AIAA

AEROSPACE MICRO-LESSON

Easily digestible Aerospace Principles revealed for K-12 Students and Educators. These lessons will be sent on a bi-weekly basis and allow grade-level focused learning. - AIAA STEM K-12 Committee.

SPUTNIK 1

Sixty years ago, the first artificial object was launched into orbit: Sputnik 1. Launched by the Soviet Union on October 4th, 1957, the satellite orbited the Earth a total of 1,440 times until it burned up in the atmosphere roughly three months later. Sputnik's success was not celebrated everywhere, because it pre-empted American efforts to launch a satellite into space. The achievement is still an important one for humanity and sparked the space race which ultimately led to Americans landing people on the moon.

Next Generation Science Standards (NGSS):

- Discipline: Physical Science.
- Crosscutting Concept: Patterns.
- Science & Engineering Practice: Obtaining, evaluating, and communicating information.

GRADES K-2

NGSS: Waves and Their Applications in Technologies for Information Transfer: Use tools and materials to design and build a device that uses light or sound to solve the problem of communicating over a distance.

In 1957, the first satellite was launched into orbit. It was named Sputnik, which is Russian for "fellow-traveler." This may seem like a long time ago, but in terms of history that is relatively recent. Many things had already been invented by this time, including radio, television, basic computers, cars, and airplanes.

A Technician puts finishing touches on Sputnik 1

A satellite's primary function usually involves communicating with people still on Earth. All types of satellites use similar technology to communicate: some type of light waves on what we call the electromagnetic spectrum. You have probably heard of radio waves or microwaves, but there are many other types of waves that satellites can use to communicate as well. While all of these satellites communicate with people on Earth in similar ways, they perform a variety of tasks.

GRADES K-2 (CONTINUED)

There are now many types of satellites. Scientific satellites use sensors to collect data for scientists to study. Weather satellites help meteorologists to predict the weather. Entertainment satellites send television and radio signals to people. Global Positioning System (GPS) satellites help people to navigate and get where they are going. Military satellites help collect information for the Army, Air Force, Navy, and other armed services. All of these satellites communicate information that you and your families have probably used or heard about at some point in time.

The original satellite, Sputnik 1 used radio waves to communicate with scientists back on Earth, although, plenty of amateur radio operators were also encouraged to listen in. Scientists learned a lot about air resistance in the upper atmosphere, how objects orbit the Earth, and launching objects into space in general. There was a lot of science and math involved! Computers were essential to successful space launches and used in most if not all space missions.

Suggested Activity: Ask students to design, or "engineer," a way to communicate over distances by using unique applications of either sound or light waves. Some examples that students may attempt or be prompted to try by a teacher include: creating a pattern of sounds that communicate letters when they can't see each other (similar to Morse Code), using a light to flash a pattern that represents letters when they can't hear each other (again, similar to Morse Code), creating something simple like a string telephone that allows them to hear each other over a distance, or some other creative yet simple option. Students in grades K-2 may need 2-3 examples that they can choose from with adult support.

GRADES 3-5

NGSS: Waves and Their Applications in Technologies for Information Transfer: Generate and compare multiple solutions that use patterns to transfer information.

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GRADES 3-5 (CONTINUED)

There are now many types of satellites: scientific satellites, weather satellites,

entertainment satellites, Global Positioning System (GPS) satellites, and military satellites. All of these satellites communicate information that you and your families have probably used or heard about at some point in time.

One of the amazing things to people was that many could see Sputnik from Earth; it looked like a moving star. In fact, today when you look up and see a slowly-moving "star" it is probably a satellite moving overhead. There are approximately 4,500 artificial satellites currently orbiting the Earth. That's a lot!

Sputnik was mostly a scientific endeavor at first, but quickly the launch took on a political tone as Americans became concerned and even jealous of the Soviet Union's accomplishment. The Space Race was on in earnest and in the following year, 1958, America launched Explorer 1. Soon after the launch, citizens across the US began demanding some sort of concerted effort in response. Math and science education were suddenly prioritized in schools across the country as was engineering work.

The United States' response to the Soviet Union's satellite launch is referred to as a "Sputnik Moment." It made newspaper and radio headlines across the world (there are five links here) and motivated the United States to action. To this day, professional pundits often muse as to whether or not a major accomplishment by another country such as Russia or China will result in another "Sputnik Moment." Fortunately, in recent years, the emphasis on science and math education has increased greatly through the current STEM movement.

Suggested Activity: Ask students to design, or "engineer", a way to communicate over distances by using unique applications of either sound or light waves. Some examples that students may attempt or be prompted to try by a teacher include: created a pattern of sounds that communicate letters when they can't see each other (similar to Morse Code), using a light to flash a pattern that represents letters when they can't hear each other (again, similar to Morse Code), creating something simple like a string telephone that allows them to hear each other over a distance, or some other creative yet simple option.

GRADES 6-8

NGSS: Motion and Stability: Forces and Interactions: Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.

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There are now many types of satellites: scientific satellites, weather satellites, entertainment satellites, Global Positioning System (GPS) satellites, and military satellites. There are approximately 4,500 human-made satellites currently orbiting the Earth and all of these satellites communicate information that you and your families have probably used or heard about at some point in time. While all of these satellites communicate with people on Earth in similar ways, they perform a variety of tasks.

Just as there are many types of satellites in orbit, there are many types of orbit. Orbits are classified by several different categories: the body being orbited, how high the orbiting object is, the inclination of the orbit, its eccentricity, its synchronization with the orbited body's rotation, and whether it is a normal orbit at all. An orbit is geocentric, heliocentric, or lunar depending on whether the satellite is orbiting the Earth, the Sun, or the Moon; orbits around other planets have other names. Satellites orbiting the Earth are classified as being in Low-Earth Orbit (LEO, below about 2000 km above the Earth's surface), Middle Earth Orbit (MEO, from 2000 km to geosynchronous altitude), Geosynchronous Orbit (GSO, at 35,786 km above the Earth's surface), and High Earth Orbit (above geosynchronous orbit). One could classify orbits around other astronomical objects similarly but there has not been any need to and so it has not been done. Inclination refers to the angle between the plane of the orbit and some reference plane such as the central body's equator or the plane of the central body's orbit. In particular, a "polar orbit" passes near the central body's North and South poles; this is useful for satellites whose main mission is to photograph the central body as it allows it to pass over pretty much all of that body. Finally, the eccentricity of an orbit is a measure of how far its shape deviates from a circle. A circular orbit has an eccentricity of zero; elliptical orbits have eccentricities between zero and one; a parabolic "orbit" has an eccentricity of one; and a hyperbolic "orbit" has an eccentricity greater than one. These last two are not true orbits in the sense

GRADES 6-8 (CONTINUED)

that the "orbiting" body will not follow the same path twice; the parabola and hyperbola extend to infinity and a body following such a path will not come back.

The orbit of an object has all of these properties: a central body, an altitude, an inclination, and an eccentricity. Sputnik 1 was in a low geocentric orbit with an inclination of 65.1

degrees and an eccentricity of 0.05201.

In addition to these common classifications of orbits, there are certain "special" orbits that satellites can have. The most common of these is the Geosynchronous Orbit; a satellite in geosynchronous orbit goes around the Earth once every day—specifically, once every sidereal day. The orbit may be elliptical and it may be inclined with respect to the Equator, so the satellite will not be stationary in the sky relative to an observer on the Earth, but it will stay near the same point in the sky. A special case of geosynchronous orbits is the Geostationary Orbit, or GEO, which is circular and has an inclination of zero. A satellite in GEO will stay in the same place in the sky above the Equator. Most satellites in GEO are weather satellites and communication satellites.

Another common orbit for communication satellites, especially for those serving parts of the Earth in the far north or south, are the "semi-synchronous" Molniya orbits. A Molniya orbit, named after the Soviet communication satellites placed in those orbits, is highly inclined (about 63 degrees from the Equator) and highly elliptical with its apogee above the area being served. The semi-synchronous nature of the orbit means that the satellite returns to the same position in its orbit twice a day; the high apogee means that it will move slowly while it is near there and will thus be very easy for receivers on the ground to track.

There are several other special types of orbit in addition to these. There are "sun-synchronous orbits" which precess so that the satellite passes over the point below it at the same time of day every day. There are transfer orbits which satellites follow to get from one primary orbit to another (such as from LEO to GEO). Somebody has also proposed a non-orbiting "statite" which would use a solar sail to keep itself in the same position above the Earth. Moving beyond the Earth, there are horseshoe orbits, in which the satellite appears to orbit the Earth but in fact is in a nearby orbit around the Sun which is being affected by the Earth's gravity. There are halo orbits, in which a spacecraft moves around a Lagrangian point of a larger body's orbit. And there are more.

GRADES 6-8 (CONTINUED)

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to hear each other over a distance, or some other creative yet simple option. An additional challenge for older students might be to introduce programming as a way to use patterns to communicate. For example, students can create graphical representations for binary code of the alphabet. Students can then "code" secret messages to each other.

GRADES 9-12

NGSS: Waves and Their Applications in Technologies for Information Transfer: Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.

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There are now many types of satellites, but a satellite's primary function usually involves communicating with people still on Earth. All types of satellites use similar technology to communicate: some type of light waves on what we call the electromagnetic spectrum. You have probably heard of radio waves or microwaves, but there are many other types of waves that satellites can use to communicate as well. Waves, and their applications in technology for information transfer are an important part of applied engineering when it comes to satellites and space communication--or communication in general for that matter.

Just like there are many types of satellites in orbit, there are many types of orbit. Orbits are categorized by the body being orbited and by the altitude, inclination, and eccentricity of the orbit. In addition, there are several types of "special orbit" such as geostationary, sun-synchronous, and horseshoe orbits.

GRADES 9-12 (CONTINUED)

All of these types of orbits have one very important thing in common: they are very high above Earth and therefore not connected to our power grid or easily accessible for refueling. So, how do satellites get their power, or energy then? Well, light waves can be used to communicate because they are a type of energy that travels through space, but because they are a type of energy light waves can be transformed into other types of energy as well. Solar cell technology converts light wave energy into electrical energy that the satellites can use to perform a variety of functions. Aren't waves amazing?

The next possible or perhaps even logical step, is using satellites to collect energy and then beam that collected energy back to Earth's surface for use in our electrical infrastructure, or power grid. This would be another application of our scientific understanding of waves and wave technology. Many engineers who work on the electromagnetic spectrum have actually suggested this exact application.

Sputnik was mostly a scientific endeavor at first, but quickly the launch took on a political tone as Americans became concerned and even jealous of the Soviet Union's accomplishment. To this day, we often diminish the launch of the first satellite in the US and highlight the first lunar landing because that accomplishment was American. Soon after the launch, citizens across the US began demanding some sort of concerted effort in response. Math and science education were suddenly prioritized in schools across the country as was engineering work.

While most Americans were shocked that the Soviet Union had gotten a satellite into orbit first, the reality of the matter was not so simple. In addition to the competition with the Soviets, the United States satellite efforts were competing internally with each other. The United States Army Ballistic Missile Agency (ABMA) had its Project Explorer; the United States Navy had Project Vanguard; and the Air Force was designing its Atlas rocket. Even though the ABMA had launched a payload to an altitude of 682 miles in September 1956, the Department of Defense Committee on Special Capabilities selected Project Vanguard to put the first American satellite into space and ordered the ABMA to concentrate on designing a missile with military applications. After the launch of Sputnik 1 and the failure of Vanguard 1, Project Explorer was reactivated.

There were also geopolitical considerations involved in launching a satellite. A nation has legal control over its borders and can decide who and what gets to come into and go out of it. With the advent of flight, this concept of controlled space was extended upward into the

GRADES 9-12 (CONTINUED)

atmosphere; even nowadays airplanes from one nation need permission from another nation to fly over its territory. President Eisenhower was concerned that if the United States had launched the first satellite, the Soviet Union would have claimed sovereignty over the space outside the atmosphere over its landmass and forbidden the use of satellites. As it was, the Soviets launched the first satellite, no country claimed sovereignty above the atmosphere, and in August 1960 the first American spy satellite returned pictures of the Soviet Union from space. But this was not made public for decades.

The United States' response to the Soviet Union's satellite launch is referred to as a

"Sputnik Moment." It made newspaper and radio headlines across the world (there are five links here) and motivated the United States to action. Also, unlike a "Pearl Harbor moment," it was not an act of war. To this day, professional pundits often muse as to whether or not a major accomplishment by another country such as Russia or China will result in another "Sputnik Moment." Fortunately, in recent years, the emphasis on science and math education has increased greatly through the current STEM movement.

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Sixty Years Ago in the Space Race:

October 4th, 1957: The Soviets successfully launched a satellite (Sputnik 1) into space via an R-7 rocket.