Hands on Astronomy Activity 4

Topic: Designing a Planet
Learning Objective: Give students an understanding of how scientists here on Earth are able to use technology to determine the characteristics of planets and moons out in the Solar System.

Alignment with NGSS Grades 3-5
Science and Engineering Practices
Developing and using Models 3-5

- Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events.
- Develop and/or use models to describe and/or predict phenomenon.

Crosscutting Concepts and Connections to Engineering, Technology, and Applications/Applications of Science Interdependence of Science, Engineering, and Technology

- Science and technology support each other.
- Tools and instruments are used to answer scientific questions, while scientific discoveries lead to development of new technologies.

Materials:

- Pencil
- Paper

Detailed Description

- Introduction
    - Questions for students
        - What is the weirdest, most alien, eye-popping place you can think of?
    - Strange destinations
        - Ask students to ponder these destinations
            - Clouds rain gasoline, forming hugelakes.
            - Volcanoes spew red-hot lava and the sky is full of poisonous sulfur gas.
            - As far as you can see in all directions is bright white ice, broken only by dark, rough rivers of moreice.
            - It is far colder than Earth’s South Pole all the time.
            - It’s hot enough to melt lead and the atmosphere weighs down on you as if you were diving far beneath the ocean’s surface.

        - These would not be healthy places for humans or just about any other Earthlings. But, believe it or not, all these environments are real places in our own solar system. They are, in order:
            - Titan (moon of Saturn)
            - Io (moon of Jupiter)
            - Europa (moon of Jupiter)
            - Mars, Pluto, and most places in the solar system
            - Venus
        - No person has ever visited any of these places, so how do we know what they are like? Because we have sent our technological “spies” to investigate, and they have faithfully reported back their often surprising findings.
    - Explanation
        - We have sent light sensors, image makers, rock sniffers, matter analyzers, magnetic field sensors, temperature detectors, particle counters, pressure indicators, and sample collectors. These instruments, for the most part, have given us information that even our own five senses would not be able to tell us had we gone to these places personally—that is, if we could survive and operate in these harsh surroundings, which we couldn’t.
        - All the instruments we have sent into space were designed and built especially to operate in these harsh, alien environments. They are tough enough to withstand huge temperature extremes, intense radiation, and the vacuum of space. They are sturdy enough to withstand the bone rattling vibration of being blasted off the surface of Earth on a rocket.
        - How do NASA engineers know what kinds of planetary instruments to develop in the first place? Well, they ask. What do scientists want to know about space and about alien worlds? And, once engineers know the questions to be answered, they use their know-how, ingenuity, and imaginations to come up with the kind of “sense enhancer” that will get the right kind of information and be tough enough to survive its task.
        - Here on Earth, we ordinarily get our information through our five senses: seeing, hearing, smelling, tasting, and touching. The instruments that give us information about other worlds are, in a way, like our five senses, greatly enhanced and made quite portable and autonomous. One way to classify scientific instruments is by which sense they are most like. Table one describes some examples of instruments that are a bit like our eyes, ears, noses, tasting tongues, and touching fingers.

- Activity
    - Divide the class into two groups.
    - In each group, one person is the recorder, ready with paper and pencil.
    - Now, in each group, use your imaginations to create an alien world. Brainstorm! Your world can be a planet, a moon, or even an asteroid. Throw out wild ideas. The recorder, in addition to offering his or her own ideas, will write down everybody's ideas as they come up. It may be tempting to populate your world with strange, intelligent creatures and maybe even civilizations. However, for simplicity, stick to worlds with either no life forms or only very primitive ones (like bacteria or one-celled plants). And don't forget to give your world a name!
    - You could ask yourselves some of the questions below to get your imagination going.
        - Does the world have a solid surface, or is it a gas ball like Jupiter and Saturn?
        - How bright and what color is your world?
        - What is the material covering the surface?
        - Is there water on your world?
        - If so, is it frozen, liquid, or vapor? And where is the water?
        - What is the surface texture like? (smooth, cracked, cratered, mountainous, hilly, unusual formations,etc.)
        - How hot or cold is the surface?
        - How much does the temperature differ on the day and night sides?
        - Does it have seasons?
        - Is there an atmosphere?
        - What kind of gases are in the atmosphere?
        - Are there clouds?
        - Is the surface hard packed or loose and dusty?
        - Is the same material under the surface as on top?
        - Does it have a magnetic field?
        - What is in the sky? One sun? Two? Anymoons?
        - If your world is a moon of a bigger planet, what does the planet look like in the sky?
    - The recorder will now make a legible listing or narrative description of the agreed-on characteristics of your imaginary world, including its name! Someone may even make a cool sci-fi drawing of it.
    - Now, pick one person to represent the group. This person will describe the world you have designed to the rest of the class.

  - Once all the groups have shared their "designs," swap worlds! Pass your group's description to another group.
  - Put yourselves in the place of a team of scientists (including different kinds of scientists, such as astronomers, planetary geologists, or atmospheric chemists) from Earth who would like to learn more about this newly discovered world. Use Table 2 as a guide for how to design and describe your mission of discovery.
    - First, ask yourselves "What do we already know?" Select one or two questions from the list above to which you already know the answers.
    - Now, what do you want to know? Pick three to five questions from the list above. Then think about which type of instrument(s) (second column in Table 1) would help you find out the answers to these questions.
    - What would be the best type of mission that could use these instruments to answer these questions?
      - An orbiter that goes around and around a planet or moon, studying it for several months or years?
      - A lander, such as the Mars Rovers, that will explore the surface?
      - A flyby spacecraft that will study the planet or moon for just a few days as it passes, perhapson to several more "flyby"destinations?
      - A ground penetrator that burrows or drills under the surface?
      - Something else?
    - Now, assume the mission is accomplished. What did you learn?
    - What didn't you learn? Did the answers to the original questions bring up more questions? (This often happens in science!)
    - What would be a good follow-up mission for the future?
  - Get together as a whole class again, and have someone from each group present your team's space science mission, its findings, and what kind of mission should be done next.
- Conclusion
  - The worlds that nature has made may be even stranger than anything your imagination can dream up. It is important for NASA to keep developing new instrument technologies so that missions of exploration can gather information never before captured and in places never before visited.
  - NASA's Planetary Instrument Definition and Development (PIDD) Program has the job of picking and developing likely technologies that will help scientists to learn new things from future missions to explore the solar system. Some of the instruments are meant to be part of a spacecraft that will orbit or fly by a planet or moon or asteroid. Some are meant to be part of a spacecraft that will land on the surface of a mysterious world or penetrate beneath the surface.

- Developing a scientific instrument technology is, in a way, a mission on its own. Besides coming up with an idea, or a "new and improved" idea, for gathering needed science information, engineers try to make the technology as small, power-efficient, and low cost as possible. With computers and electronics shrinking in size and growing in capability all the time, spacecraft can be smaller and, therefore, less expensive to build and launch. But that means everything else that goes into the spacecraft, including the science instruments that are the "payload" must shrink too.
- Here are some of the new instruments and technologies the PIDD Program has developed so far:
    - Ice penetrating radar: Could be used on a mission to Jupiter's moon Europa, as shown in this artist's rendering, to find out the depth of the ice covering the surface and learn whether a liquid ocean lies below it.
    - Rock crusher and sorter: Could be used to prepare a rock or a core sample of the ground (drilled out by a different instrument), crushing it into fine particles for an x-ray spectrometer to analyze. Table 1 showed this instrument under"feelers."
    - New Aerogels: Aerogel is the lightest solid material ever made. It is 99.9% air. So far,the only material used for the other .1% has been silicate, which is like sand. This aerogel material was used by the Stardust mission to capture comet particles and return them to Earth for analysis. The trouble is, some of the comet particles were very similar to silicate and therefore hard to separate from the aerogel. So the PIDD program is developing some aerogels made of different materials not likely to be found in such samples. The photo above shows samples of some new aerogels under development.
    - Imaging spectrometer: This is a special instrument that can take a picture of something and analyze what substances are in it at the same time. This instrument has already found a use right here on Earth in diagnosing human eye disease.
- Without engineers working hard on these new kinds of instruments for planetary exploration, our knowledge and understanding of the solar system—and all the other solar systems out there—could not advance.
- You can read about another new kind of spectrometer that uses a laser and find out how laser light is different from ordinary light. Visit http://spaceplace.nasa.gov/en/kids/laser.

Table 1 - Kinds of Planetary Sensing Instruments

- Viewers (“eyes”)
    - For example, imagers, infrared radiometers
    - These would include any kind of imagers (sort of like fancy cameras) that detect light, including light our eyes cannot see, such as infrared and ultraviolet light. Imagers tell us about surface brightness, color, shape (topography), and texture.
    - One type of imager, an infrared radiometer, can measure the temperature of a surface based on how much infrared light (which we cannot see, but rather feel as heat) is being emitted.
- Listeners (“ears”)
    - For example, sounding radar (or sounders), imaging radar, profiling radar
    - There’s no sound in space, unless there’s an atmosphere to conduct the sound waves. But instruments called sounders or radars do listen, in a way. Sounders and imaging or profiling radars riding on a spacecraft transmit radio waves downward and then “listen” for echoes as the waves bounce off the clouds or surface, or even penetrate beneath the surface. These “listeners” can measure distances to different parts of the surface or heights of clouds based on the strength of the echo or how long it takes to “hear” the echo. Thus sounder and radar data can be used to make 3D maps of the surface as the spacecraft passes over it. Profiling radar can also measure depths of clouds and sounders can measure depths of ice layers or layers of different materials below the surface.
- Sniffers (“noses”)
    - For example, spectrometers
    - Your nose detects even tiny amounts of substances in the air. A spectrometer, although it works more like an imager than a “sniffer,” can analyze the composition of a gas, a liquid, or a solid.
    - Here’s how: Light travels in waves. Light is a combination of many different wavelengths, or colors. Combined, they make white light. If you shine light through a gas (such as water vapor), the gas will absorb some wavelengths (colors) of the light and let others pass through, depending on the gas. Each substance has a unique “fingerprint.”
    - An absorption spectrometer separates the wavelengths of light (as a prism) that has passed through a gas, making a kind of rainbow. The spectrometer then detects which wavelengths are missing. They are missing because they were absorbed by the gas they passed through. The spectrometer matches this pattern of missing wavelengths, or “fingerprint,” with those of known substances, thus identifying the unknown gas.

    - An emission spectrometer analyzes the light coming from (being emitted by) a source, such as a star, and identifies the source material (that is, what is burning or glowing) by the wavelengths (colors) of light it emits.
- Tasters ("tongues")
    - For example, x-ray spectrometers
    - Your tongue works with your nose to identify what you are eating or drinking. So, spectrometers might also be considered tasters, since they can analyze what's in a substance that has emitted light or a substance that light has passed through. Other special x-ray spectrometers can directly bombard with x-rays solid things such as rocks and then detect the rock's composition based on the energy "fingerprint" that echoes back into the instrument. In this pictured model of the Pathfinder "Sojourner" rover that explored Mars in 1997, the x-ray spectrometer is helping Sojourner "taste" a rock.
- Feelers ("fingers")
    - Examples are drillers, scrapers, corers, sample collectors, rock crushers, ice scrapers, particle detectors
    - If you wanted to know about a substance, you would probably touch it directly. You would feel its texture, hardness, temperature, wetness, etc. "Feeler" instruments might be mechanical devices such as drillers or scrapers or corers. Or, maybe even rock crushers to find out how hard the material is and get it ready for the spectrometer (sniffer/taster) to analyze it. This sequence of pictures shows a rock (of Earthly origins) being crushed for analysis by a spectrometer.
    - Other types of "feelers" are sample collectors (as if they are grabbing or trapping something with their hands) or particle or dust detectors (which sense when, say, an electrically charged particle strikes a surface, or the instrument's "skin"). This picture shows how a human-made substance called "aerogel" can trap particles for later analysis.
- "Sixth"sensors
    - An example is a magnetometer.
    - Some scientific instruments directly detect things that none of our five senses can detect. Magnetic fields fall into this category. (Although some birds and other animals may sense Earth's magnetic field and use it to navigate.) If not for a compass, we humans might not know about Earth's magnetic lines of force. An instrument that detects and measures magnetic fields is called a magnetometer. As on the Voyager spacecraft in this picture, a magnetometer is often placed at the end of a long boom so magnetic fields from the spacecraft itself do not interfere.

Table 2 - Summary of a mission to an alien world

Name of mission	
Destination (name of planet, moon, asteroid, etc.)	
Known characteristics of destination	1. 2.
Questions (3 to 5) to be answered, plus science instrument needed for each investigation	Question: Instrument: Question: Instrument: Question: Instrument:
Type of mission:	❏ Orbiter ❏ Lander ❏ Flyby ❏ Other (If "other," describe)
What we learned:	
What we didn't learn:	
Proposal for a future	

mission?	

Science Process Skills Used
Conceptualization, planning, engineering

Safety Precautions
None
THE LISA GAME

Topic: Gravitational waves
Learning Objective: Show students the importance of studying gravitational waves through a short lesson followed by an interactive trivia game.

Materials:

- A timer
- Two bells
- Whiteboard
- Markers

Detailed Description

- Introduction
    - Questions for students
        - Have you ever seen a wave on the ocean?
        - Did you know that there are waves out in space as well?
    - Types of Waves
        - Water
            - Waves are created by ocean disturbances far out at sea. Storms or other atmospheric conditions disturb the fluid mound of water that flows over our planet. These large disturbances ripple through the ocean currents, carrying waves—large and small—to far away shores.
        - Electromagnetic
            - Radio waves, x-rays, gamma rays, visible light, and more
        - Gravitational Waves
            - Predicted by Albert Einstein in 1916
            - First detected here on Earth by the LIGO observatory on September 14, 2015

    - LIGO uses a system of mirrors and lasers to detect disturbances caused by gravitational waves

- Game Information
    - Einstein
        - Albert Einstein was a great scientist who figured out many new things about the Universe. One of his ideas was that objects cause the space around them to be warped or curved. Picture a bowling ball sitting on a soft mattress. The heavy ball would cause the mattress to sag. A marble placed on this bowling-ball-laden mattress might roll right into the ball.
        - In Einstein's picture of the Universe, the mattress is three-dimensional space. The space around a large object or mass, like a planet or the Sun, is so curved that other objects passing nearby follow the curvature and end up in orbit around the planet or the Sun.
        - And this is what gravity is all about! Gravity is the warping of space around a mass. The part of space that is warped around the mass is its gravitational field. Other objects inside this field, such as your body on Earth's surface, or the moon in orbit around Earth, or Earth in orbit around the Sun, influence and are influenced by this gravitational field. The more massive the object, the more it warps space, and the more gravitational influence it has on anything near it.
        - Let's follow Einstein's idea a bit further. Because of how masses warp whatever space is around them, when they move they cause disturbances, or ripples, in space. Think how disturbing the calm surface of a pond causes ripples. From a single point, the ripples move outward in bigger and bigger circles. And, just as violent atmospheric (weather) disturbances (hurricanes or typhoons) cause huge waves on Earth's oceans, cosmic disturbances cause the biggest gravitational waves in space.
    - Cosmic Disturbances
        - But, what is considered a cosmic disturbance? Well, it might be a supernova explosion. It might be two very large stars orbiting each other in what is called a binary system. It might be a massive star orbiting a black hole or two black holes orbiting each other. Just as a huge boulder causes bigger ripples than does a pebble when dropped onto the surface of a calm lake, these kinds of cosmic events produce the strongest gravitational waves.
        - The strength of the gravitational wave created by a binary star system depends upon the size of the two stars and the period of time it takes for

them to orbit each other. As the gravitational waves carry energy away, the stars in a binary system gradually move closer together. As they get closer, the amount of time for each orbit gets shorter. While this is happening, the amount of energy they lose increases, meaning that the gravitational waves are getting stronger. The very strongest of waves is created just before the two massive objects collide.

        - And when objects come near a black hole, its strong gravitational field sucks them in. Nothing escapes the extremely dense matter of a black hole, not even light!
        - But if no one has ever detected a black hole, how do we know they exist? Well, scientists have observed the motion of massive orbiting objects and their gravitational fields. Many scientists believe that every galaxy has a massive black hole at its center. (The Milky Way isn't the only galaxy in the Universe—it's just the one we live in). The motion of a black hole and another huge object orbiting each other cause strong gravitational waves that we, even as far away as we are, might be able to detect. Their gravitational waves may even be detectable several years before the two objects collide!
    - LISA
        - Scientists want to know more about these gravitational waves and their sources because they could us help us understand more about the Universe. How? Well, we think that gravitational waves don't break up and scatter like electromagnetic light waves. We think that although they get weaker as they travel across space, gravitational waves aren't changed when they pass through matter. So, the signals they carry will be unchanged across time and space. This means we may be able to learn how the Universe began.
        - The Laser Interferometer (in-ter-fear-AH-muh-ter) Space Antenna (LISA) is a space mission that NASA hopes will be able to find some of these gravitational waves. LISA will have three spacecraft flying in the shape of an equilateral triangle (a triangle with three equal sides) five million kilometers (3 million miles) apart. LISA will look for gravitational waves in our galaxy, the Milky Way, and in other galaxies. If approved by NASA, LISA will bring us a new vision of the cosmos.
- The Game
    - Procedure

- Divide the entire class into two teams, evenly if possible. Name each team something relevant to the subject. For example, one team may be called the "Red Giants," while the other team is called the"Supernovas."
- At the start of the game the instructor will choose one member of each team to be the first bell ringer. Every three question, the bell ringer duties will pass on to a new team member.
- Post all the game answers in plain view in large letters on the whiteboard. The answer list is provided on the following page. Game questions and their corresponding answers (in parentheses) begin on the following page. Some incorrect answers, such as "astrology," have been thrown into the mix for fun.
- Select a moderator, generally a teacher, to present the questions. Randomly select questions from the list provided here. Each question and answer is a round. In keeping with the subject matter, we suggest calling each round a "wave."
- For each wave the moderator poses a question from the list to both panels simultaneously. The panelists on each team collaborate to come up with an answer based on the material they have studied. To keep the game fun-fast-and-furious, each wave should be timed. We recommend one minute per question. It is a race against time and the other team.
- When either team, as a group, decides upon an answer from the listed answers, panelist number four writes it on the erasable board and then rings the bell, signaling they are ready. Whichever team rings its bell first gets to answer. If neither team rings its bell before the time limit is reached, the moderator calls time and moves on to the next question. The unanswered question is saved for another wave or another game.
- Each group of panelists is playing for points for their entire team. Correct first answers win 10 points. Incorrect answers cause a loss of 5 points, or negative points. If the team answering first comes up with an incorrect answer, they lose points for their team. The question then goes to the other team. If they have the correct answer written on their slate, they win the points for that wave. However, if they too give an incorrect answer, no points are lost, since they did not choose to risk any points by being first to answer (possibly incorrectly). Not being first with the answer loses no points.
- A way to engage all team members is to have them do the "stadium wave" (standing with arms extended overhead and sitting, in quick sequence) when their panelists are first to answer a question correctly.

Doing this may depend upon class size and, in general, class temperament.

- Following a suggested minimum of four waves (four questions and answers), all four panelists in the hot seats on each team return to the larger team group. A new group of four panelists from each team moves to the hot seats. The moderator then poses the question for the next set of waves.
- After each team member has had an opportunity to sit on the panel in the hot seats and answer the determined minimum set of questions as suggested above, the moderator may call the game "over." The team with the most points wins and all players on the team get to redeem game points in a manner determined by the teacher. For example, they might win extra credit, an amount of free time, etc.

- Answers
    - Write these on the board
        - Gravitational Waves
        - Star
        - Sun
        - Andromeda
        - Binary System
        - Black Hole
        - Chandra
        - Supernova
        - Einstein
        - Light
        - Milky Way
        - Red Giant
        - Astronomy
        - Electromagnetic Spectrum
        - Gravitational Field
        - Galaxy
        - LISA
        - Equilateral Triangle
        - Spacecraft
        - Cassini
        - Electromagnetic
        - Isaac Newton
        - Energy

        - Hubble Space Telescope
        - Orbit
        - Astrology
        - Curvature
        - LISA Spacecraft
- Questions
    - Instructor will read these out loud
        - To learn about stars you might study this. (Astronomy)
        - A gravitational wave causes a ripple in this. (Space)
        - Shining stars dancing around each other in space could be this. (Binary System)
        - This is a spacecraft formation good for detecting gravitational waves. (Equilateral Triangle)
        - These carry signals unchanged across space and time. (Gravitational Waves)
        - This kind of super star explodes in a big way. (Supernova)
        - This scientist thought about warps and curves. (Einstein)
        - Cosmic events in space cause these. (Gravitational Waves)
        - Binary star systems lose this as they orbit closer together. (Energy)
        - All of space and everything in it is called this. (Universe)
        - This is the name of our galaxy. (Milky Way)
        - These kinds of space waves do not change when they pass through matter. (Gravitational Waves)
        - The LISA mission will fly in this shape. (Equilateral Triangle)
        - LISA will look for gravitational waves in this galaxy. (Milky Way)
        - This kind of space wave hasn't been detected yet. (Gravitational Wave)
        - Many scientists think this is at the center of each galaxy. (Black Hole)
        - Not even light can escape this. (Black Hole)
        - This is the warping of space around masses. (Gravity)
        - Moving masses cause disturbances in this. (Space)
        - Gravitational waves carry this away. (Energy)
        - The motion of objects in space causes this. (Gravitational Waves)
        - X-ray, visible light, and radio are some types of energy in this. (Electromagnetic Spectrum)

        - If we study gravitational waves we may be able to learn how this began. (Universe)
        - These get weaker as they travel across space. (Gravitational Waves)
        - As stars in a binary system get closer, the amount of time for each of these gets shorter. (Orbit)
        - Cosmic disturbances in space cause the biggest of these. (Gravitational Waves)
        - As gravitational waves carry energy away, the stars in this move closer together. (Binary System)
        - We know these exist because of the motion of orbiting objects. (Black Holes)
        - In addition to gravitational waves there is this type of space wave. (Electromagnetic)
        - This NASA mission will study black holes. (LISA)
        - When objects collide, the very strongest of these are created. (Gravitational Waves)
        - The more massive an object, the more it warps this. (Space)
        - This scientist predicted gravitational waves. (Einstein)
        - Among the LISA spacecraft, these are like a spider web made of light. (Laser Beams)
        - Using different telescopes, we have observed different wavelengths of this. (Electromagnetic Spectrum)
        - This is the most mysterious force in the Universe. (Gravity)
        - Most of his ideas have been proven correct. (Einstein)
        - These are usually very weak by the time they reach us. (Gravitational Waves)
        - These have never been measured. (Gravitational Waves)
        - These will be 3 million miles apart. (LISA Spacecraft)
        - Very large masses moving quickly create ripples in this. (Space)
        - These will be five million kilometers apart in space. (LISA Spacecraft)
        - The Milky Way is one of these. (Galaxy)
        - Many scientists think this is at the center of each galaxy. (Black Hole)
        - Earth orbits this. (Sun)
- Conclusion
    - Questions

- What are gravitational waves?
- How do we measure them?
- What kind of information can we learn from them?

Science Process Skills Used

Identification of terms, physical processes

Safety Precautions

None