Peculiar Pluto

Which sentence best describes Pluto?

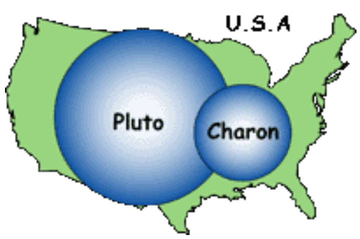
a. Pluto is actually closer to the Sun than Neptune for about 8% of its orbit.
b. Pluto is just one of many icy objects in a distant area of our solar system.
c. Pluto and its large, orbiting companion object Charon, are tipped on their sides.
d. All of the above.

Well, just pick the answer you like best, because they are all true!

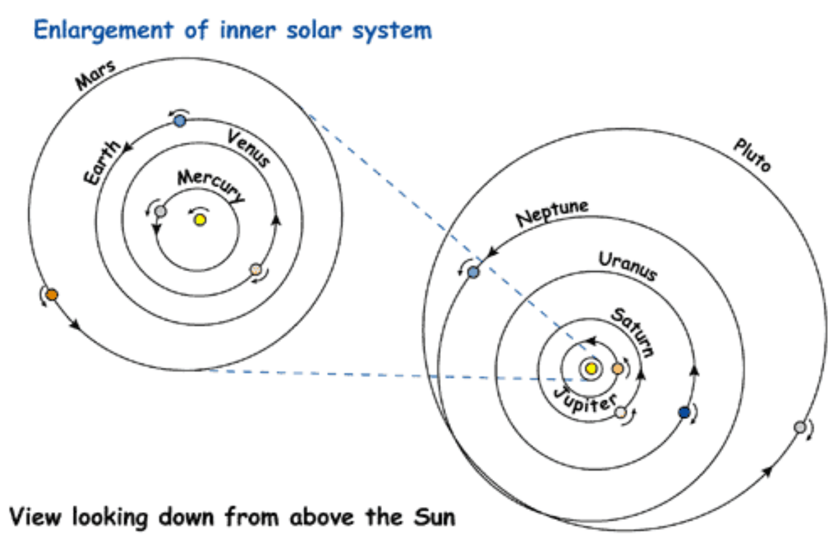
One thing is certain. Pluto and its neighborhood are very peculiar. If scientists could unravel some of their mysteries, we would know more about how our solar system formed.

More Fun Facts About Pluto:

- Pluto is only about half the width of the United States. Charon is about half the size of Pluto. Charon is the largest moon compared to the body it orbits (whether planet or dwarf planet) of any moon in the solar system.



- Almost all the planets travel around the Sun in nearly perfect circles. But Pluto does not. It takes an oval-shaped path with the Sun nowhere near its center. What's more, its path is quite tilted from the nice, orderly plane where all the planets orbit. (Mercury has a slightly lop-sided orbit, although not nearly so much as Pluto's.)



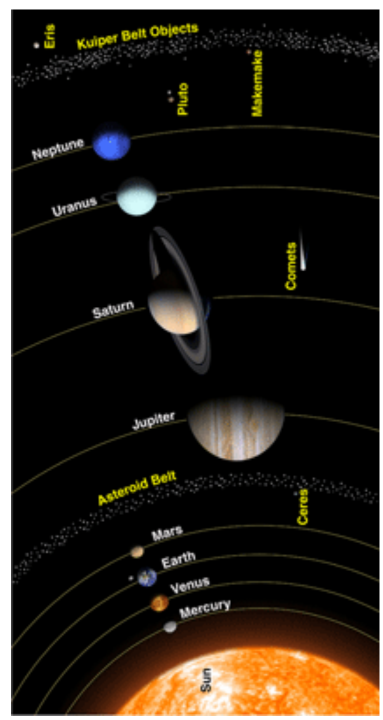
In the picture above, the arrows show the direction the planets and Pluto rotate. Notice Pluto's spin goes the opposite way of all the others except Venus and Uranus.

Why Pluto is not a planet

Until recently, Pluto was the ninth planet from the Sun. It was also the smallest planet.

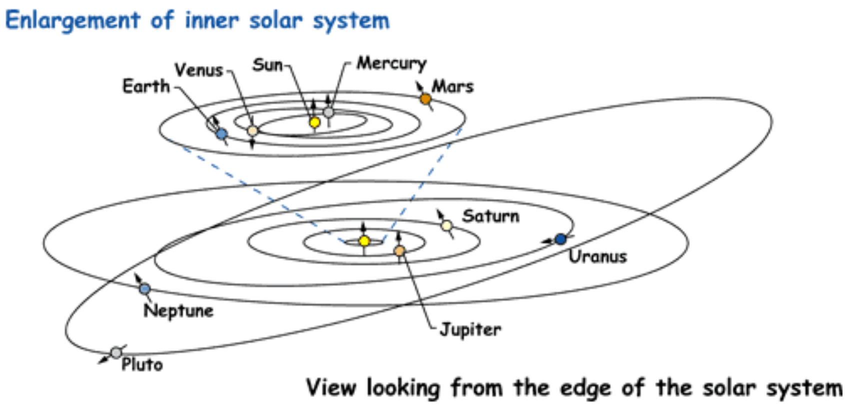
Poor Pluto. Just how did he get "kicked out" of our family of planets?

And who are his "real" family members? Astronomers have already named three other objects in the solar system that are about the same small size as Pluto. They are Ceres [SEAR-ees], Makemake (MAH-kee-MAH-kee], and Eris (AIR-iss]. These objects, along with Pluto, are much smaller than the "other" planets.



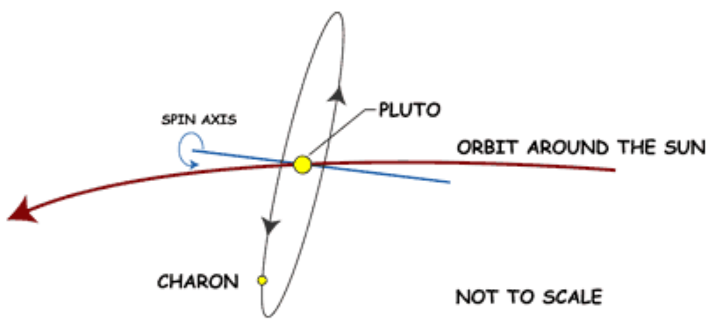
(/review/ice-dwarf/solar-system-lrg.en.png)
Ceres orbits in the Asteroid Belt between Mars and Jupiter. Makemake, like Pluto, is part of the "Kuiper [KI-per] Belt," which is a region of trillions of icy objects orbiting beyond Neptune. Eris' orbit is even farther out.

Astronomers have put these objects into a new family called dwarf planets.



In the picture above, the arrows show which direction the planets' and Pluto's axes of rotation point. Notice Pluto's and Uranus' point along the same plane as their orbits, instead of more or less "up and down."

- Compared to most of the planets and their moons, the whole Pluto-Charon system is tipped on its side. Like the planets, Pluto's spin axis stays pointed in the same direction as it orbits the Sun. But unlike all planets except Uranus, Pluto is tipped on its side. The planets' axes of rotation stand more or less upright from the plane of their orbits.



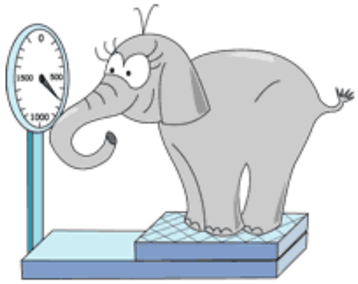
- If you lived on Pluto, you'd have to live 248 Earth years to celebrate your first birthday in Pluto-years.

- If you lived on Pluto, you would see Charon from only one side of the planet. Charon's orbit around Pluto takes about six and one-half Earth days. Pluto's day (that is, one complete rotation) takes exactly the same amount of time. So, Charon always "hovers" over the same spot on Pluto's surface, and the same side of Charon always faces Pluto.
- At Pluto's current distance from the Sun, the temperature on its surface is about 400 degrees below zero Fahrenheit! It will get even colder as it moves farther from the Sun. From Pluto, the Sun looks like just a bright dot in the sky, the brightest star visible. The light from the Sun is as bright on Pluto as the light from the full Moon is on Earth.

(/review/ice-dwarf/all_dwarfs-lrg.en.png)

This picture shows the sizes of dwarf planets Pluto, Ceres, Eris, and Makemake as compared to Earth and Earth's Moon, here called "Luna." None of the distances between objects are to scale.

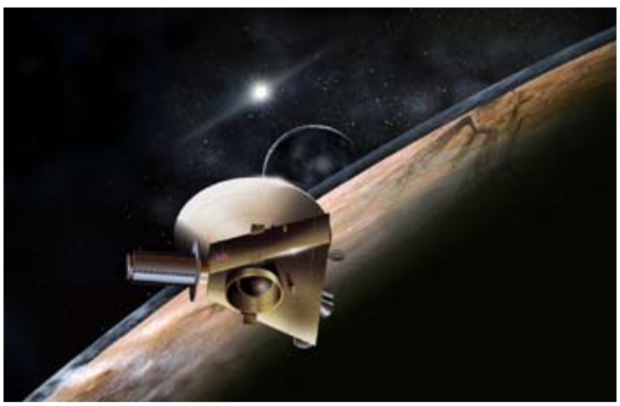
- If you weigh 100 pounds on Earth, you would weigh only 7 pounds on Pluto!



- Pluto orbits in a far-out region of the solar system called the Kuiper (rhymes with viper) Belt. There are lots of icy, rocky objects out there. But they are so far from the Sun they are really hard to see, even with powerful telescopes.

Let's Go There!

We will finally get to visit Pluto, Charon, and the Kuiper Belt! On January 19, 2006, NASA launched a robot spacecraft on the long journey. This mission is called New Horizons. The spacecraft will arrive at Pluto in the summer of 2015, then go on to study other objects in the Kuiper Belt from 2018 to 2022.



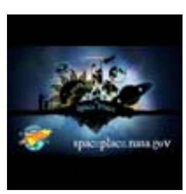
(/review/ice-dwarf/new-horizons-lrg.en.png)

With New Horizons, we will visit and learn about the objects at the very edge of our solar system. They may help us understand how our solar system formed.

If you liked this, you may like:

(/story-planet-awards)
The First Annual Planet Awards (/story-planet-awards)

(/comet-ocean)
Thirsty? Have a comet! (/comet-ocean)



(/wallpaper)
Space Place Desktop Wallpaper (/wallpaper)

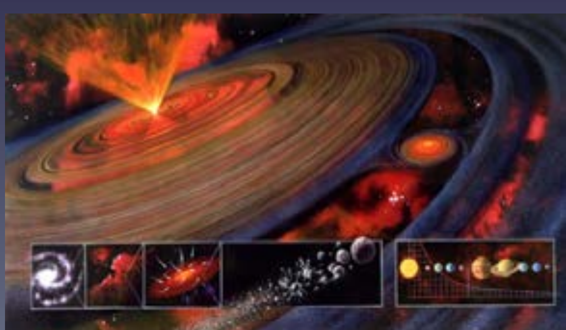

Welcome
to
From Out-of-School to
Outer Space :
Make Science Fun with NASA
Leslie Lowes
Shari Asplund
NASA/ Jet Propulsion Laboratory

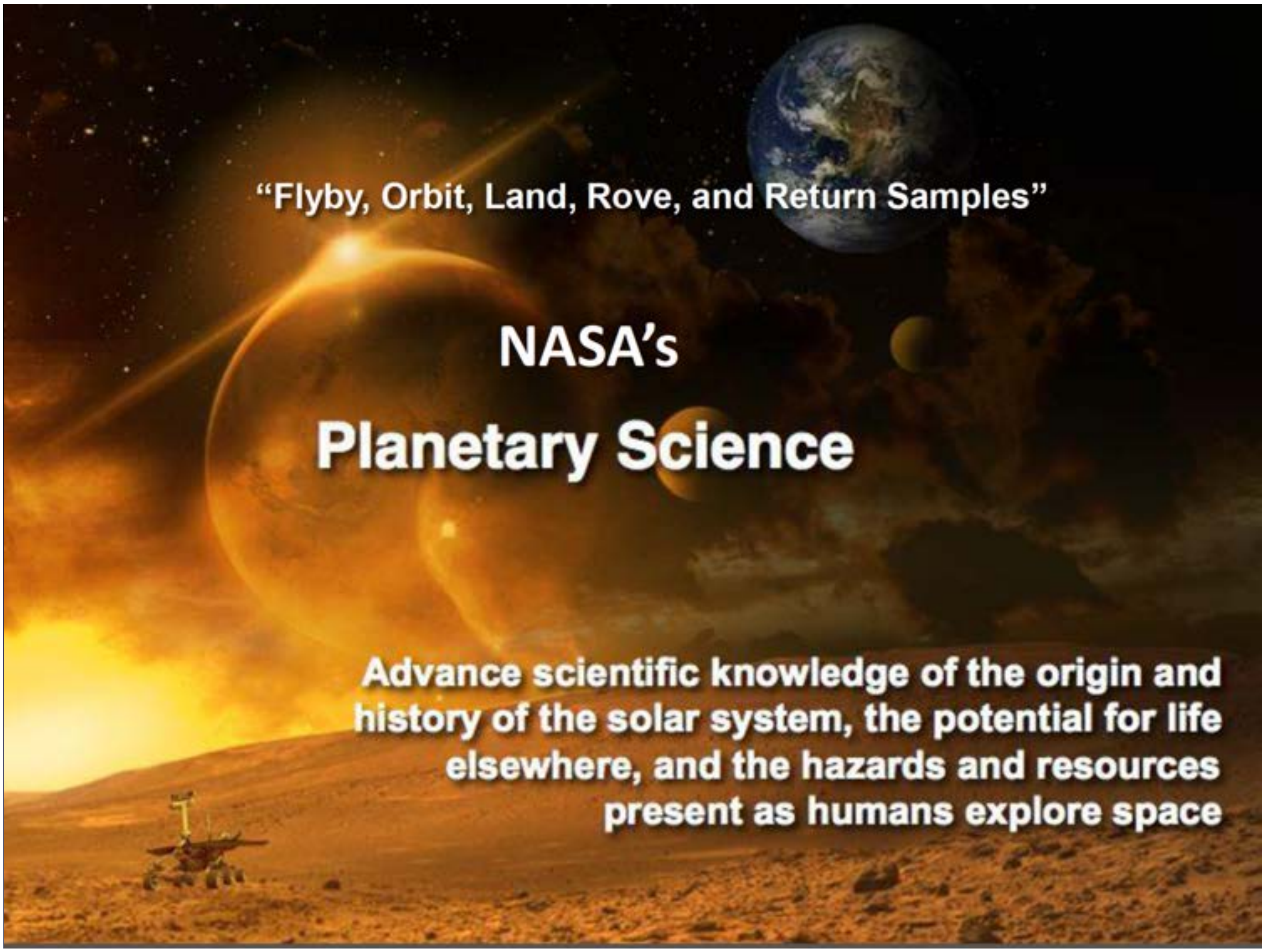
Planetary Science –
It's About the Questions

Where do we come from?

Where are we going?

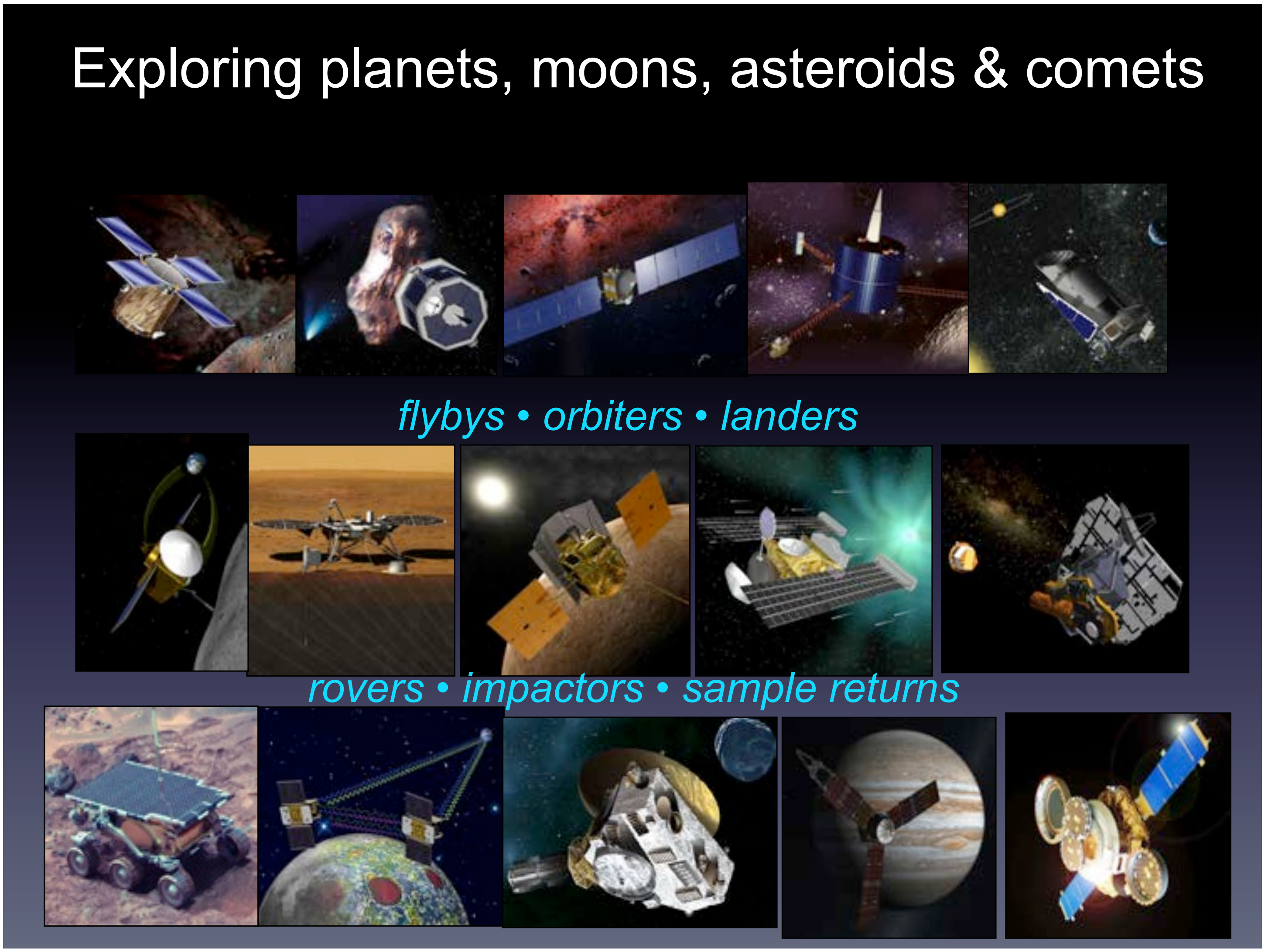
Are we alone?




"Flyby, Orbit, Land, Rove, and Return Samples"
NASA's
Planetary Science
Advance scientific knowledge of the origin and history of the solar system, the potential for life elsewhere, and the hazards and resources present as humans explore space

NASA’s Discovery and New Frontiers Programs

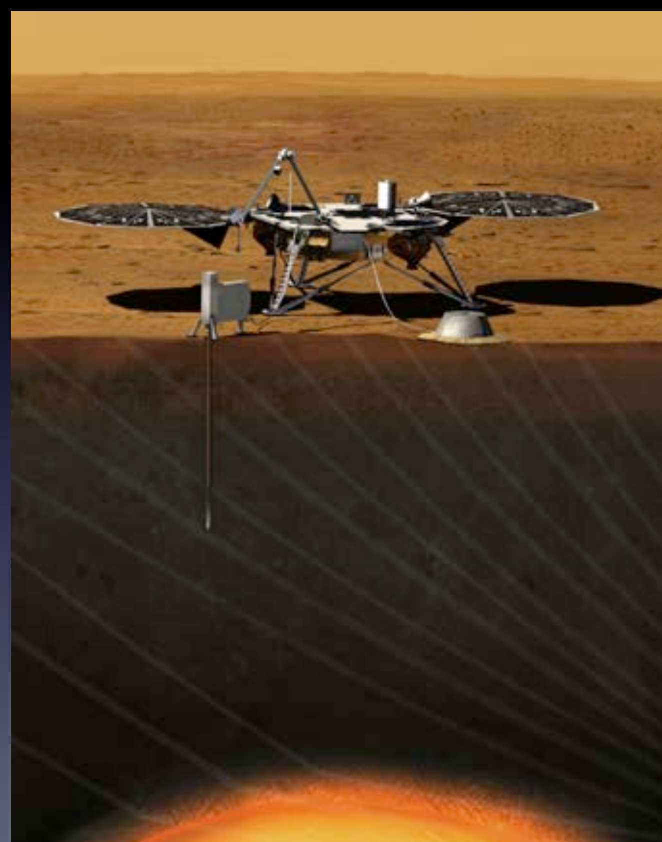
- Lower-cost planetary science missions searching for answers
- Proposed by a “Principal Investigator” along with a large team of scientists and engineers
- People with lots of questions
- Revolutionizing perceptions and challenging long-held theories with amazing new images, data and samples


Exploring planets, moons, asteroids & comets
flybys • orbiters • landers
rovers • impactors • sample returns

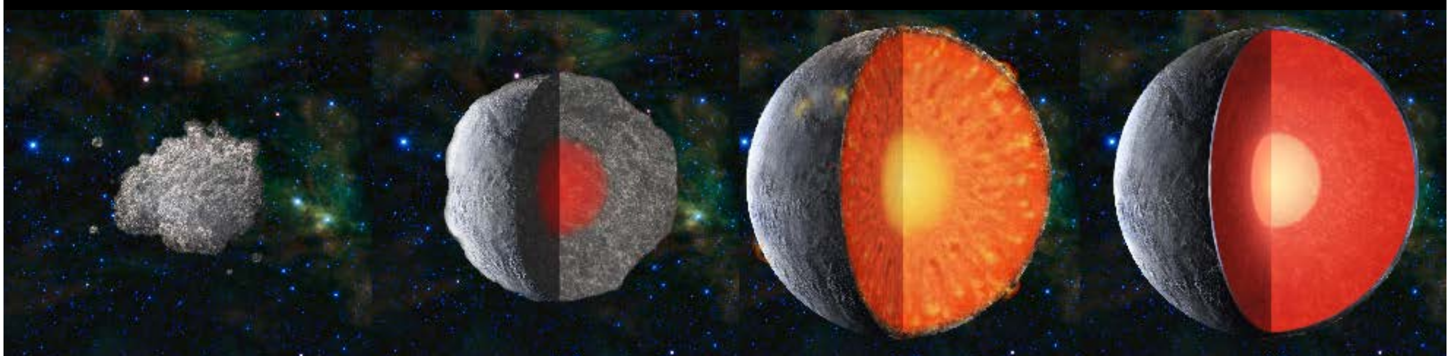
InSight into Mars Quakes!

Interior Exploration using Seismic Investigations, Geodesy and Heat Transport

- Will place a geophysical lander on Mars to study its deep interior
- **InSight** into the processes that shaped the formation of the rocky planets of the inner solar system
- Launch March 2016
- Arrival at Mars 6 months later
- Two years of science operations



How Does a Terrestrial Planet Form?



A Rocky Body Forms and Differentiates

• The planet starts forming through accretion.

• As it gets bigger, the interior begins to heat up.

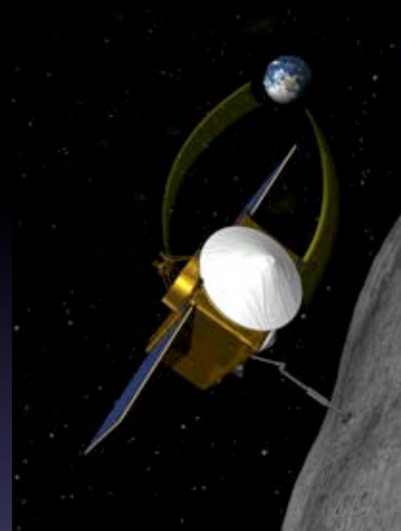
• Stuff happens… this is where InSight will help fill in the gap!

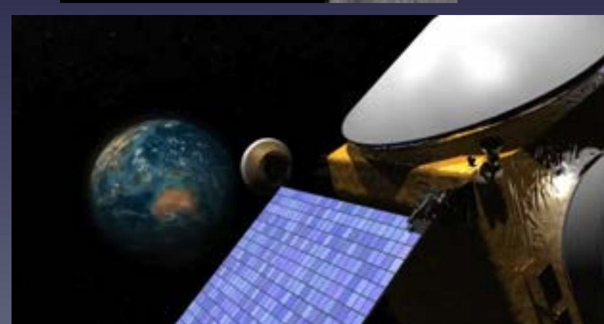
• End up with a crust, mantle, core

Returning Asteroid Dirt

OSIRIS-REx

NASA’s first asteroid sample return
• Sept. 2016 launch
• 2019 arrival at Asteroid Bennu to map, measure, then grab a soil sample
• 2023 return to Earth after a journey of 800 million miles





Touch-And-Go Sample Acquisition Mechanism (TAGSAM)

After collecting 2 oz – 4 lbs of material, the TAGSAM head will be stowed in the Sample Return Capsule for the journey home

Jupiter Orbiter

Juno

- How and where did Jupiter form?
- Juno will peer through the clouds to reveal hidden secrets from the formation and early evolution of the our solar system

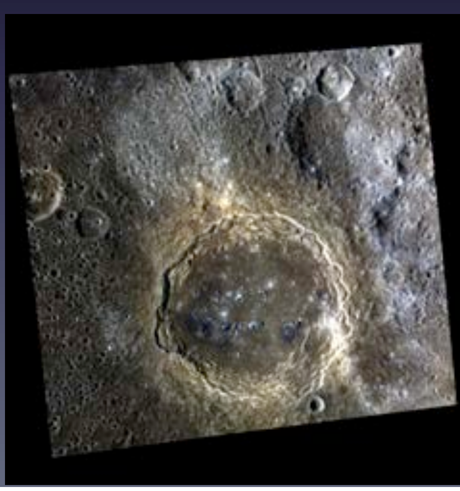
Juno

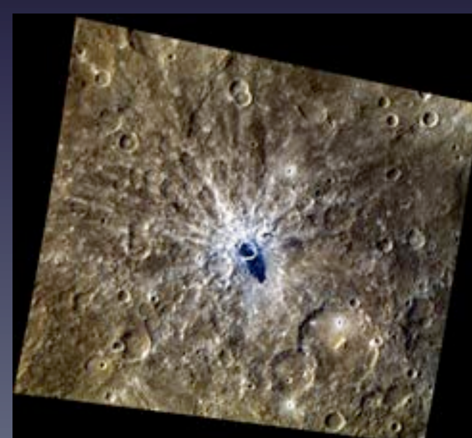
- First solar-powered mission to Jupiter
- Eight science instruments plus a camera for education and public outreach
- Launched in August 2011
  - 5-year cruise to Jupiter, arriving July 2016
  - About 1 year at Jupiter, ending with de-orbit into Jupiter in 2017

Mercury Revealed!

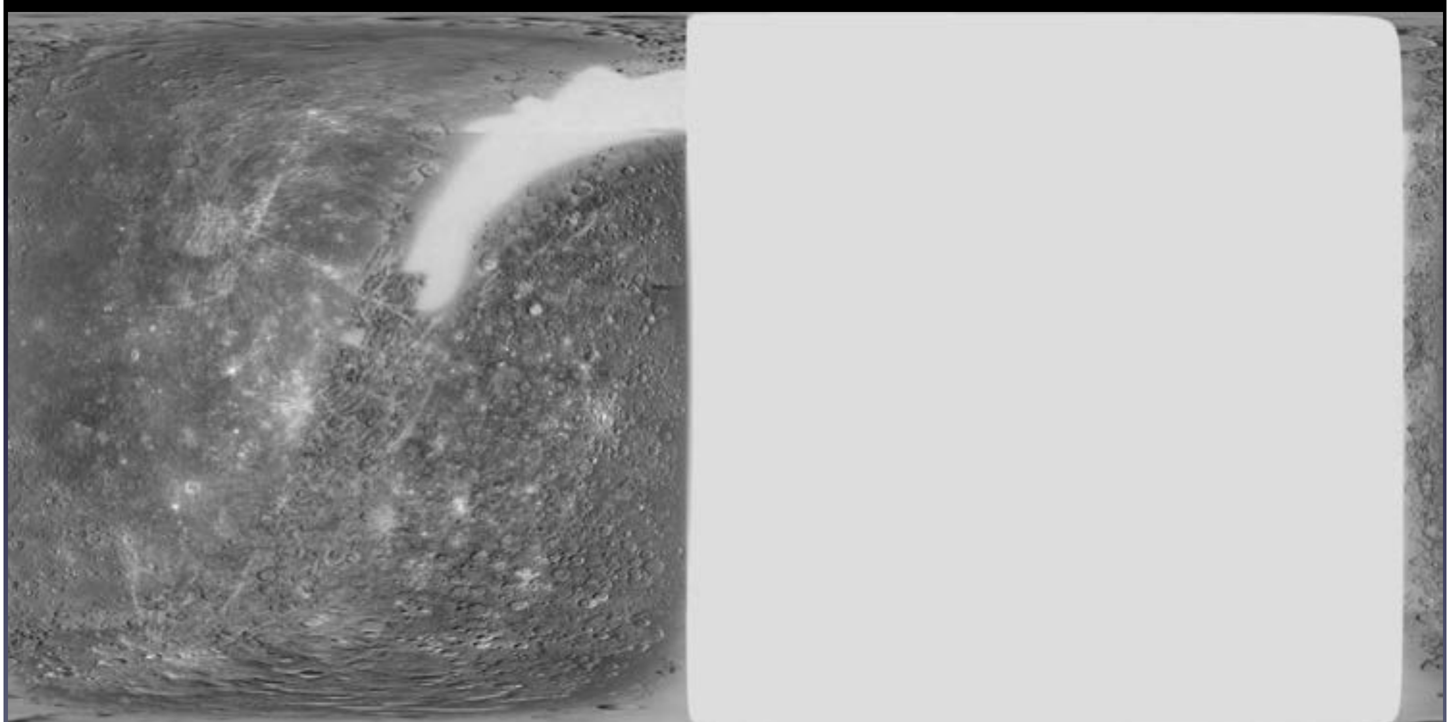
MESSENGER

First spacecraft to orbit the planet closest to the Sun, beginning in March 2011. Continues to return fantastic close-up images that are generating new questions

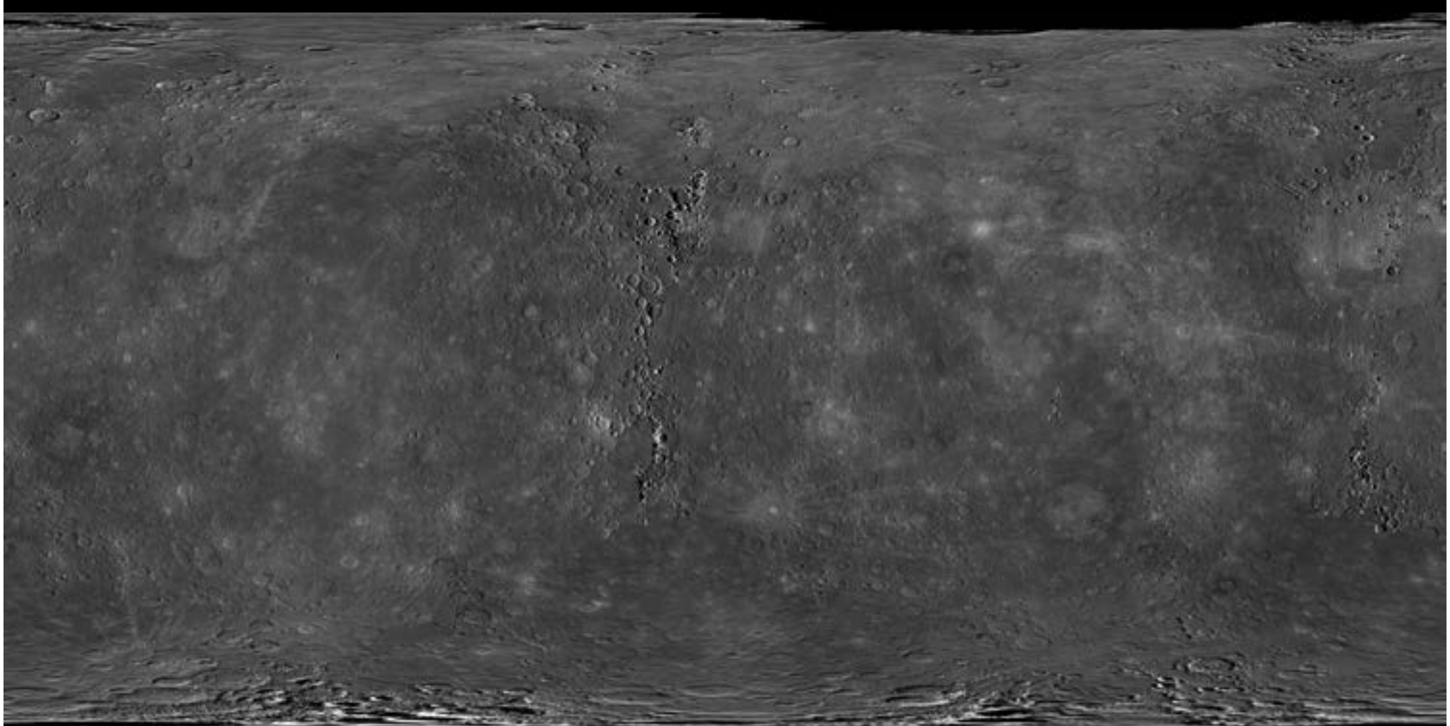




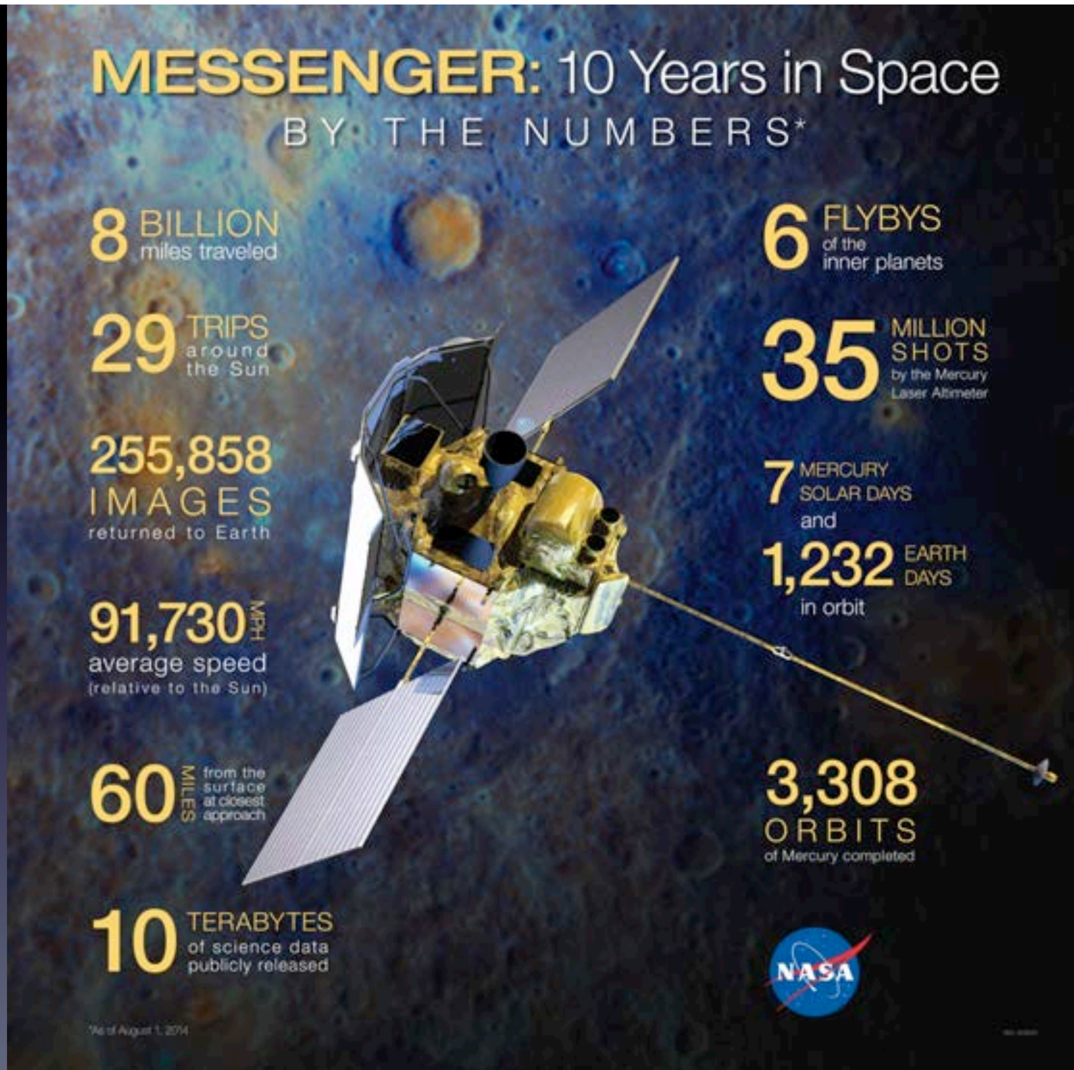
Before MESSENGER



After MESSENGER



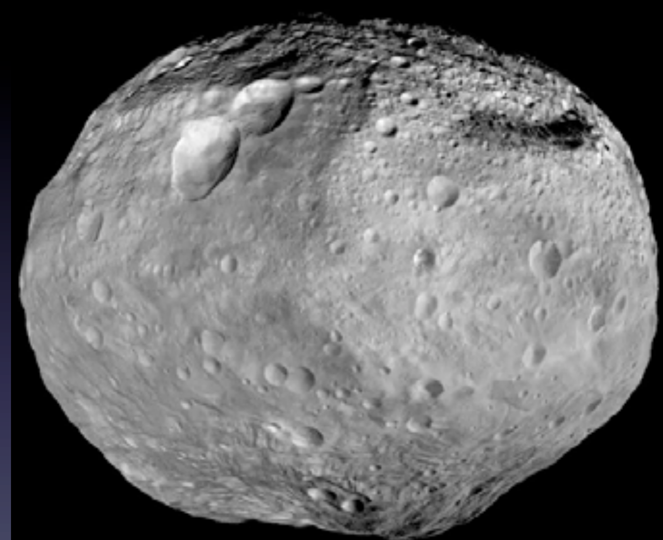
New views of Mercury


MESSENGER: 10 Years in Space
BY THE NUMBERS*
8 BILLION miles traveled
29 TRIPS around the Sun
255,858 IMAGES returned to Earth
91,730 MPH average speed (relative to the Sun)
60 MILES from the surface at closest approach
10 TERABYTES of science data publicly released
6 FLYBYS of the inner planets
35 MILLION SHOTS by the Mercury Laser Altimeter
7 MERCURY SOLAR DAYS
and
1,232 EARTH DAYS
in orbit
3,308 ORBITS of Mercury completed
NASA
*As of August 1, 2014

Comparing Asteroids

Dawn

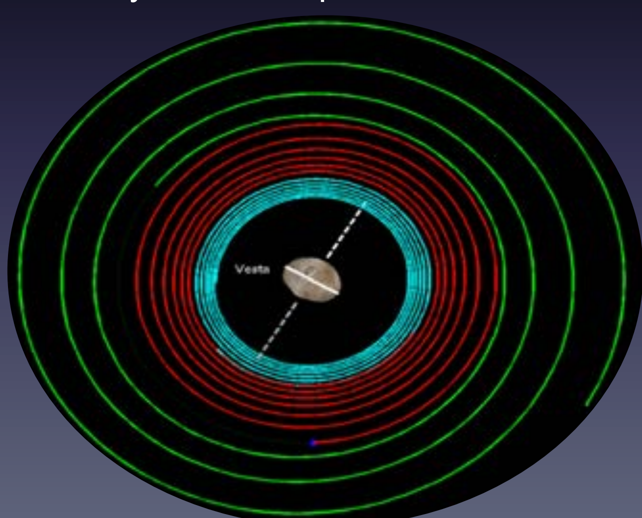
Orbited Vesta for 12 months, now circling Ceres for a close-up comparison of these two very large and very different asteroid belt objects

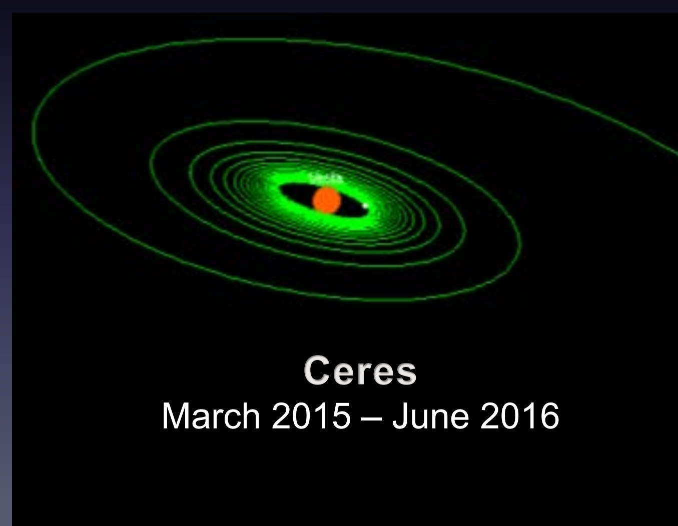


Dawn is the first mission to orbit and explore *any* two extraterrestrial destinations

Vesta

July 2011 – September 2012





Ceres

March 2015 – June 2016

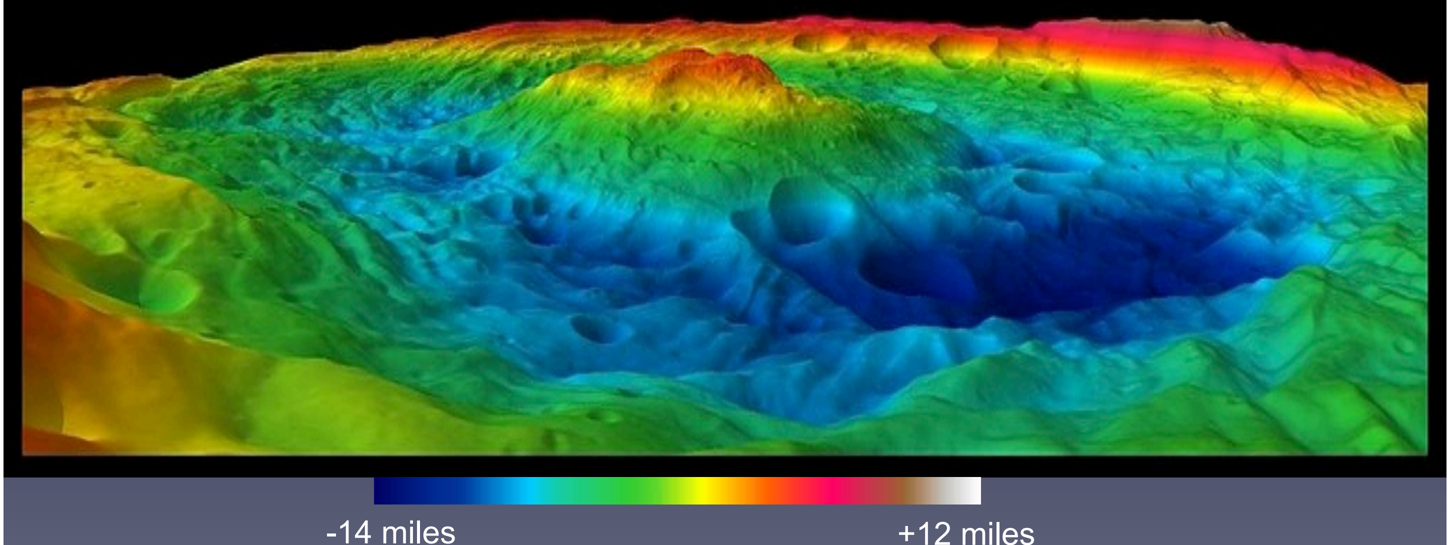
Dawn Uses Ion Propulsion

Impacts Sent Pieces of Vesta to Earth

More Meteorites from Vesta than from the Moon and Mars Combined

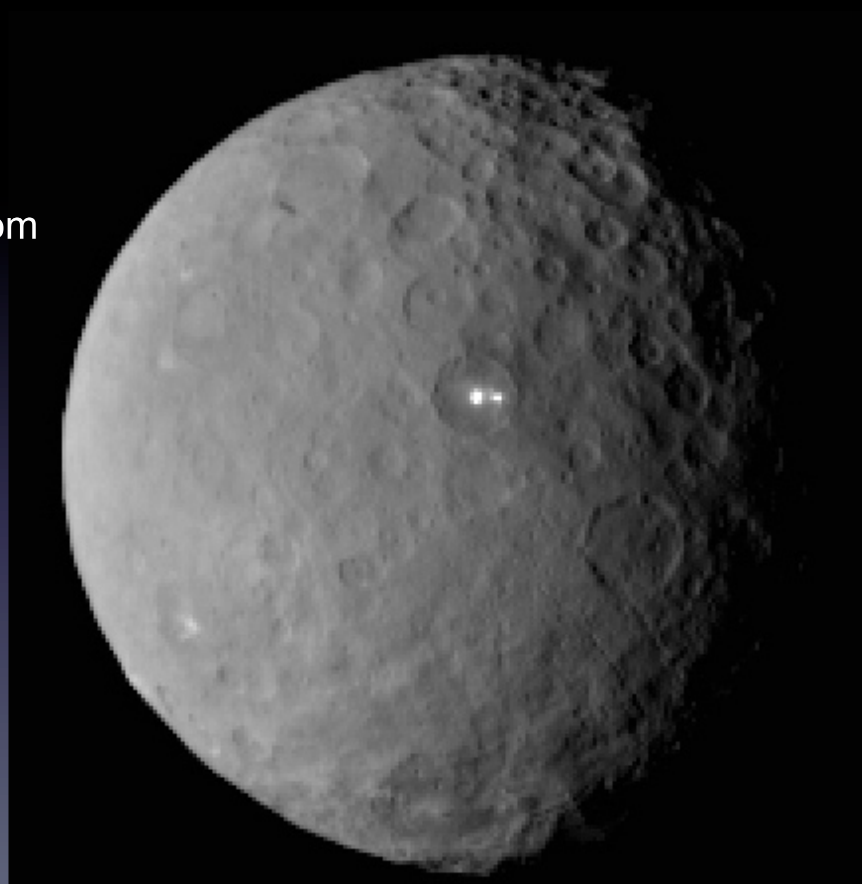
Largest Mountain

Rheasilvia's central peak is more than twice as high as Mt. Everest – rivaling Olympus Mons (on Mars) as the tallest mountain in the solar system



Mysteries on Ceres

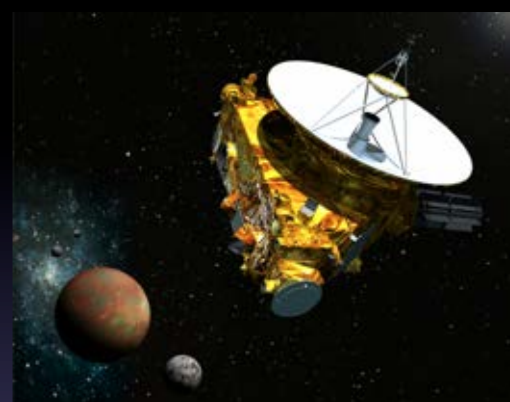
- Bright spots revealed from 29,000 miles away
- Volcanic origin?
- Stay tuned!

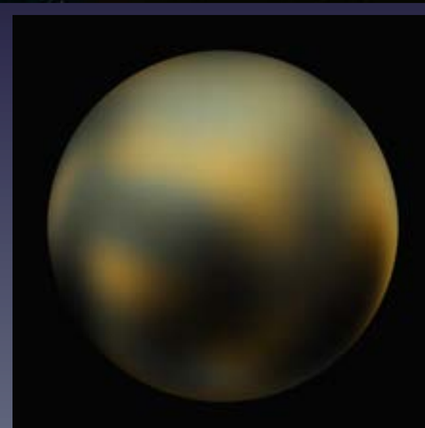


Pluto – Flyby on July 14!

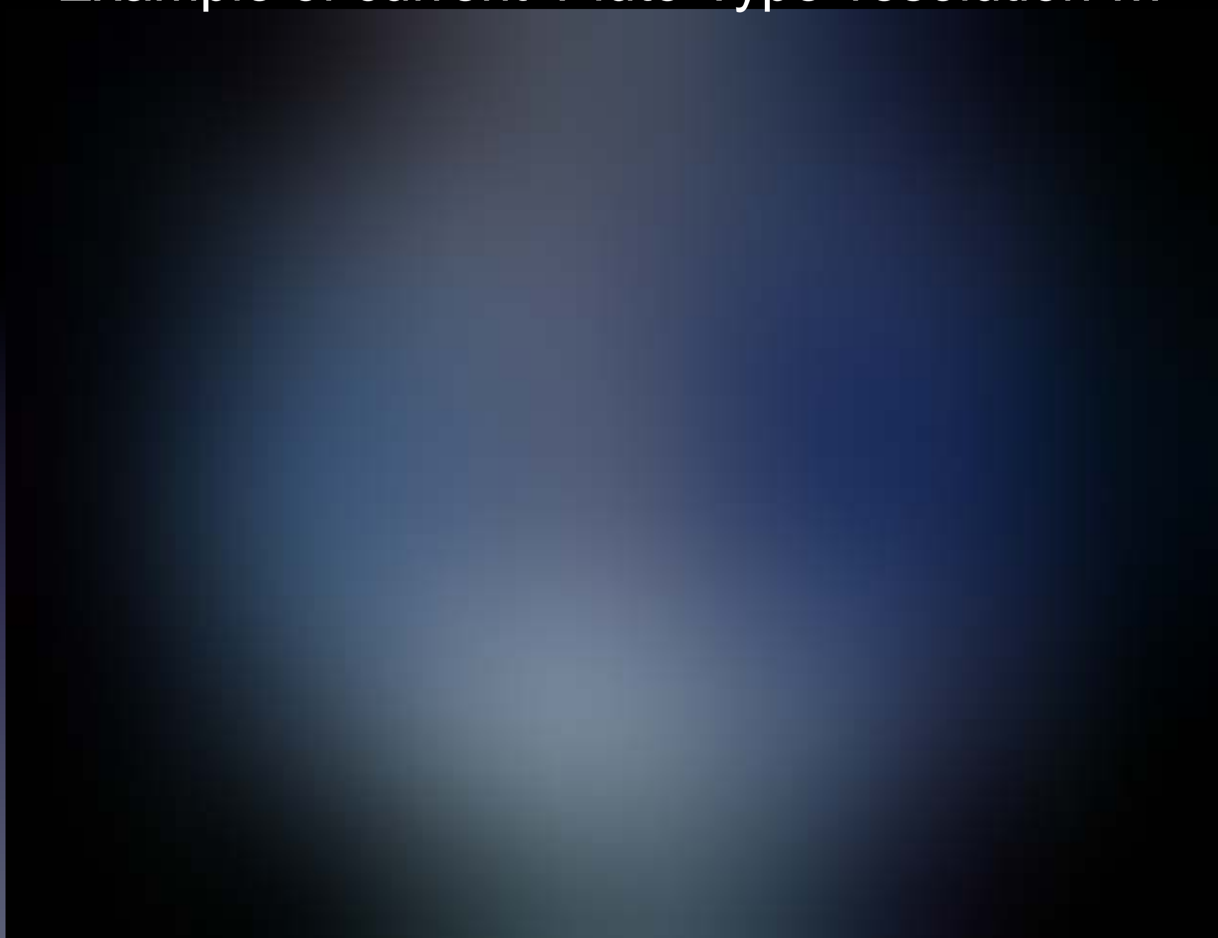
New Horizons

First mission to study Pluto, its moons and Kuiper Belt objects, to reveal how ice dwarf planets formed and have evolved over time and where they fit in with other solar system objects





Example of current ‘Pluto-Type’ resolution …



Expect Dramatic Results!

Opportunities to Participate

Each mission requires hundreds of people to formulate the sciences questions, build the machines, design the flight path, develop the software, program the computers, create graphics and animations, tell the story and get the mission launched into space!

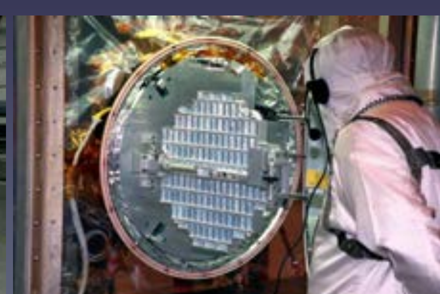
Learn More

Find out much more about all these missions and discover engaging activities and interactives

discovery.nasa.gov

newfrontiers.nasa.gov

YOUR STUDENTS should be part of NASA's exciting work!



"Rocking Around the Solar System"
Program Unit Overview
Excerpts - Solar System Scale and Exploration

STORYLINE	ACTIVITY NAME	ACTIVITY TYPE	SCIENCE/ENGINEERING	NUMBER OF 40-MIN SESSIONS	THINGS TO MAKE	SKILLS AND FUN FOR THE KIDS
What's Out there?						
Finding a Home for creatures from another world	Search for Habitable Planets	Hands-on, Design, Art	Understanding the conditions and composition of other planets	2	An imaginery "creature" from another world	Learning the right planet composition and conditions to house their imaginery "creature"
The Neighborhood of Our Solar System	The Solar System in Your Neighborhood	Kinesthetic, Hands-on	Learn the size, distance and movement of the planets	3	Food solar system, human solar system, paper solar system	Using analysis, prediction and math to make solar system scale models
Storytellers in the Solar System						
Meteorites and What's Inside Them	Edible Rocks	Hands-On,	Learning how scientists study a rock's composition	1	Candy/snack bar rocks	Learning to categorize rocks using edible samples
Meteorites - Rocks From Space Are Here on Earth	Searching for Meteorites	Hands-on, Exploration	How scientists decide where to search for meteorites	1	Launching a balloon meteorite	Simulate meteorite impact and retrieval of "fragments"
Comets - Icy Clues to Solar System Formation	Comet on a Stick	Hands-On, Art	Team collaboration and modeling a comet	2	Model of a comet from recyclable items	Team consensus, modeling and artistic communication
Looking At Surface processes						
Volcanoes - Layering the Earth From the Inside Out	Lava Layering	Hands-On, Demonstrate	Finding the history of Earth's and other planets' surfaces through volcano layering	1	Make a volcano and build layers with clay	Learn how volcanic layers build onto planetary surfaces and tell its history
Impacts and Craters on Surfaces	Holes in the Ground	Hands-On, Interactive	Finding the history of Earth's and other planets' surfaces through craters	1	Create and evaluate craters in layered material	Look at crater formation as a way of telling in what order the surface changed
The Moon - Reading History on Its Face	Lunar Surface	Hands-On, Art	Learning to read the story of the Moon's history through making accurate models	1	Make a clay version of the Moon's surface	Find clues on a surface that has not changed through weathering
Our Future In Space						
Searching the Solar System For Earth-Like Wonders	Strange New Planet	Hands-On, Kinesthetic	Learning engineering methods for exploring other planets in the solar system	2	Make paper telescopes (option) and sample clay planets	Become spacecraft simulating different forms of solar system exploration
How Do We Get There?	Soda Straw Rockets	Hands-On, Kinesthetic	Learning engineering lessons in thrust, force and trajectory	4	Make and improve paper rockets	Make, launch and re-design rockets to improve flight
Sharing the Solar System With Others	Be a "Rock Group"! Share the Solar System with Others	Hands-On, Arts	Being vested in new knowledge and sharing it with others	2 or 3 @ 40 min and event	Make exhibits, art, samples from activities	Plan/implement an event to share new knowledge and products

Designed to address National science and mathematics standards; specific standards listed in each individual activity

From Out-of-School to Outer Space

Rocking Around the Solar System

INTRODUCTION

Our Solar System rocks!

Right now, the most advanced scientific space fleet ever assembled is out there in our solar system, helping to answer big questions: Where do we come from? Where are we going? Are we alone?

Never before have so many different spacecraft been poised to probe so many mysteries about so many different solar system bodies. Clues to these mysteries are scattered among the planets and multitude of moons, comets and asteroids that make up our solar system. Evidence of the earliest days of the solar system may exist in rocks on the cratered surfaces of Mercury, Mars and Earth's moon. Chemical clues to our origins may linger in the icy hearts of comets and distant Kuiper Belt Objects. NASA's robotic explorers must endure extreme heat and cold and intense radiation during these long journeys across almost un-imaginable distances.

Take your afterschool youth on a journey of science and engineering to rocky places in our solar system with this *Rocking Around the Solar System* afterschool program unit for grades 4-5. Designed for leaders with no science background, this hands-on, teamwork-based unit explores the vastness and scale of the solar system, major surface processes like volcanoes and meteor impacts that "rock" the inner planets, conditions on the planets, and how NASA "rocks around" the solar system – investigating with robotic spacecraft. The unit also exposes students to engineering challenges much like those NASA engineers face in exploring with robotic spacecraft.

Beyond the science and engineering, *Rocking Around the Solar System* contains extensions to help students make literacy and math connections, learn about citizen science opportunities, and explore types of careers available at NASA and in the fields of science, technology, engineering, and mathematics (STEM). It introduces students to scientists, engineers, and astronauts currently working at NASA and those whose contributions have moved space exploration forward in the past. Because the activities in this program unit are related, yet independent, a sequence of experiences can be built based on student interest.

Rocking around the Solar System, adapted specifically for afterschool use from several related NASA units for the classroom, provides:

- Step-by-step instructions for 11 hands-on activities, divided into 21 distinct 40-minute sessions – a total of 14 hours of programming
- Activities that can be done independently and selected according to student and leader interest, but can also be done in suggested sequence for a project-based experience.
- A connection to active robotic space exploration and current science
- A materials list selected primarily from off-the-shelf items from a typical afterschool site or grocery store, that are also culturally familiar

From Out-of-School to Outer Space

Rocking Around the Solar System

INTRODUCTION

- A connection to the classroom day through the NRC National Science Education Standards and NCTM Principles and Standards for School Mathematics
- Youth-centered learning – the leader guides the students to wonder, question, and discover on their own
- Several activity styles to appeal to a variety of learners – hands-on experimentation, kinesthetic experience, artistic expression, teamwork, and engineering design and model construction – with ideas for further exploration and mathematics extensions
- Experience for students to understand and use the processes of science and engineering, and develop their "habits of mind"
- Development of teamwork and communication skills
- Specific questions that can provide an assessment of student and leader experience
- A culminating and assessment event for youth to share their experience with other students, their parents, and their community

This program unit was pilot- and field-tested in several afterschool programs in New York City and Los Angeles, and staff made specific recommendations about what should be included to make the unit the most "user-friendly." Everything you need to know to do one activity is condensed into a 5-6 page format, followed by the materials to be photocopied.

"Check It Out!" page	**"Do It!"** page(s)	**"Take it Further!"** page
Time/Number of Sessions, Activity Type, Space Needed	Student Activity – step-by-step instructions for each session	Information for Families
Activity Goals		
Background: Where's the Science and Engineering?	Questions for the Youth (Informal Assessment)	NASA Resources, Careers at NASA, Role Model Resource
National Science Education Standards	Sharing the Findings (Informal Assessment)	
Equity/Leveling the Playing Field	Leader Reflection and Assessment	Taking the Science to the Next Step
Materials List, Getting Ready		
Leader Tips – suggestions based on actual experiences	Glossary	Literacy

As you take your students exploring the solar system with this guide - focusing on solid, rocky surfaces, and how to get around and "rock" the solar system - you can keep up to date with the latest discoveries and spacecraft missions at NASA's solar system exploration website:
http://solarsystem.nasa.gov

Rocking Around the Solar System
INTRODUCTION

Be sure to explore the worlds you want to see, and visualize where planets and spacecraft are today! Visit:
http://eyes.nasa.gov

Enjoy the trip!

From Out-of-School to Outer Space

Rocking Around the Solar System

INTRODUCTION

A Note to Site Coordinators. This guide provides resources to assist in preparing, observing, and assessing the activities.

- The "Materials Summary" lists what you'll need for the entire unit from a photocopier or printer, and from your closet stocked with standard supplies. (Leaders may require a storage bin for keeping student projects between sessions and for collecting household recyclables for building spacecraft models.)

- The "Internet Resource List" provides the addresses to allow leaders' and students' access to supporting materials (pictures, podcasts, games, etc.).

- The "Check It Out!" page for each activity describes the particular space and materials needed, what the students will gain from the activity, and tips for its implementation. Use this page along with the "Informal Assessments" and "Leader Reflection and Assessment" (from the "Do It!" pages) for your discussions with the leaders and observations of them doing the activities.

- Plan ahead for the final culminating and assessment activity "Be a Rock Group! Share the Solar System with Others", which will require space for displays and an audience, along with invitation. Like an exhibition, students draw from the products they have created and the skills and knowledge they have gained to communicate their findings and discoveries about "rocking" and exploring the solar system.

For that person connection, encourage your leaders to utilize NASA volunteers in your area. NASA has several national volunteer networks who are specially trained for working with the public and in educational settings. Instructions for requesting a local volunteer are on their websites.

- The *Solar System Ambassadors* are motivated volunteers across the nation, who communicate the excitement of JPL's space exploration missions and information about recent discoveries to people in their local communities.
  http://www2.jpl.nasa.gov/ambassador
- The *Night Sky Network* is a nationwide coalition of amateur astronomy clubs bringing the science, technology, and inspiration of NASA's missions to the general public. They share their time and telescopes to provide unique astronomy experiences at science museums, observatories, classrooms, and under the real night sky.
  http://nightsky.jpl.nasa.gov/
- NASA *Student Ambassadors* are high performing interns and fellows, who volunteer their time to advance the NASA mission, by focusing on STEM research, education, and outreach. They are looking for opportunities to serve, learn, and inspire. The ambassadors serve as speakers and exhibit supporters.
  https://intern.nasa.gov/intern/

From Out-of-School to Outer Space

Rocking Around the Solar System

INTRODUCTION

- The NASA *Speakers Bureau* is composed of engineers, scientists, and other professionals who represent the agency as speakers at civic, professional, educational and other public venues. Each year, NASA speakers provide hundreds of presentations to thousands of people.
  http://www.nasa.gov/about/speakers/

ACTIVITY #2 – THE SOLAR SYSTEM IN YOUR NEIGHBORHOOD

Overview
[graphics insert image of planets to scale here]
During this activity, your youth:

- Use familiar food items for a scale model of the size of planets in our solar system
- Walk the distance between planetary bodies in the solar system on a scale model they calculate to fit to their school ground
- Make a foldable scale version of the solar system with a piece of paper
- Compare their scale version of the solar system to the neighborhood around their school
- Use science and mathematics skills of observing, communicating, predicting, gathering and organizing data, team work, measuring, using proportions

Time/Number of Sessions
Three 40-minute sessions

Activity Type
Hands-on, kinesthetic

Space Needed
Session 1 and 3 - Tables and chairs
Session 2 – Large field or schoolyard (requires preparation)

Activity Goals
Youth will:

- Understand the importance of using models for representations of larger or more complex objects
- Understand the basic mathematics to use transfer actual solar system scale to smaller scale
- Gain appreciation for the vastness of the solar system by comparing to something familiar – a piece of paper, their school yard, the neighborhood
- Observe that the solar system is mostly empty space, and that the outer planets are much further part than the inner planets
- Kinesthetically experience solar system scales by holding fruit, folding paper, and walking

Where's the Science and Engineering

- Scientists use measurement and scale calculations on an everyday basis. It's important because they can help visualize answers to questions about the solar system.
- Engineers also depend on measurement and scale calculations for planning and building spacecraft, calculating the trajectory of a spacecraft's flight path, and many other important steps for a mission into the solar system.
- Both scientists and engineers need to be very familiar with the locations of planets and other bodies in the solar system - the distance from Earth, distance between them.
- Our solar system is made up of the Sun, eight planets, many Kuiper Belt objects and dwarf planets including Pluto, over 140 moons, millions of small asteroids, and countless comets. Most of the mass in the solar system is concentrated in the Sun, which is a medium-sized star. (Jupiter, the largest planet, has a mass just 1/100 that of the Sun.) However, most of the solar system is empty of any large bodies – the planets orbit the

Sun at distances that are thousands of times larger than their planetary diameters. Because of this, it is difficult to make models that show both distances and sizes together.

National Education Standards

5-8
Earth and Space Science
- Relative sizes of the Sun and planetary objects including small bodies (comets, asteroids, moons) can be calculated and modeled
- Relative distances of the Sun of planetary objects including small bodies (comets, asteroids, moons) can be calculated and modeled

Science as Inquiry
- Models of the solar system show patterns that cause seasons and the appearance of planetary objects in the night sky

Understanding about Science and Technology

Mathematics Standards
- Problem Solving
- Communication
- Patterns and Functions

Equity/Leveling the Playing Field
- This activity introduces mathematics in an enjoyable way. Help them to understand that making these simple calculations is going to let them compare the solar system to their own school.
- The different exercises in this activity span several learning modalities and allow students to learn about the solar system from different perspectives.

From Your Supply Closet

Session	For Leader	For Students
1	From the grocery store – substitute as needed (approximate diameters given): • Small cantaloupe or large round squash (11 cm or 4 ½”) • Grapefruit (9 ½ cm or 3 ¾”) • Small lime (4 cm width or 1 ½”) • Large strawberry (just under 4 cm width) • Green grape (1 cm width or 3/8”) • Blueberry (1 cm or 3/8”) • 2 Peppercorns (1/2 cm or 3/16”) • 1 grain of rice (2 mm or 1/16”)	For each student team of 4-5: • Pencils
2	• 9 grocery bags • Ball(s) of string, enough for 9 times the length of your outdoor location • 18 rounded sticks (such as Popsicle™ sticks) to stick in ground • Tape to attach sticks to lithographs and index cards	For each student team of 2-3: • Pencil or pen • Planet/dwarf planet kit (leader constructs) • (Optional) calculator

	• 9 - 5x7" index cards • 9 Meter measuring sticks, yard sticks, or measuring tapes (or teams should share fewer) • Role of masking tape for students	
3	• Chart paper/ whiteboard/ chalkboard and markers/chalk	• Colored pencils or thin markers (white board markers are too thick)

From a Photocopier/Printer

Session	For Leader	For Students
1	*Solar System Scale Model – Planetary Sizes* Answer Key	For each student team of 4-5: • *Solar System Scale Model – Planetary Sizes* Student Handout
2	*NASA Solar System Lithographs* *Solar System Scale Model – Distances from the Sun* Answer Key	For each student team of 2-3: • *Solar System Scale Model – Distances from the Sun* Student Handout
3	Copy of map of school neighborhood on legal (8 ½" x 14"), or regular (8 ½" x 11"), sized copy paper (See Getting Ready for instructions)	Copy of map of school neighborhood on legal (8 ½" x 14"), or regular (8 ½" x 11"), sized copy paper

Getting Ready

For Session 1

- Gather fruit, grains, and other items to represent the planets and dwarf planet Pluto in our solar system
- If you use any substitutions for the food items, be sure to note it on your *Solar System Scale Model – Planetary Sizes* Answer Key.
- Familiarize yourself with the *Solar System Scale Model – Planetary Sizes* Answer Key so that you can help guide the students.

For Session 2

- Find a location for the solar system walk. Measure the length of the longest side.
- You have two options depending on the size of your location. Both introduce units used by engineers and astronomers.
  1. An open area of at least 100 meters (328 feet) on a side, like a football or soccer field. With this option, the students work with metric units (meters and kilometers), and perform division.
     - Your "scale factor" will be 1 meter to 60,000,000 kilometers.
  2. An area smaller than Option 1, but at least 36 meters (120 feet) on a side. In this option, the students work with Astronomical Units (1 AU = distance between the Earth and the Sun), and perform multiplication.
     - You will need to figure out your "scale factor" – measure the long edge of your area, then divide by 40. Round down to the nearest integer. That integer = 1 AU. Example: Your area is 150 feet long. 150 feet/40 = 3.85 feet. Round down to 3. Your scale factor is 3 feet to 1 AU.
- Write the "scale factor" for your chosen location in the box on "Do-It!" pages for Session 2, and also on the box on the *Solar System Scale Model – Distances from the Sun* Student Handout.

- Walk out the planets yourself so that you become familiar with the planetary distances, and the "scale factor" (the distance each unit in your solar system model represents in space) for your location.
- Attach the *Sun Lithograph* (from the *Solar System Lithographs*) to a stick.
- Make a kit in a grocery bag for each of the 8 planets and dwarf planet Pluto, consisting of:
  - A pre-cut ball of string length of the longest edge of the location you have chosen.
  - The name of the planet/dwarf planet written with a large marker on a 5x7" index card. Underneath the name, write "(Prediction)".
  - If your location has a soft surface, such as a grassy field, attach the following items to sharp pencils or sticks that can be put into the ground:
    - *Solar System Lithographs: Mercury, Venus, Mars, Earth, Jupiter, Saturn, Uranus, Neptune, Pluto*
    - Index card with matching planet/dwarf planet name
  - Meter measuring stick, yard stick, or measuring tape
- Use your knowledge of your session time and student development for options within this activity:
  - You may pre-cut the string and have them do the math calculations that they confirm with your string length.
  - You may decide to skip the math calculations and pre-cut the string and have them just walk out the distance.

For Session 3

- If you have legal sized copy paper (8 ½" x 14"), it will be easier for the students to make all the folds. 8 ½" x 11" will work, but some students may need extra help making the folds for the inner planets.
- You can use a photocopy of a map of the local neighborhood around your school, or a map or satellite view from an on-line map website (the latter may help the area be more recognizable to your students). Having the paper with the short edges on the left and right (8 ½" side), choose an enlargement that puts your school at the far left of the paper and covers the neighborhood in one direction away from the school. Showing an area covering a few blocks works well, but you can choose the area you want to cover
- A map image handout of the *National Mall in Washington DC* is included if you don't have a different map to use.
- You may want to choose one street that runs the across the length of the page. This allows students or families to observe the solar system model on a continuous route through the neighborhood.
- The Sun's location will be represented on the far left of the page, and Pluto's location on the far right.
- Trim the short sides to the actual photocopied/printed edges where the Sun and Pluto will be.

Leader Tips

Be sensitive to create teams that have a mix of students of varying levels of math skills, and encourage those who can make calculations quickly to show others how to do it.

Session 1

- Point out to the group that these are "scale" models that don't come close to representing the actual size of any or distance of the planets. They can tell that by looking at the model of Earth.

- In preparing them for Session 2, make sure they understand that the scaled size of their food model will not relate to the distance they walk out the solar system. The distances of the planets would be much smaller for the solar system walk.

Session 2

- Give each team more string than they need to mark their planet distance with tape so you don't need to take scissors outside.
- Set any ground rules you need to before taking the group outside – this could include staying with the group at all times or agreeing on a signal that it's time to stop walking, etc.

Session 3

- If you don't have access to maps, you can still do this activity and use the paper folds as a model for the planetary distances.
- If you are able to make your neighborhood map copies Sun location be at the same location (field corner) as you did in Session 2, it will have greater connection for the students.

Student Activity

Session 1 . Scale the Size of Planets with Foods

1. Divide students into teams of 4 – 5, each sitting at separate tables. (9 teams are ideal, so have smaller teams if needed.) Then introduce the activity with the following conversation guide:
   - Can you imagine how far away the Earth is from the Sun, or how big the Earth is compared to other planets? (Let students guess.) Would any of them fit inside your neighborhood, or on our school ground? (No, all the planets, even the dwarf planets, are too big.) To find out, we will explore sizes and distances in the Solar System, and to do that, we'll make three different scale models – one here in the room, another outside, and one using a map of the neighborhood. They'll each represent different things about the scale of the solar system.
   - Think about all the planets in our solar system, and imagine you wanted to show your friends and family how big they are, or how far away from each other they are. How could you do it? (Let them brainstorm for some answers.)
   - You would need a scale model. To scale something is to use math to bring it from one size to another in the proper proportion. You may have seen scale models of planes or buildings. They are much smaller in size but they are correctly proportioned to the actual thing.
   - Scientists and engineers often build models to visualize something that is too big, too small, too far away, or too complicated to observe directly. Their model could be as simple as drawing something on a white board, or as complex as creating a computer program. Using mathematics to determine the size and scale of bodies in the solar system and the distances between them is critical to scientists and engineers because they are sending spacecraft that must navigate these planets.
   - But models can't represent everything about the actual thing (otherwise, they'd be a copy!). We must pick and choose and communicate the key things we can easily represent with our model. Some traits of the original we won't be able to represent accurately.

2. Tell them that today, using food items, they will make a scale model of the size of planets in the solar system (including dwarf planet Pluto), and put them in order in the proper part of the solar system. Let them know that each team will be asked to investigate and represent a planet or dwarf planet. They will have three jobs – to choose the food that best represents the size of their planet, decide which part of our solar system it belongs (inner, outer, or beyond) by learning about what it's made of, and put it in order of their distance away from the Sun.

3. Give them some background and hints using this conversation guide.
   - One of the ways scientists classify the parts of our solar system is by the type of planets that are there and what they are made of. While our solar system was forming, near to the Sun its heat and radiation removed most of the gases and ice that were originally there, leaving behind solid rocky materials and metal which planets could be made from. The outer planets, being further away from the Sun, kept much of their gasses and so they became the major part of those planets. Their gasses turn to liquid much deeper in the planet, due to increased pressure.
   - From this, we get the identification of our "rocky inner planets" and our "outer gas giants". This gives you a clue to the general order of placement for them in our model. Another clue is that the outer gas giants – Jupiter, Saturn, Uranus, and Neptune – are much larger (or giant) than the inner rocky planets. The inner planets – Mercury, Venus,

Earth and Mars – are made of rock and metal and have solid surfaces. Pluto doesn't seem to fit into its location furthest from the Sun and scientists have had a lot of discussion about its being - not a planet - but a dwarf planet, one of a number found in what's called the "Kuiper Belt" (pronounced K"EYE" - per) out beyond the gas giants.

4. Have students take a look at the items on the table while you name each food. (Use the food name, not the planet name.)

5. Hand each team a copy of the *Solar System Scale Model – Planetary Sizes* student handout. Explain that they are to do the things below and record their answers in the corresponding column of the handout. (If the session time is limited, you may want to have each team look at a different planet/dwarf planet and only fill in those corresponding columns.)
   - Decide which food represents which planet (fill in the "Food Model" column)
   - Using the "Percent Rock, Metal, or Gas" columns, decide on which part of the solar system the planet belongs (fill in the "Part of Solar System" column with one of "Inner/Rocky", "Outer/Gas Giants", or "Kuiper Belt")
   - Order the planets/dwarf planet from closest to the Sun to furthest away from the Sun (use a number from 1-9 to fill in the "Order from Sun" column)

6. Pass among the tables and answer questions, but encourage them to use the data on diameter and percent of rock, metal, or gas to make their decisions.

7. When the students have completed their tables, have them select one planet they want to represent. Make sure all planets and Pluto are represented. Have each team send one member forward and pick up the food item they believe represents their planet.

[picture of students lined up in proper order, holding up their fruit]

8. Next, finish this model of the solar system by having the representatives put themselves in order they think is their planet's distance from the Sun. (You can use the *Solar System Scale Model – Planetary Sizes* Answer Key.) If there are any disagreements, ask them to discuss why they chose that particular food item or order. If they had a good reason for their selection, correct it, but applaud that they used data to make their decisions. Make the point that the planets are not this close to each other in space, but since this model is not about proper distance between planets, they can stand right next to each other.

9. Once everyone has the correct food item and order for this model, ask the students where they would divide the food between the rocky inner planets and the outer gas giants (Answer: between Jupiter and Mars). What is the area where dwarf planet Pluto is? (Kuiper Belt)

10. As a fun exercise, tell them that the Sun is 109 times bigger across (in diameter) than the Earth. What could we use to represent the Sun in our model? (Suggestions: on this scale, the Sun =109 cm (about 3 ½ feet), the height and arm span of a typical kindergartener, or a 1000 pound pumpkin) [picture of such child here and such pumpkin here]

11. You can give them this easy saying to remember the order of their planets, which includes dwarf planet Pluto: "**M**y **v**ery **e**legant **m**other **j**ust **s**erved **u**s **n**ine **p**izzas – Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto.

12. In closing, have the student return to their seats. Prepare the group for the next session by telling them that they will use calculations to make a different scale model, out on the school ground - the distance between the planets in the solar system.

13. Collect the *Solar System Scale Model – Planetary Sizes* student handouts to keep for the group. You may choose to keep the planet size scale food model out until after they complete the next session and can appreciate the difference between the two models.

Session 2 . Walking out the Solar System

1. For this session, move to the school ground as quickly as possible. Gather everyone near one corner for this session. Quickly set guidelines for behavior and signals for "walking", "stopping", and "return to the Sun", as they get a distance away.

2. Divide the group into 9 teams of 2 – 3 students, and have one student volunteer to be the Sun (this student will be stationary for the session).

3. Explain that today's model will compare the "neighborhood of the solar system" to "the neighborhood of their schoolyard". Tell them that together, they will form a scale model of the distances between the Sun and the planets. Ask them how that compares with the model they developed in Session 1. (Answer: In Session 1, they modeled the sizes of the planets, but not the distances between them.)

4. Give the student who represents the Sun the *Sun Lithograph* (from the *Solar System Lithographs*), and give each of the student teams one of the 9 planet kits you made. Tell them they will use their kit to walk the scale model distance between the Sun and their planet/dwarf planet - the dwarf planet Pluto will be also be included in this activity.

5. First, each team must make a prediction about where they think the location of their planet/dwarf will be on the field. Standing at the Sun person, have each team discuss and predict a location for their planet on the field, and then walk to that location – in any direction on the field - and stick their planet-name "prediction" index card with into the ground (or tape it down if on a hard surface.) Then have teams return to the Sun's location.

6. Next, the teams will use scientists' calculations to decide where their planet should actually be on the field. Give them copies of the *Solar System Scale Model – Distances from the Sun* Student Handout and a pencil.

7. Note to leader: Be sure to have written below the units and scale factor you chose to use for your field's size. (See the "Getting Ready" section earlier in this activity). Recall that for Option 1, a field with a size of 120 meters or larger, you will convert the units of kilometers that engineers use to meters that the students will measure. The conversation factor in this case is 1 meter to 60,000,000 kilometers.

8. Explain the meaning and value of the scale factor, using the following conversation guide:
   - To be able to figure out the correct distance for each planet in our model, we'll need to use a "scale factor". This is a number that we use to convert our model from the units that scientists and engineers to measure distances in space, to the units that we'll use to measure and size your planet's distance on the field.
   - [Option 1]
     - Today, we will use the scale factor to convert meters to kilometers.
     - Our scale factor is 1 meter to 60,000,000 kilometers.
     - This means that each 1 meter that we measure on the field represents 60,000,000 kilometers in space!

    - We’ll be looking at the “Actual distance (kilometers)” column on *Distances from the Sun* student handout.
- [Option 2]
    - Today, we will use the scale factor to convert feet to Astronomical Units. An Astronomical Unit is an “interplanetary ruler” used by astronomers to mean the distance in space between the Earth and the Sun. We can see from these numbers how closer or further away from the Sun the other planets are.
    - Our scale is _____ feet to 1 AU.
    - This means that each _____ feet that we measure on the field represents 1 AU.
    - Please write your scale factor in the box on your *Distances from the Sun* student handout.
    - Next, we’ll be using the “Actual distance (AU)” column on your *Distances from the Sun* student handout.
- Now find the row for your planet on the handout.

9. If you decided your students are prepared to do the math calculations, have them multiply the scale factor by the corresponding “Actual Distance” for their planet, and on the same row, write it in the “Model Distance” column. Otherwise, read off the numbers from the *Solar System Scale Model – Distances from the Sun* Answer Key. This can also be done as an answer check.

10. Ask each team to take the string and picture of their planet from their kit.

11. If you decided that you have time, have each team measure the correct model length from Sun to their planet, starting from one end of the string; mark that distance point on the string with a piece of masking tape, and write the name of the planet on the tape. (You can distribute the tape from one roll.) At the opposite end of their string, they should put a piece of masking tape with the word “Sun” on it. Give them a stick, or piece of cardboard to wrap their string around so that the tape mark “Sun” is on the outside end. (You can prepare this step in advance to save time if needed, although students will not get the measuring skills.)

12. While they are still all together at the Sun point, tell them that it is time to see the difference between their prediction and the true scale distance.

13. One at a time, have each team hand the end of their string marked “Sun” to the student who is the Sun - or one of the team members can remain behind to hold the string.

14. Have a second team member start at the Sun and, going in the same direction as their prediction, walk out the length of string until they come to the tape mark. They should stop there and anchor their picture to the ground. (If they decide that their original estimate is no longer valid, they will want to move their prediction card but they should not.)

15. When all teams have finished, have them leave the strings on the ground and walk <u>carefully</u> back to the model Sun.

16. Call attention to the entire field and the difference between their initial predictions and the proper distance of their planets in this model. You can use these conversation tips:
    - What is accurate about this model? (The distances from the Sun to the planets.)

- You can now see the properly scaled distance between each of the planets and appreciate their distance from the Sun – even though you aren't observing the actual distances in space.
- Are the planet sizes to the correct scale? (No – they are too large for the distances on the field, and they aren't all the same size, like they appear in the pictures.)
- Imagine you were planning a mission for NASA based on your original predictions, rather than calculations. Would your spacecraft get to their destinations? Scientists and engineers work carefully to model all their work on Earth to a smaller scale of the solar system so that it becomes a model just as yours is a model on this field.

17. If there is time, you can use one of the Planetary Position charts for a given day, and have the students move their planets to the position on the chart, keeping the strings straight and the distance from the Sun the same. Have the group return to the Sun location and look at the new solar system model they have created – representing the distances **and** the correct positions in space as they appear on a certain day.

18. Have teams return all their planet lithographs, index cards, strings, and materials to their kit bag.

Session 3 . Solar System Map Scaled to the School Neighborhood

1. In this Session, students will make a scale model of the solar system by matching locations on a map of the neighborhood around their school to the orbits of the planets in the solar system, including dwarf planet Pluto.

2. Remind them about the previous model they made on the schoolyard, and ask them to recall what surprised them about the distances of the planets in the last session. Ask what about that scale model was represented accurately. What didn't the model represent well? Chart their responses.

3. Tell them that today they are using a map of an even much bigger area to form their model of distance in the solar system **-** the amazing thing is that they will be able to take a copy of a map or satellite picture of their school neighborhood and fold it to places that represent the approximate distance from the Sun of the planets and Pluto! (We might call it Planetary Origami!) They will be able to help their friends and family learn the scale the solar system, too, right around their school.

4. Hand each student a copy of the map, and orient them to what they are seeing. Show them where the school is on the map and help them locate other buildings and street names nearby.

5. Demonstrate each fold as you give the students these instructions. Walk among the tables to check that the folds are being properly made. [graphics, leave space in the margin for 4 pictures of the various stages of folding]
   - Lay your paper on the table with the short edges on the left and right. Write "Sun" (or "S") in small letters along the left edge of the paper. (Students might do better writing along the crease vertically.) Write "Pluto/Kuiper Belt" (or "P") along the right edge. All the rest of the planets are going to be fit to scale between these two.

- Now fold your paper by making the two short edges meet (bring the “S” and “P”) together. Crease the paper. Then unfold it, face up. Write “Uranus” (or “U”) along the crease. Uranus’ orbit is half-way to Pluto!
- Again take one of the short edges, but instead fold it half-way by bringing the edge to the center crease, where Uranus is marked. Crease the paper at this fold. Take the other edge and bring it to the center crease, too. Unfold both sides. Write “Saturn” (or “S”) on the new crease on the left, and write “Neptune” (or “N”) on the new crease on the right.
- Now, take only the left edge and fold it to the crease marked “Saturn”. Unfold and write “Jupiter” (or “J”) on this newest crease.
- Wow! What parts of the solar system do we have represented so far? (Answer: The outer solar system and the edge of the Kuiper Belt.) We now have all the gas giants placed on our model. But what about the inner solar system – how much room is left for that? (Answer: 1/8 of the page, the part to the left of the last fold.)
- So we aren’t done yet! We’re going to add something new here, which is the Asteroid Belt where small rocky remnants left from the formation of the solar system orbit the sun. Fold the left edge to the crease marked “Jupiter”. Unfold and write “Asteroid Belt” (or “AB”) on the new crease.
- And now, for the inner planets! We need two more folds! First, fold the left edge to the “Asteroid Belt” and crease. Unfold and write “Mars” (or “M”) just to the right of the crease, and write “Earth” (or “E”) just to the left of the crease.
- The paper to fold is getting really small now. (You might need to help the students particularly for this fold.) One more time, fold the left edge to the previous crease (in between Earth and Mars). Unfold. If there is room, write “Venus” on the right of the crease, and “Mercury” on the left.
- You now have the Sun, all eight planets, and the dwarf planet Pluto.
- Open your paper completely and discuss your findings with your team.

6. Close by asking them what is accurately modeled with this paper model (answer: distances between the planets and the Sun), and what is not represented well (suggestion: planets are not in a straight line). Suggest this is a solar system model the students can talk about with family and friends at school, or show people when they are are passing by.

Questions for Youth (Informal Assessment)

- What surprised you most about the size of the solar system and the position of the planets within it? (Chart answers)
- When we walked the solar system, what surprised you about the difference between your predictions and the actual scale distance of your planets to the Sun?
- Were there surprises about the difference in scale size among the planets? What were they?

Sharing the Findings (Informal Assessment)

- What do you think about Pluto being re-assigned from a planet to a dwarf planet now that you know more about its composition, size and distance from the Sun? (You can remind them of some of Pluto’s characteristics from their data sheets if they have forgotten).
- Do you think that scientists should be able to change the designation of a planet or other body in the solar system once it is established? Why or why not?
- Who do you think might enjoy learning the scale model we used on the school ground? Who could we share it with and how would we do that?
- What about the solar system you made on paper? How could we share that?

Leader Reflection/Assessment

1. Did students seem to understand the difference between rocky inner planets and outer gas/ice giants in terms of their placement and composition?
2. Were all students engaged in the active walk of the solar system?
3. Did the new information lead them to ask questions about the formation of the solar system?

Glossary

Astronomical Units – a unit of measure used by astronomers to mark distances away from the Sun (1 AU = distance between the Earth and the Sun).

Diameter — the length of a straight line through the center of an object. The diameter gives us the measurement of how far it is straight through the middle of a planet, dwarf planet, moon, or the Sun.

Kuiper Belt (KYE – per) – the region of the solar system beyond the gas giants (beyond the orbit of Neptune from about 30 to 55 AU) and is probably populated with hundreds of thousands of icy bodies larger than 100 kilometers (62 miles) across.

Metric units - a decimal unit of measurement of the metric system (based on meters and kilograms and seconds)

Model – a three dimensional example for imitation or comparison; a representation (sometimes in miniature) to show how something is configured or constructed

Scale factor – A number used to multiply or divide a quantity when converting from one system of units to another and sizing for a particular model representation

Solar System- the configuration of a sun with planets and other bodies that revolve around it

Information for Families
Have students take home the list of food items for the planetary sizes scale model, and encourage them to plan a demonstration of the scale, followed by a side of fruit salad made from some of the same fruits!

If they have access to a computer, they can try running a copy of their own neighborhood and fold it to represent a scale model of the solar system near their home.

NASA Resources

Careers at NASA
Putting a probe into space around another planet takes a team of dedicated scientists, engineers, and others at NASA working together. Learn about some of the people who make space exploration possible.
Visit: http://www-robotics.jpl.nasa.gov/people/index.cfm

Role Model Resource
When Eugene Chiang was 12 he would haul his telescope out at night on Long Island, New York, only to find his view wrecked by city lights or tall trees. On many nights, the cold drove him inside. "It was hard to find a good patch of sky that was really open," Chiang remembers with a laugh. "That's why I became a theorist" instead of an observing astronomer.

Chiang is now a university professor who has worked on a team using powerful telescopes to search for giant chunks of ice and rock - the fossils of our solar system - in the Kuiper Belt, that are just about at the edge of what a telescope can detect, using predicted paths of these mysterious objects.

Chiang is happy to leave most of the actual observing to his colleagues. One trip to a telescope high atop a dormant volcano in Hawaii reminded him of his chilly introduction to stargazing. The theoretical world is much warmer. "I prefer to sit in my sunny office and think," he said. Chiang credits his love of physics to role models both real and fictional. He grew up watching real-life scientist Carl Sagan's *Cosmos* and the British science fiction series *Dr. Who* on television. "I remember telling my mom I couldn't decide who I admired most," Chiang said. "Carl was real. But science fiction interested me, too, because it is about the future possibilities of physics. As far as I could tell, *Dr. Who* used physics to save the universe every week. It wasn't magic. It was physics."

Read more about Eugene Chiang at http://astro.berkeley.edu/people/faculty/chiang.html
[graphics please take Eugene's picture from the link above]

Resources
Our Moon is slowly moving away from the Earth. Learn more about it at NASA's Eclipse website:
http://eclipse.gsfc.nasa.gov/SEhelp/ApolloLaser.html

Visioning a Solar System Scale Model at Johnson Space Center.

The central plaza of Space Center Houston, JSC's official Visitor Center, is a large black-floored circle, with a black path that extends down a corridor to the JSC tours tramline. Using a scale factor of 1 AU=2 meters, the solar system model fits nicely in Space Center Houston. With the Sun represented by a shooter marble at the center of the plaza, Jupiter's location is still inside the central circle, and Pluto orbit is just outside the door to the tram, 80 meters from the center of the "solar system". Where else can you envision a solar system scale model, and what scale factor do you need?

Taking the Science to the Next Step
Add Sun, Moon, asteroids and comets to the solar system. Moon orbits Earth at 1 AU, asteroids are in asteroid belt at 2.2-3.3 AU, and comets travel on highly elliptical orbits from beyond Pluto to near the Sun.

Have your students calculate how big a space they would need to represent distances in the solar system on the scale of sizes of their fruit. (Answer: if Earth is the width of a small (1 cm) grape, the scale of this model would be 1 cm = 12,756 kilometers. The distance from Earth to Sun would be (149,600,000/12,756) cm = 11,728 cm, or about 117 meters – bigger than the average football field! The Sun, at the other end of the field, would be 109 times larger than the Earth = 1.1 meters.)

Align your scale model of the planet distances with where the planets are positioned today – bring up http://solarsystem.nasa.gov/eyes and chose "Explore the Solar System", then "Zoomed Out View", and use the "In/Out" dial to zoom out to show all the planets. You will also see the current paths of some of the robotic spacecraft exploring the solar system.

Give your students more experience with scales in the solar system with the NASA Space Math activity "Earth and Moon to Scale". Students create a scale model of the Earth-Moon system and compare with artistic renditions and actual NASA spacecraft images.
http://spacemath.gsfc.nasa.gov/weekly/5Page23.pdf

In "Planets, Fractions, and Scales", students work with fractions of planetary sizes to determine the actual sizes of the planets, given the diameter of the Earth.

In "Planetary Conjunctions", students study a simple solar system with three planets and use geometry and patterns to work out how often the planets will "line up".
http://spacemath.gsfc.nasa.gov/weekly/6Page42.pdf

Literacy
Ask the students to write a short science fiction story about space travel. Tell them to include as many facts as possible. Which planet would they go to? How long would it take to get there? What would they expect to find? Include information like how far away the planet is, or the name of its largest moon. Share the stories with the group.

Want to know more about the planets? Learn the words to the rap song "Planetary Posse", from NASA's Space School Musical http://discovery.nasa.gov/musical/index.cfml

Materials

- *Solar System Scale Model – Planetary Sizes* Student Handout
- *Solar System Scale Model – Planetary Sizes* Answer Key
- *NASA Solar System Lithographs (Our Solar System, Sun, Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto, Kuiper Belt and Oort Cloud)*
- *Solar System Scale Model – Distances from the Sun* Student Handout
- *Solar System Scale Model – Distances from the Sun* Answer Key
- *Map of National Mall in Washington DC*

Solar System Scale Model – Planetary Sizes Student Handout

Order from Sun	Planet & Diameter	Kilo-meters	Miles	Food Model	% Rock	% Metal	% Gas/ Liquid	Solar System Location
	Earth	12,756	7,926		55	45		
	Jupiter	142,984	88,846		15		85	
	Mars	6,794	4,222		91	9		
	Mercury	4,880	3,032		58	42		
	Neptune	49,528	30,766		9		91	
	Pluto (dwarf)	2,360	1,466		42		58	
	Saturn	120,536	74,898				100	
	Uranus	51,118	31,764				100	
	Venus	12,104	7,520		61	39		

Solar System Scale Model – Planetary Sizes ANSWER KEY

Order from Sun	Planet & Diameter	Kilo-meters	Miles	Food Model	% Rock	% Metal	% Gas/ Liquid	Solar System Location
3	Earth	12,756	7,926	Green grape	55	45		Inner/rocky
5	Jupiter	142,984	88,846	Cantaloupe	15		85	Outer/gas giant
4	Mars	6,794	4,222	Peppercorn	91	9		Inner/rocky
1	Mercury	4,880	3,032	Peppercorn	58	42		Inner/rocky
8	Neptune	49,528	30,766	Strawberry	9		91	Outer/gas giant
9	Pluto (dwarf)	2,360	1,466	Rice grain	42		58	Kuiper Belt
6	Saturn	120,536	74,898	Grapefruit			100	Outer/gas giant
7	Uranus	51,118	31,764	Small lime			100	Outer/gas giant
2	Venus	12,104	7,520	Blueberry	61	39		Inner/rocky

Scale Factor (check one)

○ **Option 1:** $\frac{\text{1 meter}}{\text{60,000,000 kilometers}}$

○ **Option 2:** $\frac{\text{\_\_\_\_\_ feet}}{\text{1 AU}}$

Average Distance from the Sun	Kilometers (Rounded)	Miles (Rounded)	AU	Model Distance (Rounded) ________ (units)
Mercury	57,910,000	35,980,000	0.4	
Venus	108,210,000	67,240,000	0.7	
Earth	149,600,000	92,960,000	1.0	
Mars	227,940,000	141,630,000	1.5	
Jupiter	778,410,000	483,680,000	5.2	
Saturn	1,426,730,000	886,530,000	9.5	
Uranus	2,870,970,000	1,783,940,000	19.2	
Neptune	4,498,250,000	2,795,080,000	30.1	
Pluto	5,906,380,000	3,670,050,000	39.5	

Solar System Scale Model – Distances from the Sun ANSWER KEY

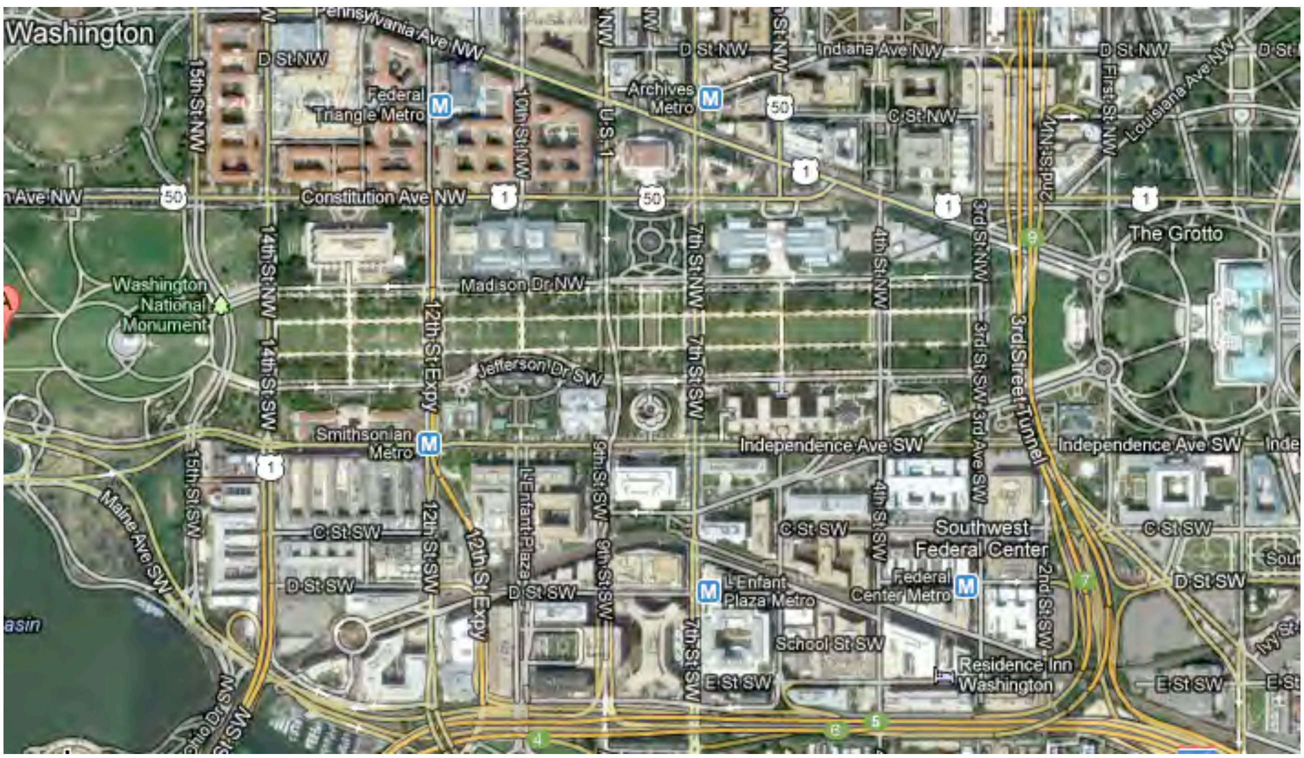
Scale Factor (check one)

○ **Option 1:** $\frac{\text{1 meter}}{\text{60,000,000 kilometers}}$

○ **Option 2:** $\frac{\text{feet}}{\text{1 AU}}$

Average Distance from the Sun	Kilometers (Rounded)	Miles (Rounded)	AU	Model Distance (Rounded) ___Meters____ (units)
Mercury	57,910,000	35,980,000	0.4	1.0
Venus	108,210,000	67,240,000	0.7	1.8
Earth	149,600,000	92,960,000	1.0	2.5
Mars	227,940,000	141,630,000	1.5	3.9
Jupiter	778,410,000	483,680,000	5.2	13.0
Saturn	1,426,730,000	886,530,000	9.5	23.8
Uranus	2,870,970,000	1,783,940,000	19.2	47.8
Neptune	4,498,250,000	2,795,080,000	30.1	75.0
Pluto	5,906,380,000	3,670,050,000	39.5	98.4

Map of National Mall in Washington DC – Washington Monument to the US Capitol



ACTIVITY #9 – STRANGE NEW PLANET

Overview
During this activity, your youth are given a challenge form NASA where they:

- View small models of unusual planets using simulated telescopes, and act kinesthetically as spacecraft that fly, orbit, land and take samples from "strange planets" (the models)
- Are given brief views of "strange planets" and must remember what they saw and report it out to a team
- Collaborate as teams and play key science and engineering roles to decide how to explore these "strange planets" for the data they hope to obtain
- Use science skills of observing, classifying, communicating, inferring, predicting, gathering and organizing data, developing hypothesis, extending senses, researching, team work

Time/number of sessions
Two Sessions – 40 minutes

Activity Type
Kinesthetic, Team discussion

Space Needed
Classroom, cafeteria, or gym with approximately 30 clear feet for walking
Tables and chairs

Activity Goals
Youth will:

- Gain insight into the processes involved in planetary observation through a sequence of progressive robotic exploration missions.
- Learn to clearly and accurately describe observations and record them.
- Engage in gathering data and planning missions to reach their goals for space exploration.
- Experience scientific habits of mind as they use their curiosity to develop science experiments.
- Think like engineers and use team collaboration to plan methods for implementing science experiments.

Where's the Science and Engineering

- Clues to the formation and history of the solar system are scattered out there among the planets and other bodies. Evidence about the formation of the solar system may exist in the rocks, chemical signatures and atmospheres of many of our planetary bodies.
- In places where it is not safe for humans to explore, NASA depends on robotic missions outfitted with remote sensing and cutting edge hardware that can retrieve, analyze and even return data and samples to Earth for the science community to study.
- Engineers are constantly pushing limits to find ways to equip spacecraft with more and more advanced techniques for robotic exploration, many of which, emulate human senses and abilities.

National Standards

Science Standards
- Science as Inquiry
- Origin and History of the Earth
- Earth in the Solar System
- Understanding about Science and Technology
- History and Nature of Science

Mathematics Standards
- Problem Solving
- Measurement
- Communication
- Patterns and Functions

Equity/Leveling the Playing Field
- Encourage students to take turns being the team leader, recorder, scientist, and the person who reports out. Each requires different skills.
- Make sure each student's voice is heard in the descriptions, planning, and mission critique.

From Your Supply Closet

Session	For Leader	For Students
1	Chart paper/ whiteboard/ chalkboard and markers/chalk Roll of masking/painter's tape (to mark the viewing distances) **"Strange Planets"** • Modeling clay, Playdough™, Styrofoam™ balls, small plastic balls, or rounded fruit (cantaloupe, pumpkin, oranges, etc.) • Small stickers, sequins, candy, marbles, beads anything small and interesting! • Cotton balls • Blunted toothpicks • Objects that can be pierced with a toothpick to make a moon • Cloves, vinegar, or mild scents like peppermint • Glue (if needed) • Push pins **Viewing Platform** • Table or flat surface, in a location easy for students to view while standing and walking close by. • Towel or cloth to place over "strange planets"	For each student team of 4-5: • Pencils • Colored pencils or thin markers • Blank piece of drawing paper (no lines is preferable) **"Telescopes"** • Rolled sheet of paper, paper towel roll, or toilet paper roll • Pre-cut squares 12 cm x 12 cm (5" x 5") of blue cellophane • 2 thin rubber bands

2	Roll of masking/painter's tape (to mark the viewing distances)	For each student team of 4-5: • "Telescopes" from Session 1 • Piece of paper with "strange planet" drawings from Session 1 • Pencils • Colored pencils or thin markers • Small sticker or blunted toothpick to mark landing site on planet

From a Photocopier/Printer

Session	For Students
1&2	(Optional to send home to families) • *Exploration Extras – Seeing Mars* • *Mars Exploration Timeline Graphic*

Getting Ready

[graphics: picture of sample "strange planet"]

"Strange Planets": Create 2-3 "strange planets" that students will explore. Use objects for the core to which you can attach smaller things to make the surface interesting to observe, and some things from which a "sample" can be extracted. Make sure all sides are decorated. Place some features discreetly so that they are not obvious upon brief or distant inspection. Make sure these features are evident among the planets:

- Volcanoes – clay, etc
- Evidence of volcanic lava flow, clay, etc
- Craters – dig into planet or build into surface
- Evidence of ice – polar ice caps, etc
- Rocks – beads, clay, etc
- Mountains – clay, etc
- Evidence of current or past water – carve or lay channels

In addition, these are other features you can include:

- Create clouds by using cotton and glue or toothpicks
- Moons - Attach a grape using a toothpick
- Affix small stickers or embed other objects into the planet
- Apply scent sparingly to a small area

[graphics: picture of covered table and markings on floor around viewing platform]

Viewing Platform: Place the planets on a desk, table or chair in the back of the room. Cover the objects with a towel before students arrive. Make 2 distance markers with masking tape on the floor – one at a 2-foot distance away from the platform, and the other a 5-foot distance.
Make another tape mark at the other end of the room to be the "launch" and ground observation point..

"Telescopes":

Gather enough empty paper towel or toilet paper rolls to have one for each team. Alternatively, you can use a sheet of paper rolled up from the short end. Place one clear, blue cellophane square over one end of the tube and attach with a rubber band. Students can do this construction if needed.

Leader Tips

- Plan time to create your "strange planets" in advance. Make sure there will be a variety of features on all sides of each planet.

- Create planets that are not too Earth-like, or student observations may be tainted by what they already know about the Earth's surface.
- Students will observe the planets from different distances, ranging from the opposite side of the classroom to 2 feet away.
- When the students walk with the telescope at their eye, they don't see surrounding areas well. Post students on the edges of the area to help keep the observers heading forward safely and clear furniture and other trip-hazards from the area.
- At the beginning, observation data from the students will be mostly shape and color information and progress to more specific information, as they get closer to the planets.
- Most of the steps for considering each type of mission are the same, and teams will learn how to organize themselves with your guidance. It is important that all steps are followed so that teams develop the skills of observing, recording data, reporting and developing observations for the next mission.
- If you are using 2 sessions for this activity, feel free to make a break between any 2 missions that suit your schedule – one is given as a suggestion in the activity.
- Use more than one sheet of blank paper per team if you find students have trouble fitting to one piece of drawing paper.

Student Activity

Session 1 . Observing Planets from the Ground and Space

1. Make sure you have prepared the room in advance (see "Getting Ready"). Divide the group into teams of 4 or 5 at tables on the side of the room away from the Viewing Platform. Tell them that across the room are some very strange planets that scientists at NASA have found and wish the group to observe for their surface features. Introduce the areas of the room they will use during this session - their tables are Mission Control stations and the tape mark on the floor is their ground observation and launch area.

2. Next, prepare the group to think like scientists and engineers, using the following conversation guide:
   - You have a challenge from NASA to explore some new worlds that have just been discovered. First, they have asked me to brief you on some background to help you make decisions about that exploration. Here are the key points to the briefing.
   - Lots of the surface features on Earth are also on other planetary bodies in the solar system: craters, volcanoes, ice, rock, and water channels to name a few. These surface features are a roadmap to the history of that planetary body and sometimes reveal its early formation.
   - In places where it's not safe or too expensive for humans to explore, NASA depends on remote robotic missions. Engineers are constantly challenged to equip spacecraft with advanced techniques for robotic exploration, many of which, copy human senses and abilities.
   - It isn't practical to send humans to new worlds when we don't know much about them yet. It is critical, though, to use robotic spacecraft with equipment that can collect data on planetary materials in the same way you would evaluate something through your senses of sight, touch, taste, smell and hearing.
   - NASA has many kinds of missions and science and engineering teams that must decide what kind of mission will best carry out their experiments, and then propose a mission to NASA for funding.

3. Tell the group that they are going experience the different ways that NASA explores with robotic missions so that they learn about the surface features of planetary bodies. Students will act as mission teams to find as many of the following features as possible the "strange planets". Write each on chart paper as you mention them, and keep them posted for the class to see:
   - Volcanoes or evidence of volcanic lava flow
   - Craters
   - Surrounding moons
   - Evidence of ice
   - Rock samples
   - Mountains
   - Evidence of current or past water

4. Have each team assign themselves roles and assure them that they will rotate.
   - Mission Observer – Make observations and report them to your team as data.
   - Data Recorder – Translate the observation data into a drawing with labels.
   - Scientist – Guide your team toward future plans.
   - Data Reporter – Present the data drawings and your team findings.

Give each team a sheet of drawing paper. Have the Data Recorder write the names of the students on the sheet. Next the recorder should divide the drawing paper into three areas on each side, for a total of 6, so they can draw their findings from each observation. They should label the first area "Ground Observation".

Ground Observation

5. Tell the group that for initial work, NASA has only "funded" them to observe from the ground. Getting time on a large telescope is expensive, so they will have only 15 seconds to get their first view of these "strange planets".

6. Have the Mission Observer from each team stand at the first tapeline, farthest from the planets. Hand each one a "telescope" with blue filter. The students at the desks become "Mission Control", waiting to receive data, so they must turn their backs and look away from the Viewing Platform.

[graphics: picture of students looking through their "telescopes"]

7. Ask the Mission Observers to put the "telescope" to one eye and close their other eye. Lift the towel for just 15 seconds for them to view the planets through their telescopes, and then re-cover the planets again completely.

8. Mission Observers should return to their teams. Each team member now has a role in dealing with the data that the observers gathered.

9. Mission Observers return to their tables and report what they saw about each planet, sharing answers to the following questions:
   - What did you see?
   - What advantage was there to using this technology – observing from a distance at a focused point - for observation?
   - What disadvantage was there to using this technology for observation?

   Data Recorders listen to and draw in one section of the drawing paper - only what the Observer saw. They should include descriptive labels, and also note what the team learned about the planets.
   Data Reporters prepare a report based on the drawing, data and team input.
   Scientists lead the team to decide what they want to learn next about the planets, and what would make those observations easier to make.

10. When the teams have completed their reports, ask Data Reporters to hold up their team drawings so the group can see them. Ask the group what the teams decided would make it easier to see the surfaces of the planets. Guide them toward: getting off the Earth's surface and above the atmosphere. (If they jump immediately to flying to the planets, tell them that NASA has not yet approved funding for that step!)

11. Tell the group that the blue cellophane represents the atmosphere around Earth and that telescopes on the ground are at a disadvantage because the atmosphere makes it harder to see clearly into space.

Near Earth Orbiting Mission

12. Have them take the cellophane off of the telescope for this next observation, which represents getting above the Earth's atmosphere. This type of mission is even more expensive, because the telescope must be launched into orbit!

13. Have your teams rotate roles, and fulfill the following assignment for a near-earth orbiting mission. Mission Control should again turn away. Have the teams follow these steps for observing and reporting, similarly to before.
    - Mission Observer: Move to the tapeline and take one step closer to the planets. Put the telescope to one eye and close the other. Make the observation the team planned to answer the questions they have about the planets.
    - Leader: Remove towel – showing the front half of each planet. Allow 15 seconds for observations. Re-cover planets with cloth.
    - Mission Observer: Return to team with "data" from the new observation.
    - Data Recorders: Label the second section of their paper "Earth-Orbiting", and draw a picture based on the Observer's data. These drawings should have more detail in color, shape, texture, etc.
    - Scientists: Lead the team to decide if they think they see any of the surface features that NASA has asked them to look for and if they think they do, they should draw and label those portions of their picture. Ask the teams to think about what they want to explore next on the planets.
    - Data Reporters: Share the team's labeled picture with the rest of the class.

14. Ask the Data Reporters to comment on the team findings. Do they think they saw any surface features from the NASA list? If so, what were they? What have the teams decided to look at next?

15. Tell the group that taking off the blue filter was like getting up beyond the atmosphere so that it is clearer for observing. Explain that NASA's Hubble Space Telescope is mounted on what is called a "near-Earth orbiting spacecraft", up above the Earth's atmosphere – much can be observed and discovered in this way. But what if the new planets were inside our own solar system, close enough to send robotic spacecraft?

Deep Space Mission : The Fly-By

16. The team roles and steps in observing, reporting, and recording in the next "deep-space" missions will work similarly as before, with the exception of the way the observations are made.

17. Tell the teams that to get closer, NASA will have to "fund" them for a deep-space mission that leaves the Earth behind. Some of the group may have guessed that the next step to getting closer to these planets is to fly past them. Let them know that in a fly-by mission, a spacecraft flies past one side of the planets, but it cannot stop to observe - it is a cost-effective way to investigate several planets on the same mission. Let them know that most such deep space missions have more than a telescope - they have equipment to take images and also different kinds of data and sent it back to Earth.

18. Have the members of each team rotate to a new role and bring the Observer to the tape representing the original observing line – from where they will launch their mission - while Mission Control turns away. Explain that the Mission Observers will pass by the planets no closer than the tape mark that is five feet from the planets. They should not cross that tape mark. Tell them that NASA often funds more than one mission to a planet, and the teams for those missions share and support each other's data to make discoveries together.
    - Mission Observers: Use their telescopes to walk past the front uncovered side of the

planets (the other side remains draped under cloth). When all observations are made and the planets are covered, Observers return and report their new data to their teams.
- Data Recorders: Label the third section of their paper "Fly-By". Make a labeled drawing based on the data, and make notes on what the team learned in this mission.
- Scientists: Guide the team to decide whether they think they have identified any of the features that NASA has asked for, and what they want to examine more closely with a future mission.
- Data Reporters: Hold up their finished labeled drawings of data for other teams to see.

19. Ask the teams to report how flying past the planets helped them see more surface detail. Ask them what would be a good next mission to observe even more details about the planets. Guide them toward orbiting around the planet – there is no current funding for landing.)

20. **If time is up**: Tell students that in the next session, they will be looking at more kinds of missions NASA funds for exploration of the solar system. Put all materials away and gather the data sheets for the next session. **Got more time**: Continue on for more deep-space missions!

Session 2 . Observing Planets, from Orbit to Sample Return

Deep Space Mission : The Orbiter

1. In advance, arrange the room and put out the covered "strange planets" as with the first session.
2. Regroup the students into their teams of 4-5. Recombine teams as needed to accommodate new or missing students. Redistribute each team's drawing papers from Session 1. Remind them of the kinds of observation they have already experienced:
   - From the ground
   - Near Earth Orbiter
   - Fly-By
3. Have team members rotate to new positions. Confirm their last discussion that a logical next request from the NASA science community would be for a study of surface features on the far unseen sides of the planets and in this case, NASA would fund an "Orbiter mission" during which spacecraft would circle around the planet and make observations.
4. Explain that the next Observers will walk to the tape line 2 feet from the planets and go around them using their telescopes to see if they can clearly identify some of the surface features. Tell them that NASA sometimes uses these kinds of missions to choose a site upon which to land a future mission, so Observers should also carefully look for an interesting surface feature for closer exploration that has a good landing area around it.
5. Bring the next Observer to the launch point with the telescope. Mission Control should look away. Take the towel completely away from the planets and step out of the area so the Observers are able to orbit completely around the planets.
   - Mission Observers: Walk around the planets in a full circle twice. They may slow a little but cannot stop during their observation. Keep moving in one direction and without running into each other. After all Observers are finished and the planets are covered, they return to their teams.
   - Data Recorders: Label the fourth section of their paper "Orbiter". Draw and label a new

drawing based on the Observer's data. Have a drawing for each side of the planets and label any new surface features that have become more clear, along with what they learned from this mission, and where they think a lander might be able to land.
- Scientists: Lead the team in deciding which surface feature should be proposed for future landing and exploration. (This is a whole team decision.)
- Data Reporters: Hold up the labeled drawings for all teams to see.

6. Once the Reporters have shown their drawings, ask the group how orbiting the planets helped them see more detail, and what new details they saw.
7. Ask each team what kind of feature they have chosen to study further. Congratulate them on their curiosity and on their selection - NASA has "funded" them to do a "Lander mission"!

Deep Space Mission : The Lander

8. Introduce NASA landing missions using this conversation guide:
   - We've learned that there are advantages and disadvantages to every kind of NASA observing effort. What would be the advantage of a lander mission over the others?
   - Why land? What will your mission do once it lands? (Guide them toward the experiments they would do and the hardware they would need – rover, sensors, satellite etc)
   - In the orbiter mission, you chose a planet and a location with a surface feature that your team wants to explore. You also chose a feature with a safe landing spot. Take a minute now to study your drawings to make sure this is where you want to land. Since you can't walk to space to confirm your choice, your drawings are the data upon which you must depend.

9. Mission Observers come to the launch point with a sticker or blunted toothpick to mark their landing spot for future return. Remove the towel completely from the planets and clear the space for the Observers. Mission Control should turn away.
   - Mission Observers: Walk around the planets twice. Keep all observers going the same direction. On the second pass, the Observer marks their team-landing site using their sticker or blunted toothpick. Return to the team to report data. They should share the data that designates the characteristics of the team's chosen-landing site well enough for the next Observer to get back to the same site.
   - Data Recorders: Label the fifth section of their paper "Lander". Draw the observations of the chosen planet, clearly showing the landing spot chosen by the team.
   - Mission Scientist: Guide the team to decide which part of the feature they would like to sample, and how they will take the sample when they return.
   - Data Reporters: Hold up the team drawings and show the labeling for their chosen surface feature and landing spot and report how they will take a sample when they return.
10. Encourage discussion about how a lander mission prepares them for returning to take and bring back a sample.
11. Tell them that, with the next mission, they will be able to land, take and bring back a sample of the surface feature their team has chosen.

Deep Space Mission : The Sample Return

12. For the Sample Return mission, let the teams know that they can choose one tiny sample from their designated surface feature. Tell them they won't need their telescopes because the Observer will be acting as a sampling instrument instead of a telescope - a sampling instrument is typically one of many different kinds of instruments on a spacecraft. Advise them that once the sampling instrument has collected its sample, it is constructed so that it can return to Earth.
13. Bring the new Observer to the launch tapeline. Have Mission Control turn away. Mission Observers should begin at the tapeline, travel to the spot chosen for the sample return, and take a small pinch from a planet's chosen surface feature. Have them return to the team with the sample. Congratulate them on a very successful mission, and have them applaud themselves!
14. Describe to the group what happens with samples from other worlds that are returned to Earth.
    - We have samples our spacecraft have captured and returned from the Sun, a comet, and the Moon. We also have small samples from the Moon, Mars, asteroids, and comets that come to the Earth on their own in the form of meteoroids.
    - When a mission brings a sample back to Earth, it's taken to a special lab where it is very clean and the samples are protected from anything that would change them.
    - Many scientists could have the opportunity to study the sample. In some cases it may be the kind of sample that will bring a new understanding of the planetary body's history or its composition.
    - NASA has state-of-the-art equipment to analyze samples and to give scientists different kinds of data. One is a spectrometer that has several kinds of filters like you have your senses – eyes, ears, touch and nose. These filters define the chemistry; mineralogy and signs of life just like our different senses give us varied information about our surroundings.

Questions for Youth (Informal Assessment)

- What surface features were included in the group exploration?
- What did you learn about what it would take to explore a crater, volcano, ice or other surface feature on another planet? (Planning, maybe orbiting to decide where to land, a safe landing site, etc)
- How would you use samples from another planet to compare to the same kind of surface feature on Earth? (Take samples from the same kinds of places on Earth)

Sharing the Findings (Informal Assessment)

- What kind of observation do you feel was most useful for identifying surface features on the strange planets?
- If you lived on another planet and you came to explore the surface features of Earth as a strange new planet, what do you think you would find most interesting to explore?

Leader Reflection/Assessment

After each session ask yourself the following questions:

1. Did every student have an opportunity to participate in each role in the team?
2. Did the students leave with unanswered questions? This can be a good thing if it makes them wonder and investigate further.
3. Was every team's experiment respected and included?

Glossary

Fly by — the action of a spacecraft passing near to a planet to study it on its way past
Lander — a spacecraft designed to explore on the surface of a planet from a stationary position
Mission — an experiment involving a spacecraft designed to explore space, seeking to answer scientific questions
Model — a simulation that helps explain natural and human-made systems and shows possible flaws
Observations — specific details recorded to describe an object
Orbit — the path of an object in space moving about another under gravitational attraction.
Orbiter — a spacecraft designed to explore space, seeking to answer scientific questions
Rover — a robot designed to travel on the surface of a planet
Planet — a sphere moving in orbit around a star (e.g., Earth moving around the sun)

Information for Families

Send the *Mars Exploration Timeline Graphic* and/or the *Exploration Extras – Seeing Mars* home with the kids – they can show their parents what they know about how robotic exploration of the solar system progresses, and how NASA is doing it to learn more about Mars.

NASA Resources

Careers at NASA

Putting a probe into space around another planet takes a team of dedicated scientists, engineers, and others at NASA working together. Learn about some of the people who make space exploration possible.
http://www-robotics.jpl.nasa.gov/people/

Role Model Resource

[graphics: photo of Bobak here]
Bobak Ferdowsi is a NASA engineer and a Flight Director for the Mars Science Laboratory Curiosity mission at JPL. Flight Directors monitor all operations to make sure nothing puts the spacecraft at risk. He became an overnight internet sensation after Curiosity's Mars landing night in 2012, when his enthusiasm for his job - and his hairstyle – caught national attention. For each space mission that he "sits at the controls", fellow members of the team vote on the style of hairdo he dons. For Curiosity landing, it was a red, white, and blue Mohawk with stars. He was surprised by the attention, but glad it brought attention to the mission and to engineers as people, and says "it would be a dream come true" if he inspires young people to feel science and engineering are cool, too. He has a bachelor's degree in aeronautical and astronautical engineering from the University of Washington, and continued with his master's degree at Massachusetts Institute of Technology.

Read Bobak's blog entry about living on Mars time during Curiosity's mission:
http://mars.jpl.nasa.gov/blogs/index.cfm?FuseAction=ShowBlogs&BlogsID=254

Hear his update on the mission talking about the various instruments on the Curiosity
http://www.nasa.gov/mp4/683748main_CoM20120830-320.mp4

Resources

NASA's Astronomy Picture of the Day **(**http://apod.nasa.gov/apod) has photos that can be used as a reference when creating your Strange New Planet. It is also a good source of photos for extension activities.

See the history of the exploration of Mars, with Fly-bys, Orbiters, Landers, and Rovers:
http://mars.jpl.nasa.gov/programmissions/missions/

Try out some fun kids activities on Mars:
Mars Fun Zone **http://mars.jpl.nasa.gov/funzone_flash.html**

Students can build models of robotic spacecraft from actual NASA missions:
http://solarsystem.nasa.gov/kids/papermodels.cfm

Taking the Science to the Next Step

Create an imaginary solar system of planets, hang them from the ceiling and have students make observations of all the planets.

Help students imagine what it would be like to send humans to Mars, with the Imagine Mars project:
http://www.jpl.nasa.gov/education/videos/playVideo.cfm?videoID=34

Give your students more experience understanding the expenses involved in conducting science research with the NASA Space Math activity "The Dollars and Cents of Research".
http://spacemath.gsfc.nasa.gov/weekly/5Page4.pdf

Literacy

Watch singer/songwriter will.i.am share his passion for science, math, and all things Mars in this video from landing night of the Mars Curiosity Rover.
http://www.jpl.nasa.gov/education/videos/playVideo.cfm?videoID=36

Have the students learn the words to his song "Reach for the Stars", the first song to be beamed back to Earth from another planet. Watch students witness the playback:
http://www.jpl.nasa.gov/video/?id=1131

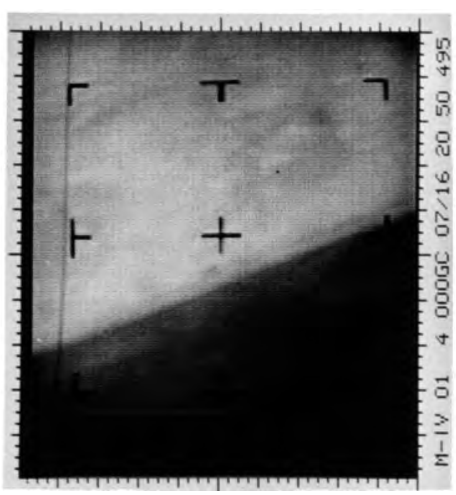
Materials
Exploration Extras – Seeing Mars
Mars Exploration Timeline Graphic

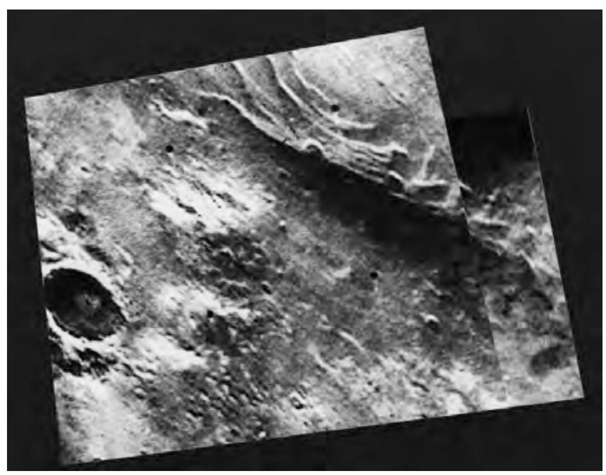
Exploration Extras – Seeing Mars

http://marswatch.tn.cornell.edu/jpeg/mars/other/telesc_07.jpg
Mars from Mt. Wilson Observatory in California

http://nssdc.gsfc.nasa.gov/image/planetary/mars/hst_mars_opp_9709a.jpg
Mars from the Hubble Space Telescope in Earth Orbit

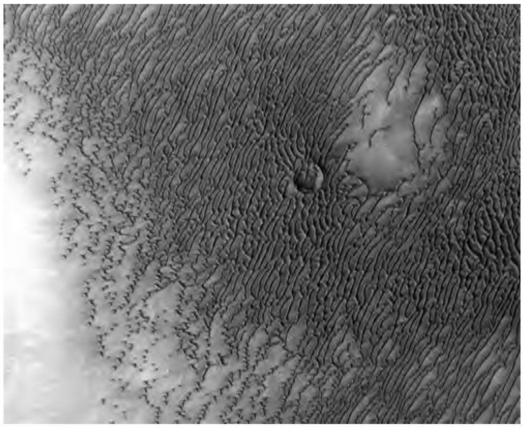
http://photojournal.jpl.nasa.gov/jpegMod/PIA14032_modest.jpg
Mars from Mariner 4 Flyby in 1964
Images from this mission where the first of another planet ever returned from deep space





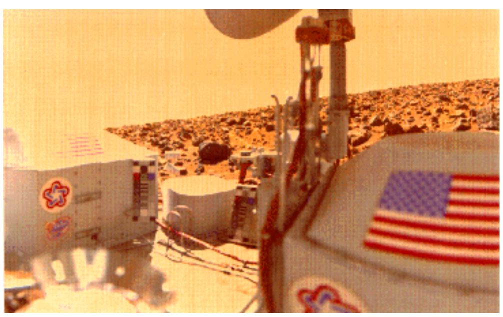
http://photojournal.jpl.nasa.gov/jpegMod/PIA02989_modest.jpg
Mars from Mariner 9 Orbiter in 1971
Mariner 9 was the first spacecraft to orbit another planet

http://mars.jpl.nasa.gov/odyssey/multimedia/images/?ImageID=3422
Mars from Mars Odyssey Orbiter in 2010
Picture showing detailed dune landscape near Mars northern polar cap



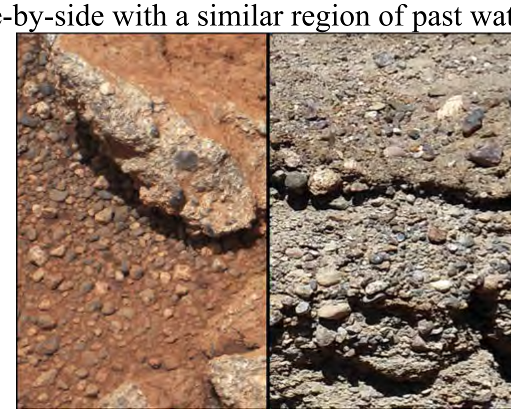
http://mars.jpl.nasa.gov/mro/multimedia/images/?ImageID=3814
Dustdevil on Mars from Mars Reconnaissance Orbiter in 2012
MRO carries the most powerful camera ever flown an a planetary exploration mission

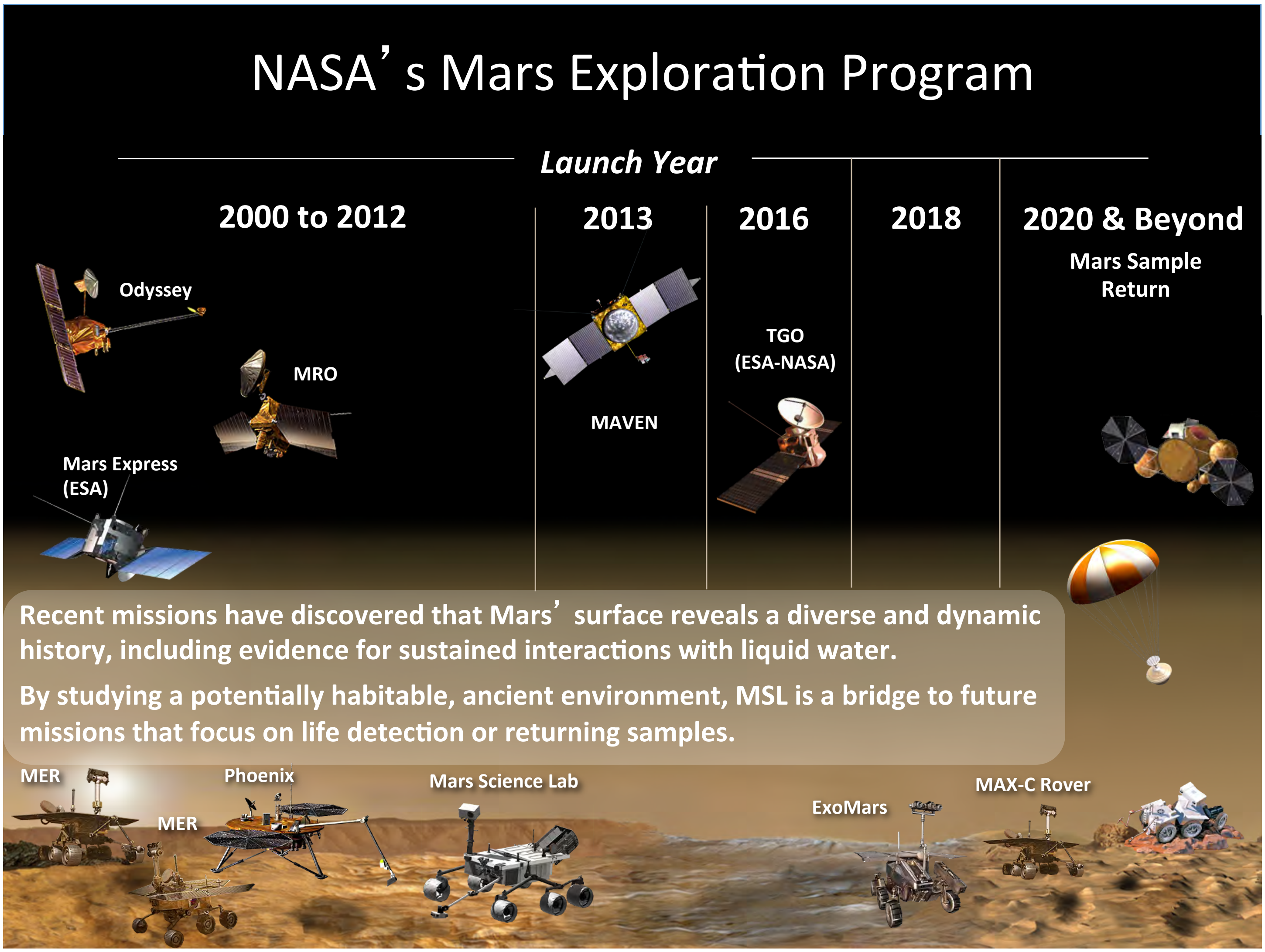
http://nssdc.gsfc.nasa.gov/imgcat/html/object_page/vl2_21c056.html
Mars from Viking Lander in 1976



http://phoenix.lpl.arizona.edu/images.php?gID=14037&cID=157
Mars from Phoenix Lander in 2008

http://mars.jpl.nasa.gov/msl/multimedia/images/?ImageID=4721
Mars from Curiosity Rover in 2012
Compared side-by-side with a similar region of past water flow on Earth




NASA's Mars Exploration Program
Launch Year
2000 to 2012
2013
2016
2018
2020 & Beyond
Odyssey
MRO
Mars Express (ESA)
MAVEN
TGO (ESA-NASA)
Mars Sample Return
Recent missions have discovered that Mars' surface reveals a diverse and dynamic history, including evidence for sustained interactions with liquid water.
By studying a potentially habitable, ancient environment, MSL is a bridge to future missions that focus on life detection or returning samples.
MER
Phoenix
MER
Mars Science Lab
ExoMars
MAX-C Rover

ACTIVITY #11 – BE A "ROCK GROUP"! SHARE THE SOLAR SYSTEM WITH OTHERS

Overview
In this activity, your youth:

- Plan and put on an event at your school to show families and/or other students what they learned
- Design exhibits or other creative ways to feature the models and products they made during this unit
- Can invite their parents or classmates in for an event to hear them talk about their work and their discoveries
- Will show an assessment of their personal growth and knowledge growth from this program unit, through the way they choose to share, and through the products themselves.

Time/Number of Sessions
2 or 3 40-minute sessions, plus the planned event

Activity Type
Hands-on, group collaboration, creative arts, presentation

Space Needed
Tables and Chairs for preparation
Large open area indoors/outdoors for event

Activity Goals
Youth will:

- Become more vested in their new knowledge in order to share it with others.
- Learn to make interesting presentations for different audiences.
- Consolidate learning that has taken place during the program unit.

Where's the Science and Engineering

- When scientists make discoveries, they put them into presentations and give them as papers at conferences. This is appropriate because the scientific community shares information through papers.
- When a scientist or engineer wants to share work with others, and particularly when they want to inspire an audience, they focus their presentation on what that audience will find engaging.
- Scientists and engineers may work nearly a year with hundreds of people to write and present NASA with a proposal for a space mission. Making that proposal interesting, thorough, and clear is critical.
- Once a mission is funded, there are people in a field called Education and Public Outreach whose job it is to bring the excitement and importance of the mission to students and the public.

National Education Standards
K-4
History and Nature of Science

- Science as a human endeavor

5-8
History and Nature of Science

- History of science

Equity/Leveling the Playing Field

- This kind of culminating activity is a celebration about what the students have learned. It can potentially cover all the learning modalities and appeal to all the learning modalities of the intended audience. Encourage students to understand that they each have a very special message to present about what they learned and a special way of presenting it.
- This is a good opportunity to encourage students to try something they haven't done often: demonstrate one of the activities, perform or present, develop a video, write, draw, make models, create exhibits.

From Your Supply Closet

For the Leader	For Students
Chart paper/ white board, markers	• Crayons, markers, colored pencils, writing pencils • Poster boards • Products and data sheets from previous activities • Photos of previous activities • Display materials (this will depend on the kind of display the students want to create)

From a Photocopier/Printer

For Students
• Pictures or information from this activity guide, or that they can find on the internet

Getting Ready

- Find out what the school will support the students to do and find a location within the school. It can be during or after school and in a room or outdoors.
- Give students enough time to plan their event. They will continue to learn as they decide what they want to teach and share with others.
- Help them make lists of products they have made, activities they might lead, ideas for ways to present and make exhibits.
- Encourage them to think as a group but to break themselves into tasks so that the work moves forward.

Leader Tips

- This is a great opportunity to share with families even if it is just an hour when parents would generally come for pickup.
- Consider a "career corner" with students describing the types of jobs it takes to run a robotic spacecraft mission – role model resources and career activities are found in the "Take It Further!" section of each activity. Students may want to select those they find most interesting as part of their display or event.
- NASA has national volunteer networks of specially-trained members in local communities, who can serve as content experts, mentors, or speakers at events. Request information on your local Solar System Ambassador at ambassadors@jpl.nasa.gov. See the "NASA Resources" section of this activity for websites of many NASA networks.

Student Activity

Session 1 . Planning the Event

1. Now students are ready to form a "Rock Group" and put on an event to share what they've learned about rocking around the solar system – what's out there, what shapes the rocky planets, and how to get there! As you go through the event planning, make several brainstorm lists with the students to help them turn their vision into a real event. Post each list before moving on to new thoughts so they see how their event is building. Connect their event to the work of scientists and engineers, using the following conversation guide:
   - When a space mission is completed, scientists and engineers put together presentations to share with the NASA community and the public. It's a very important part of the mission because discoveries in science are meant to be shared for the benefit of all.
   - For engineers, presenting often means putting together what they learned about how to make a successful mission and things to improve in the future. That knowledge is going to help the engineers and scientists on future missions.
   - For scientists, there will be conferences, press releases, TV interviews, papers, and books that are written to hold the results of their discoveries and their new questions.
   - Organized, thorough, and clear presentations and information are extremely important in sharing knowledge back to NASA and to the public. But more than that, scientists and engineers get very excited to share what they learn, and their community wants to know all about their discoveries and celebrate with them. Today we are going to think like scientists and engineers when they want to share their discoveries with their community.

2. Tell your group that they have learned a great deal about the solar system – they are now "Solar System Rockers" – and ask them how they think it would be fun to teach other kids or their families some of the activities and show some of their products. Encourage them if they are feeling hesitant and remind them of some of the things they most enjoyed doing.

3. Ask them to establish the audience they want to reach. Chart a column of possible audiences and make a list (another class, families, whole school, neighborhood, they can even prepare something for each of them to share what they liked best and why with each other). There are no wrong answers at this point so list them all. Bring the group to a vote unless there is a way to combine some audiences. Post this list.

4. Ask the students to think about what kind of event they would like to do for their audience or guide them toward an event you know if possible at their school. Should it be after school, during school, on a weekend? Help them to think about when their audience will be available. Post that kind of event on the first chart next to the audience name.

5. On a new list, name their chosen audience. Ask them what they think that audience would like to see or experience from the unit. If the group has trouble thinking about this, ask them to remember and share what they most liked doing and learning and why. Have the student brainstorm a list of ideas for sharing what they've done and learned in this unit, and chart their responses. (Remember, in brainstorming, all ideas are recorded.) This list could contain:
   - Exhibit of the planet lithographs and their strange creatures
   - Exhibit of the food solar system
   - Demonstration of walking the string distances of the solar system on a field
   - Neighborhood map of the solar system
   - Presentation display of the Edible Rock samples with their geologic terminology
   - Some of their comet models

- Exhibit of volcano models and a demonstration of eruptions
- Exhibit of lunar surface models that guests can try to match to the map
- Demonstration of the Strange New Planet activity so guests can look at the planets through a "telescope"
- Letting guests make and launch paper rockets
- Career Corner featuring role models and career information from this unit or someone from their local community
- Math applications from "Taking Science to the Next Step" sections in this guide
- Other brand new ideas like skits, songs, video, etc. they want to create

6. Have them consider their audience and use ideas from their brainstorm list to build a program of interesting items for the event. Decide on a theme for the event. In addition to activities, consider having snacks to attract visitors and music to set the mood.

7. Now that this student "Rock Group" agrees on their program, gather up the charts for the next session. Tell them to be thinking about what they would like to personally work on both in preparing the event and in presenting it.

Session 2 . Casting the Event

1. Post the student "Rock Group's" brainstorm charts on the wall as a record for their earlier decisions. If you think it is a doable program, move on to the next step. If you see challenges, help them to improve the program until it is something you and the school can support.

2. Once they have their final program list, place those items in one column on a chart and use a second column to take names of the students who would like to prepare and or present the program elements. Make sure that everyone has a part they like for both preparation and presentation. You can assign tasks if that is better for your group.

3. With the time that is left in this second session, have the group break into teams and work together on program elements. Keep taking their ideas and questions as they go along. Take as much time as is needed for students to put together their event.

Hold the Event

Session 3. Evaluating the Event

1. Once the event is completed, use a session to have students evaluate their event. If this was a really meaningful activity to them, see if they can find a place where some of their work can be displayed for the school.

Questions (Informal Assessment)

- What were some of the things you most liked about your event?
- What are things your audience liked doing during the event?
- Do you have new questions from working on this event?

Sharing the Findings (Informal Assessment)

- What new questions do you have about the solar system and the planetary bodies?
- How could we find answers to those questions?

Leader Reflection/Assessment

1. Did all the students take part both in the preparation and presentation of the event?

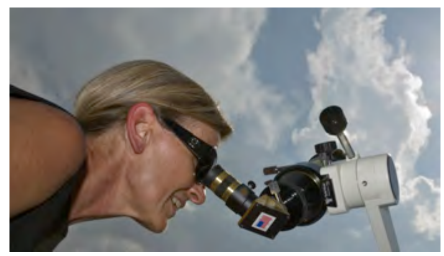
2. Did they have new questions as a result of doing the event?
3. How can you help them find answers to their questions

Information For Families
Send home a letter to families describing the event and inviting them to attend!

If appropriate, give families suggestions on websites to look at with their children – you can use *the Rocking Around the Solar System Internet Resource List* at the end of this unit.

NASA Resources
Careers at NASA
Every parent wants their child to have a secure future and to do work that they love. This website lays it all out for families—what are the benefits of working at NASA? Find out at http://nasajobs.nasa.gov/benefits/benefits.htm

Role Model Resource



Leslie Lowes is an Informal Education Specialist at NASA's Jet Propulsion Laboratory. She loves watching the sky - day and night, and revels in the immersion in science and thrill of space exploration she gets in her job. "The only thing better than watching the sky is sharing my enthusiasm and inspiring kids to look carefully and ask really good questions about the world around them!" Leslie manages the production of NASA solar system activity guides adapted for especially for the type of free-choice, fun learning that afterschool time can provide. She also helps a community of science museums and planetariums to bring NASA content to their exhibits, shows, and education programs.
Leslie earned a Bachelors Degree in Physics, and a Masters Degree in Applied Mathematics, and first worked programming computers in support of Earth atmospheric missions on board balloons, aircraft, and Space Shuttles. She is a member of the informal "90-90" club, having flown over both the North and South Poles of the Earth on NASA DC-8 aircraft missions to study the depletion of the ozone layer in Earth's atmosphere. Realizing how important it was for people to understand what scientists were finding, she switched to a career in education. Seeing the enthusiasm for space of people throughout the country, Leslie started the volunteer Galileo Ambassador to Jupiter Program, which grew to become the nationwide *Solar System Ambassadors*.

Caption: Leslie witnessing the transit of Venus across the Sun, through a protective solar filter.

Resources
NASA has several national volunteer networks who are specially trained for working with the public and in educational settings. Instructions for requesting a local volunteer are on their websites.

- The *Solar System Ambassadors* are motivated volunteers across the nation, who communicate the excitement of JPL's space exploration missions and information about recent discoveries to people in their local communities.
  http://www2.jpl.nasa.gov/ambassador
- The *Night Sky Network* is a nationwide coalition of amateur astronomy clubs bringing the science, technology, and inspiration of NASA's missions to the general public. They share their time and telescopes to provide unique astronomy experiences at science museums, observatories, classrooms, and under the real night sky.

http://nightsky.jpl.nasa.gov/

- NASA *Student Ambassadors* are high performing interns and fellows, who volunteer their time to advance the NASA mission, by focusing on STEM research, education, and outreach. They are looking for opportunities to serve, learn, and inspire. The ambassadors serve as speakers and exhibit supporters.
  https://intern.nasa.gov/intern/
- The NASA *Speakers Bureau* is composed of engineers, scientists, and other professionals who represent the agency as speakers at civic, professional, educational and other public venues. Each year, NASA speakers provide hundreds of presentations to thousands of people.
  http://www.nasa.gov/about/speakers/

Everything you wanted to know about the solar system can be found in NASA's solar system exploration website:
http://solarsystem.nasa.gov

For an interactive tour of the solar system, and to see where planets and spacecraft are today, visit:
http://eyes.nasa.gov

Sign up to get the latest education information from NASA:
http://www.nasa.gov/audience/foreducators/Express_Landing.html

Taking Science to the Next Step

Consider implementing in afterschool or summer school the other program guides in the "From Out-of-School to Outer Space" series. More information is available at:
http://www.jpl.nasa.gov/education/os2os

Help students imagine what it would be like to send humans to Mars, with the Imagine Mars project:
http://www.jpl.nasa.gov/education/videos/playVideo.cfm?videoID=34

Consider having your students join on of NASA's opportunities to contribute to actual scientific findings through Citizen Science. Several levels are available, from carefully examining images and classifying features, to looking for planets around other stars! Some may require that an adult assist the child and supply and email address.

Map the history of the Moon, one crater at a time.
http://cosmoquest.org/mappers/moon/

Explore cool images captured by NASA's Dawn mission at giant asteroid Vesta—many not yet released to the public.
http://dawn.jpl.nasa.gov/DawnCommunity/asteroid_mappers.asp

Identify craters on Mars (requires SilverLight™ plug-in).
http://beamartian.jpl.nasa.gov/maproom#/CountCraters

Look for planets around other stars.
http://www.planethunters.org/

Help scientists deal with the flood of data from different types of astronomy projects!
https://www.zooniverse.org/

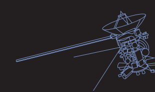
Literacy
Learn the words to the songs from NASA's 30-minute Space School Musical "hip-hopera", show the video, or perform it as part of your event:
http://discovery.nasa.gov/musical

Watch the students who performed the original video talk about what they learned about the solar system and how it inspired them to feel "science is cool!"
http://discovery.nasa.gov/musical/cool.cfml

"Big Bang" from original video production

"Planetary Posse" by Paradise Canyon Elem.

CAPTURING A *Whisper* FROM SPACE



DEEP SPACE NETWORK

Teachers — Curriculum activities on the reverse can be downloaded from http://deepspace.jpl.nasa.gov/dsn/educ/poster.html

Deep Space Network Web Site — http://deepspace.jpl.nasa.gov

THE NASA VISION

To improve life here,
To extend life to there,
To find life beyond.

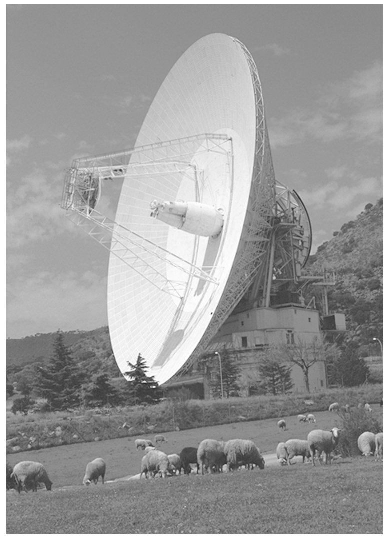
National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

JPL 400-1072 02/03
EW-2003-02-014-JPL

CAPTURING A WHISPER FROM SPACE

The National Aeronautics and Space Administration (NASA) has been sending robotic spacecraft out into the solar system for more than four decades. These mechanical explorers have ventured out to study Mercury, Venus, Mars, Jupiter, Saturn, Uranus, and Neptune. These amazing robots have been our eyes and ears on their journeys to far-off planets and even to the edge of the solar system, sending wondrous images and fascinating information back to Earth.



The largest antennas in the Deep Space Network are the 70-meter-diameter dishes — there is one at each of the three complexes. This one is in Spain. All the complexes have additional antennas of varying sizes.

But none of these missions of discovery would have been possible without the Deep Space Network — a worldwide system of sensitive antennas that communicates with NASA's interplanetary spacecraft. Signals to and from the spacecraft travel millions, even billions, of kilometers. Yet spacecraft communications equipment transmits signals at very low power, usually about 20 watts, about the same as a refrigerator light bulb. As the signal travels to Earth, it continues to lose energy, and signals arriving at the antennas on Earth can be as weak as a billionth of a billionth of a watt — that is 20 billion times less than the power required for a digital wristwatch. How is it possible to hear the tiny whisper of a signal from a spacecraft so far away?

The Deep Space Network is made up of complexes of antennas in three locations on the globe — Goldstone, California (in the Mojave Desert); near Canberra, Australia; and near Madrid, Spain. This arrangement compensates for Earth's rotation so that a distant spacecraft is in view of one of the Deep Space Network's antenna complexes 24 hours a day. The spacecraft signals are received at one site; as Earth turns, the spacecraft "sets" (like the Sun setting each night) and the next site picks up the signal, then the third site, and then the first again.

To hear the low-power spacecraft signal, receiving antennas on Earth must be very large, with extremely sensitive receivers. The signal from the spacecraft travels in a straight line, and it can be focused by a curved reflector dish (parabolic antenna), so large antenna dishes with precisely shaped surfaces are crucial. The Deep Space Network's parabolic dishes are focusing mechanisms that concentrate power when receiving data and also when transmitting commands. The antennas must point very accurately towards the spacecraft, because an antenna can "see" only a tiny portion of the sky (as though looking at the sky through a soda straw).

To hear the spacecraft's faint signal, the antennas are equipped with amplifiers, but there are two problems. First, the signal becomes degraded by background radio noise (static) emitted naturally by nearly all objects in the universe, including the Sun and Earth. The background noise gets amplified along with the signal. Second, the powerful electronic equipment amplifying the signal adds noise of its own. The Deep Space Network uses highly sophisticated technology, including cooling the amplifiers to a few degrees above absolute zero, and special coding techniques so the receiving system can distinguish the signal from the unwanted noise.

New space missions bring new challenges. NASA's Deep Space Network is continually improved and enhanced to provide communications, navigation, and tracking for distant spacecraft — our robot explorers of the cosmos.

Educators —
Please take a moment to evaluate this product at
http://ehb2.gsfc.nasa.gov/edcats/educational_wallsheet
Your evaluation and suggestions are vital to continually improving NASA educational materials. Thank you.

JPL 400-1072 02/03
EW-2003-02-014-JPL

CAREERS IN SPACE

When people think of working in space, they usually think of astronauts going to the Moon or building the International Space Station. In fact, thousands of people work in the space program, but stay on planet Earth — and they are not all scientists or spacecraft engineers. Many types of skills, and many types of individuals, are needed to make the space program a success. Here are the stories of just a few of the people who work in NASA's Deep Space Network.

I'm **David**, and I'm a member of the Navigation and Mission Design section at the Jet Propulsion Laboratory. We analyze spacecraft data that we use to fly the spacecraft from Earth, navigate them through space, and get them to planets, moons, and comets. My job is to help determine where the Mars Global Surveyor and Mars Odyssey spacecraft have been, their present positions and speed, and where they will be in the future. This information is useful to scientists who want to know where to position their instruments (such as cameras and other sensors) on board the spacecraft. I have a Bachelor of Science degree in aeronautics/astronautics from the Massachusetts Institute of Technology.

My name is **Carol** and I develop computer software called the Science Opportunity Analyzer. Scientists use this software to design observations that will be made by the Cassini spacecraft. They simulate the views their instruments on Cassini will "see," and in this way determine the best opportunities to collect data as the spacecraft orbits Saturn on its scientific tour. I enjoy working with the diverse international community of scientists and engineers that make up the Cassini science teams. I have a doctorate in planetary science, a master's degree in geophysics from the California Institute of Technology, and a dual bachelor's degree in physics and astronomy from Pennsylvania State University. I am currently working part-time in order to spend two days a week at home with my four-year-old daughter.

My name is **Ramona**, and I work as a telecom analyst for several JPL missions. My job involves monitoring the health and status of the spacecraft telecommunications subsystem, and ensuring that the spacecraft can communicate with the Deep Space Network at all times, even in an emergency. The part of my job I enjoy most is seeing data appearing on my computer screen, knowing that it is being broadcast by a spacecraft on its way to Mars, Jupiter, Saturn, or even near the edge of the solar system. Some of that data is processed to produce pictures of great scientific importance. I have a bachelor's and a master's degree in electrical engineering from the Massachusetts Institute of Technology.

I am **Alfonso**, and I am the supervisor of the Antenna Mechanical and Structural Engineering Group in charge of all the Deep Space Network ground antennas. My group is in charge of antenna design, analysis of components, and maintenance. I worked on the construction of a new 34-meter-diameter antenna at the Communications Complex in Madrid, Spain, and we are also studying the possibility of constructing a large array of smaller antennas that are each 12 meters in diameter. I received B.S. and M.S. degrees in mechanical engineering from the National University of Mexico and a Ph.D. from the University of Wisconsin–Milwaukee.

My name is **Martin** and I work in the Deep Space Operations Center where I'm the senior data controller. My job is to manage the data coming from deep space and interplanetary spacecraft, including missions to Mars and Saturn, space telescopes, and European missions. I make the data available to scientists, laboratories, and schools around the world. I started my career in the U.S. Air Force working on space and missile electronics. I'm an Air Force reservist at a space operations squadron, where we manage all the military's space assets, such as the Global Positioning System of Earth-orbiting satellites as well as communications and weather satellites. I don't have a degree yet; instead, I have many years of hands-on experience.

Hello all, my name is **Steve** and I work at the Goldstone Deep Space Communications Complex. I work in the operations department where I configure and monitor the subsystems for communicating with and receiving information from spacecraft. A few of these systems are antennas, transmitters, receivers, command, ranging, and telemetry groups. The people in the operations department at Goldstone are required to work on a 24-hour/365-day schedule — because spacecraft never sleep. I track many different spacecraft, including Earth-orbiting satellites as well as spacecraft at Mars, Saturn, Jupiter, and out beyond Pluto. I have been with the Deep Space Network for more than eight years. I have a bachelor's degree in electronic engineering from ITT Technical Institute.

My name is **Jonni** and I work in the Network Operations Control Center at the Jet Propulsion Laboratory. I am responsible for sending information known as support products to the three Deep Space Communications Complexes in California, Spain, and Australia. My job is exciting because I supply information to the sites that tells them where to point the antennas to receive data from the spacecraft, thus ensuring that the various projects receive their scientific data. I am still in school and am working toward a bachelor's degree in computer science.

My name is **Jorge** and I work at the Goldstone Deep Space Communications Complex in the Mojave Desert in California. I troubleshoot and repair digital system equipment that is vital to operations. My job is critical because I'm responsible for the functionality of the antenna pointing and telemetry subsystems. Among the missions I have supported are Mars Odyssey, Voyager, Genesis, and the Solar and Heliospheric Observatory. I have an associate's degree in electronics from ITT Technical Institute.

My name is **Tim**. I am the antenna maintenance specialist for the three NASA Deep Space Network tracking stations located in Canberra, Australia; Madrid, Spain; and Goldstone, California. The tracking antennas at each station are used to upload (send) and download (receive) information and guidance commands to and from numerous spacecraft. My job is to keep the antennas operational. I have a Bachelor of Science degree in engineering technology–welding technology from California Polytechnic State University, San Luis Obispo.

EW-2003-02-014-JPL

PURPOSE

To give students a mathematical model of how the Deep Space Network antennas work and how the antennas concentrate electromagnetic radio waves in a single direction.

QUESTION

Does the size of an antenna influence wave detection?

LEARNING OBJECTIVES

The students will learn that it takes mathematics to talk to spacecraft:

- Scientists on Earth must communicate information to spacecraft and be able to receive the faint signals from spacecraft that carry new information about the cosmos.
- The parabolic shape of the antenna dish helps to increase the distance at which radio waves can be detected by means of concentration and directionality.
- Sound waves emitted from a source are a good analog for radio waves used to communicate with spacecraft.
- The volume of the sound decreases as the distance from the source increases, according to the inverse square law.

GRADES 6–8 MATHEMATICAL STANDARDS

(from "Principles and Standards for School Mathematics," NCTM, 2000)

This investigation will encourage students to:

- Communicate their mathematical thinking coherently and clearly to peers, teachers, and others.
- Recognize and apply mathematics in contexts outside of mathematics.
- Develop and evaluate inferences and predictions that are based on data.
- Use observations about differences between two or more samples to make conjectures about the data sets from which the samples were taken.
- Understand both metric and customary systems of measurement.
- Use representations to model and interpret physical, social, and mathematical phenomena.

ADVANCE PREPARATION

For making parabolic dish antennas, make student copies of the antenna pattern on cardstock and collect recycled 1- to 3-liter soda bottles (one per student). Additionally, make copies of the data tables for the activities students will carry out.

ACTIVITIES

There are three activities that can be scheduled over three days, preceded by introductory discussion and development of predictions and hypotheses. There is also an Extension involving discussion of the inverse square law and the logarithmic scale of decibels.

YOU WILL NEED

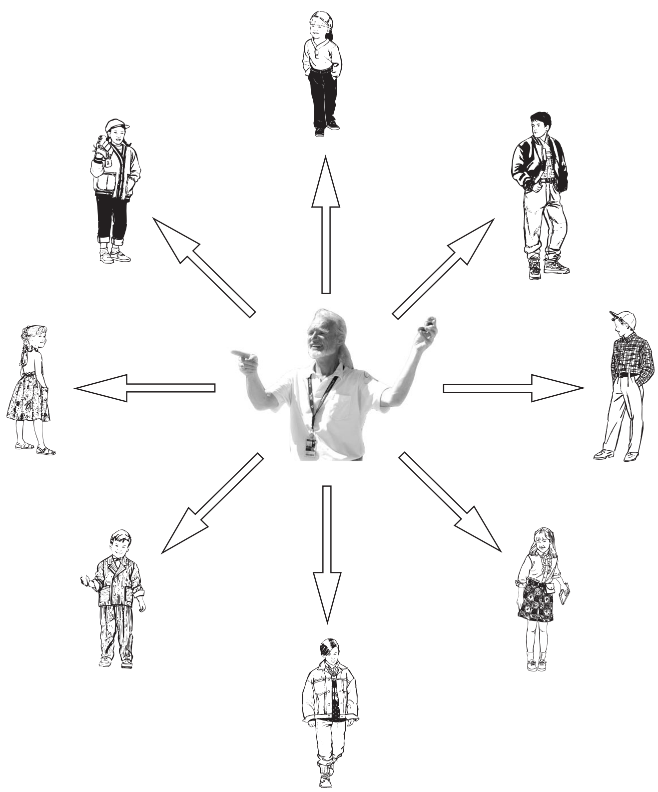
An open area with at least 120 meters of space (such as a football or soccer field); patterns and student directions for constructing a cardstock parabolic dish antenna, student directions for making an antenna from a soda bottle, scissors and X-acto knife, tape, copies of student data tables in which students will record data, metric measuring tapes or trundle wheels, and two or more umbrellas of different diameters (student groups can change variables by trying different sizes of soda bottles and umbrellas). Additionally, you will need a digital wrist watch with a timer mode that can be used to create a repeating beeping timer (set "timer mode" for "1 second," and "CR"–count down, beep, reset).

P R E L I M I N A R I E S

HYPOTHESIS/MATHEMATICAL CONTEXT

(Discussion, Inferences, Predictions)

Out in the field: Ask students to gather around to listen to the sound of the timer (watch) beeping at 1-second intervals. (The beeping timer represents a communication signal sent from NASA scientists on Earth to the spacecraft or a signal sent from the spacecraft to Earth.) Ask the students to predict a distance, in meters, they think they can walk away from the source of the beeping and still hear it with their ears alone; have the students write their predictions in their data tables. Now have them develop a hypothesis about how they think using a parabolic antenna will affect their ability to hear the signal the farther away they walk and why.



A C T I V I T Y 1

CAN YOU HEAR ME?

(Ears Alone)

(a) No Antenna (Umbrella)

Students form a circle around the Sender (teacher or a student) who is the transmitter or spacecraft sending a signal with the beeping timer. They should record the number of meters that they are from the signal to start. Tell the students to raise one hand if they hear the signal. The Sender should turn, timer against body, facing the signal in the direction of each student. Why would the direction the Sender is facing change the strength of the signal that each student receives?

Tell the students to step approximately 1 meter farther away from the Sender after each time they hear the signal, until they reach a distance at which the signal is too weak to hear. Repeat the experiment three times and ask the students to record the greatest distance for each test in their data table. Students should calculate their average distance for the three trials and compare data. Why might there be variation in the point at which different students lose the signal?

(b) Sender with Antenna (Umbrella)

Have the sender tape the watch to the umbrella handle, then repeat the activity as shown in picture. Sender should turn as before. Repeat three times and record greatest distances.

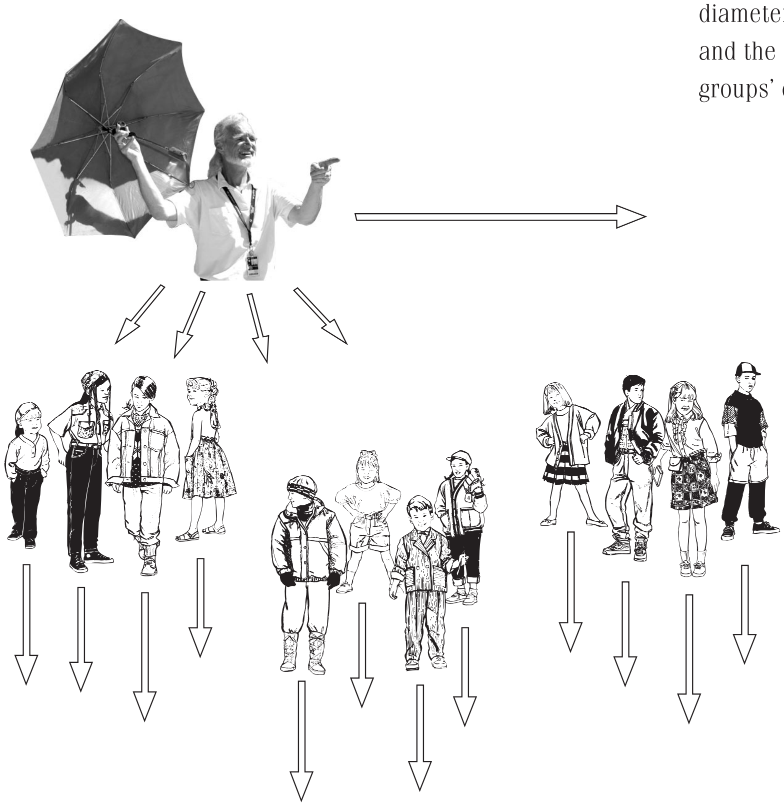
Sender holding umbrella; beeping watch is taped to umbrella handle.

ACTIVITY 2

USING AN ANTENNA

(Ear Antennas and Beeping Watch)

In the classroom, students construct "ear" antennas — cardstock antennas from patterns or antennas made from plastic soda bottles — and then return to the field. Students stand side by side in groups of four across the field, directing their ear antennas toward the Sender with the beeping timer and umbrella antenna. The Sender aims the umbrella handle at each student, keeping the watch in the same position by taping it to the shaft. Students hold their antennas next to their ears and continue to move farther away from the signal each time they hear it. Repeat the experiment three times and ask the students to record the greatest distance for each test in their data tables. Have students calculate their average distances for the three trials. Compare and discuss the observations and the distance data recorded in Activity 1 and Activity 2. How do the antennas increase the distance that the signal can be heard?



Sender with beeping watch taped to umbrella handle moves across line of students.

Groups of four students with "ear" antennas move farther away as they hear the signal; students raise their hands each time they still hear the signal.

ACTIVITY 3

FURTHER EXPLORATION

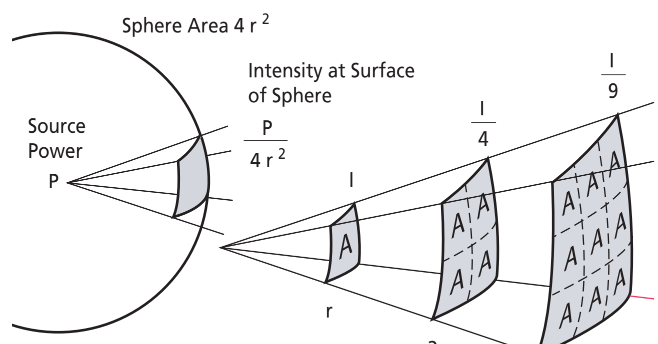
Does the size of the antenna/umbrella make a difference? Students work in groups of four using two different sizes of umbrellas, a wrist-watch beeping timer, and student-made antennas. Students take turns being the Sender (watch holder), Listener, Measurer, and Recorder. The Sender holds the watch at a fixed height and position as the Listener steps away from the beeping signal until he cannot hear it while using his ear antenna. The Measurer measures the diameter of the antennas they are using and the distance between the two students (Sender and Listener). The Recorder writes down the measurements in the data tables. Repeat the experiment using umbrellas of two different sizes. Try sending the signal from both the umbrella antenna (the Deep Space Network) and the student-made antenna (the spacecraft antenna). The students record and compare differences they observe related to the size of the antennas, then analyze their data to see if there is a correlation between the antenna's diameter and the distance between the Sender (watch holder) and the Listener. Discuss the results and conclusions of each groups' experiment.

EXTENSION

Discuss the inverse square law and see how it might apply to the data collected. Students can be introduced to the logarithmic scale of decibels and solve mathematical equations related to it. Research the number of watts of the signal that is sent from the Voyager spacecraft compared to the number of watts received by the Deep Space Network. (Voyager = 13 watts compared to one billionth of one billionth of a watt received by Deep Space Network)

INVERSE SQUARE LAW

The inverse square law applies to both electromagnetic waves and sound waves. Antennas (radio telescopes) on Earth and spacecraft emit electromagnetic waves; a beeping watch emits sound waves. The beeping watch in the activities described here is similar to the emitting antenna or spacecraft; the person listening is the receiver, similar to the receiving spacecraft or antenna. When the distance between the beeping watch and the listener increases, the volume of the sound decreases by the square of the increased distance. If the volume of the sound at distance *r* is *I*, the volume at distance 2*r* is *I*/*r*^2, the volume at distance 3*r* is *I*/*r*^3, and so on.



The energy twice as far from the source is spread over four times the area, hence one-fourth the intensity.

LOGARITHMIC SCALE OF DECIBELS

The volume, or intensity, of sound waves can be measured in watts per square meter. The inverse square law can be used easily with these units. However, the preferred units for volume intensity are decibels (abbreviated dB). Decibels do not easily follow the inverse square law because they are logarithmic — every increase by 10 decibels is an increase in sound of 10 times. This means that 10 decibels are 10 times greater than 0 decibels, 20 decibels are 10 times greater than 10 decibels, 30 decibels are 10 times greater than 20 decibels, and so on. Here are the equations to switch between watts per square meter to decibels:

I(dB) = 10*log(*I*/*I*0)

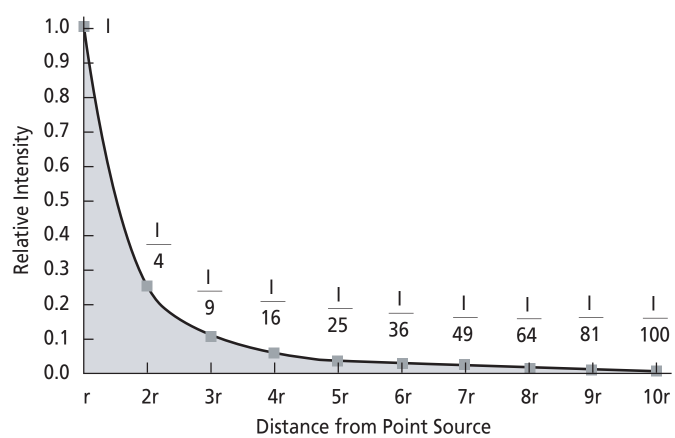
I = *I*0*10^(*I*(dB)/10)

I(dB) is volume intensity in decibels

log is logarithm base 10

I is volume intensity in watts per square meter

*I*0 is the threshold of hearing, 10^–12 watts per square meter



Diagrams courtesy of HyperPhysics ©C.R. Nave, 2002, Georgia State University. Used with permission. HyperPhysics is at http://www.phy-astr.gsu.edu.

STUDENT DATA TABLES

ACTIVITY 1

CAN YOU HEAR ME?

NAME_________________________DATE_________________

Distance Where Signal Is First Inaudible	(a) No Umbrella, distance (m)	(b) Watch with Umbrella, distance (m)
Prediction		
Trial 1		
Trial 2		
Trial 3		
Average of 3 trials		

ACTIVITY 2

USING AN ANTENNA

NAME_________________________DATE_________________

Diameter of Sending Umbrella_____________________________

Diameter of Receiving "Ear" Antenna _______________________

Distance Where Signal Is First Inaudible	Student with Antenna, distance (m)
Prediction	
Trial 1	
Trial 2	
Trial 3	
Average of 3 trials	

ACTIVITY 3

FURTHER EXPLORATION

NAME_________________________DATE_________________

Diameter of Umbrella 1_________________________________

Diameter of Receiving "Ear" Antenna_______________________

Distance Where Signal Is First Inaudible	Student with Antenna, distance (m)
Prediction	
Trial 1	
Trial 2	
Trial 3	
Average of 3 trials	

Diameter of Umbrella 2_________________________________

Diameter of Receiving "Ear" Antenna_______________________

Distance Where Signal Is First Inaudible	Student with Antenna, distance (m)
Prediction	
Trial 1	
Trial 2	
Trial 3	
Average of 3 trials	

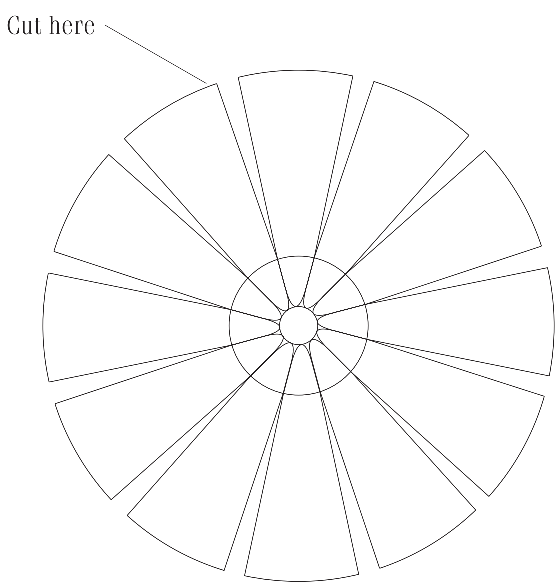
CARDSTOCK PARABOLIC DISH ANTENNA

Teacher

Using cardstock, enlarge the antenna pattern twice on a photocopier: once at 165%, then enlarge at 165% again.

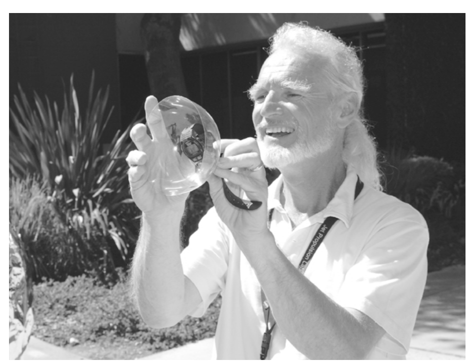
Student

Cut between the petals, stopping at the first circle. Bring the petals together, overlapping them slightly and taping them on the back, forming a curved dish. Cut a small hole in the center of the dish at the innermost circle, then reinforce the center hole on the back with tape.



SODA BOTTLE PARABOLIC DISH ANTENNA

Use an X-acto knife (caution — very sharp) and/or scissors to cut the top off a plastic soda bottle above the label and at the bottom of the neck. This cut-off section will become your parabolic dish antenna. Trim off any rough edges with the scissors.



Example of "ear" antenna made from soda bottle.