SOLAR SYSTEM ODYSSEY

Standards-Based LEARNING ACTIVITIES FOR MIDDLE SCHOOL

UNC
MOREHEAD PLANETARIUM
AND SCIENCE CENTER

SOLAR SYSTEM ODYSSEY
Learning Activities

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A NOTE FOR TEACHERS

Characters in *Solar System Odyssey*. (Image credit: Morehead)

Morehead Planetarium and Science Center's *Solar System Odyssey* is an animated, fulldome digital show that provides an immersive learning experience for students. This science-fiction adventure takes its visual inspiration from Japanese anime in order to teach about space exploration, comparative planetology, and the importance of sustainability on our own planet. The Morehead's award-winning digital production team created the show in collaboration with Will Osborne, who also scripted the Morehead's popular *Magic Tree House® Space Mission*.

Drawing on discoveries by the Mars Exploration Rovers, Hubble Space Telescope, and other NASA missions, *Solar System Odyssey* compares and contrasts geological, atmospheric, and other physical characteristics of the worlds visited by Commander Larson, young Ashley Trout, and their robotic sidekick, Beemer. This approach helps students understand the criteria used to classify Solar System bodies and appreciate the environmental conditions needed to support life as we know it. They learn why Earth—with a balance of systems and resources found nowhere else—is an "amazing oasis" in our Solar System.

While audiences of all ages can enjoy *Solar System Odyssey*, the show targets students in grades five through eight, the range in national standards where Solar System concepts figure prominently. As a teacher, you can build on the show's excitement by including related activities in your classroom. This curriculum guide describes several approaches to involving students in technology design, Earth and space sciences, and language arts lessons inspired by *Solar System Odyssey*. We hope you will find that the show and related classroom activities introduce and reinforce content you need to cover, while also addressing your students' varied interests and learning styles.

LESSON PLANNING

This standards-based curriculum guide ("Connections to Standards," pp. 45–47) describes learning activities that draw upon and reinforce the rich content presented in *Solar System Odyssey*. All of these activities can be conducted during periods after students see *Solar System Odyssey*; several can also be used to prepare students for the experience of seeing the planetarium show. The following **sample lesson plans** use activities selected from the guide.

Plot Summary. *Solar System Odyssey* is set in the future, at a time when humans have depleted Earth's resources. A business tycoon recruits pilot Jack Larson for a mission to discover another world that humans can colonize. The tycoon's stowaway daughter and a robot join Larson in this adventure across the Solar System. Can any of the planets or other worlds in the Solar System support human life? Larson and his crew try to answer this question. (A list of places they investigate is on p. 19.)

TEACHER'S GUIDE—BEFORE THE SHOW

PLAN 1: SCIENCE

Conduct the lessons included in "Part I. Using *Solar System Odyssey* to Teach about Technology Design": discussing and researching robots, creating a dexterous model, and prototyping a robot.

PLAN 2: SCIENCE, LANGUAGE ARTS

Ask students (independently or in groups) to complete the "*Solar System Odyssey* Word Search." Discuss unfamiliar terms and ask students to imagine what the two characters depicted may be like and what space adventures they may be involved in.

PLAN 3: SCIENCE, LANGUAGE ARTS

Conduct Lesson 2 in "Part III. Using *Solar System Odyssey* to Integrate Science and Language Arts." This lesson introduces students to NASA and eight space science topics.

TEACHER'S GUIDE—AFTER THE SHOW

PLAN 1: SCIENCE

Conduct the lessons included in "Part II. Using *Solar System Odyssey* to Teach about Environmental Systems": discovering a new species, determining habitability, and making a hypothesis about biological adaptation.

PLAN 2: SCIENCE, LANGUAGE ARTS

Conduct Lesson 1 in "Part III. Using *Solar System Odyssey* to Integrate Science and Language Arts." This guided discussion of the planetarium show builds students' spoken and written science vocabularies.

PLAN 3: SCIENCE, LANGUAGE ARTS

Conduct the lessons in "Part III. Using *Solar System Odyssey* to Integrate Science and Language Arts." Lead students through the "Building Vocabulary" and "Creative Writing from Research Exercises," then assign the writing prompt in Lesson 3 that best fits your students' interests and your syllabus or pacing guide.

PART I

Using *Solar System Odyssey* to Teach About Technology Design

A robot is one of the main characters in *Solar System Odyssey*. In these lesson plans, students learn about current and potential uses of robots in space and on Earth. They also build simple dexterous robot models and design prototype robots.

One of the characters who is vital to the success of the space mission undertaken in *Solar System Odyssey* is not human. It is Beemer, a BMR 1200 on-board interface unit. While a BMR 1200 is a robotic device imagined by the digital production team at Morehead Planetarium and Science Center, it represents the reality that robots play significant roles in space exploration and in our day-to-day lives on Earth.

Solar System Odyssey's BMR 1200 On-Board Interface Unit. (Image credit: Morehead)

Around the world and across our Solar System, robots carry out extraordinary tasks that require levels of strength, precision, and endurance that humans simply do not possess. Innumerable robots also undertake relatively ordinary tasks that humans find far too repetitive or time-consuming to carry out themselves.

None of these tasks, even those that seem most ordinary, is actually easy for a robot to carry out. Even an action that is relatively simple for a human—like pushing or grasping an object, which we learn to do as infants—becomes complex when a robot is expected to do it. Robots are dependent on human inventors to predict, then program, every action a robot's task requires. The sequence of lesson plans presented here helps students learn about and experience aspects of this technology design process.

Robotics and other technology design activities can sometimes be too expensive or time-consuming to include in a middle school syllabus.

These lesson plans do not require specialized materials and, depending on optional steps taken, can be completed in a total of two to four class periods.

Lesson 1 is a class discussion about robots, with research about unusual robots as an optional follow-up. Lesson 2 and Lesson 3 are hands-on, inquiry-based activities that involve students in designing and building models. By allowing students to experiment with the best ways to build the dexterous model, the teacher increases the challenge of this exercise. The second model, which students develop from idea to prototype, provides another opportunity for students to think creatively about the steps one must take in designing technological solutions to human needs.

TEACHER'S GUIDE—LESSON 1
Discussing Robots

STEP 1

Engage your class in a discussion about robots—what they are, what they do, and what their potential uses are.

- Explain that a robot is a machine controlled by a computer that has been programmed with all the actions that are required by the robot to complete a specific task.
- Robots got their name in 1920 from *R.U.R.* (*Rossum's Universal Robots*), a drama by Czech playwright Karel Čapek.
- Ask your students if they have encountered robots in science fiction stories and games (e.g., Wall-E, Transformers, Sonny in *I, Robot*, R2-D2 and C-3PO in the *Star Wars* movies, HAL9000 in *2001, A Space Odyssey*). What kinds of tasks did these robots carry out? What did they look like? How did these robots help humans? Were there any dangers associated with the robots?

STEP 2

If your students have already seen *Solar System Odyssey*, they will be able to discuss Beemer. They may recall physical details (e.g., spherical, able to fly, able to "see," able to communicate through beeps and other noises, able to project holograms) and tasks that Beemer carried out on board Commander Larson's spacecraft (e.g., responding to spoken instructions for the spacecraft's operation, providing audio-visual information about the Solar System). Ask your students if they would find it useful to have a BMR 1200 themselves? In what ways would it be useful? (It might be helpful for homework!) If your students have not seen *Solar System Odyssey*, omit this step or point out that this robot will be featured in the show.

STEP 3

Discuss the fact that robots are not restricted to the worlds created in science fiction. Many types of robots are currently used in real space explorations, and others are being designed to carry out additional tasks in space. Examples include:

Dextre. The Special Purpose Dexterous Manipulator built by the Canadian Space Agency is a two-armed robot capable of handling delicate assembly tasks outside the International Space Station. Dextre has arms more than nine feet long and can attach power tools as fingers. The two arms allow Dextre to move objects, use tools, and install and remove equipment on the space station. Dextre is attached to Canadarm2, another robot on the ISS.

Robonauts. See "About Robonauts: Information for Teachers" included in this guide.

Rovers and Orbiters. In 2004, Spirit and Opportunity became the first rovers to land on Mars as part of NASA's Mars Exploration Program. Primary among this mission's scientific goals is the search for and characterization of rocks and soils that hold clues to past water activity on Mars. The Mars Science Laboratory rover, which is named Curiosity, is the newest Mars rover. NASA's 2001 Mars Odyssey, another type of robotic explorer, orbits the red planet. This orbiter maps the amount and distribution of chemical elements and minerals that make up the surface of Mars. Through this process, 2001 Mars Odyssey discovered water ice buried just beneath the Martian surface.

Personal Satellite Assistant (PSA). Though Beemer is an invention of the Morehead's digital production team, it has similarities to real-world robotic devices like the PSA. Prototyped by NASA, the spherical (volley ball-sized) PSA was designed to float through a spacecraft, keeping astronauts safe by monitoring the atmosphere. In use, it would also respond to astronauts' requests to perform certain tasks (e.g., gather data for onboard scientific experiments, stream audio-visual communications, monitor supplies, and provide instructions for needed repairs).

STEP 4

Robotic technology is now used so widely for routine tasks on Earth that we sometimes take it for granted. But we also marvel when inventors design new robots that can help us with even more tasks! Ask your students to help you make a list of jobs that they know robots already do on Earth. Some of the categories of robots you can discuss with the class include:

Industrial robots. Robots are used extensively in automobile factories, where they lift, assemble, and weld parts. (Robonaut 2 was developed through a collaborative effort between NASA and General Motors, because both organizations can use this technology.)

Medical robots. Increasing numbers of surgeons are learning to use robotic instruments to conduct delicate, less-invasive surgery.

Assistive robots. Robotic wheelchairs and robots with arms and hands that can reach and hold are examples of robots designed to assist people with physical impairments as they carry out some of their daily tasks.

Household or domestic robots. Many people use autonomous (independent) robots to vacuum or wash the floors in their homes and to clean swimming pools.

STEP 5 (OPTIONAL)

Ask students to work individually or in teams to investigate unusual types of robots. Examples of robots that students can discover and online resources that students can use for their research are:

Non-Disturbing Under-Ice Robotic Antarctic Explorer. Students can look in NASA's Robotics Image Gallery for this and other unusual robots: http://www.nasa.gov/audience/foreducators/robotics/imagegallery/index.html.

StickyBotIII. This climbing robot developed at Stanford University takes its inspiration from geckos, which can climb vertical surfaces. The researchers envision that climbing robots have potential for undertaking tasks on Earth and for space exploration. Students can start their search for more information about StickyBoxIII, DelFly (a robotic dragonfly), ShrewBot (based on animals with whiskers), and other animal-inspired robots here: http://www.economist.com/node/18925855 ("Zoobotics: A new generation of animal-like robots is about to emerge from the laboratory").

Robots Involved in Artistic Creations. "Seraph," a dance that debuted in New York in 2011, was choreographed in collaboration with MIT robot engineers and programmers. In this piece, human dancers are joined on stage by flying X-shaped robots that, according to the *New York Times* reviewer, "dart about the stage like alien wasps." Students can search for information about robots in the *New York Times* and other newspapers: http://www.nytimes.com.

After sharing their findings about unusual robots in a class discussion, students can turn their research notes in to the teacher for a grade. Their notes should include a citation (formal or informal, depending upon the students' knowledge of bibliography) for any source of information on which they relied.

TEACHER'S GUIDE—LESSON 2
Making a Dexterous Model

MATERIALS

- Cardboard. (At least 1 piece the size of the front or back of a cereal box for each student. Cereal box cardboard is a good weight for this model. Provide cardboard of different weights, if available.)
- Tape. (At least 3 feet of tape per student. Ordinary invisible tape works well; provide different kinds, if available.)
- Straight plastic drinking straws wide enough for string to be threaded through. (At least 2 straws per student; provide straws of different widths, if available.)
- String, twine, wool, elastic, big rubber bands (cut each once to make a length), and similar materials to create the dexterous model's "tendons." (At least 5 feet of string or other materials per student.)
- Rulers (to enable students to replicate measurements that appear to work best).
- Safety scissors (enough for pairs of students to share).
- Markers (enough for pairs of students to share).
- Small objects (e.g., marbles, toy cars, ping pong balls) that can be moved with a light tap.
- 1 copy of the "Dexterous Model Design Report" worksheet for each student. (Alternatively, write the questions on the board.)

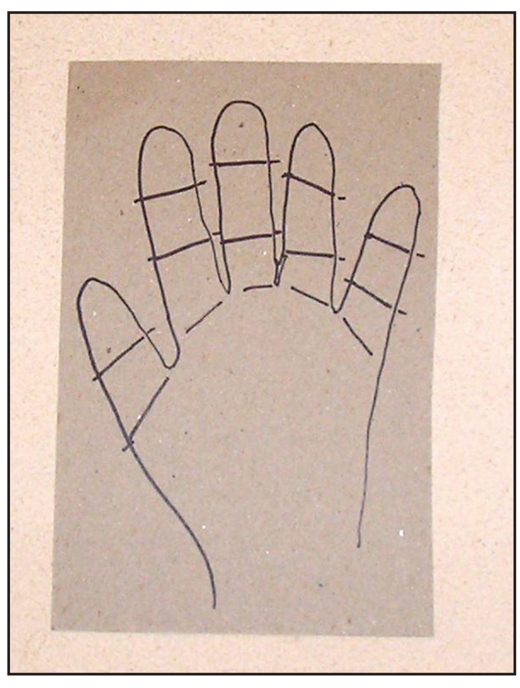
STEP 1

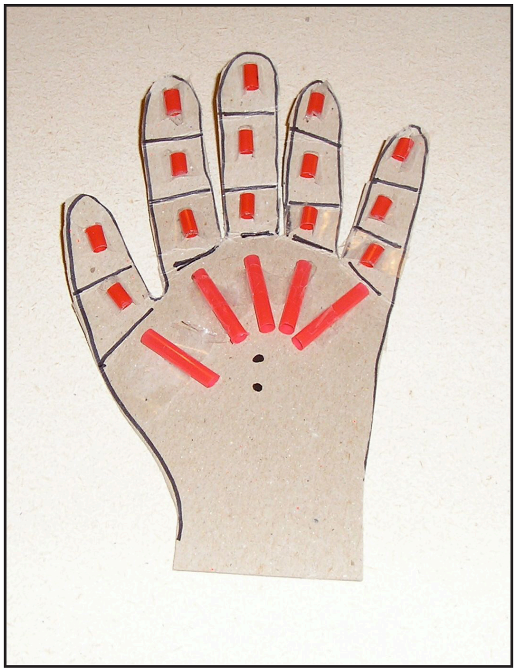
Discuss dexterous robots and the concept of dexterity.

- *Solar System Odyssey*'s Beemer could use its hologram projector to show an image of a hand, but picking up a real object would be out of the question for this robot. Fortunately, Beemer doesn't need to pick up anything during its mission! However, just like people on Earth, astronauts do sometimes need a robotic "helping hand."
- Robots that have hands to do work have a capability called "dexterous manipulation."
- Robonaut and Dextre are examples of dexterous robots involved in space exploration.

STEP 2

Tell students that they are going to build dexterous models. Provide model-building supplies for the students to experiment with. Also provide small objects with which students can





test their models. This activity will help students understand the complexity of building a robot that can mimic the human hand.

STEP 3

Show the class a dexterous model you have made and describe the steps of constructing it:

- Draw the shape of a hand (your own, someone else's, or one that you design yourself) on a piece of cardboard.
- Cut out the cardboard shape you have drawn.
- Mark on the cardboard the places where each finger's joints are.
- Bend the fingers at each of the joints so they can move easily. Use a valley fold so the fingers bend inward, toward the palm.
- Cut a small piece of straw for each segment of the fingers (a total of 14 pieces for a five-fingered hand). To allow the fingers to bend and curl, these pieces of straw must be smaller than the segments of the fingers.
- Tape one small piece of straw vertically on each joint. The tape will likely be wider than the straw and need to be trimmed to fit.
- Mark a point in the middle of the palm. Then mark another point about a half-inch below the first mark. Placement of this second mark may vary depending on the size of the model and the position of the thumb, which is typically lower than the other fingers.
- Cut pieces of straw that will fan out on the palm toward the fingers (a total of five pieces for a five-fingered hand). One piece of straw will radiate from the lower (second) mark toward the thumb. The other pieces of straw will radiate from the upper (first) mark toward the other fingers.
- Tape these longer pieces of straw to the palm. Again, make sure that the spacing of the pieces of straw allows the fingers to bend freely.
- Measure a length of string or similar material for each finger (five pieces for a five-fingered hand). The length of each piece of string should be sufficient that, after being

threaded through the four pieces of straw on the finger and palm, the user can hold the string and manipulate that finger.

- For each finger: thread a piece of string through the four pieces of straw associated with that finger. Use tape to secure one end of the string at the fingertip. Let the rest of the string dangle freely in the palm. Repeat for the other fingers.

While describing this general method, the teacher's goal will be to encourage students to experiment. They should select construction materials that they believe will work best (or that they're curious about working with); decide on a model/hand size that they want to experiment with; measure, cut, and test lengths of straw until they move easily in their models; and so on.

STEP 4 (OPTIONAL)

Students can decorate their models with markers, paints, decoupage, and other media. This can be done before or after the model-building begins. If the classroom has a limited supply of scissors, rulers, and other tools, including this step may prevent students' having to wait too long for their turn to share.

STEP 5

Provide marbles, toy cars, and similar small objects that will move with a light tap. Students can use these objects to test the efficacy of their models. While holding their models steady, students will use the strings to manipulate their models' fingers in order to tap, pull, and push the objects.

STEP 6

Ask students to report on their models. These reports can be made in writing; or they can be made during an informal class discussion or a formal oral assessment activity. The "Dexterous Model Design Report" included in the *Solar System Odyssey* curriculum guide can be used for both the written and the spoken options.

TEACHER'S GUIDE—LESSON 3
Designing a Prototype Robot

MATERIALS

- Unlined paper and pencils (color pencils or crayons, if available) for sketching preliminary designs.
- Class-set of rulers for designing and constructing models to scale.
- Scrap materials (e.g., boxes of various sizes, plastic bottles and cups, aluminum cans, fabric, buttons, paper, old CDs). These materials can be provided by the teacher before the activity begins, or students can be asked to gather the materials that will meet their design needs.
- Glue, tape, scissors, markers, poster paints and brushes, and other craft tools.
- 1 copy of "Robot Design Planning Report" for each student or team.

STEP 1

Tell students that they are going to design and build prototype robots. You can narrow the focus of the designs by asking students to design robots for space exploration missions or for other specific purposes (e.g., household or industrial tasks, or for tasks that are particularly relevant to the students' school or community). This assignment can be carried out by individual students or by teams.

STEP 2

Provide a copy of the "Robot Design Planning Report" to each student or team. Ask students to brainstorm their robot designs and fill out Part A. When students have had sufficient time to complete all or most of Part A, engage them in a discussion about their ideas so far. This will serve as an opportunity for you to monitor students' progress and assess their understanding of the assignment. After this discussion, students may proceed to Part B.

STEP 3

Review or explain the concept of "scale" and how this will enable students to model accurately even extremely tiny or massive designs. You may wish to practice this concept with your students by asking them to help you make scale drawings of objects in the classroom (e.g., the classroom door drawn to a scale of 1 inch = 1 foot, and then drawn to a scale of ½ inch = 1 foot). Show students how to add a scale legend to their drawings.

STEP 4

Set aside time for students to brainstorm their robots and sketch their preliminary designs. (If scheduling allows, you may wish to partner with an art teacher, who can provide additional guidance to students during this step.)

STEP 5

Using scrap materials, students will create scale models of their robot designs. The students' models will not function as robots (i.e., they will not have computers controlling them); rather, the models will indicate how the robots might appear if they were built. Prototypes of this sort help designers to discover construction problems and potential users (e.g., investors, manufacturers) to visualize the final products.

STEP 6

Tell students that this information should be included on a label accompanying each model: name of model, designer(s), date of design, scale used, and the model's primary purpose(s).

Prototype robot, 31 inches tall, constructed from cardboard, plastic cups, duct tape, stickers, screws, and a push-on light. According to the student designers, if this were a working robot, it would gobble up garbage.

STEP 7

When the prototype models are complete, host a technology design fair in the classroom. Half of the students can tour the models and talk to the designers; after 15 or 20 minutes, the rest of the students can have a turn looking at and discussing their classmates' work. Students should be sure to include the descriptive labels with their models. Additionally, if it is practical to do so, the models can be displayed in the school's media center or display cases.

STEP 8 (OPTIONAL)

In addition to Step 7, or as an alternative to that summative activity, students can design small advertising campaigns for their models. They can brainstorm logos and slogans, design ads for print or web use, and even write scripts for television commercials. They can display their materials in the classroom and act out the scripts as skits for their classmates.

DIFFERENTIATION STRATEGIES

An alternative approach to teaching these lessons can employ discussion and oral assessment rather than model-building and writing. Using this approach, replace the model-building in Lesson 2 with a discussion activity involving ready-made objects that students (particularly those who have visual and physical impairments) can easily and safely explore by touch. Modify Lesson 3 by asking students (independently or in groups) to brainstorm new robot designs and share their ideas during an informal class discussion or a formal oral assessment activity.

Teacher's Preparation. Bring examples of domestic robots (e.g., a Roomba vacuum cleaner, a battery-operated toy robot) and robot figurines (e.g., sci-fi action figures, models of robotic space craft) into the classroom for this activity. Use the "Robot Design Planning Report" as a teaching guide for the questions you pose at the discussion and assessment stages of this lesson.

ADDITIONAL ACTIVITY

Explore Careers. Students may wonder about jobs that involve designing robots and how people become robotics experts. Scientists and engineers give their personal perspectives on these topics in interviews gathered at NASA's online Career Corner. One of the scientists profiled is college student Kody Ensley, a descendant of the Confederated Salish and Kootenai Tribes in Montana who interned on the Robonaut 2 project:

> "I was very excited to work with Robonaut 2 as he is the pinnacle of 'robot cool,' " said Ensley. "What I found particularly interesting about [R2] were his hands and fingers. This led me to a project where I was able to build a testbed for evaluating new designs for future Robonaut fingers."

NASA's Robotics Career Corner is here: http://www.nasa.gov/audience/foreducators/robotics/careercorner/index.html.

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Designer:

Dexterous Model Design Report

Brief description of the dexterous model I made (25 words or fewer):

Question	Answer	Reasons
Based on this experiment, I think the most difficult step in constructing this model is:		
If someone asked me how to make a model like this, the most important construction advice I would give them is:		
If I made this model again, I would change this (size, material, other):		
If this model were a real robot controlled by a computer, I would program it to perform this task:		
The best thing about the dexterous model I made is:		

Designer(s):

ROBOT DESIGN PLANNING REPORT — PART A		
Name of robot:		
Brief description of this robot (20 words or fewer):		
FEATURE	**ANSWER**	**REASONS**
Purpose What is the most important task this robot performs?		
Other Purposes What additional tasks can this robot perform?		
Users Who will be the main users of this robot?		
Moving Does this robot stand in one place or does it walk, climb, slide, etc?		
Seeing Does this robot need visual cues in order to perform its task(s)?		
Other Sensing Does this robot need any sensory information (other than visual)?		

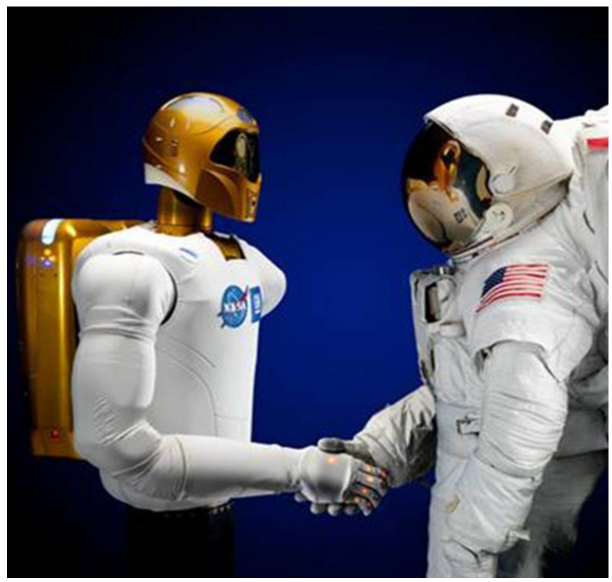
ROBOT DESIGN PLANNING REPORT — PART B		
FEATURE	**ANSWER**	**REASONS**
Communicating Does this robot need to speak, beep, buzz, etc.?		
Dexterity Does this robot need to have "hands" to grasp and manipulate objects?		
Humanoid? Does this robot need to be human-like?		
Size What size does this robot need to be to carry out its task(s)?		
Control Source Does this robot control itself, does an operator control it, or is it semi-autonomous?		
Energy Source Is this robot powered by a battery, the Sun, biofuel, or another source?		
Material(s) What are the main materials this robot can or must be made of?		
Safety Are there any potential safety issues associated with this robot?		

ABOUT ROBONAUTS

BACKGROUND INFORMATION FOR TEACHERS

Adapted from materials created by National Aeronautics and Space Administration

On February 24, 2011, NASA launched the first humanoid robot into space to become a permanent resident of the International Space Station. Robonaut 2 Unit B (R2-B) was created by NASA and General Motors under a cooperative agreement to develop a robot that can work alongside humans, whether they be astronauts in space or workers at automobile manufacturing plants on Earth. The value of a humanoid robot (a robot with human characteristics) over other robot designs is its ability to use the same workspace and tools as humans.



Robonaut 2 with a human astronaut. (Photo credit: NASA)

WHAT IS A ROBONAUT?

Robonauts are humanoid robots designed and built at NASA's Johnson Space Center in Houston. A 300-pound R2 consists of a head and a torso with two arms and two hands. These hands are dexterous—that is, able to grasp and manipulate objects. At the time R2-B was launched into space, there were four Robonauts in existence, with others in development. R2-A, the "twin" of R2-B, remains involved in experiments on Earth.

HOW WERE THE ROBONAUTS DESIGNED?

Work on the first Robonaut began in 1997. The idea was to build a humanoid robot that could assist astronauts on tasks in which another pair of hands would be helpful or to venture forth to perform jobs either too dangerous for crew members to risk or too mundane for them to spend time on. The prototype that resulted is called R1. By 2006, R1's performance in numerous experiments had proven that the concept of a robotic assistant was valid. After seeing what NASA had accomplished, General Motors (which had been developing their own dexterous robots) proposed teaming up. A Space Act Agreement signed in 2007 allowed GM and NASA to pool their resources and work together on the next-generation Robonaut.

HOW WAS A ROBONAUT PREPPED FOR SPACE TRAVEL?

R2 was designed to be used on Earth to help researchers understand what would be needed to send a robot to space. But when it was unveiled in February 2010, R2's potential was quickly recognized. Arrangements were made for an

R2 to ride to the space station on one of the few remaining shuttle missions. To make this possible, R2-B was upgraded with new outer skin materials that meet the station's stringent flammability requirements, shielding to reduce electromagnetic interference with other station systems, and improved processors to increase its radiation tolerance. The robot's original fans were replaced with quieter ones to accommodate the station's restrictive noise environment, and its power system was rewired to run on the station's direct current system rather than the alternating current used on Earth. R2-B also underwent vibration testing that simulated conditions it would experience during its launch on board space shuttle *Discovery*.

HOW IS R2-B OPERATED?

The space station crew can operate R2-B, as can controllers on Earth. However, it does not need constant supervision. In anticipation of destinations where distance and time delays would make continuous management problematic, this robot was designed to perform set tasks autonomously with periodic status checks.

IS R2-B MOBILE?

R2-B is currently on a fixed pedestal. Later, an added lower body and upgraded software could allow it to move around, climb through the station's corridors, and work outside in the vacuum of space. R1 spent time atop a Segway and a four-wheeled chassis; and a four-wheeled rover (Centaur 2) is being evaluated on Earth as an example of future lower bodies for Robonauts. As the technology matures, Robonauts could be sent farther into space to be tested in more extreme thermal and radiation conditions. For instance, legs and wheels could propel Robonauts across Lunar and Martian terrains.

WHAT WILL R2-B DO?

Initially, R2-B will be used to test how a dexterous humanoid robot performs in microgravity. The space station provides an ideal laboratory for this experiment. As R2-B proves its mettle, it may graduate to such tasks as vacuuming or cleaning filters. With upgrades, it could operate on the station's exterior, making repairs or helping astronauts as they work outside. In addition to carrying out station maintenance tasks, robots like R2-B could directly benefit Earth by servicing communications, weather, and reconnaissance satellites. Another step would be the development of Robonauts to explore near-Earth objects, including asteroids and comets, and eventually Mars and Mars's moons. These robots could go ahead of their human counterparts to scout safe locations, provide maps and soil samples, and begin work on needed infrastructure. When astronauts arrive, the robots could work alongside them. Anywhere astronauts go or want to go, Robonauts are likely to be an asset.

SOURCES

NASA. (n.d.). *Robonaut: R2.* Retrieved from http://robonaut.jsc.nasa.gov.

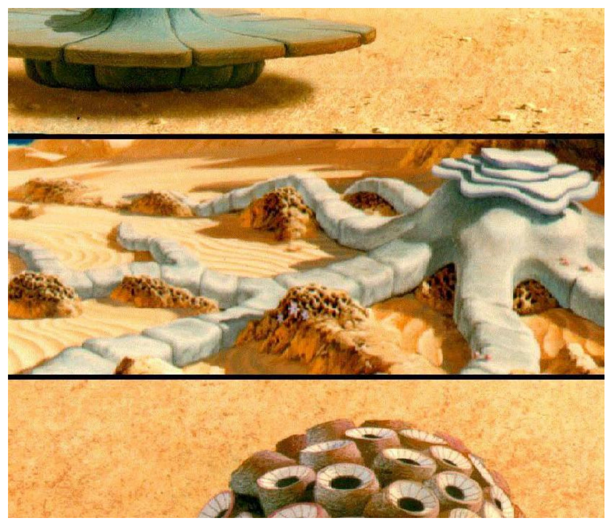
Many facts about Robonaut 2 are summarized for the general public in a downloadable four-page *NASAfacts* document from Johnson Space Center: http://www.nasa.gov/pdf/469616main_Robonaut2_factsheet.pdf.

Robonaut 2 Unit B has its own Twitter account—http://twitter.com/astrorobonaut. (The updates are actually provided by humans on Earth.) This is a source of timely information about R2-B and the Robonaut program that students will find accessible and engaging.

PART II

Using *Solar System Odyssey* to Teach About Environmental Systems

These lesson plans involve students in a scenario that develops out of *Solar System Odyssey*. First, students hypothesize about life forms that could inhabit the planets, moons, and other Solar System objects discussed in the planetarium show. Then, using their knowledge of Earth's systems, they hypothesize about the potential survival of these speculative life forms on our own planet.



An artist's speculative drawings of Martian life forms.
(Image credit: NASA/JPL)

The *Solar System Odyssey* planetarium show tells the story of a search for a place in our Solar System that can support human life. This quest leads the main characters to evaluate the habitability of the planets, our own Moon and the moons of Jupiter and Saturn, and a number of other space objects. Their guiding question: do any of these places have the combination of environmental systems that life as we know it needs in order to survive?

The lesson plans described here involve students in a sequel to *Solar System Odyssey*. In this new adventure, Commander Larson and Ashley Trout return to Earth with a form of life that originated elsewhere in space.

In Lesson 1, students conduct research on the worlds visited in *Solar System Odyssey* and make hypotheses about life forms that could exist there. In Lesson 2, they evaluate how differences between these other worlds and Earth may affect the life forms' survival in their new environment.

In Lesson 3, students consider the potential for change over time as generations of these life forms adapt to their habitats on Earth. By exploring what is known about the Solar System, hypothesizing about future discoveries, and considering issues that may be involved, students develop their understanding of the science of life on Earth.

These lesson plans do not require specialized materials and, depending on optional steps taken, can be completed in a total of two to six class periods.

TEACHER'S GUIDE—LESSON 1
Discovering a New Species

MATERIALS

- Access to research materials for all students (text books, reference works in the school's media center, NASA.gov and other relevant Internet sites).
- Unlined paper and pencils (color pencils or crayons, if available) for creating scale drawings of the newly discovered species.
- 1 copy of "Guidelines: Gathering Comparative Habitability Data for Newly Discovered Solar System Species" for each group.
- 1 copy of the "Trout Enterprises Memorandum" for each group.

STEP 1

After your class has seen *Solar System Odyssey*, explain that when Commander Larson and Ashley Trout returned to Earth, they discovered unfamiliar life forms had stowed away on their spacecraft. (Your students will recall that Ashley, too, was a stowaway, much to the surprise of the Commander and her father!) You do not know how this happened. You also cannot tell students what the life forms are, what they look like, or where in the Solar System they came from. This is what the students are going to find out—in their new roles as astrobiologists! They will create this part of the adventure!

STEP 2

Discuss the fact that even on Earth scientists are still discovering new species, often in places (e.g., hot springs and hydrothermal vents) where conditions were once considered far too extreme to permit life to flourish.

In 1997 scientists discovered a new species, Methane Ice Worms, living on the floor of the Gulf of Mexico. (Image credit: NOAA)

STEP 3

Different environments in our Solar System provide different opportunities and challenges for speculation about life forms that have the potential to live there. Some examples to share with your students:

Imagining Life on Mars. An artist working for NASA's Jet Propulsion Laboratory in the 1970s took into account what was known at that time in order to prepare speculative drawings of life forms that could inhabit Mars. The artist drew three potential forms of Martian life with characteristics that fitted them for the arid surface of that terrestrial planet. Information about these drawings is located here: http://www.nasa.gov/multimedia/imagegallery/image_feature_1904.html ("Imagining Mars").

Floaters and Other Jovian Life Forms. Jupiter does not have a solid surface like that of Mars or the other terrestrial planets. In *Cosmos: A Personal Journey,* the scientist Carl Sagan described how he and a colleague hypothesized that life forms—which they categorized as Sinkers, Floaters, and Hunters—could exist in the atmosphere of that gas giant planet. *Cosmos* can be viewed online:

http://www.hulu.com/cosmos. (This topic occurs at approx. 52–56 minutes of Episode 2, "One Voice in the Cosmic Fugue.")

STEP 4

Divide the class into groups of four or five students. Assign each group a Solar System object (other than Earth) that the *Solar System Odyssey* explorers evaluated as colonization sites:

- The terrestrial, or inner, planets other than Earth (Mercury, Venus, Mars).
- The gas giant, or outer, planets (Jupiter, Saturn, Uranus, Neptune).
- Earth's Moon.
- Titan (one of Saturn's moons).
- Callisto, Io, and Europa (three of Jupiter's moons).
- Dwarf planets (e.g., Pluto, 2003 UB313).

Each group will speculate about a life form that could have originated on their assigned world.

STEP 5

Provide a copy of "Guidelines: Gathering Comparative Habitability Data for Newly Discovered Solar System Species" and the "Trout Enterprises Memorandum" to each group. These handouts (located at the end of Part II of the *Solar System Odyssey* curriculum guide) may be used as checklists on which students mark each task as they complete it.

STEP 6

Students in each group will work together to find out more about their assigned world and answer the questions in section A of "Guidelines: Gathering Comparative Habitability Data for Newly Discovered Solar System Species." They may consult their textbooks, resources in the school's media center, and reliable online reference tools such as NASA.gov. (Students should record basic bibliographic information for the sources they use.)

STEP 7

Using the "Trout Enterprises Memorandum" as a guide, each group will speculate about a life form that could inhabit their assigned world. What characteristics would make the life form fit for this world? Does it need to withstand great heat or deep cold? Does it need a solid surface to stand on or liquid to swim in? Does it need to see, smell, or have any of the same senses we humans do? Is it a plant or an animal? What is its scientific name? Each group will answer these and other questions as they prepare a report for Mr. Trout.

STEP 8

Review or explain the concept of "scale" and how this will enable students to model accurately even extremely tiny or massive designs. If you have not done so previously, ask your students to practice this concept by helping you make scale drawings of several objects in the classroom (e.g., the classroom door drawn to a scale of 1 inch = 1 foot, and then drawn to a scale of ½ inch = 1 foot). Show students how to add a scale legend to their drawings.

STEP 9

Ask students to make scale drawings of the life forms they have hypothesized. Students should label any special physical characteristics that enabled the life forms to live in their native environments. Each member of a group can take on the task of illustrating a different stage in the life cycle of their new species. Every drawing should include a legend indicating the scale used. This assignment can be carried out in class (in collaboration with an art teacher, if scheduling allows) or as homework.

STEP 10

Students will share their reports with their classmates. They will describe their assigned worlds and the speculative species that could live there, and they will display their drawings.

STEP 11

Review students' progress. Each group will have completed three tasks in this lesson: answering questions in Section A of "Guidelines: Gathering Comparative Habitability Data for Newly Discovered Solar System Species," drawing the life cycles of their newly discovered species, and writing a report in response to the "Trout Enterprises Memorandum." If there is time available to do so, you may wish to continue on to Lesson 2.

TEACHER'S GUIDE—LESSON 2
Determining Habitability

MATERIALS

- 1 copy of "Guidelines: Gathering Comparative Habitability Data for Newly Discovered Solar System Species" for each group (continued from Lesson 1).
- Students' reports on newly discovered life forms (completed in Lesson 1).

STEP 1

Solar System Odyssey provides us with an opportunity to consider the habitability of many worlds. Naturally, we do so from our point of view. We ask, "Given what science has revealed about their characteristics, could we inhabit those worlds?" To build on this understanding in ways that scientists would and develop new hypotheses to explore, your students will take another stance. They will be asking, "Could inhabitants of any of *those* worlds live on *Earth*?"

STEP 2

Using the same research methods as in Lesson 1, students will complete Section B of "Guidelines: Gathering Comparative Habitability Data for Newly Discovered Solar System Species." Section B asks questions about Earth's environment.

STEP 3

Students will complete Section C of "Guidelines: Gathering Comparative Habitability Data for Newly Discovered Solar System Species." Section C guides each group in making comparisons between the environment of the world where their newly discovered species originated (Section A) and Earth's environment (Section B). Students will use this knowledge, along with their previously completed reports on newly discovered life forms, to carry out Step 4.

STEP 4

In their roles as astrobiologists for Trout Enterprises, each group of students will write a memorandum to NASA and other concerned government agencies based on their findings. Some questions each group can address:

- Where on Earth can this life form be relocated? How will the chosen environment benefit the life form? Does this environment pose any potential harms to the life form?
- Should a special structure (habitat? zoo?) be built to house this life form? Will this be costly or pose other problems for the human community?
- Should additional changes in the environment be made to accommodate the life form? What impact will these changes have on other species in this environment?
- Should PSAs (public service announcements) about this life form be issued? What should the main message of these PSAs be?
- Is the Trout Enterprises astrobiology team (the group of students) willing to continue their involvement with the relocation of this species on Earth? If not, why?

Tell students that their memoranda should provide information and reasoning to assist decision-makers. Individual group members can take responsibility for preparing particular sections of their group's memorandum, with all group members then collating the sections and proofreading the entire document.

STEP 5

Students will share their memoranda during a class discussion. The discussion can be free-flowing or organized around themes. For instance:

- Geographic locations of species' new habitats.
- Structures and other changes in the new environments to accommodate the species.
- Impact of these changes on the environments.
- Content of PSAs, if needed.
- The astrobiology teams' hypothetical next steps.

STEP 6

Review the students' progress. Each group will have completed two tasks in this lesson: answering questions in Parts B and C of "Guidelines: Gathering Comparative Habitability Data for Newly Discovered Solar System Species" and writing a memorandum to government agencies involved in making decisions about the new species. If there is time available to do so, you may wish to carry out Lesson 3.

TEACHER'S GUIDE—LESSON 3
Making a Biological Adaptation Hypothesis

STEP 1

Introduce or review the concepts of natural selection and biological adaptation.

STEP 2

Ask your students to think about the future of the life forms they have introduced into the ecology of planet Earth. Ask them to imagine that these life forms survive for many generations. Given the features of our planet, which characteristics (e.g., in anatomy or behavior) of these life forms are likely to be advantageous or disadvantageous in this new environment? Which characteristics are likely to be selected for over time? How and why will these life forms change? If any group speculates that, after several generations, its life form becomes extinct, the students should explain why that happened.

STEP 3

The hypotheses developed by the groups can be shared in a class discussion. They can also be written up in memoranda similar to those prepared in Step 3 of Lesson 2.

DIFFERENTIATION STRATEGIES

An alternative approach to teaching these lessons can emphasize listening, discussion, and oral assessment. Using this approach, talk to your students about one or more of the worlds listed in Step 4 of Lesson 1. Ask them (as a class or in small groups) to hypothesize about species that could potentially live there and how these life forms would fare on Earth. Students can report on their hypothetical life forms during informal class discussions or formal oral assessment activities.

Teacher's Preparation. If students will not be carrying out the research steps in each lesson, gather facts about Earth and one or more of the worlds listed in Step 4 of Lesson 1. NASA's "Homework Topics" website (http://www.nasa.gov/audience/forstudents/5-8/features/homework-topics-index.html) is a convenient source of general information about Earth, Jupiter, Mars, Mercury, and Pluto; while the "Planetary Fact Sheets" (http://nssdc.gsfc.nasa.gov/planetary/planetfact.html) provide details about all the planets in our Solar System and their satellites. Use the "Guidelines: Gathering Comparative Habitability Data for Newly Discovered Solar System Species" and "Trout Enterprises Memorandum" as teaching guides for the information you provide and the questions you pose to the class.

ADDITIONAL ACTIVITIES

Give a Planet an Extreme Makeover. NASA's *Extreme Planet Makeover* web-based game gives students the opportunity to create their own planets by varying parameters such as star type, distance from star, planet size, and planet age. Descriptions of how each parameter might affect habitability on the planet are given, and a picture of the planet created can be downloaded. A reviewer noted:

> If it seems like there's only a few, very limited ways to "win" this game ... well, that's kind of the point. The planet-builder is based on what we know about what it takes to produce life as we know it. And that list of requirements and contradictions really narrows your options. Ultimately, this site should make it clear why finding a "Goldilocks" planet is such a chore, and why everybody is so prone to get excited about the possibility that "life as we know it" isn't the same thing as "life."

Extreme Planet Makeover can serve as a stand-alone activity before or after students view *Solar System Odyssey*, and it can be included as a step in Lesson 1 or Lesson 2. This free game is available here: http://planetquest.jpl.nasa.gov/system/interactable/1/index.html.

Read a Comic Book about Astrobiology. To mark 50 years of exobiology and astrobiology at NASA, the NASA Astrobiology Program has created a series of graphic novels for teen and young-adult readers. The first issue of *Astrobiology: The Story of Our Search for Life in the Universe* (2010) chronicles the growth of astrobiology—from its roots in early cave paintings, through speculations by ancient Greek philosophers on the existence of other worlds, to contributions by modern scientists. This issue is available here: http://astrobiology.nasa.gov/articles/astrobiology-graphic-novel/. The second issue of *Astrobiology* (2011), focusing on Mars exploration, is available here: http://astrobiology.nasa.gov/articles/astrobiology-graphic-novel-issue-2/. These are free resources that can be downloaded as PDFs or mobile apps.

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GUIDELINES

GATHERING COMPARATIVE HABITABILITY DATA FOR NEWLY DISCOVERED SOLAR SYSTEM SPECIES

A. Conduct research about the world where the species originated.

1. How large is this world?
2. How far from the Sun is this world? What effect does the Sun's distance have on this world?
3. Is water present in this world? Where? In what form(s)?
4. Describe the surface of this world.
5. Describe gravity on this world.
6. Describe the atmosphere of this world. What is the atmosphere composed of?
7. What is the climate like on this world? Describe any dangerous weather conditions. Describe the seasons.
8. How long are the days and nights on this world?

B. Conduct research about the world where the species may be relocated.

1. How large is this world?
2. How far from the Sun is this world? What effect does the Sun's distance have on this world?
3. Is water present in this world? Where? In what form(s)?
4. Describe the surface of this world.
5. Describe gravity on this world.
6. Describe the atmosphere of this world. What is the atmosphere composed of?
7. What is the climate like on this world? Describe any dangerous weather conditions. Describe the seasons.
8. How long are the days and nights on this world?

C. Compare information gathered for Sections A and B to evaluate how the new environment may potentially affect the newly discovered species. Rate each of these characteristics as Very Helpful, Helpful, Neutral, Harmful, or Very Harmful to the species and briefly explain your rating.

1. Size of this world
2. Distance from the Sun
3. Presence or lack of water
4. This world's surface
5. Gravity on this world
6. This world's atmosphere
7. This world's climate
8. Length of days and nights on this world

TROUT ENTERPRISES™

M E M O R A N D U M

TO: Astrobiology Team

FROM: A. S. Malfish, Vice President, Research and Development

RE.: Newly Discovered Life Forms

Mr. Trout wishes to be updated about the life forms discovered on Commander Larson's spacecraft. Following are 20 questions your report should answer. Thank you!

1. What is the scientific name that has been given to this species?
2. Where in the Solar System did this species come from?
3. Is this species classified as a plant, an animal, or something else? Why?
4. What did these life forms look like when they were first discovered? Have they changed in appearance since that time? In what ways? Have all of them survived?
5. How large (tall, wide) does this species typically grow?
6. How much does this species typically weigh as an adult?
7. Describe the surface of this species. Is it covered with scales, fur, bark, or something else? How is this covering related to its home environment?
8. If this species can move, how does it move and how fast can it go? Describe the terrain over/through/on which it normally needs to move.
9. How many offspring does this species typically have at one time? How does it reproduce? Internally or externally? Through egg, seed, other?
10. How long does this species typically live? Describe the stages of its life cycle.
11. Can this species see, hear, taste, feel (by touch), or smell? If so, how? Does it have other (previously unknown) senses?
12. Does this species appear to have defense mechanisms? If so, what do these mechanisms suggest about possible predators in its home environment?
13. What is this species' usual source(s) of energy? How does it feed or take in energy?
14. Does this species tend to be solitary or to stay in small or large groups? What is a group of these life forms called (e.g., herd of deer, gaggle of geese, bunch of flowers)?
15. Does this species require water? Why? Does it require another liquid?
16. Does this species sleep? Does it hibernate? For how long? How do these periods of rest relate to environmental factors in its home world (length of day, seasons, etc.)?
17. Does this species require light? Why? Why not?
18. Can this species communicate? How? Can this communication be interpreted by humans?
19. Is this species a threat to humans? Why? Why not?
20. Can this species be helpful to humans? Why? Why not?

ABOUT ASTROBIOLOGY

BACKGROUND INFORMATION FOR TEACHERS

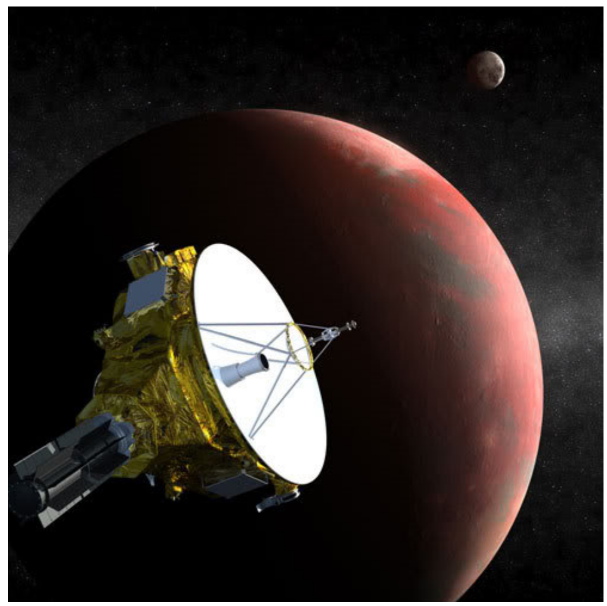
Adapted from materials created by National Aeronautics and Space Administration

Astrobiology is the study of the origin, evolution, distribution, and future of life in the universe. This multidisciplinary field encompasses the search for habitable environments in our Solar System and habitable planets outside our Solar System, the search for evidence of prebiotic chemistry and life on Mars and other bodies in our Solar System, laboratory and field research into the origins and early evolution of life on Earth, and studies of the potential for life to adapt to challenges on Earth and in space.

The possibility of finding life elsewhere is for many people the most compelling reason to explore beyond Earth. NASA's Astrobiology Program addresses three fundamental questions. How does life begin and evolve? Is there life beyond Earth and, if so, how can we detect it? What is the future of life on Earth and in the universe? In striving to answer these questions and improve understanding of biological, planetary, and cosmic phenomena and relationships among them, experts in astronomy and astrophysics, Earth and planetary sciences, microbiology and evolutionary biology, cosmochemistry, and other relevant disciplines participate in astrobiology research.

ARE THERE HABITABLE ENVIRONMENTS BEYOND EARTH?

Habitability—the ability of worlds to sustain life—is a unifying theme in NASA's current exploration efforts. Conditions for habitability



Artist's conception of the *New Horizons* spacecraft approaching Pluto in 2015. (Image credit: NASA Jet Propulsion Laboratory)

remain poorly understood. If, as we believe, liquid water, carbon, and a source of energy are required for life, many places in our solar system have provided these, at least for a time—not only planets, but also some moons and even certain comets. But we presume that a hospitable environment must be more than just transient in order for life to arise there. Earth is in the continuously habitable zone—meaning that at its size and distance from the Sun, water has been stable on the surface even though the Sun's brightness has varied.

Not all planets are so lucky. We now know there once was liquid water on Mars's surface, but was it there long enough for life to develop? And if water were there long enough, might life still linger beneath Mars's surface? Venus also shows signs that it lost the equivalent of Earth's oceans into space. Did life have a chance to evolve before that planet became the dry, superheated world we know today?

On Earth, microbial life forms have been discovered surviving and even thriving at extreme temperatures and pressures and in conditions of acidity, salinity, alkalinity, and concentrations of heavy metals that were not long ago regarded as invariably lethal. These discoveries include the wide diversity of life near sea-floor hydrothermal vent systems, where some organisms live essentially on chemical energy in the absence of sunlight. Similar environments may be present elsewhere in our solar system.

Jupiter's icy moon Europa almost certainly has a liquid-water ocean beneath its surface. If there are hydrothermal vents at the bottom of this ocean, that would seem a very hospitable place for life. Other moons that might have liquid water deep below the surface include Jupiter's moons Callisto and Ganymede and perhaps Saturn's moons Titan and Enceladus.

Life might also occur where other liquids substitute for water, and in planetary environments where organic molecules are briefly exposed to liquid water and then preserved. This possibility, too, makes Titan a high-priority for more detailed exploration.

HOW DID LIFE BEGIN AND EVOLVE ON EARTH AND HAS IT EVOLVED ELSEWHERE?

Our own planet and our roughly 4.6-billion-year-old cosmic backyard harbor a wealth of clues—and collectively they tell the story of our solar system.

We can find on Earth direct evidence of the dramatic changes life has undergone as the planet evolved. However, understanding these processes is complicated by the actions of biology itself. Earth's atmosphere today bears little resemblance to the atmosphere of the early Earth in which life developed. And our planet has since been nearly reconstituted by the bacteria, vegetation, and other life forms that have acted upon it over the eons.

Fortunately, our solar system has preserved an array of natural laboratories in which we can study life's raw ingredients (volatiles and organics), their delivery mechanisms, and the prebiotic chemical processes that led to life. Comets, for example, are believed to have delivered many of life's ingredients to Earth after the planet cooled. The comets we see now in our night sky contain records of the earliest days of our solar system, which makes them important targets for robotic explorers.

The moons of Jupiter and Saturn harbor some of life's key ingredients and have been targeted for study by robotic spacecraft. Mars and Venus—so different from Earth even though they share a seemingly prime location in our solar system—also provide platforms to hunt for signs of life and clarify how planets evolve. Did life evolve on those worlds early in their development? If so, what happened? The only way to find out is to explore these places.

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PART III

Using *Solar System Odyssey* to Integrate Science and Language Arts

Solar System Odyssey provides students with a rich experience that teachers can draw upon for writing assignments. A guided discussion after the show builds vocabulary by helping students spell and pronounce a large group of words associated with the many things they saw and heard during the planetarium show. Students also consult an online reference tool for a short research assignment about space science topics and include the information they gather in pieces of creative writing. Additional writing prompts result in pieces that range from critical reviews and persuasive essays to science fiction stories and tweets from space.

Students given the task of writing creatively—perhaps to explore a literary form or to develop their general interest in writing—are often faced with not having vocabularies extensive enough to convey all their ideas, not having information they need to make the most of their topics, or simply feeling they have nothing to write about.

The lessons described in this part of the *Solar System Odyssey* curriculum guide are designed to overcome these hurdles, while also bolstering students' confident use of scientific language and concepts. The three lessons—which involve students in discussing, researching, and writing—can be used separately or together.

TEACHER'S GUIDE—LESSON 1
Building Vocabulary

Engage students in this exercise soon after they have seen *Solar System Odyssey*. At each step, questions you ask and discussions you spark will guide students toward content you wish to cover.

STEP 1: REMEMBERING

Ask your students to close their eyes for a few minutes and, in silence, remember their planetarium experience. They should think about (but not answer aloud during this step) the questions you ask:

- Do you remember waiting outside? Did you hear anything? Did you say anything?
- What do you remember about going into the planetarium? What did you see around you? Who was sitting on either side of you?
- When the show started, what was it like? Were you expecting it to look like that? Sound like that?
- In the next five seconds, fast-forward through the show in your mind. Start now.

- Can you remember the planets you saw? Can you list them in your mind? Maybe some, but not all? What about the moons?
- Do you remember anything that was dangerous? Beautiful? Really strange?
- Do you remember anything that made you laugh? Worry? Wonder?
- Near the end of the show, what did you think about when you watched the spacecraft getting closer and closer to Earth? How would you feel if you *really* were in that spacecraft?
- Can you remember what you thought when the show ended?
- What did you talk about when you left the planetarium?

STEP 2: DISCUSSING

Ask your students to open their eyes and say out loud some of the things they remember. Give every student the chance to mention at least one thing she or he remembers. You can make a rule that they must mention things that haven't already been mentioned.

STEP 3: RECORDING

Write vocabulary words on the board as they are mentioned so that students can see how they are spelled. (Later, if you assign a writing prompt, students can look at the board and draw from this vocabulary as they respond.)

TEACHER'S GUIDE—LESSON 2
Creative Writing from Research

Before or after they have viewed *Solar System Odyssey*, lead your students through the "Homework Topics" pages on NASA's education site. Geared to grades five through eight, "Homework Topics" contains information about concepts encountered in the planetarium show.

Asking students to write creatively, in a poem or other literary form, encourages them to explore the information from their points of view and make it their own. A worksheet keyed to "Homework Topics" and the planetarium show is included in the *Solar System Odyssey* curriculum guide. A worksheet for an alternative assignment involving more topics and reference tools is also provided.

NASA's "Homework Topics" Website
http://www.nasa.gov/audience/forstudents/5-8/features/homework-topics-index.html

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MATERIALS

- 1 copy of the "Creative Writing about *Solar System Odyssey* Topics" worksheet (or the alternative "Pre-Writing Research on *Solar System Odyssey* Topics" worksheet) for each student.
- Computer access for all students.

STEP 1

Lead a brief discussion about NASA so that students will understand the source of the information they will be gathering. Ask students:

- What does the acronym NASA stand for?
- What does NASA do?
- Who works at NASA?

Write out "NASA—National Aeronautics and Space Administration" on the board and mention NASA's history:

> Since its inception in 1958, NASA has accomplished many great scientific and technological feats in air and space. NASA technology also has been adapted for many non-aerospace uses by the private sector. NASA remains a leading force in scientific research and in stimulating public interest in aerospace exploration, as well as science and technology in general. Perhaps more importantly, our exploration of space has taught us to view Earth, ourselves, and the universe in a new way. While the tremendous technical and scientific accomplishments of NASA

demonstrate vividly that humans can achieve previously inconceivable feats, we also are humbled by the realization that Earth is just a tiny "blue marble" in the cosmos.

STEP 2

Explain that the NASA website is a reliable source of information about space and aeronautics (the science of flight). Write the URL (http://www.nasa.gov) on the board and tell students they will use a part of this site that is dedicated to helping students.

STEP 3

Pass out the worksheets, mentioning that all the topics listed are connected to the *Solar System Odyssey* show. Read the list of topics aloud so that students associate the correct pronunciation with the spelling of each word.

STEP 4

Ask the students to circle a topic on the worksheet about which they would like to learn more. Alternatively, you may prefer to assign topics or put the topics on folded slips of paper and have each student pick one, which will ensure that all the topics are chosen (enabling students to learn more during class sharing).

STEP 5

Once students have chosen topics, direct them toward the computers and explain the structure of the "Homework Topics" website. Ask students to fill in their worksheets as they find and read about their topics. (Alternatively, if all students will have access to computers, this step may be assigned as homework.)

STEP 6

When students have finished reading about their topics and writing their notes, give them time to write a short story, poem, scene from a play, or song lyrics. (Even if they are unable to write melodies for their songs, students choosing this option may find this form of writing most familiar and accessible.) Give students a word- or page-limit that fits into the time you have available for this assignment.

STEP 7

Tell students that an important requirement of this assignment is that they must use accurate scientific information even when they are writing from their imaginations.

STEP 8 (OPTIONAL)

Talk together as a class about the topics the students chose and why they were interested in them. What were the most surprising or interesting things the students discovered as they researched? Involve your students in making a graph on the board showing the most and least popular topics.

TEACHER'S GUIDE—LESSON 3
Writing for Different Purposes

The following writing prompts are provided in the form of scripts that can be adapted to the suit the teacher's style. When giving any of these prompts, assign the length depending upon the time available and your students' level of writing skill. Some of the assignments can be accompanied by artwork you ask the students to create.

PROMPT A: EXPLORE FACT AND FICTION

Solar System Odyssey tells the fictional story of a journey into space (and back again). In this assignment, you will write two versions of an odyssey you have made—one factual, the other fictional.

STEP 1: WHAT IS AN "ODYSSEY"?

What is an "odyssey"? The word "odyssey" is often used to refer to a long, eventful journey. It derives from *The Odyssey*, a literary work said to have been composed by Homer, a blind bard living in Greece thousands of years ago. Homer's epic poem recounts the amazing adventures of a soldier, Odysseus, on his way home from the Trojan Wars. Some other adventures, real and fictional, have adopted this name (e.g., the film *2001: A Space Odyssey* and NASA's 2001 Mars Odyssey, a robotic explorer of the red planet). Can you think of others?

STEP 2: DISCUSS FACT AND FICTION

How closely Homer's work was based on real events, people, and places is a matter of scholarly debate. Fortunately, the division between fact and fiction in *Solar System Odyssey* is far easier for us to discern! After discussing differences between fact and fiction, participate in a class discussion of factual and fictional aspects of *Solar System Odyssey*. With your classmates, make lists of these things on the board under two columns: "FACT" and "FICTION" (e.g., FACT: *Solar System Odyssey* takes place in our own real Solar System and refers to real environmental challenges on planet Earth. FICTION: the show is set in a fictional future where humans are able to travel to very distant planets and spacecraft have artificial gravity).

STEP 3: WRITE A FACTUAL ODYSSEY

Write a factual account of a real odyssey you have taken. (A family vacation to the beach or this morning's journey on the school bus could be just some of the possibilities!)

STEP 4: WRITE A FICTIONAL ODYSSEY

Now write a second, fictionalized account of your odyssey based on your first piece of writing. Introduce the following elements of fiction into your fictional odyssey:

- A new character.
- A new complication or conflict.
- A new point of view.
- A new setting.

To focus the scope of imagined possibilities, your fictional odyssey must have a space theme. You can even use elements from *Solar System Odyssey* if you wish. (Perhaps the family vacation now takes place on Mars rather than at the beach, or the school bus is now being driven by a Robonaut—or even Commander Larson!)

STEP 5: SHARE AND DISCUSS

Share your work with your classmates. Discuss the challenges and opportunities you found in writing your factual odyssey. Then discuss the challenges and opportunities you found in writing your fictional odyssey.

PROMPT B: ADOPT A CRITICAL STANCE

For this assignment, you will review *Solar System Odyssey*. Pretend that you are a writer for a popular entertainment website and that you have been assigned to review this planetarium show. Be sure to include the following elements in your review:

- An opening statement that will grab your readers' attention.
- A factual description of the show. In this part of your review you are not stating your opinion. Instead, you are providing informative details: the show's name, the type of show it is (comedy, drama, documentary, etc.), the show's theme, and other facts that will help potential viewers decide if the show will interest them.
- A plot summary that briefly describes the show's main story (without providing spoilers, of course!), introduces the leading characters, and highlights any unusual, interesting, or otherwise noteworthy features of the show.
- Your opinion of the show. Remember that you are stating your opinion for the benefit of your readers. You are trying to share your experience in order to help them make a decision about seeing the show. Explain your

opinion so that your readers will find what you say to be reasonable and useful— and in a manner that will give them confidence in your viewpoint.

- Because *Solar System Odyssey*'s primary goal is to be educational, you may wish to state the most interesting, important, or surprising thing you learned as a result of seeing the show.

PROMPT C: MAKE A RECOMMENDATION

Pretend that you are one of these characters in *Solar System Odyssey*: Ashley Trout, Jack Larson, or Beemer. Mr. Trout has given you the task of writing a formal report about your mission.

- Give your report a title.
- Describe your investigation of potential sites for space colonization.
- Weigh the advantages and disadvantages of at least four sites you investigated.
- Based on your investigation, recommend one of the sites as most suitable for Trout Enterprises to colonize.
- Be sure to provide your reasoning for your recommendation.

As a pre-writing step, conduct research by looking in your science textbook, reference works in the media center, and reliable online reference tools (e.g., the Earth Science and Space Science sections of NASA's "Homework Topics" site at http://www.nasa.gov/audience/forstudents/5-8/features/homework-topics-index.html). Record basic bibliographic information for each of the sources you use.

PROMPT D: PERSUADE READERS ABOUT UIUMO

The motto of Trout Enterprises—the business for which Commander Larson, Ashley Trout, and Beemer conduct their space exploration in *Solar System Odyssey*—is "Use it up, move on" (or UIUMO for short). Write a persuasive essay in which you either support or oppose the general concept of UIUMO and call upon your readers to agree with you.

- Be sure to explain UIUMO to your readers.
- Use what you learned in *Solar System Odyssey* and any additional research that your teacher assigns to provide examples of UIUMO's good or bad effects on Earth.
- Present specific reasons that your readers should join you in supporting or opposing UIUMO.
- Provide a powerful concluding statement that follows reasonably from the ideas and evidence you have presented.

PROMPT E: WRITE A PREQUEL OR SEQUEL

Write a prequel or sequel to *Solar System Odyssey* (i.e., a narrative that takes place before or after the story we see in the planetarium show). The scene you imagine could take place right before or after the story told in the show, or it could have taken place a long time before or a very long time after! Depending on the time available, your teacher will ask you to write a short story or a vignette.

Here are steps you can take in the pre-writing or planning phase:

STEP 1: DEVELOPING CHARACTERS

Decide which character or characters from *Solar System Odyssey* you will focus on. Also decide if you will introduce one or more new characters who did not appear in *Solar System Odyssey* but will appear in your story.

STEP 2: CONCOCTING A COMPLICATION

Decide what problem or conflict faces your main character or characters. How does this situation connect with what happens in *Solar System Odyssey*? Decide how (or if) this situation will be resolved by the end of your story.

STEP 3: SETTING A TONE

What is the tone of *Solar System Odyssey*? Will your story be similar in tone? Decide if the tone of your writing will be comic or serious and how this will be reflected in your choices as a writer.

STEP 4: CREATING A MOOD

What is the mood of *Solar System Odyssey*? Decide on the mood you wish to set in your own piece of writing. For instance, will your readers feel hopeful (sombre, amused, etc.) as they read? Will the mood vary?

STEP 5: VISUALIZE THE SETTING

Close your eyes and take time to envision the setting where the action of your story will take place. Will the action take place on Earth, on another planet, in a spacecraft, or in some other location? Envision your characters in that setting.

STEP 6: NOW YOU'RE READY TO WRITE!

As you write, describe the setting with details that will let your readers see what you imagined. Include details that involve other senses (like touch and smell), because those will interest and involve your readers. Use dialogue that reflects the personalities and life experiences of your characters. Remember to give your story an interesting title!

PROMPT F: CONDUCT AN INTERVIEW

Pretend that you are a journalist assigned to interview one of these characters in *Solar System Odyssey* show: Ashley Trout, Commander Jack Larson, Mr. Trout, or Beemer.

STEP 1

Decide where you work as a journalist. Is it a magazine, newspaper, website, or television show that currently exists, or is it one that you imagine could exist in the future (the time frame of *Solar System Odyssey*)? Your interview should be aimed for the audience that this media outlet tries to reach.

STEP 2

Prepare a list of ten interesting questions for your chosen character.

STEP 3

Write out answers to the questions from your chosen character's perspective. (Alternatively, pair up with a fellow student, who will role-play your chosen character and answer your questions as you conduct the interview. This can be done as an impromptu skit in front of class or as a team writing assignment.)

PROMPT G: TWEET FROM SPACE!

Compose a series of "tweets" in the voice of one of the *Solar System Odyssey* characters.

STEP 1

Discuss the social media site Twitter, which allows individuals to post messages of no more than 140 characters.

- Though originally intended as a type of personal micro-blogging service where users could report on their daily activities, Twitter has also become a global vehicle for news, marketing, activism, art, and more.
- NASA uses Twitter as one method to connect with all kinds of people who are interested in space, sharing news about its missions and answering the public's questions.
- Twitter has even been used for college scholarship applications (e.g., University of Iowa's MBA program, KFC's $20,000 Colonel's Scholars Twitter scholarship). Reasons for this use of Twitter include the wish to spark applicants' creativity and encourage their conciseness in communication.

STEP 2

As a pre-writing step, check out some tweets from space and space travellers and discuss them in class. The first live tweet from space was sent by Timothy Creamer (http://twitter.com/Astro_TJ) on January 22, 2010. Col. Creamer was working on the International Space Station, which has a network that enabled this direct communication by an astronaut.

- Tweets by NASA astronauts are gathered in this account: http://twitter.com/nasa_astronauts.
- Robonaut 2 Unit B, the first humanoid robot in space, has a Twitter account: http://twitter.com/astrorobonaut. R2-B's tweets, like those of other NASA robots, are actually composed by humans on Earth.
- In 2008 the Mars Phoenix Lander (http://twitter.com/MarsPhoenix) tweeted about the discovery of ice on Mars: "Are you ready to celebrate? Well, get ready: We have ICE!!!!! Yes, ICE, *WATER ICE* on Mars! w00t!!! Best day ever!!"
- Some other NASA robots have Twitter accounts. The Twitter account of Spirit and Opportunity (Oppy, for short)—the robots sent in 2003 and 2004, respectively, to explore the geology of Mars—is http://twitter.com/MarsRovers. The account for Curiosity, the newest Mars Rover, is http://twitter.com/MarsCuriosity.

STEP 3

Choose one of the characters in *Solar System Odyssey* (Ashley Trout, Commander Larson, Mr. Trout, or Beemer) and imagine that this person or robot has a Twitter account.

STEP 4

Select a scene from *Solar System Odyssey.* Here are some examples:

- The scene in which Mr. Trout describes the mission he would like former Space Fleet Commander Jack Larson to undertake for Trout Enterprises.
- The scene immediately after the launch of the spacecraft—when Commander Larson discovers that Mr. Trout's daughter, Ashley, has stowed away.
- The scene in which Ashley Trout argues with her father.
- The scene in which the spacecraft flies too close to Jupiter and its radiation belts.
- The scene in which the spacecraft collides with space junk.
- The scene in which Ashley Trout and Commander Larson see Earth coming closer as they return home.

Alternatively, imagine a new scene in which your chosen character plays a part. This scene could take place in the same time frame as the story told in *Solar System Odyssey* (e.g., revealing Mr. Trout's off-screen actions), or it could take place before or after the story told in the show.

STEP 5

After selecting a scene that you recall from *Solar System Odyssey* or imagining another scene that involves your chosen character, write a description of the scene.

STEP 6

Imagine that your chosen character is tweeting before, during, and/or after the scene. Write 5-10 tweets (up to 140 letters, numbers, and symbols in each) from this character's perspective. As you compose your tweets, you will be doing so from your chosen character's point of view, not your own. You will also be using language that is consistent with this character's background and style, which also may be very different from your own.

Use your imagination to understand what, how, and why this character communicates.

DIFFERENTIATION STRATEGIES

Lesson 1 emphasizes language acquisition through a discussion activity that can be modulated to meet students' needs. If the language level of the online materials will pose a barrier to carrying out Lesson 2, provide students an option to work in groups or to join you in working together as a class to explore one topic of their choice. The prompts in Lesson 3 provide a variety of approaches, several of which can emphasize listening, discussion, and oral assessment. Prompt B can become a class project, with one review being developed as the teacher leads students in a discussion of each bulleted step. Prompt D can spark a class debate. Pairs of students can carry out Prompt F by developing and performing skits.

Teacher's Preparation. If computers are unavailable to students for Lesson 2, print out the relevant "Homework Topics" pages to distribute in the classroom. Ask students to save and return these pages so that future classes may use them.

ADDITIONAL ACTIVITIES

Share the Writing. Ask the class for several volunteers to read their work aloud to everyone. As you respectfully listen to, praise, and thank each volunteer and engage the class in follow-up discussion, you are modeling the behavior you expect from all the students. Now divide the whole class into groups of four or five students. Those who did not read aloud before will now read their work to their fellow group members. This ensures that everyone has the opportunity to be heard and to receive attention and praise for her or his writing.

Find Out Even More. Ask the class if there is anything in the show that they would like to know more about. Involve students in exploring these topics by sharing prior knowledge with their classmates, looking at books and magazines in the media center, or going on webquests. Ask students to take notes about what they learn and share this information with their classmates during a class discussion or in posters or presentations.

SOURCES

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Name: ______________________________

CREATIVE WRITING ABOUT *SOLAR SYSTEM ODYSSEY* TOPICS

All these topics are in NASA's "Homework Topics" (http://www.nasa.gov/audience/forstudents/5-8/features/homework-topics-index.html). Circle one topic to research. You're going to write a short story, scene from a play, poem, or song that includes your chosen topic!

What Is Earth?	**What Is Mars?**	**What Is Orbital Debris?**	**What Is Robotics?**
What is Jupiter?	**What's an Orbit?**	**What Is Pluto?**	**What Is a Rocket?**

As you read about your chosen topic in "Homework Topics," note anything you want to remember when writing your creative piece later. Put quotation marks (" ") around sentences or phrases you copy verbatim (word for word). Use the back of this worksheet to write more notes and make sketches of interesting details you see in the photographs or illustrations that NASA has provided with your topic.

My notes: ______________________________

____

____

____

____

____

____

____

Four words on the topic page that rhyme with each other. At least one word must have two or more syllables:

______________ ______________

______________ ______________

The most interesting fact I learned about this topic: ______________________________

____

An important requirement of this assignment is that you must use accurate scientific information even when you're writing from your imagination. Your teacher will tell you how long your piece of writing should be. Have fun writing!

Name: ____

PRE-WRITING RESEARCH ON *SOLAR SYSTEM ODYSSEY* TOPICS

Circle one topic to write a short story, scene from a play, poem, or song about.

asteroid	energy	meteoroid	solar system	star
atmosphere	gas giant planets	moon	space colony	sun
comet	gravity	oxygen	space junk	telescope
dwarf planets	greenhouse effect	planets	space probe	terrestrial planets

As a pre-writing step, find out about your topic by looking at three different reliable sources. Note things you want to remember when writing your creative piece later. Put quotation marks (" ") around sentences or phrases you copy verbatim (word for word). Sketch interesting details you find in photographs or illustrations related to your topic.

An important requirement of this assignment is that you must use accurate scientific information—even when you're writing from your imagination. Your teacher will tell you how long your piece of writing should be.

MY NOTES:

MY SOURCE (1):

MY NOTES:

MY SOURCE (2):

MY NOTES:

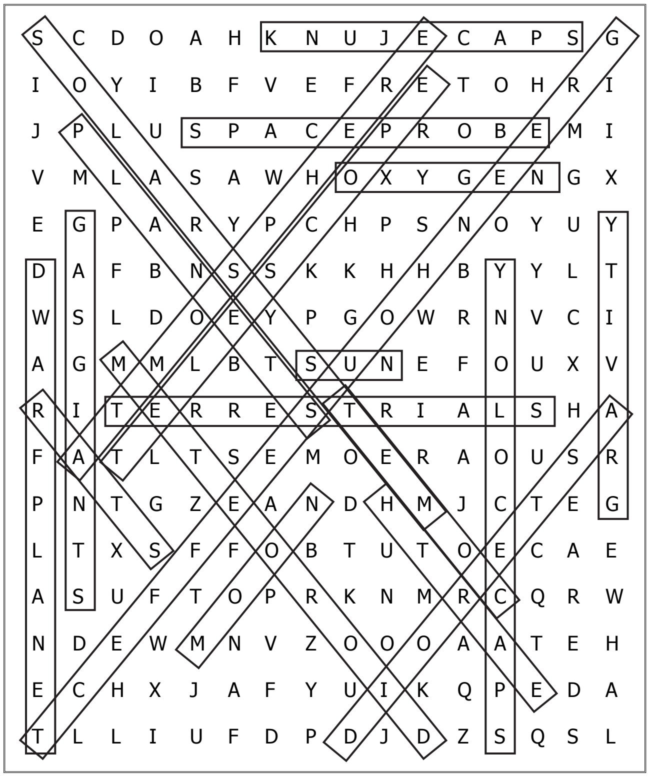
MY SOURCE (3):

Solar System Odyssey Word Search

FIND THESE SPACE SCIENCE TERMS

S	C	D	O	A	H	K	N	U	J	E	C	A	P	S	G
I	O	Y	I	B	F	V	E	F	R	E	T	O	H	R	I
J	P	L	U	S	P	A	C	E	P	R	O	B	E	M	I
V	M	L	A	S	A	W	H	O	X	Y	G	E	N	G	X
E	G	P	A	R	Y	P	C	H	P	S	N	O	Y	U	Y
D	A	F	B	N	S	S	K	K	H	H	B	Y	Y	L	T
W	S	L	D	O	E	Y	P	G	O	W	R	N	V	C	I
A	G	M	M	L	B	T	S	U	N	E	F	O	U	X	V
R	I	T	E	R	R	E	S	T	R	I	A	L	S	H	A
F	A	T	L	T	S	E	M	O	E	R	A	O	U	S	R
P	N	T	G	Z	E	A	N	D	H	M	J	C	T	E	G
L	T	X	S	F	F	O	B	T	U	T	O	E	C	A	E
A	S	U	F	T	O	P	R	K	N	M	R	C	Q	R	W
N	D	E	W	M	N	V	Z	O	O	O	A	A	T	E	H
E	C	H	X	J	A	F	Y	U	I	K	Q	P	E	D	A
T	L	L	I	U	F	D	P	D	J	D	Z	S	Q	S	L

asteroid
atmosphere
comet
dwarf planet
Earth
gas giants
gravity
greenhouse effect
meteroid
moon
oxygen
planets
solar system
space colony
space junk
space probe
star
sun
telescope
terrestrials



Key to the "*Solar System Odyssey* Word Search."

KEY SCIENTIFIC VOCABULARY

This information about key scientific vocabulary is provided as a convenient reference tool for teachers who are preparing lesson plans related to *Solar System Odyssey*.

Students will be exposed to the following words and concepts during the planetarium show, and their knowledge can be reinforced through classroom activities. Lesson 1 in "Part III. Using *Solar System Odyssey* to Integrate Science and Language Arts" is one method for engaging students in discussion while also developing their spoken and written science vocabularies. Other methods include building a word wall, playing a *Jeopardy*-like game to assess students' understanding, and assigning students to define selected terms in their own words and make drawings to illustrate them.

asteroid. A rocky fragment left over from the formation of the Solar System. Most asteroids are found orbiting the Sun in an area between Mars and Jupiter called the Asteroid Belt. The three main groups of asteroids are M-type ("metallic"), S-type ("stony"), and the most common C-type (carbon-rich—probably composed of clay and silicate rocks). Ceres, the largest and first-known asteroid (discovered in 1801), is about 600 miles across. One of the smallest asteroids, 1991 BA (discovered in 1991), is only about 20 feet across. Most asteroids are less than 18 miles across. More than 500,000 asteroids have been discovered so far.

atmosphere. The mixture of gases that surround a planet, moon, or star and are held near it by gravity.

comet. An icy body that releases gas or dust. A comet consists of a solid core surrounded by a cloudy atmosphere (called "the coma") and one or two tails. Most comets are too small or too faint to be seen without a telescope, but some comets become visible to the unaided eye when they pass close to the Sun. We can see comets because the gas and dust in their comas and tails reflect sunlight; and the gases release energy absorbed from the Sun, causing them to glow. Astronomers classify comets according to how long they take to orbit the Sun. Short-period comets need less than 200 years to complete one orbit, while long-period comets need 200 years or more. Astronomers believe that comets are leftover debris from a collection of gas, ice, rocks, and dust that formed the outer planets about 4.6 billion years ago. Some scientists believe that comets originally brought to Earth some of the water and carbon-based molecules that make up living things.

dwarf planets. The IAU divides objects that orbit the Sun into three major classes: planets, dwarf planets, and small Solar System bodies. Like a planet, a dwarf planet orbits the Sun, has enough mass that its own gravitational pull compacts it into a round shape, and may have smaller objects (satellites or moons) orbiting it. However, unlike a planet, a dwarf planet does not have a gravitational pull strong enough to clear the region of its orbit. The Solar System's dwarf planets consist primarily of rock and ice and feature little or no atmosphere. With a diameter of around 1,500 miles, a body designated 2003 UB313 ranks as the largest dwarf planet. Some astronomers have suggested calling the outer dwarf planets "plutonians" in honor of Pluto, the first one discovered. From its discovery in 1930, Pluto was generally considered to be the ninth planet. However, its small size and irregular orbit led many astronomers to question whether Pluto should be grouped with worlds such as Earth and Jupiter. Pluto more closely resembles other icy objects found in a region of the outer Solar System called the Kuiper Belt.

energy. The ability to do work. One way or another, most of the energy on Earth comes from the Sun, traveling here in the Sun's rays. All living things need energy to stay alive. Plants use the Sun's rays to make food. Animals eat plants and other animals and use the energy in this food to move and live. Energy has a potential (stored up) form and a kinetic (moving) form, and it changes from one form to the other. A girl who swings backward on a swing set has stored-up, or potential, energy at the top of her swing. After she swings down, kinetic energy, or the energy of movement, moves her forward.

gas giant planets. The outer planets—Jupiter, Saturn, Uranus, and Neptune. Consisting mainly of hydrogen and helium, all four of these planets have gaseous atmospheres and no solid surfaces. Smaller amounts of other materials also occur, including traces of ammonia and methane in their atmospheres. They range from 3.9 times to 11.2 times Earth's diameter and from 15 times to 318 times Earth's mass. Jupiter, Saturn, and Neptune give off more energy than they receive from the Sun. Most of this extra energy takes the form of infrared radiation, which is felt as heat, instead of visible light. Scientists think the source of some of the energy is probably the slow compression of the planets by their own gravity. (As students learn in *Solar System Odyssey***,** these "soggy giants" are not candidates for colonization because they provide no solid surfaces on which to land or build, their climates are too extreme for human habitation, and the intense pressure deep inside them would, as Ashley Trout says, "squash you like a bug!")

gravity. The attractive force that one body of mass acts upon another. Every object has its own force of gravity. The force of gravity gives things their weight and causes them to fall when they are dropped. Earth's gravity keeps us from floating off our planet. The Sun's gravity keeps the planets in orbit, and Earth's gravity keeps the Moon on its path around Earth. The Moon has its own gravity, but it is not as strong as that of Earth. That is why astronauts on the Moon can carry equipment that would be too heavy to carry on Earth. Gravity depends on the amount of material that makes up an object. The more material an object has, the stronger is its force of gravity. The force of gravity between two objects decreases as the objects get farther apart. Astronauts typically experience certain effects—apparent "weightlessness," for instance—as they move away from the pull of Earth's gravity. (In *Solar System Odyssey*, the space explorers do not need to cope with these effects because their spacecraft is equipped with artificial gravity. While NASA is, in reality, investigating the feasibility of artificial gravity for use in future long-term space flight, the device employed on board Commander Larson's spacecraft is available only in the fictional future imagined by Will Osborne and the Morehead digital production team!)

greenhouse effect. This phenomenon gets its name from glass structures in which people grow plants. Greenhouses let in heat from sunlight and trap it. Earth's atmosphere also traps heat, which warms the land and the air around it. Most astronomers believe that the high surface temperature of Venus, "Earth's twin sister," can be explained by the greenhouse effect. The Sun's radiant energy readily filters into Venus's atmosphere. But the large droplets of sulfuric acid present in Venus's clouds—and the great quantity of carbon dioxide in its atmosphere—seem to trap much of the solar energy at the planet's surface.

IAU. International Astronomical Union, the recognized authority in naming heavenly bodies.

lunar colony. NASA envisions the possibility that scientists could build a colony on the Moon n the future. Such a colony would be self-sufficient and would accommodate human visits that lasted months or even years.

meteoroid. A piece of rock or debris floating in outer space. This type of object can range widely in size; while some are considerable larger, most are about the size of pebbles. If a meteoroid enters Earth's atmosphere, it is called a meteor. As the atmosphere's friction causes it to burn, it makes a flash across the sky that we usually call a shooting star. If the meteor lands on Earth, the piece that remains after entry is called a meteorite.

moon. A rocky body that travels around a planet. A moon is held in place by the gravity of that planet. In our solar system, all the planets except Mercury and Venus have moons. Earth has one moon (typically capitalized, Moon, to indicate its unique relationship to Earth), while Jupiter has more than 60.

oxygen. Nearly all living things need oxygen—a kind of gas found in the air, soil, and water. The atmosphere around Earth contains two forms of oxygen. One kind is ordinary oxygen, which has no color, taste, or smell. Another form is ozone, which is found in small amounts high up in the atmosphere and provides Earth with essential protection from the Sun's dangerous rays.

planets. Large balls of mass that rotate around stars. Planets can be made of gas (like Jupiter and Neptune) or of rock (like Earth and Mercury). They are the largest objects in the Solar System, besides the Sun. The IAU divides objects that orbit the Sun into three major classes: planets, dwarf planets, and small Solar System bodies. A planet orbits the Sun and no other body. It has so much mass that its own gravitational pull compacts it into a round shape. In addition, a planet has a gravitational pull strong enough to sweep the region of its orbit relatively free of other objects.

R2. See **Robonaut**.

Robonaut. A dexterous humanoid robot built and designed at NASA's Johnson Space Center in Houston. R2-B, a Robonaut successfully launched up to the International Space Station on February 24, 2011, is the first humanoid robot in space.

robot. A machine controlled by a computer programmed with all the steps the robot must take to complete a specific task. Robots are particularly useful for tasks that people find too difficult, dangerous, or boring to do themselves. Robots got their name in 1920 from *R.U.R.* (*Rossum's Universal Robots*), a work of science fiction by Czech playwright Karel Čapek.

small Solar System body. The IAU divides objects orbiting the Sun into three major classes: planets, dwarf planets, and small Solar System bodies. The term "small Solar System body" is a recent IAU definition. All objects orbiting the Sun that are not massive enough for their own gravity to pull them into a nearly spherical shape are now classified as small Solar System bodies. This class currently includes most of the Solar System asteroids, near-Earth objects (NEOs), Mars and Jupiter Trojan asteroids, most centaurs, most trans-Neptunian objects (TNOs), and comets.

solar system. A group of objects that travels through space. It is made up of a star and the planets and other objects that orbit, or travel around, that star. Our solar system (often capitalized for specificity) is made up of the

Sun, eight planets (including Earth) and their moons, and many smaller objects that also travel around the Sun.

space colony, space colonization. Human settlement in space. A major environmental concern here on Earth is the increasing consumption of natural resources as more nations become industrialized and the planet's population grows. Space colonies may be one answer to the limitations of using the resources of just one world out of the many that orbit the Sun. Space colonists could potentially mine the Moon and the minor planets and build beamed power satellites that would supplement or even replace power plants on Earth. They could take advantage of the plentiful raw materials, unlimited solar power, vacuum, and microgravity to create products that we cannot while inside the cocoon of Earth's atmosphere and gravity. Since space colonists would inhabit self-supporting environments, they could also refine our knowledge of Earth's ecology.

space junk. Any man-made object in orbit around Earth that no longer serves a useful purpose. Also called "orbital debris," space junk includes such materials as derelict spacecraft and upper stages of launch vehicles, carriers for multiple payloads, debris intentionally released during spacecraft separation from its launch vehicle or during mission operations, debris resulting from satellite explosions or collisions (the main source of large orbital debris), solid rocket motor effluents, and even tiny flecks of paint released by thermal stress or small-particle impacts. Approximately 19,000 objects larger than 10 centimeters are known to exist. The estimated population of particles 1-10 centimeters in diameter is approximately 500,000. The number of particles smaller than 1 centimeter probably exceeds tens of millions.

space probe. A spacecraft controlled by computers and people on Earth. Space probes are one of the most important tools scientists use to study space. Scientists have used probes to take pictures of the Moon, planets, and other objects in space, with some probes even going beyond Pluto.

star. A ball of hot gas that gives off heat and energy. Stars are powered by nuclear fusion in their cores. A star's color depends on the amount of heat it gives off. Blue stars are the hottest. Red stars are the coolest (even though they are still millions of degrees!).

Sun. Our solar system's sun is a yellow dwarf star—and the closest star to Earth. The Sun is large enough to hold a million Earths and generates its tremendous heat through the fusion of hydrogen atoms into helium at its core. Its heat and light are what make day and night, as well as weather, on Earth.

sustainability. The 1970 National Environmental Policy Act established as a national goal the creation and maintenance of conditions under which humans and nature "can exist in productive harmony, and fulfill the social, economic and other requirements of present and future generations of Americans." Over the past 30 years, the concept of sustainability has evolved to reflect perspectives of both the public and private sectors. A public policy perspective would define sustainability as the satisfaction of basic economic, social, and security needs now and in the future without undermining the natural resource base and environmental quality on which life depends. From a business perspective, the goal of sustainability is to increase long-term shareholder and social value, while decreasing industry's use of materials and reducing negative impacts on the environment.

telescope. An instrument that uses glass lenses or mirrors to help us see far things close up. Hans Lippershay invented the telescope in 1608, and Galileo Galilei soon thereafter pioneered its widespread use by astronomers.

terrestrial planets. The four innermost planets in our solar system—Mercury, Venus, Earth, and Mars. These Earth-like planets take their name from the Latin word for Earth, *terra*. Like Earth, they are composed mainly of rock and metal, so they all have solid surfaces where we might build space colonies. Because they're closer to the Sun, the terrestrials have smaller, quicker orbits than do the gas giant planets.

weightlessness. A sensation that astronauts describe when they are orbiting around Earth. Actually, objects in space are not weightless; they are experiencing microgravity. For example, a space shuttle and everything in it are in free fall toward Earth. (Because of Earth's curvature and the shuttle's fast velocity, the objects do not actually fall to Earth.) The effect of the equal "falling" velocity of the shuttle and its contents makes the astronauts and other objects float, thus seeming weightless.

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CONNECTIONS TO STANDARDS

NATIONAL SCIENCE STANDARDS FOR GRADES 5–8

PART I. Using *Solar System Odyssey* to Teach about Technology Design

SCIENCE AS INQUIRY STANDARDS

Abilities necessary to do scientific inquiry
8ASI1.5, 8AI1.7

SCIENCE AND TECHNOLOGY STANDARDS

Abilities of technological design
8EST1.1, 8EST1.2, 8EST1.3, 8EST1.4, 8EST1.5

Understandings about science and technology
8EST2.3, 8EST2.5

SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES STANDARDS

Science and technology in society
8FSPSP5.3

PART II. Using *Solar System Odyssey* to Teach about Environmental Systems

SCIENCE AS INQUIRY STANDARDS

Abilities necessary to do scientific inquiry
8ASI1.5, 8AI1.7

Understandings about scientific inquiry
8ASI2.7

LIFE SCIENCE STANDARDS

Regulation and behavior
8CLS3.1, 8CLS3.4

Populations and ecosystems
8CLS4.1, 8CLS4.3, 8CLS4.4

Diversity and adaptation of organisms
8CLS5.2, 8CLS5.3

EARTH AND SPACE SCIENCES STANDARDS

Earth in the Solar System
8DESS3.1, 8DESS3.2, 8DESS3.3, 8DESS3.4

NATIONAL SCIENCE STANDARDS FOR GRADES 5–8

PART III. Using *Solar System Odyssey* to Integrate Science and Language Arts

SCIENCE AS INQUIRY STANDARDS

Abilities necessary to do scientific inquiry
8ASI1.4 [Lesson 3, Prompt C], 8ASI1.5 [Lesson 3, Prompt C]

EARTH AND SPACE SCIENCES STANDARDS

Earth in the Solar System
8DESS3.1 [Lesson 2; Lesson 3, Prompt C]

SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES STANDARDS

Personal health
8FSPSP1.7 [Lesson 3, Prompts C, D]

Natural hazards
8FSPSP3.2 [Lesson 3, Prompt D]

Risks and benefits
8FSPSP4.1 [Lesson 3, Prompts C, D]

COMMON CORE STATE STANDARDS FOR GRADES 5–8

PART I. Using *Solar System Odyssey* to Teach about Technology Design

WRITING STANDARDS

Text types and purposes
2 [Lesson 2, Lesson 3]

Research to build and present knowledge
7 [Lesson 1]
8 [Lesson 1]

SPEAKING AND LISTENING STANDARDS

Comprehension and collaboration
1 [Lesson 1]

Presentation of knowledge and ideas
5 [Lesson 3]

PART II. Using *Solar System Odyssey* to Teach about Environmental Systems

WRITING STANDARDS

Text types and purposes
1 [Lesson 2, Lesson 3]
2 [Lesson 1, Lesson 2]

Research to build and present knowledge
7 [Lesson 1, Lesson 2]
8 [Lesson 1, Lesson 2]
9 [Lesson 1, Lesson 2]

SPEAKING AND LISTENING STANDARDS

Comprehension and collaboration
1 [Lesson 1]

Presentation of knowledge and ideas
5 [Lesson 1]

COMMON CORE STATE STANDARDS FOR GRADES 5–8

PART III. Using *Solar System Odyssey* to Integrate Science and Language Arts

WRITING STANDARDS

Text types and purposes

1 [Lesson 3, Prompts B, C, D]
2 [Lesson 3, Prompt F]
3 [Lesson 3, Prompts A, E, G]

Research to build and present knowledge

7 [Lesson 2; Lesson 3, Prompts C, D, G]
8 [Lesson 2; Lesson 3, Prompts A, C, D, G *]
9 [Lesson 3, Prompts B, C, D]

** Prompts A, C, D, G address this standard for Grade 5; while prompts C, D address this standard for Grades 6–8.*

SPEAKING AND LISTENING STANDARDS

Comprehension and Collaboration

1 [Lesson 1]

LANGUAGE STANDARDS

Vocabulary acquisition and use

6 [Lesson 1, Lesson 2]

