputnik* was a wake-up call.

The Significance of *Sputnik* and *Explorer*

Sputnik 1 was a small satellite. It weighed less than 200 pounds. It spent only three months in orbit.

But it greatly worried Americans. They remembered how Soviet leader Nikita Khrushchev had threatened that his country would "bury" the Americans. Was *Sputnik 1* a sign that he was right?

Then on 3 November 1957, the Soviets launched *Sputnik 2*. It had a dog named Laika aboard. This satellite weighed 1,120 pounds.

Americans swung into action. Congress held hearings to find out why the United States had fallen so far behind the Soviets.

Meanwhile American scientists scrambled to get a *Vanguard* satellite into space. They sent the first one up on 5 February 1958. But four miles up, the launch vehicle exploded.

Then Wernher von Braun entered the picture. He'd been working with the US Army. He had a plan for something called Project Explorer. He dusted off the plan, got it approved, and put things in motion.

His team had to abort a couple of launches. But on 31 January 1958 a Juno 1 booster carrying *Explorer 1* lifted off from Cape Canaveral, Florida.

It took a while to be sure the satellite had made it into orbit. Early the following day confirmation came from the Jet Propulsion Laboratory at the California Institute of Technology in Pasadena. A day later, US newspapers showed Von Braun and two associates beaming in triumph after announcing the news.

The United States hadn't been first off the mark. But it was still in the space race.

How NASA Was Established

The success of *Explorer 1* relieved many Americans. But soul-searching continued. How should the United States respond to the Soviet challenge in space?

The White House and the US Congress wanted a permanent federal space agency. Some suggested creating a Cabinet-level department of science and technology.

But other players were in the picture. The Department of Defense claimed a role in space. The Army and the Air Force were working on a plan to send robotic probes to the moon. In March 1958 the secretary of defense announced plans to send robotic probes elsewhere in the solar system.

But President Dwight Eisenhower didn't want the military to take the lead in the space race. He preferred a civilian space agency. A peaceful approach to space would win more friends at home and abroad, he reasoned.

Congress supported his idea. It passed a law creating the National Aeronautics and Space Administration, which quickly became known as NASA. NASA began operations on 1 October 1958.

The Space Act of 1958, which created NASA, commits the United States to peaceful purposes in space. But the United States reserves the right to use space systems for military deterrence. It wants to do what it can to keep away potential enemies, as long as it can do so without putting another country's security at risk.

The military continued to play an important role in space, even after the creation of NASA. In 1982 the Air Force created Space Command. The command is responsible for strategic surveillance—for warning of missile attacks. The space systems included under Space Command also help the military with communications, navigation, and weather information.

For many Americans, winning the space race was a matter of national security. The decade of the 1960s would determine whether the agency Congress created was up to the task.

Skynotes

NASA and the Air Force

NASA is a civilian agency, but many of its astronauts have come from the Air Force. Three of the original seven Mercury astronauts named in the early 1960s were active-duty Air Force officers: Capt Virgil I. (Gus) Grissom, Capt Donald K. (Deke) Slayton, and Maj L. Gordon Cooper Jr.

These men were the first of more than 80 Air Force astronauts in NASA programs, from Mercury on through the space shuttle and the International Space Station. Eight Air Force astronauts became general officers. Most notable is Gen Kevin P. Chilton, who became the head of Air Force Space Command in 2006. He reached four-star rank after flying on three space shuttle missions, becoming the first astronaut to earn a fourth star.

Sadly, Air Force officers have also borne the cost of space travel. Of the 27 NASA astronauts who have died while on a space mission, eight were from the Air Force.

GEN KEVIN P. CHILTON

Courtesy of the US Air Force

CHECKPOINTS

Lesson 2 Review

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

1. How did Col William Congreve improve rockets?
2. How did Konstantin Eduardovich Tsiolkovsky advance rocket science?
3. What influence did Jules Verne have on Hermann Oberth?
4. Why did the Allies fear the V-2 rocket?
5. What did the Allies do with pieces of the V-2 they captured during World War II?
6. How are rocket engines like jet engines? How are they different?
7. What are the four systems of a rocket?
8. What effect did *Sputnik 1* have on Americans?
9. What effect did *Explorer 1* have on Americans?

Applying Your Learning

10. Do you think it was a good idea for President Eisenhower and Congress to establish NASA as a civilian agency instead of a military agency? Why or why not?