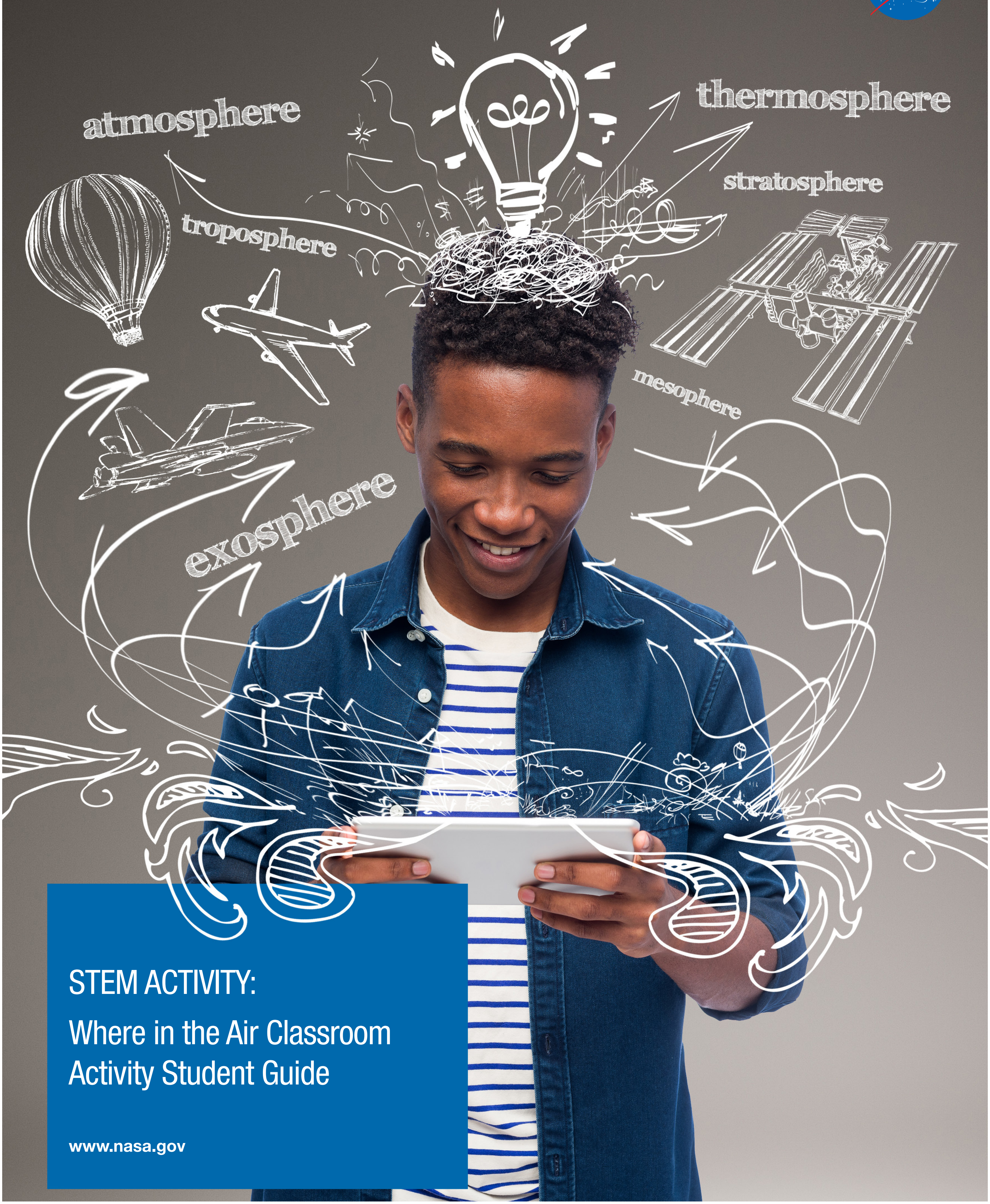
National Aeronautics and Space Administration



STEM ACTIVITY:

Where in the Air Classroom Activity Student Guide

www.nasa.gov

OVERVIEW

In this lesson, you will learn about the layers of the atmosphere as well as some of the things that can be found in each layer.

Objectives

Students will be able to:
- Identify the layers of the atmosphere, including their location relative to the other layers
- Determine in which layer of the atmosphere different objects can be found

Directions

Complete the following worksheet.

1. **Part 1:** You will be given an informational sheet which describes the object that you are to learn about. Read through this sheet to become the class expert. As you read, fill in the information on part 1 of the worksheet. When you have finished, use this information to complete the portion of the table in part 2 about your object. Prepare to share this information with the class.

2. **Part 2**: Each group will take turns sharing the information they gathered about their object. As they teach you about their object, use the information they provide to complete the rest of the table in part 2 of the worksheet.

3. **Part 3**: On the chart in part 3 of the worksheet, fill in the names for each layer of the atmosphere. Then, write the name of each object in its appropriate layer. If time permits, add a small drawing for each object.

NAME: ____

“Where in the Air?” Student Worksheet

PART 1

You are going to become an expert on one object found in Earth’s atmosphere.

Read the informational sheet to learn about the object and fill in the information below. Use this information to fill in the portion of the table in part 2 about your object. Be ready to share what you have learned with the rest of the class. Your information is important for everyone in the class to be able to complete the atmospheric diagram in part 3.

Object: ____

In your own words, describe the object’s function:

Where in the atmosphere is the object usually found?

- Altitude: ____________________________________
- Layer of the atmosphere: __________________________

Why do you think the object is found there rather than higher or lower?

List two interesting facts about the object:

1. ____

____

2. ____

____

PART 2

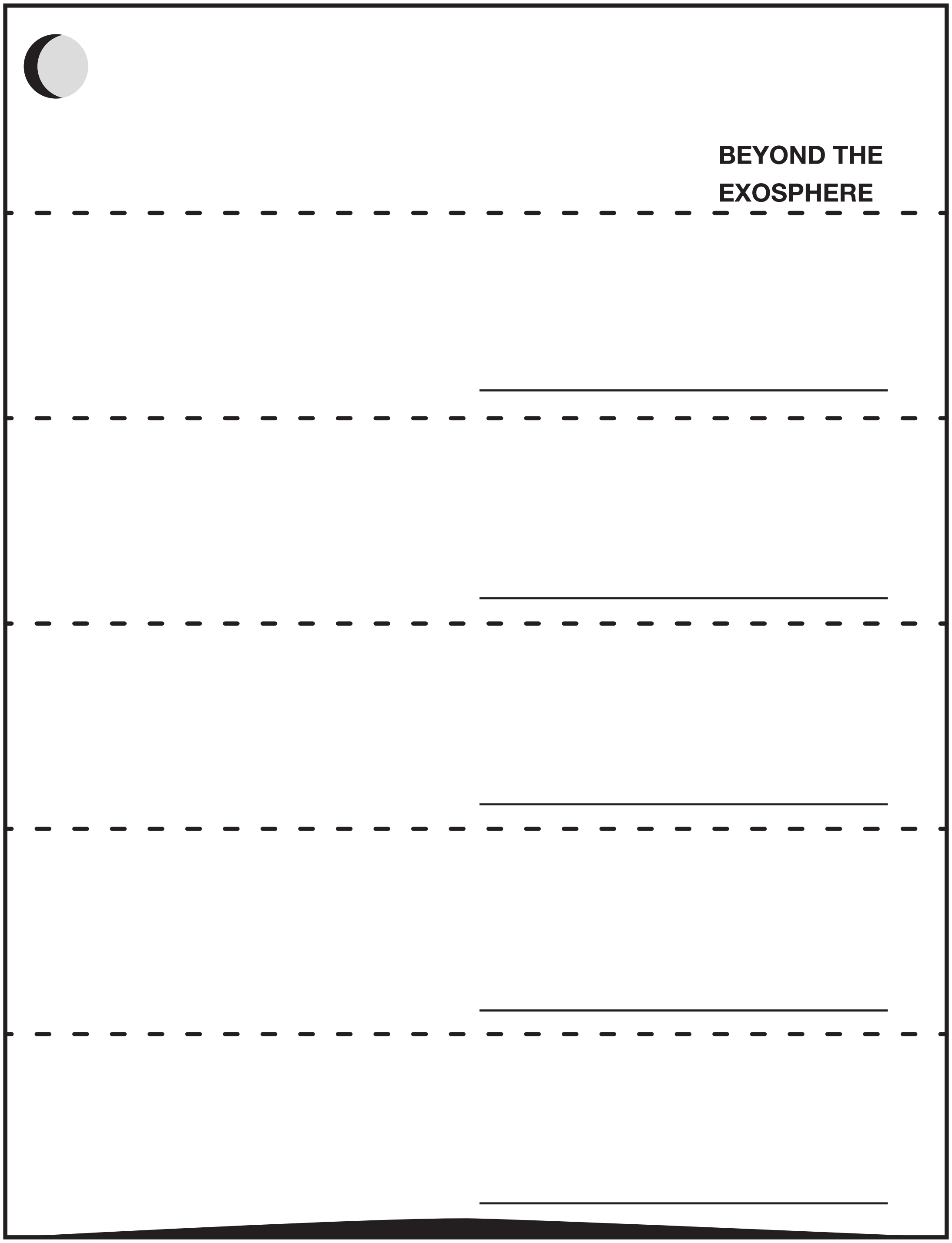
Now that you know about one object found in Earth's atmosphere, it's time to learn about other objects. Other groups have been busy learning about these other objects. As they share information about their object, write down what they teach you. Make sure you also fill in the information about your object! There may be some objects on the list that are not covered.

OBJECT	ALTITUDE	LAYER OF THE ATMOSPHERE	EXPLAIN ABOUT THE OBJECT— WHAT IS IT? WHAT IS ITS FUNCTION? (etc.)
1. Armstrong Line			
2. Birds			
3. Clouds			
4. Commercial Jetliner			
5. Communication Satellite			
6. ER-2			
7. Fighter Aircraft (F-35)			
8. Hang Glider			
9. Helicopter			
10. Hot Air Balloon			
11. Hubble Space Telescope			
12. International Space Station			
13. James Webb Space Telescope			
14. Lunar Gateway			

OBJECT	ALTITUDE	LAYER OF THE ATMOSPHERE	EXPLAIN ABOUT THE OBJECT— WHAT IS IT? WHAT IS ITS FUNCTION? (etc.)
15. Meteors (Shooting Stars)			
16. Model Rockets			
17. Mount Everest			
18. Ozone Layer			
19. Parachutist			
20. Small Airplane (Cessna)			
21. Small UAV			
22. Sounding Rocket			
23. Weather			
24. Weather Balloon			
25. X-57 Maxwell			
26. X-59 QueSST			

PART 3

On the following atmospheric diagram, label each layer of the atmosphere in the blanks. Then, enter the name of each of the objects you learned about from your classmates. Make sure each object is in the correct layer of the atmosphere. If time permits, draw a picture for each object.



INFORMATION SHEETS

ARMSTRONG LINE

The Armstrong Line, also known as the Armstrong Limit, is the altitude at which the atmospheric pressure is so low that water would boil at the normal human body temperature of 98.6°F (37°C). This occurs at an altitude of approximately 62,000 feet (19 kilometers). It was discovered by and named after Harry George Armstrong, the founder of the U.S. Air Force Department of Space Medicine.

Above the Armstrong line, a pilot needs to wear a full pressure suit, which completely encloses them and provides everything needed to survive. Without enough air to breathe, or enough air pressure to keep human body systems functioning normally, the pilot could not survive more than about 90 seconds. Without more pressure exerted on the body, fluids such as saliva, tears, and the lining of your lungs would boil. A full pressure suit, which is similar to a space suit, is quite bulky. It can impede a pilot's ability to fly because the multiple layers of the suit, along with the air pressure within the suit, make it less maneuverable.

Air Force pilot Deborah Lee James wears a pressure suit which allows her to fly above the Armstrong Line. Credit: U.S. Air Force photo/Senior Airman Dana J. Cable

BIRDS

The altitude at which birds fly can vary depending on the species of bird, the weather, and other factors. It takes a great deal of energy to fly higher in the atmosphere, so most frequently birds fly under 500 feet (0.15 kilometers) unless they are migrating. Smaller birds also fly below 500 feet to stay away from predators and to avoid the dangers of high winds. Hawks and other predators would be able to easily spot smaller birds if they were high in the air and there would be very little around them to confuse predators.

When migrating near the Caribbean, most birds are observed migrating at an altitude of around 10,000 feet (3 kilometers). When migrating long distances, birds will often start out at about 5,000 feet (1.5 kilometers), then climb to about 20,000 feet (6.1 kilometers) over time. Like aircraft, birds have optimum "cruising altitudes," and as a bird's weight decreases during migration, their cruising altitude increases. Vultures can also soar at 10,000 feet while searching for food down below. A flock of Whooper Swans was once visually identified by an airline pilot at 29,000 feet (8.8 kilometers) over northern Ireland.

Just like people, birds need to breathe oxygen, which limits how high they can fly. Bird lungs can extract larger percentages of oxygen from air than mammal lungs. Because of this, birds are more capable of functioning in the higher altitudes of Earth's atmosphere where there is less oxygen in the air.

Sandpipers can be seen flying near Kennedy Space Center. Credit: NASA photo/ Frankie Martin

CLOUDS

Clouds may appear to be made of gases, but they are actually made of water droplets or ice crystals that are suspended in the air. When temperatures in the atmosphere get low enough, water vapor condenses into liquid water on the surface of airborne particles of dust or other substances. When enough water vapor has condensed in a certain area, a cloud will become visible. This process happens throughout the troposphere, although some clouds can extend slightly into the stratosphere. Above that, clouds don't form because there is not enough air or water vapor. Clouds form at various heights ranging from Earth's surface up to about 60,000 feet (18 kilometers).

There are many different types of clouds. Cumulonimbus clouds, also known as thunderheads, form on hot days when warm, wet air rises very high into the atmosphere. These clouds often produce heavy rains, thunder, and lightning. Some can even produce tornadoes in the right conditions. A cumulonimbus cloud can be many kilometers thick, with a flat base near Earth's surface (under 20,000 feet) and a top frequently reaching an altitude of 33,000 feet (10 kilometers).

Cirrus clouds form in the upper regions of the troposphere, making them the highest clouds. The term cirrus, meaning "curly," refers to the horsetail-shape of these clouds. Formed at altitudes of 30,000 to 60,000 feet (9 to 18 kilometers), cirrus clouds are composed of ice crystals which trap and scatter incoming sunlight, reducing the amount of sunlight that reaches Earth's surface. This results in surface cooling. However, cirrus clouds also absorb infrared radiation reflected off Earth's surface and lower atmosphere, producing a surface-warming effect by trapping heat and energy that might otherwise escape into outer space.

Clouds are made of condensed water vapor and can be found primarily in the troposphere. Credit: NASA photo/Dominic Hart

COMMERCIAL JETLINER

he average commercial jetliner flies at altitudes between 32,000 and 39,000 feet (9.8 and 11.9 kilometers), depending on the flight route. Without pressurizing the cabin with additional air, humans would not be able function at this altitude. Pilots and passengers would suffer from hypoxia, a condition where the body does not receive enough oxygen. Lower levels of hypoxia can cause lightheadedness, poor judgement, inattentiveness, memory loss, and a loss of coordination. Higher levels of hypoxia can lead to coma, seizures, and even brain death. To prevent this, cabins are pressurized to the equivalent air pressure of 8,000 feet (2.5 kilometers) above sea level or lower. In comparison, Denver, Colorado is 5,280 feet (1.6 kilometers) above sea level. Some newer aircraft such as the Boeing 787, known as the Dreamliner, are pressurized to the equivalent of 6,000 feet (1.8 kilometers) above sea level. Increasing the air pressure decreases the number of people who feel some of the milder effects of hypoxia.

The Federal Aviation Administration, or FAA, regulates flight in the United States. According to FAA regulations, pilots in unpressurized aircraft are required to use supplemental oxygen at all times if flying above 14,000 feet (4.3 kilometers). Above 15,000 feet (4.6 kilometers), all occupants must have supplemental oxygen without additional cabin pressurization.

If you have ever taken a full, closed water bottle with a straw up a mountainside or in an airplane, you were probably squirted with water when you opened the bottle. That is because the air pressure inside the bottle equals the air pressure outside the bottle while at the lower altitude. As your altitude increases, the air pressure outside the bottle decreases; but, pressure stays the same on the inside of the bottle, leading to a higher pressure inside the bottle than outside it. When you open the bottle, the higher air pressure inside the bottle pushes its way out of your straw—along with the water.

The pressure changes also affect your ears. When you increase in altitude, the higher air pressure still inside your ears pushes its way out. When it comes out, your eardrums “pop.” After that pop, the air pressure inside your ears becomes the same as the air pressure outside your ears. This popping does not harm your ears (in fact, it keeps them safe). Ear drums are more like flaps, and are designed to accommodate changes in pressure.

Winglets on the wings of commercial airliners help improve fuel efficiency. Credit: NASA photo

COMMUNICATION SATELLITE

A communication satellite is an artificial satellite orbiting Earth. It uses a transponder to receive communication signals, amplify them (make them stronger), and then retransmit them. This enables the signals to cover much larger distances than they otherwise could. When transmitting on Earth's surface without the assistance of a satellite, the range is limited by Earth's curvature.

Communication satellites are used for radio, television, internet, phone, and more. They have made worldwide communication possible.

A communication satellite orbits the Earth at altitudes ranging from 100 to 22,000 miles (160 to 36,000 kilometers). The highest of these satellites are geostationary, meaning that they always stay above the same spot on Earth. This is done by matching the satellite's orbital speed with the speed of the Earth's rotation. Having the satellite remain above the same spot on Earth makes it much easier to locate. For example, for satellite television, an antenna can be mounted and pointed at the location of the satellite. If the position of the satellite changed, the antenna would have to constantly move to stay connected.

This 4.5-ton Intelsat VI communications satellite is being deployed. Credit: NASA photo

ER-2

NASA currently operates two Airborne Science ER-2 airplanes from its Armstrong Flight Research Center in California. These planes serve as platforms for a range of high-altitude science missions flown over different parts of the world. They can collect information about Earth resources, atmospheric chemistry and dynamics, and oceanic processes. They also are used for celestial observations, electronic sensor research and development, satellite calibration, and satellite data validation.

The ER-2 is extremely valuable for scientific research because of its ability to fly in the lower stratosphere at subsonic (slower than the speed of sound) speeds. At these speeds, it can sample air in the atmosphere and spend more time over an area conducting experiments. Most other planes that can fly at these high altitudes travel much faster.

High altitude aircraft such as NASA's ER-2 research aircraft fly at altitudes between 65,000 and 70,000 feet (20- and 21 kilometers). This is high enough to see the curvature of the Earth below and the darkness of space above. In 1998, the ER-2 set a world record for medium weight aircraft when it reached an altitude of 68,700 feet (20.9 kilometers).

Without wearing a full pressure suit, humans could not survive at this altitude. The full pressure suit is a fully-contained environment. It provides pressure to allow the body to function normally, as well as oxygen to breathe. A pilot eats food and drinks water through a straw inserted through a one-way valve in the pilot's helmet that keeps air from escaping the helmet.

NASA operates two Airborne Science ER-2 aircraft for a wide variety of environmental science, atmospheric sampling, and satellite data verification missions. Credit: NASA photo/Carla Thomas

U.S. Navy F-35 flying near Lemoore, California. Credit: U.S. Navy photo/Chief Mass Communication Specialist Shannon E. Renfroe

FIGHTER AIRCRAFT (F-35)

Fighter aircraft are used by the military to help protect the country. Most of these planes are stationed at air bases around the world. The U.S. Navy, however, can also launch and land figher aircraft from large ships called aircraft carriers.

These planes are designed to fly at high speeds and are extremely maneuverable. Fighter pilots undergo years of intense training before being certified to fly these aircraft.

A fighter aircraft is designed to fly at different altitudes, depending on the situation. It can fly very low to the ground when it needs to and, for fighter aircraft like the F-35, it can fly as high as 60,000 feet (18 kilometers). Above that altitude, there is not enough air for the engines to operate or for pilots to survive without full pressure suits.

A fighter pilot wears a partial pressure suit, or a “g-suit,” which exerts pressure on specific parts of a pilot’s body, such as their lungs, allowing the body to function properly. Without these suits, pilots would be at risk of becoming unconscious from not enough blood getting to their brains. They also wear an oxygen mask when flying above 14,000 feet (4.3 kilometers).

NASA Pilot Nils Larson wears a U.S. Navy harness configuration including the g-suit. Credit: NASA photo/Carla Thomas

HANG GLIDER

Birds are well suited for gliding through the air, riding on the air currents that push it upward or downward. Humans, on the other hand, cannot naturally do the same thing. But, with the help of hang gliders, we can experience what this feels like.

Hang gliders are non-powered aircraft composed of an airframe and sailcloth. The triangular airframe is usually made of a lightweight metal such as aluminum alloy or a composite material. The sailcloth covers the frame and is made of special material which is lightweight but strong.

Hang gliders are engineered to allow the rider, who is suspended from the airframe, to glide as far as possible. In fact, the record for the longest straight distance flown by a hang glider is over 450 miles! They are also designed to take advantage of upward moving currents in the atmosphere, called updrafts, to move the glider higher than its takeoff point. It is not uncommon for hang gliders to reach altitudes of 12,000 to 15,000 feet (3.7 to 4.6 kilometers).

Although attempts were made to create efficient hang gliders for many years, it wasn't until Francis Rogallo, a former NASA engineer, created his "flexible wing" in the 1940s that it became feasible. NASA even looked into using Rogallo's design for landing spacecraft before eventually going with circular parachutes instead.

Hang gliders can carry passengers long distances without being powered. Credit: NASA photo/Sean Smith

HELICOPTER

A helicopter is a type of aircraft that uses rotating or spinning wings (called blades) to fly. Unlike an airplane or glider, a helicopter has wings that move. Unlike a balloon, a helicopter is heavier than air and uses an engine to fly.

To fly, an object must have lift, or a force pushing it upward. Lift is usually made when air flows over an airplane's wings. A helicopter's rotor blades are actually wings that create lift by spinning. As they spin, the air that moves over them creates the lift. An airplane must fly fast to move enough air over its wings to create lift, but a helicopter moves air over its rotor blades by spinning them.

The helicopter's rotating blades, or rotor, allow it to do things an airplane cannot. Unlike an airplane, a helicopter does not have to move quickly through the air to create lift. That means it can move straight up or down. A helicopter can also takeoff or land without a runway. It can fly backwards or sideways and turn in the air in ways airplanes cannot. It also can hover in one spot in the air without moving. This makes helicopters ideal for many missions an airplane cannot do. For example, a helicopter can pick up someone with a medical problem where there is no runway; it can then land in a small area on top of a hospital.

Helicopters can fly as high as 25,000 feet (7.6 kilometers), although they cannot hover above about 11,000 feet (3.4 kilometers) without the help of air currents. Above these heights, the air becomes too thin to create the needed lift.

NASA conducts research on ways to improve helicopter performance and safety. Crash tests help NASA study how new materials can keep passengers safe in the event of a crash. Wind tunnel tests determine how to make helicopters quieter and more fuel-efficient. New ideas could help engineers create bigger, better, and faster helicopters. Someday helicopters could carry 100 people on trips of 300 miles (483 kilometers) or more. NASA is even sending a helicopter to fly on Mars!

Source: https://www.nasa.gov/audience/forstudents/5-8/features/nasa-knows/what-is-a-helicopter-58.html

Helicopters use either one or two sets of rotor blades to create lift. Credit: NASA photo/Ken Ulbrich

HOT AIR BALLOON

On a cool autumn morning, you might be able to see a hot air balloon rising into the air. Why do you see hot air balloons in the morning? And why do you see them in autumn?

Hot air balloons need to be filled with air that is warmer than the air outside of the balloon, or it will not be able to rise into the air. As air warms, the molecules move faster, causing the air to expand and become less dense. Less dense air rises above cooler, denser air. When a hot air balloon is filled with air that is less dense than the air surrounding it, the balloon will rise. Morning air is cool and dense near the ground, which makes it a great time to launch a hot air balloon. And, the air temperatures in autumn are cool, but the weather is usually still good enough to fly.

Balloons usually rise to between 1,200 and 2,000 feet (0.4 and 0.6 kilometers) above Earth's surface. If balloonists want their hot air balloons to go higher, they ignite a flame which further heats the air inside the balloon. If they want the balloon to sink, they extinguish the flame or can even open vents in the side of the balloon to allow some of the warmer air to escape. Once the outside air gets too warm, it is too difficult to keep the air inside the balloon warmer than the outside air, and the balloonist must find a safe place to land. A partner who drives a vehicle that chases the balloon can then meet up with the balloonist and help them pack up the balloon, the gondola (or wicker basket people ride in), and the fuel tanks.

It might seem like a balloon filled with gas would be very light, but even gases have mass. An average balloon, fuel tanks, and gondola weighs about 800 pounds (360 kilograms) before it is inflated. However, once inflated, the gear and the air inside the balloon can weigh up to 2½ tons! Larger balloons that are made in special shapes can weigh even more.

Hot air balloons use hot air with low density to make it climb in altitude. Credit: NASA photo/Bill Ingalls

Specially shaped balloons such as this are extremely heavy Credit: NASA photo/April Lanotte

HUBBLE SPACE TELESCOPE

In 1609, Italian scientist Galileo Galilei used the newly invented optical device of his day — the telescope — to view the heavens. His observations conclusively showed that there were celestial bodies that did not revolve around the Earth, launching a revolution that forever changed our view of what was previously thought to be an Earth-centered universe.

Almost four centuries later, the launch of NASA's Hubble Space Telescope in 1990 aboard the Space Shuttle Discovery started another revolution in astronomy. Developed as part of a partnership between the United States' space program and the European Space Agency, Hubble orbits 340 miles (550 kilometers) above Earth's surface. Its outward gaze lies beyond the distorting effects of the atmosphere, which blurs starlight and blocks some important wavelengths of light from reaching the ground. This vantage point allows Hubble to observe astronomical objects and phenomena more consistently and with better detail than generally attainable from ground-based observatories. The telescope's sensitive cameras and spectrographs can view nearby objects like the collision of asteroids as well as distant objects like star-forming galaxies that date back to when the universe was only three percent of its current age. In fact, Hubble observations have played a key role in discovering and characterizing the mysterious dark energy that now appears to permeate space. Results like these have changed our fundamental understanding of the cosmos.

Source: https://www.nasa.gov/content/goddard/2017/highlights-of-hubble-s-exploration-of-the-universe

The Hubble Space Telescope hovers at the boundary of Earth and space in this picture, taken after Hubble's second servicing mission in 1997. Credit: NASA photo

INTERNATIONAL SPACE STATION

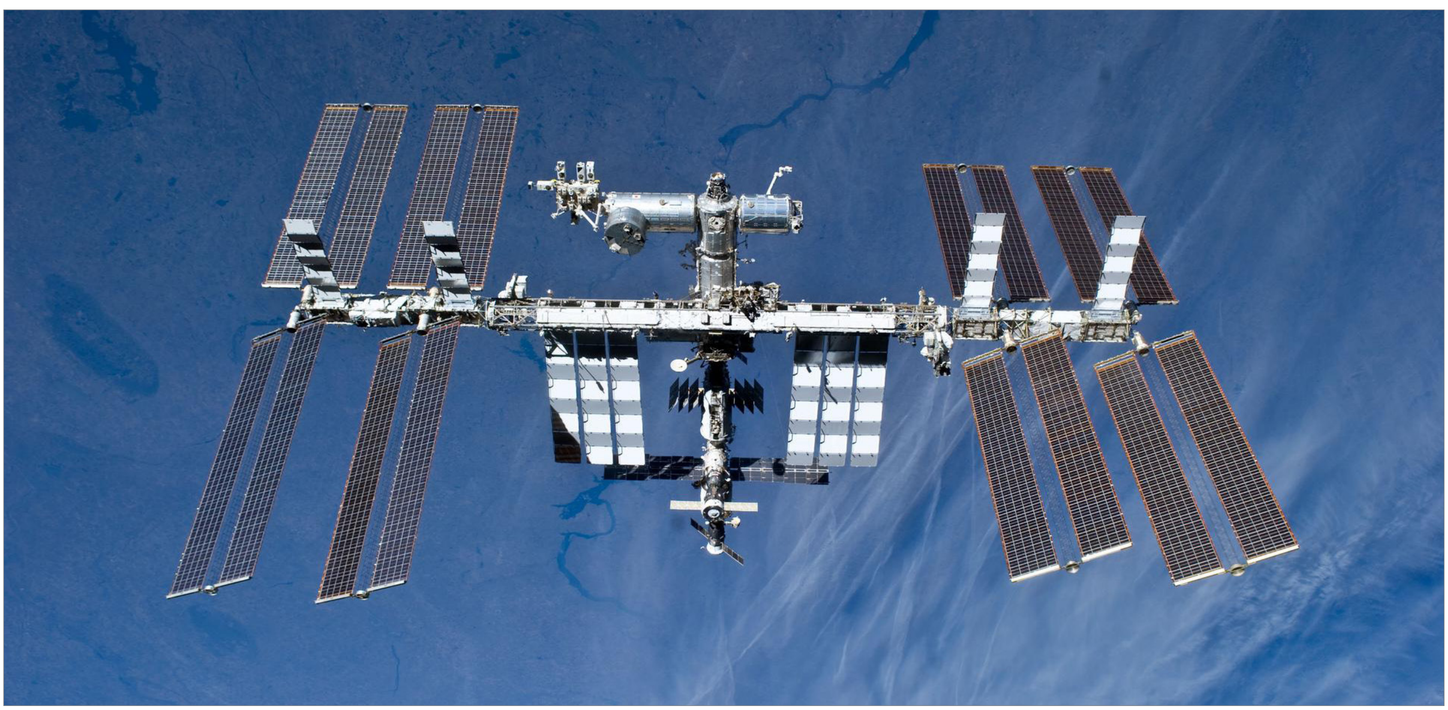
The International Space Station, or ISS, is a large spacecraft orbiting the Earth which has been permanently occupied since November 2, 2000. The ISS is made up of modules built by different countries and assembled in space by astronauts. Although NASA leads the ISS project, over 15 different countries have contributed to its construction and operation.

The ISS orbits the Earth in space, but space is not as easy to define as you think. Years ago, space was defined as anything more than 50 miles above Earth's surface. But after learning more about Earth's atmosphere, the newer definition of where space begins is about 62 miles (100 kilometers) above sea level. The ISS orbits at an average altitude of 250 miles (400 kilometers) and travels at 17,500 miles per hour.

Even though the ISS is within Earth's thermosphere, NASA still considers it to be in space. Astronauts need to wear spacesuits when they are outside the station to protect them from the extreme temperatures, the lack of air, solar radiation, and tiny pieces of debris which orbit Earth.

The ISS has benefited society in many ways. Having a constant presence in space has made it possible to study the effect of microgravity on humans and other organisms. The station serves as a huge science laboratory with conditions that cannot be replicated on Earth. Experiments conducted there have led to new medical procedures and continue to lead to a wide range of spinoffs, or things we use on Earth that are based on technologies used on the ISS. It has also been an educational tool because astronauts have worked with students around the world in different ways.

Note: You can learn more about spinoffs at http://spinoff.nasa.gov and https://www.nasa.gov/homeandcity.



The International Space Station uses several solar panels to generate the power it needs. Credit: NASA photo

JAMES WEBB TELESCOPE

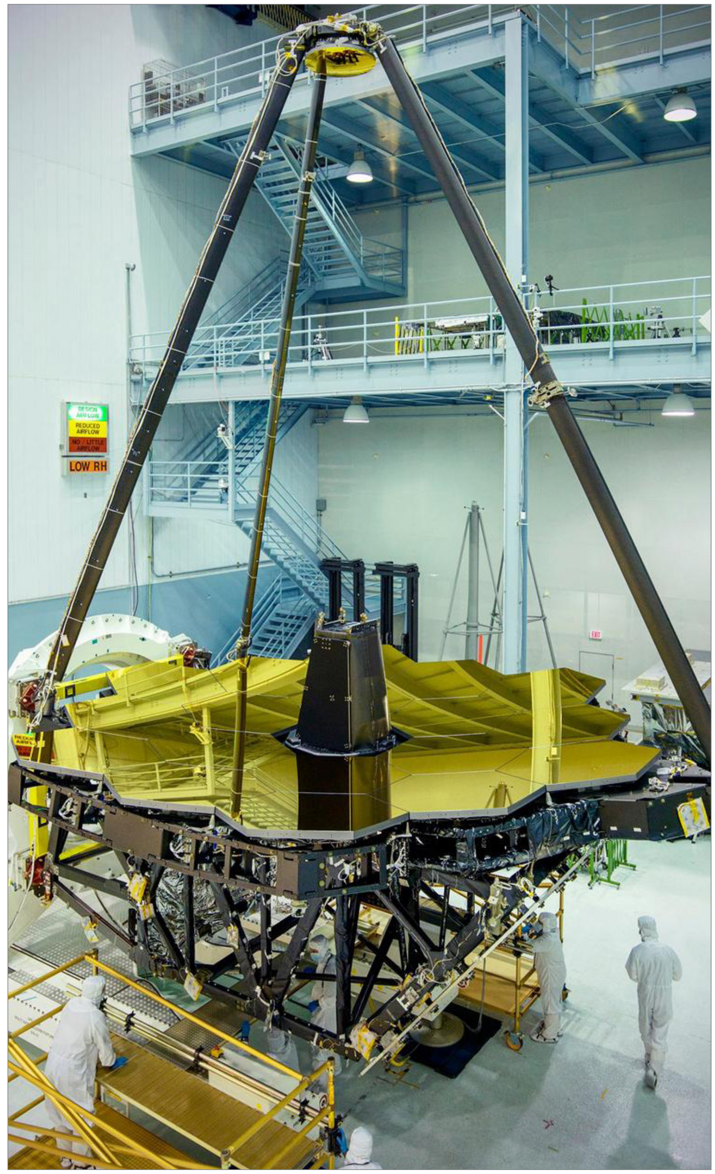
Telescopes provide scientists and hobbyists with the ability to view far away objects in space. To see objects that are further away, bigger and better telescopes are used. Observing anything in space from Earth has limitations due to light, cloud cover, and the refraction (or bending) of light rays as they pass through the atmosphere. To combat these issues, scientists use space telescopes located far above Earth's surface.

NASA and its international partners are working on the James Webb Space Telescope (sometimes called JWST) which will be the most powerful space telescope ever built. It is a large infrared telescope that uses a 21.3-foot (6.5 meters) mirror to gather visible light and infrared rays.

The telescope is scheduled to be launched on an Ariane 5 rocket from French Guiana in 2021. It will not be in orbit around the Earth - it will instead orbit the Sun, 930,000 miles (1.5 million kilometers) away from Earth. This is a special location, known as a Lagrangian point, where the gravitational pull of the Earth and the Sun are perfectly balanced by the centrifugal force of an object's orbit. When the JWST moves to this point, it will stay there without having to correct its course, thereby providing better astronomical observations. Orbiting in this location also shields the telescope from the Sun's rays, which is important because it is designed to operate at a temperature just above absolute zero.

The JWST is so powerful that scientists worldwide will be able to see objects that are millions of light years away. It promises to provide insight to the formation of the universe.

JWST was formerly known as the Next Generation Space Telescope; it was renamed in September 2002 after former NASA administrator James Webb.



The golden mirror is a major part of the James Webb Space Telescope. Credit: NASA photo/Chris Gunn

LUNAR GATEWAY

When astronauts visited the Moon in the late 1960s and early 1970s, the historic visits were brief. Even so, scientists learned a great deal with the samples and data that were brought back. When we go back to the Moon again with the Artemis program, it will be to establish a permanent presence on the Moon. The Lunar Gateway is an important part of this strategy.

The Gateway will be a small spaceship orbiting the Moon. This puts it about 239,000 miles (384,000 kilometers) away from Earth. Much like the International Space Station, it will have living quarters, science labs, and docking ports for visiting spacecraft. Even though it will not be continuously occupied, NASA and its partners will send people there on a regular basis to work, train, and shuttle down to the Moon's surface. The Gateway will initially be a base for visiting the Moon, but eventually it will also serve as a staging point for people visiting Mars.

NASA wants to use the Gateway as a science platform to look back at the Earth, observe the Sun, and get unobstructed views of different parts of the universe. Also, by studying the geology of the Earth, the Moon, and Mars to find ways in which they are similar and different from each other, we can learn important things about how planets form and change over time.

The lunar gateway will orbit the Moon. Credit: NASA/JPL/USGS

METEORS (SHOOTING STARS)

Have you ever seen a shooting star? Do you know what these are or where they are located?

Actually, shooting stars are not stars at all. They are meteoroids from space that enter Earth's atmosphere. Meteoroids are small broken off pieces of asteroids or comets.

As they enter the atmosphere at high speeds, they encounter air resistance from the gas molecules of Earth's atmosphere. This causes them to heat up to extremely high temperatures; subsequently, most of them burn up high in the atmosphere. When they burn up, they often create a streak of light across the sky. As they travel through the atmosphere, they are called meteors, the scientific term for a shooting star.

Meteors usually burn up in Earth's mesosphere. The faster the meteor hits the atmosphere, the sooner and higher in the atmosphere it will start to glow. That is because it creates more friction (like rubbing your hands together quickly). Faster moving meteors show up 60 miles (97 kilometers) in altitude. Slower-moving meteors get as low as 40 miles (65 kilometers) in altitude before beginning to burn.

If a meteor is able to survive all the way to Earth's surface, the piece that lands is called a meteorite. Meteorites provide scientists with evidence for studying space.

This time lapse photo shows some of the meteors from the Perseid meteor shower. Credit: NASA/JPL photo

MODEL ROCKETS

If you've ever built and launched a model rocket, it was probably exciting to see it take off into the atmosphere. But how high did it go?

A basic model rocket you buy at a hobby store is also known as a low-powered rocket. It typically weighs about 1 ounce (28 grams). Depending on what kind of engine you put into the rocket, your rocket will usually reach an altitude between 190 and 1,000 feet (0.06 and 0.3 kilometers). In the United States, the National Association of Rocketry defines a model rocket as "one that is made out of paper, wood, plastic, and other lightweight materials."

For high-powered model rockets, there are different rules to follow and some of those rockets can reach altitudes of up to 9,000 feet (2.7 kilometers). They are heavier than model rockets (they must weigh at least 53 ounces or 1,500 grams) and are made of stronger materials than model rockets. People who launch high-powered rockets need to get permission from the Federal Aviation Administration, or FAA, before they can fly them. The FAA needs to make sure these rockets do not get in the way of manned aircraft.

A model rocket is launched at the Marshall Space Flight Center. Credit: NASA photo/Emmett Given

MOUNT EVEREST

Mount Everest rises 29,029 feet (8.8 kilometers) above Earth's surface, making it the highest point on Earth. That is higher than many of the other objects your classmates are learning about right now! Without special training and equipment like oxygen masks, climbers who climb to the peak of Mount Everest cannot survive.

When climbing to the top of Mount Everest, climbers first stay at the base camp. This is located part of the way up the mountain to let climbers' bodies adjust to changes in atmospheric pressure before continuing to the summit. Here are some of the reasons why. When first climbing to higher altitudes, a person's heart rate increases, and they breathe faster and deeper. Their hands, feet, and face swell, and they have trouble sleeping. Once their bodies get used to higher altitudes, those symptoms go away. Once a person is above 26,000 feet (7.9 kilometers) in altitude, they cannot acclimatize, or get used to being at that altitude, without extra support including supplemental oxygen.

Flying to the summit of Mount Everest is extremely challenging. There is not enough room for a fixed wing aircraft to land at the peak, and helicopters typically cannot fly above 25,000 feet (7.6 kilometers). However, in 2005, a French pilot named Didier Delsalle made history by becoming the first person to land atop Mount Everest. He used updrafts, or upward moving air currents that often occur near large mountains, to help fly his Eurocopter AS350 helicopter to the top where he landed for nearly four minutes before flying back down.

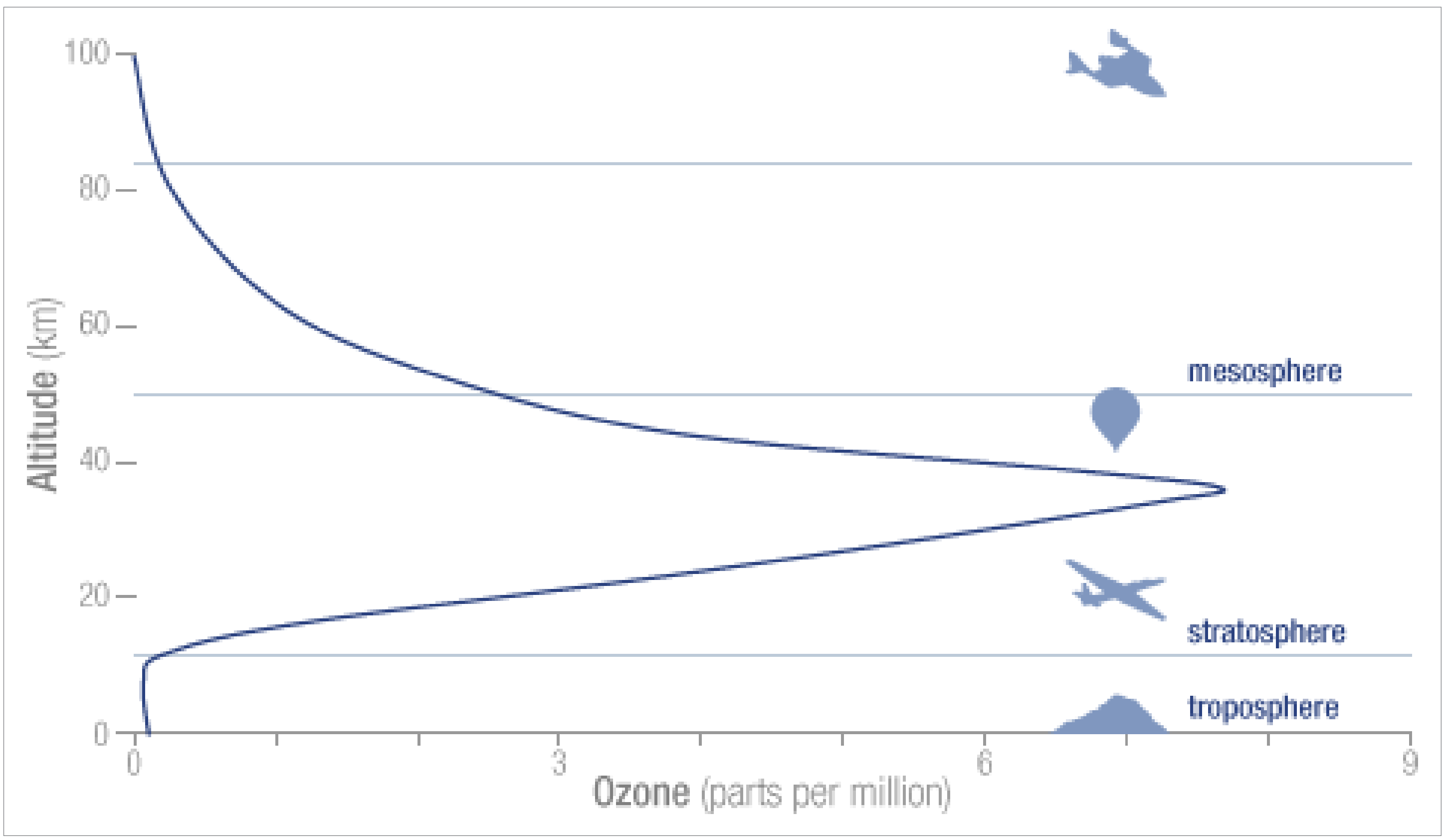
Mount Everest as seen from the International Space Station. Credit: NASA Photo

THE OZONE LAYER

Ozone is a colorless gas that naturally occurs high in our atmosphere. It is found in the stratosphere between the altitudes of 10 and 30 miles (24 and 48 kilometers). Since ozone is important for human safety on Earth, NASA helps monitor the amount of ozone in the stratosphere using satellite and plane-based instruments.

Made up of three oxygen atoms, ozone readily reacts with other substances. It also reacts with sunlight, effectively blocking some of the Sun's dangerous ultraviolet-B rays from reaching Earth's surface. These rays can lead to health problems for humans while also heating up Earth's surface.

Certain chemicals, called CFCs, that are used here on Earth can rise into the stratosphere and interfere with the reaction between ozone and sunlight. This damages the ozone layer, allowing ultraviolet rays to penetrate the atmosphere and reach Earth's surface. Once scientists discovered the dangerous effect of CFCs, their use was largely banned. As a result, the damage to the ozone layer has slowly decreased.



This graph shows the amount of ozone found in different layers of the atmosphere. Credit: NASA Ozone Watch

PARACHUTISTS

Gravity is a force throughout the universe that pulls objects together. The larger and closer an object is, the stronger its gravitational pull is on another object. For us, the Earth is very large and very close, explaining why its gravity affects us so much. A person or object in the air gets pulled toward the Earth.

Parachutists are people who use parachutes to slow their fall through the atmosphere. The reason parachutes slow the fall of a parachutist is air resistance. As an object or person moves through the atmosphere, it hits air molecules and pushes on these molecules. According to Newton's first law, every action has an equal and opposite reaction. This means that the air molecules also push back on the object, causing it to slow down slightly. If the object is larger, it hits more air molecules and gets slowed even more. The weight of the object also affects how much it is slowed – lighter objects are easier to slow down.

Parachutes are designed to be large and light so that air resistance greatly affects it. This means that the parachute, as well as the person attached underneath it, slows down. Without a parachute, a person falling from high in the atmosphere would be travelling at around 300 miles (483 kilometers) per hour when they reached the ground. At this speed, the fall would be fatal. But, with a standard parachute, a person is only travelling at around 17 miles (27 kilometers) per hour when they reach the ground.

A typical parachutist jumps from a plane at around 13,000 feet (4 kilometers). At this altitude, the only equipment required (aside from the parachute) is eye protection and a jacket.

High-altitude parachutists can jump from much higher, but need to wear special pressure suits due to the lack of oxygen. The highest jump for a parachutist was 135,908 feet (41.4 kilometers) by Dr. Alan Eustace in 2014.

Pararescuemen from the U.S. Air Force's 414th Combat Training Squadron jump as part of a training exercise. Credit: U.S. Air Force photo/Master Sgt. Kevin Gruenwald

SMALL AIRPLANE (CESSNA)

Small, single-engine, personal aircraft such as a Cessna 172 (the most popular single-engine aircraft ever built) typically operate anywhere between 2,500 and 9,500 feet (0.8 and 2.9 kilometers), depending on the specific type of aircraft and its use. They are designed to be used in different situations.

A common flight certificate that pilots in the United States earn is the Airplane, Single Engine, Land certificate, which certifies that the pilot holds a license for flying a fixed-wing aircraft with one engine that only lands on land. Licenses and certifications for flying helicopters or seaplanes must be earned separately. A pilot will be certified at a privilege level such as a student pilot, sport pilot, private pilot, and commercial pilot. They are then rated to fly specific categories of aircraft that include airplane, glider, rotorcraft, or lighter than air; each category then contains sub-categories.

Small airplanes like this Cessna Citation usually fly at altitudes between 2,500 and 9,550 feet. Credit: NASA photo/KSC

SMALL UNMANNED AERIAL VEHICLES

How would you like to look out your window and see a flying taxi go by? Wouldn't it be great to have a package delivered to your home by a self-flying drone?

NASA is leading the nation to quickly open a new era in air travel called advanced air mobility, or AAM. The vision of AAM is that of a safe, automated, accessible, and affordable air transportation system for passengers and cargo in both urban and rural locations.

Many of the aircraft operating in this new system are small unmanned aerial vehicles, or UAVs. As the name implies, small UAVs do not have pilots onboard. Instead, many of them fly autonomously.

Small UAVs typically fly below 400 feet (0.1 kilometers) over densely populated areas. It is important that they stay below 400 feet so as not to interfere with larger planes and helicopters that fly higher than that. Flying so low over cities presents numerous challenges for which NASA and its partners are developing technologies to overcome.

Small UAVs are capable of performing many different tasks. They can be used to transport objects, make aerial observations, and more. Some farmers, for example, use them to check on their crops or even to spray fertilizers and pesticides on their fields. As small UAVs become more popular, more uses for them will emerge.

Small quadcopter drones like this can be modified to carry packages and other items. Credit: NASA photo/Dominic Hart

SOUNDING ROCKET

Sounding rockets are rockets launched high into Earth's atmosphere or into space to conduct high-altitude experiments, without ever attaining orbit around Earth. Used by NASA for over 40 years, these rockets can reach an altitude of approximately 75 miles (120 kilometers) and are in space from 5 to 20 minutes, depending on the trajectory. The experiments they hold can be extremely helpful because they can research aspects of Earth's atmosphere that are too low for satellites to operate in. Sounding rockets are also less expensive to operate than larger rockets, making it possible for many different experiments (including student experiments) to be conducted. Several different experiments can be included in one launch.

Sounding rockets are unmanned, so there is no specific human requirement for sounding rockets besides the large number of ground crew who support their launch and recovery. Sounding rockets land in the ocean for safety, so boat crews are also needed to help with recovery operations.

A NASA Oriole IV sounding rocket is launched from Alaska. Credit: NASA Goddard photo/Lee Wingfield

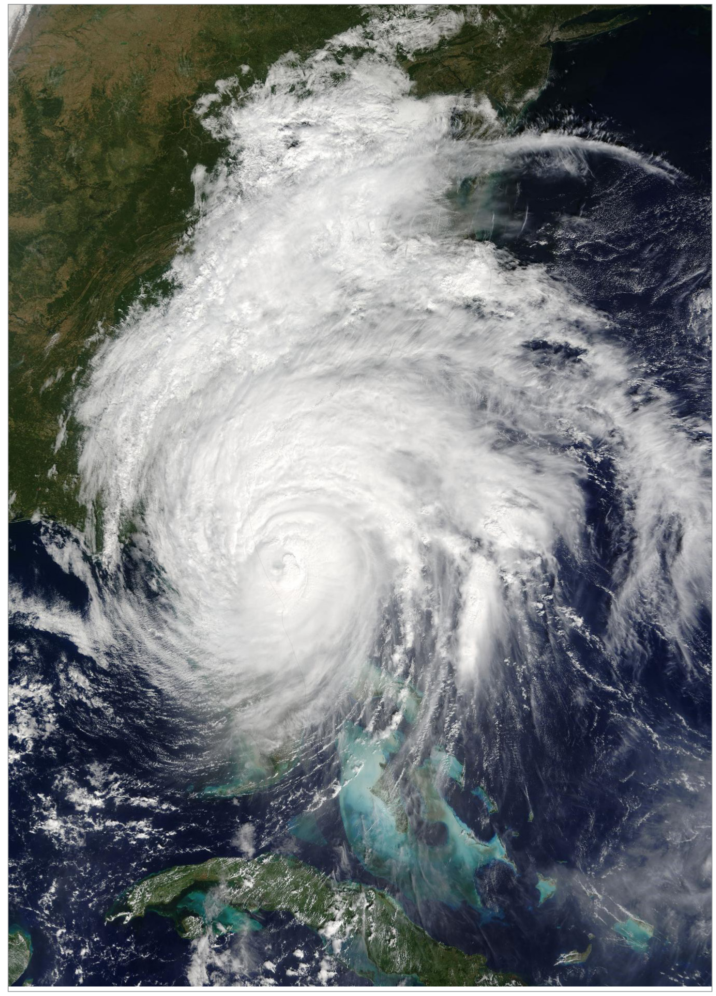
WEATHER

Wind, rain, snow, hurricanes, and tornadoes – these are just a few examples of weather that you might experience where you live. Weather is defined as the state of the atmosphere at a specific place and at a specific time. It can change quickly and is what you would experience if you went outside.

Climate, on the other hand, refers to expected weather in an area over a long period of time. For example, if you go to northern Maine in January, you expect that it will be cold. This is the climate. On a given day in January, you might find that it is actually warm in northern Maine. This is weather. Another way to explain the difference between weather and climate: climate is what you would expect to experience, and weather is what you actually do experience.

Weather occurs throughout the troposphere, the lowest layer of the atmosphere (up to about 9 miles or 14 kilometers). The relatively small amount of air above that precludes weather from occurring in the other layers of the atmosphere.

Weather is an important consideration for all the other objects found in the troposphere. Flying unmanned aerial vehicles, airplanes, hot air balloons, etc. can be extremely dangerous if weather conditions are bad.



This aerial photograph of Hurricane Matthew over the southeastern United States was taken by a NASA satellite. Credit: NASA's Goddard MODIS Rapid Response Team

WEATHER BALLOON

There are several different high-altitude balloons, but the most common type is a weather balloon. Large weather balloons are often filled with helium and can rise to around 25 miles (40 kilometers) in altitude. They are inexpensive and can carry sensors and other scientific instruments on them without having to carry people. These instruments send the information collected back down to a receiver on the ground. Weather balloons are usually made from latex and expand in size as they rise into the atmosphere. Eventually, when the balloon expands too much, it breaks, sending the sensors and other parts of the balloon back to Earth. GPS tracking devices help scientists track the balloon while it's in the air and locate it once it lands.

Other high-altitude balloons rise even higher in the atmosphere. Some can get up to 120,000 feet (37 kilometers) in the air! Such high-altitude balloons can be 400 feet (122 meters) in diameter, which is much larger than a weather balloon. A weather balloon's diameter is anywhere between 6 to 40 feet (1.8 to 12 meters).

Weather balloons and other high-altitude balloons need to be launched when the air is calm because they can break if it's too windy. They also need to be launched from an open area, where they won't get caught in trees, power lines, buildings, or anything else that might get in the way.

A researcher prepares to launch a weather balloon at Summit Station in Greenland. Credit: ARCUS photo

X-57 MAXWELL

Electric cars are becoming more prevalent because they help protect the environment. The technology continues to improve, making them more reliable. But, have you ever heard of an electric airplane large enough to carry passengers?

One of NASA's newest experimental planes, or X-planes, is the X-57 Maxwell. This plane is the first all-electric X-plane capable of carrying people and is designed to demonstrate the validity of electric propulsion for airplanes. The goal is for quieter flight with increased cruising efficiency and zero emissions.

The X-57 has a cruising speed of 172 miles (276 kilometers) per hour at a height of 8,000 feet (2.4 kilometers) and that is where it will usually fly. It is, however, capable of reaching a maximum altitude of 14,000 feet (4.3 kilometers).

To fly the plane, 860 pounds of batteries provide power to two large propellers and 12 smaller ones. The reason for having so many propellers is to produce the needed lift at takeoff. Once the plane reaches cruise mode, the 12 smaller propellers stop rotating and fold in to reduce drag. The two large propellers on the wingtips then maintain flight. Prior to landing, the smaller propellers reengage to once again produce lift.

The X-57 Maxwell uses batteries to power its 14 propellers. Credit: NASA Graphic / NASA Langley/Advanced Concepts Lab, AMA, Inc.

X-59 QUESST

Back in 1947, Chuck Yeager piloted the very first X-plane and broke the sound barrier. This means the plane flew faster than sound could travel. The X-1 flew at Mach 1.05, or 1.05 times the speed of sound (approximately 770 miles per hour).

As technology progressed, planes were capable of flying even faster. But, there was one major drawback – sonic booms. When a plane breaks the sound barrier, pressure waves build up. These waves create a very loud noise called a sonic boom that can be both heard and felt on the ground. They are so strong that they have been known to set off car alarms and rattle windows.

As a result of the damage sonic booms can cause, supersonic flight, or flight faster than the speed of sound, is not allowed over land for anyone except the military. NASA's newest X-plane, the X-59 Quiet Supersonic Technology (or X-59 QueSST), is designed to fly at supersonic speeds without producing such loud sonic booms. Instead, it produces a series of much quieter sonic thumps that should be no louder than the sound of a car door closing.

Thanks to extensive designing and engineering, the X-59 is designed to fly at Mach 1.4 (940 miles or 1,513 kilometers per hour) at an altitude of 55,000 feet (16.8 kilometers).

Once the plane has been completed and deemed safe to fly, it will conduct flights over selected communities across the United States. Data will be scientifically gathered to measure the impact of and reaction to the sonic thumps. This data will then be presented to U.S. and international regulatory agencies to work toward the approval of supersonic flight over land. The technology NASA developed for the X-59 will be shared with partners to help them develop their own supersonic aircraft.

The X-59 QueSST can reach speeds of Mach 1.4 without producing harmful sonic booms. Credit: NASA Graphic

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