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Illustrations

1. Space Dreams and War Drums

> The earth is the cradle of mankind, but one cannot stay in the cradle forever.
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> *Russian spaceflight theorist Konstantin Tsiolkovsky*

This famous assertion by Tsiolkovsky is always cited to support the idea that humanity must go into space to survive and flourish. Yet few people have noted the implications of the first part of his statement. Instead of saying humans originated on the earth, he called the earth our “cradle.” Tsiolkovsky chose his words to reflect his belief that life is widespread throughout the universe and that earthly life didn’t necessarily start on the earth. And the explosion of scientific knowledge in the twentieth century suggests that in this respect Tsiolkovsky might be correct. Consider this fact: The chemical composition of humans and other living things more closely resembles the stars than the earth. The four most common elements in living beings are hydrogen, oxygen, carbon, and nitrogen. Scientists have determined that these four elements are the four most common elements in the universe, except for helium and neon, which don’t form compounds. The four most common elements on earth are silicon, iron, magnesium, and oxygen.

Some researchers have gone so far as to suggest that comets, meteorites, or other debris from space “seeded” life on earth, but this idea remains controversial at best. Yet it is clear that forces that came from beyond earth’s atmosphere affected the long and difficult evolution of earthly life—humanity’s time in the cradle. The moon’s impact on earthly life through tides and biological cycles is well known. In recent years, scientists have tied the mass extinction of the dinosaurs sixty-five million years ago to the impact of a gigantic asteroid that caused major climate change on earth. In the more than three billion years that life has existed on earth, there have been more than a dozen mass extinctions, and many of them may be related to similar impacts by comets or asteroids. Other researchers are looking into aspects of radiation and other "weather" in space that could have affected life on earth.

Humankind's reach into space is changing our view of the universe and our place in it. It remains to be seen whether it will be necessary to establish colonies beyond earth to save humanity and other earthly life from some future catastrophe. The answers to such questions are beyond the scope of this book, but the fact that they are being seriously raised represents just the latest thrust in a long evolution of human thought that at first barely acknowledged the existence of anything beyond earth.

We can only conjecture what our early ancestors thought they saw when they looked up. There are many suggestions that they saw the sky simply as a continuation or reflection of what they saw on the ground. The design of the great megalithic monuments such as Stonehenge strongly imply that their builders had a good knowledge of the movements of the sun and moon. Astronomy and astrology were in evidence in the earliest civilizations, which began between five thousand and six thousand years ago. The Babylonians who lived in today's Iraq studied the skies as they did every aspect of nature in their search for omens that might warn of a disaster that could be avoided by performing an appropriate ritual. The motions of the moon, the sun, and planets were recorded by Babylonian astronomers not only to use as omens but in developing calendars and to predict celestial phenomena. Ancient Egyptians observed the sky to develop their own calendars. Most importantly, they used the appearance of the star Sirius in the sky to predict when the Nile would flood, the annual event around which Egyptian life revolved.

Among their many gifts to civilization, the Greeks advanced astronomy. The mathematician Pythagoras and his band of mystic followers in the sixth century B.C. believed in a universe based on mathematics. They correctly viewed the earth as a sphere, and Eratosthenes, who lived in Egypt in the third century B.C., made a reasonably accurate estimation of the earth's size. Aristarchus and others believed that the earth orbited the sun, but in the end, Greek science put the earth at the center of a universe bounded by a larger sphere to which the stars were attached. They believed that the sun, moon, and the wandering stars known as planets were attached to their own spheres that rotated about the earth. These beliefs, as propounded by the philosopher Aristotle and codified by the second-century B.C. astronomer Ptolemy, persisted for more than fourteen hundred years with the support of the Catholic Church, even though Ptolemy did not consider his work to be the final word on the subject. Though Aristotle believed firmly that there were no worlds beyond the earth, Plutarch, who lived in the first and second centuries A.D., wrote of the moon as a world unto itself.

The Greeks are generally credited as being the first to think of humans taking flight, and the first to suggest that there are other worlds to visit. The myth of Daedalus and his son Icarus involved a winged escape from a blockaded Crete. But Icarus died when he flew too close to the sun, and the wax holding his wings together melted. The great philosopher Socrates was quoted as saying: "Man must rise above the earth—to the top of the atmosphere and beyond—for only thus will he understand the world in which he lives." Lucian of Samosata, a second-century A.D. satirist, wrote two stories that involved trips to the moon. The first, "A True Story," involved a voyage on a sailing ship that left the Mediterranean Sea for the Atlantic Ocean, and was intended to poke fun at the tales of the terrors of the Atlantic that Phoenicians told to discourage others from sailing there. At one point, his ship is lifted by a whirlwind, and after being airborne for seven days and seven nights, it alights in a cultivated land inhabited by men riding three-headed vultures who tell them they are on the moon. Like the real astronauts of the twentieth century, Lucian's space voyagers looked back. "We also saw another country below, with cities in it and rivers and seas and forests and mountains. This we inferred to be our own world." Lucian's voyagers were soon caught up in a war between the inhabitants of the sun and the moon in which both armies were made up of men and various fantastic animals. Lucian's men are taken prisoners by the forces of the sun, and the moon surrenders after the sun men build a wall that puts the moon in darkness. Lucian imagines that stars and comets are inhabited, but finds no women on any of these bodies. He recounts that in the end his voyagers are allowed to return to earth, where they go on to further adventures.

Lucian's other story, "Icaromenippus, or the Sky-Man," involved the third-century B.C. philosopher Menippus, who in this story decides to take flight using an eagle's wing and a vulture's wing. Since there is no wax involved, he avoids Icarus's fate, and flies to the moon. Menippus looks back at the earth, but almost fails to recognize it. Flying on to heaven, he meets with the gods and has adventures that satirize the views of the philosophers, until Zeus orders Menippus's wings confiscated, and he returns to earth. Though it is possible that some of Lucian's stories were based on earlier writings, including those of Menippus himself, his stories marked the first appearance of a literary theme that has persisted to this day: the use of space as an empty canvas useful for painting fantastic tales.

Astronomers and navigators in the Arab world, China, and India continued looking to the sky and recording what they saw, while science in Europe stagnated until the invention of printing in the fifteenth century stimulated the arts and sciences. Throughout this period, the planets were seen as starlike objects whose forward and backward motions among the fixed background of the stars required explanation. Most educated people relied on the complicated Greek concepts of epicycles and deferents to explain and predict planetary motion on the assumption that the earth lay at the center of the universe. But the Polish canon and astronomer Nicholaus Copernicus challenged this view in his groundbreaking work, *De Revolutionibus Orbium Coelesticum* (On the Revolutions of the Heavenly Spheres), which was published as Copernicus lay on his deathbed in 1543. In this work, Copernicus showed that the earth and the other planets orbited around the sun, and that the moon alone orbited the earth.

Copernicus's work was not widely accepted for many years after his death, but during the sixteenth century the work of Tycho Brahe and Johannes Kepler continued to advance astronomical knowledge. Tycho's observations of the comet of 1577, for example, showed that comets were not atmospheric phenomena but objects in outer space. Tycho also noted that the 1577 comet had moved within the planetary regions, disproving the idea that planets were attached to spheres. Based on Tycho's accurate observations of planetary motions, which questioned Ptolemaic and Copernican predictions of planetary motion, Kepler wrote that planets and other bodies in space move along elliptical and not circular paths.

In 1609, a forty-five-year-old Italian mathematics professor named Galileo Galilei got word of the invention in Holland of a new device that could magnify distant objects. Galileo began building his own versions of this device, which became known as a telescope, and he became the first person to point it at the sky and publish his findings. On January 7, 1610, Galileo saw that Jupiter was accompanied by three small points of light. On succeeding nights, he found that there were four small "stars" that stuck with Jupiter in a way that could only be explained if they were moons of Jupiter. He also pointed his telescope at our moon, a body that was considered perfect in spite of the irregular pattern on its face, which was thought to be a reflection of the earth. Instead of a perfect sphere, Galileo found mountains and other irregular structures on the lunar surface. When he looked at Saturn, he saw two strange appendages that later observers determined to be its rings, and he saw that Venus had phases like the moon. These findings led Galileo to champion the Copernican view of the universe and brought him in conflict with the Catholic Church. But most importantly, Galileo and the other observers of the seventeenth century who eagerly followed him established that there were distinct worlds beyond the earth.

The finding that there were indeed other worlds stimulated people's imaginations, and many of those imaginings soon found their way into print. Kepler, for his part, wrote a work of fantasy that was published after his death in 1630, the *Somnium*, whose descriptions of the moon benefited from telescopic observations of the lunar surface. At roughly the same time, two English bishops wrote books about the moon. Bishop Francis Godwin's fictitious hero used swans to take him to a moon inhabited by large humans who communicated using a musical language. Bishop John Wilkins wrote a more serious book suggesting that the moon was similar to the earth, could be inhabited, and could be visited by humans. In the middle of the seventeenth century, Cyrano de Bergerac wrote two books about space travel. The first one, *Voyage dans la Lune*, depicted a voyage to the moon, and the second, *Histoire des ftats et Empires du Soleil*, took its readers to the sun. In his stories, De Bergerac tried a number of devices to get into space, including bottles filled with dew that would be carried away by the rays of the morning sun, and finally a flying machine with rockets attached to it. Though these were part of a long string of fictional accounts of trips to the moon, the sun, and the planets, de Bergerac was the first to hit on the method that would actually open the way for space three hundred years later.

The Rockets' Red Glare

By the time of de Bergerac's books, rockets were long established as fireworks and more importantly, as weapons, even though the principles behind their operation weren't yet fully understood. Most historians agree that rockets originated with the invention of black powder, known since the invention of guns as gunpowder. This powder, a mixture of charcoal, sulfur, and saltpeter, is believed to have been invented by alchemists in China between fourteen hundred and two thousand years ago, and was soon adopted for fireworks and then for explosives. Fixing an approximate time for the invention of rockets is more difficult, because historical accounts of battles speak of weapons that could be either rockets or simply flaming arrows whose heads were dipped in a flammable substance and set alight before firing. It is clear that by the middle of the eleventh century, the Chinese were well acquainted with the properties of black powder, and its use in rockets likely dates back to this time.

Mongol armies are known to have used gunpowder in Europe in 1241 and rockets in an attack on Baghdad in 1258. Around this time, the Arabs also began to employ rockets as weapons, and the use of black powder quickly spread to Europe. The use of rockets in India is traced back to 1399. As the years passed, more people studied gunpowder and rockets in an effort to make them more effective as weapons and for fireworks displays. The Italian historian Muratori first used the word *rocket* in its Italian form *rochetta*, referring to its cylindrical shape, in 1379, and Italians advanced the art of fireworks in the years that followed. A well-known legend, which no evidence survives to substantiate, has it that the first human attempt to ride a rocket took place about 1500 in China. Wan Hu, a Chinese mandarin, is said to have disappeared in a cloud of smoke after assistants lit forty-seven rockets attached to his chair.

Rockets were used from time to time in battle in Europe and elsewhere after the thirteenth century, though not systematically because of their limited range and accuracy. In the 1790s, Hyder Ali, prince of Mysore, and his son Tipu Sahib, used rockets effectively against British forces in India. These rockets were made of an iron tube instead of the then typical pasteboard, and their range was about one thousand yards. Reports of these rockets impressed an English socialite and inventor who had never been to India: William Congreve.

Starting about 1801 with some fireworks rockets he purchased in London, Congreve, a former lawyer and newspaperman who had studied at Cambridge, began his work to make better rockets at the Royal Laboratory at

Woolwich, where his father held a high position. The British military, concerned by the threat of an invasion from France by Napoleon's forces, soon started to support Congreve's research. Congreve not only created a more advanced rocket; he developed what Smithsonian historian Frank H. Winter has termed a "complete weapons system." By refining the gunpowder and using special presses to pack it tighter into metal cases, Congreve obtained longer distances and better accuracy from his rockets. Congreve provided a whole family of rockets of varying calibers, ranges, and sizes that could be fitted with warheads and used to explode, spread shrapnel, set fires, or illuminate darkened battlefields. The rockets came with launching stands, and Congreve even supervised the fitting of special ships from which rockets could be launched.

Congreve's rockets were soon put to use, first at Boulogne, where Napoleon's fleet for the invasion of England was located. The first British naval attack with rockets on this French port was called off in 1805 due to poor weather, but on a second try the following year, the rockets put the city on fire. Similar rocket attacks in Copenhagen in 1807 and against Napoleon's forces at the Battle of the Nations in Leipzig in 1813 were also effective. British forces successfully used Congreve's rockets in North America in the War of 1812. Their most memorable moment came in circumstances in which the rockets did not prove decisive for the British. During an attack in September 1814 on Fort McHenry at Baltimore, the sight of "the rockets' red glare" illuminating an American flag inspired a lawyer named Francis Scott Key to write a poem called "The Star Spangled Banner," which was later set to music and became the national anthem of the United States. The fort held against the rockets and artillery of the British in what was a turning point in the war for the Americans.

All rockets are reactive devices, which means that they generate an action that causes an equal and opposite reaction, in this case the movement of the rocket. This action-reaction principle is the third law of motion spelled out by Isaac Newton in his 1687 masterwork, the *Principia*. Building on the work of Kepler and others, Newton explained gravity and the motion of bodies in the universe. Though most people believed that rockets worked by pushing against air, a belief that persisted into the twentieth century, Newton's laws showed that rockets could work anywhere, with or without air. For the military in the nineteenth century, this meant that rockets didn't recoil like cannons or other guns did, which is why Congreve equipped ships with rockets to attack port cities. No matter how many rockets were fired, the ships didn't rock as they did when cannons were fired from their decks.

In spite of Congreve's improvements, rockets still had their limitations and were best for specific situations. For example, rockets that could set towns ablaze were not useful in cases where an army wished to win over a local population. They were also more effective against unsophisticated enemies who weren't prepared for rockets or didn't know what they were. And there were still limitations on their range and accuracy. Advances in guns and artillery also caused rockets to go out of fashion until rockets themselves were improved.

Congreve, who arguably was the world's first rocket scientist, worked on perfecting rockets until his death in 1828. Though he was inspired to advance rocketry for military purposes, he also thought of flying beyond the earth. As a child, he wrote of his wish to fly to the moon in the recently invented hot-air balloon, and late in life he wrote of an "Aerial Carriage" powered by wind and muscle.

Rockets came to be used by most European armies and navies at various times in the nineteenth century. The Russian military began developing the weapons in 1810 and used them effectively in the Russo-Turkish War of 1828–29 as well as in colonial wars, including engagements in 1853 in Central Asia not far from the place that became Russia's major spaceport a century later. In 1834, Karl A. Shilder developed a submarine for the Russians that fired rockets, presaging a major weapon of the nuclear age 130 years later. In the Crimean War of 1853–56, both the Russians and their English, French, and German opponents fired rockets at each other. The U.S. Army used rockets in the Mexican War of 1846–48 and in the Civil War. A demonstration of rocketry for President Abraham Lincoln in 1862 almost turned the tide of history when a rocket exploded near the president, though luckily it didn't harm him.

For all their advances, Congreve's rockets still carried long sticks to direct them at launch. Another British inventor, William Hale, found in the middle of the century that rockets could be stabilized by spinning them during flight. Three metal vanes inserted in the exhaust nozzle and tilted slightly toward the direction of the exhaust caused the rockets to rotate. Hale also built other improvements into rockets, including a hydraulic press for the gunpowder fuel. As the nineteenth century wore on, rockets were brought into use to harpoon whales, to signal distress, and to throw rescue lines. Their use in battle declined, however, because gunpowder rockets had reached their technological limits at a time when the technology of guns and artillery continued to advance.

Even before the nineteenth century began, humans were finally realizing a longstanding dream. Thanks to advances in ballooning, they were taking to the air. On September 19, 1783, Joseph and Etienne Montgolfier launched a large lighter-than-air balloon at Versailles with a sheep, a duck, and a goat as passengers. On October 15, François Pilatre de Rozier, a teacher, became the first man to ascend in a balloon when the Montgolfier brothers let him fly in a series of tests of a tethered balloon. On November 21, de Rozier and the Marquis d'Arlandes made the first free flight in a Montgolfier balloon, flying five miles for twenty-five minutes up to a height of three thousand feet. Jacques Charles, who was experimenting at the same time with hydrogen balloons, made his first ascent with his brother Noel ten days later. The age of ballooning had begun, and over the decades that followed, balloons carried larger loads, traversed longer distances, and reached greater altitudes.

Fakes, Fantasies, and Facts

Early in the twenty-first century, it is a cliché to observe that the twentieth century produced changes that had revolutionized life in ways that people one hundred years before couldn't have visualized. There is no doubt that many people a century ago felt the same about the nineteenth century, thanks to the new modes of transportation, communication, manufacturing, and warfare that hadn't been envisioned in 1800, such as steam turbines, telephones, telegraphs, wireless communications, photography, new steels and textiles, and electrical devices, to name a few.

Technological changes in the nineteenth century took longer to propagate than they do today, however. Many of that century's advances that were known to scientists but not average people were popularized through books, newspapers, and other publications read by growing numbers of people who benefited from the dissemination of education and science. But sometimes, large numbers of people were exposed to fakery and misrepresentation, and the largely unknown realm of space was a popular set-