Teacher Information

Background Information

Most robots used for exploration of comets or other planets, such as Mars, rely on receiving instructions from staff on Earth to accomplish specific tasks. In this activity, our “robot” will only know two things: how to propel itself and how to turn using the degrees of a circle. In this exercise, we will start by talking a “robot” through a task and finish up by writing a set of instructions for the “robot” to follow. Hopefully in the first part, students will realize how much they have to adjust their verbal instructions, which should help ensure that their written instructions are accurate and complete.

Students should be allowed to develop algorithms, or sub-sequences, that their “robots” would follow for tasks that might have to be done several times. For example, they could define a sub-sequence called “right”, which would instruct the “robot” to:

1. Turn to 90 degrees (right)
2. Go forward 10 steps
3. Turn 20 degrees (left)

Then, anytime they need the robot to avoid an obstacle, they can simply give it the instruction “right”. (This assumes that the robot thinks straight ahead is 0 degrees all the time, which simplifies instructions.) This is obviously a simple example. The robot is taking steps, which might be different depending upon the robot. The students should find the need for universal units in the verbal phase of this exercise.

For robots on other planets or asteroids, after controllers send the instructions, there is a time delay. For the planet Mars, depending upon how close it is to Earth, that time delay is about 10 to 20 minutes. This makes maneuvering the rover in real time an impossibility. Therefore, the instructions sent are very important. There is no way to change the course of a robot that far away in time to help it avoid a serious accident, such as driving off of a cliff.

Key Concepts and Student Information

- Program – a set of commands or instructions to accomplish a task

Materials

NASAexplores *Exploration Systems Mission Directorate* (1 copy per student)
NASAexplores article, “Visit to a Tiny Planet” (1 copy per student)
Materials for classroom “obstacle course”
Student Sheets (1 copy per student)

Procedure

1. Before class, set up an “obstacle course” for the robots to navigate through
2. Read the related NASAexplores articles. Discuss the articles and answer any questions the students may have.
3. Discuss what would be needed for an unmanned exploratory mission to Mars, an asteroid, or a comet.
4. Explain that students will work in groups. They will take turns being the robot while the rest of the group gives instructions. The robot only knows two commands: (1) how to propel itself and (2) how to turn using the degrees of a circle (review of this concept might be needed for younger students).
5. The robot will also follow the ultimate command of “not getting hurt”. They will not follow any instructions that might cause them to get hurt. Robots used to explore space have sensors and commands built in to avoid following instructions that might tell them to do something unsafe (like drive off a cliff).
6. Make clear the course that each robot must navigate. Give group(s) time to brainstorm terminology to use in the instructions.
7. Remind students to work together to give instructions to the robot.
8. Allow the students a chance to try and navigate the course. Make sure that the groups rotate the role of being the robot.
9. After each student has had the chance to be the robot, discuss the activity with the group.
10. Tell students that they will now be responsible for writing instructions needed to navigate the course. They must write all instructions that will be needed – no changes will be allowed once the robot has started.
11. After group has turned in written instructions, have robots try to navigate the course using these instructions. Tell robots to follow instructions exactly. Guest robots (principal, other teachers, other students) would be interesting and ensure that the robots are “honest”.

Enrichment Activities

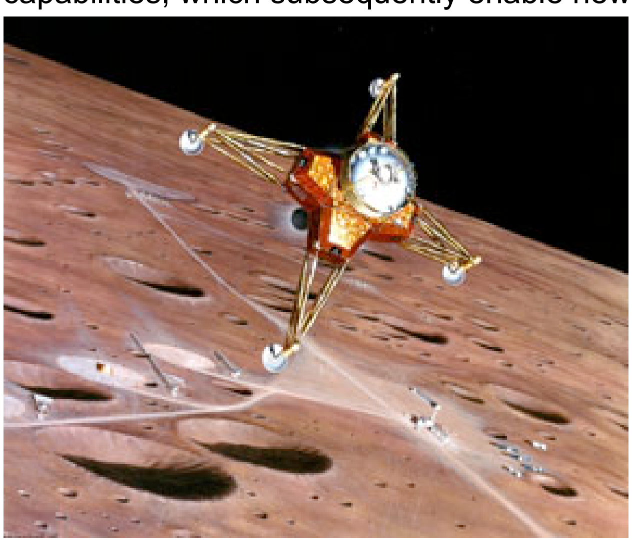
- Have students work with a partner, each taking turns being the robot. Their task would be to get the robot to tie his/her shoe by only giving verbal directions. (The robots can only follow simple commands such as left hand, right hand, pick up, let go, etc.)

NASA Exploration Systems Mission Directorate
NASAexplores article, October 27, 2004
http://www.nasaexplores.com/show2_articlea.php?id=04-213

NASA's newest mission is also one of its oldest.

On January 14, 2004, U.S. President George W. Bush issued a mandate calling for the exploration of space. One of the primary goals of this Vision for Space Exploration is to send human missions to other worlds. While previous exploration initiatives have focused on reaching a particular destination, the Vision is open-ended, with each success serving as a stepping stone for the next. Both human and robotic missions will be used to prepare for further exploration, as well as cutting-edge astronomy.

To accomplish these goals, NASA created a new program, the Exploration Systems Mission Directorate (ESMD). This group will be responsible for working with other NASA teams to prepare for future exploration and to foster the development of new technologies that will enable missions to other worlds. In that respect, this new program hearkens back to the earliest days of NASA, building on the ongoing tradition of finding ways to do things that were previously impossible. ESMD will do this through a spiral approach, using evolving modular components to develop both individual technologies as well as overarching program goals. This will allow new programs and projects to center around mature technologies while also allowing an easier implementation of newer technologies. These new innovations will provide new capabilities, which subsequently enable new missions and the inspiration of further new technologies. While working with NASA's three other mission directorates (Aeronautics Research, Science, and Space Operations) to develop these innovations and to plan missions, ESMD will identify agency programs with the most potential to aid in exploration, and find ways to maximize the exploration promise of others.



While the long-term goals of exploration are open-ended, some immediate steps have been identified.

NASA Exploration Systems Mission Directorate (Continued)

By 2008, NASA will resume robotic exploration of Earth's Moon, gathering data to be used for human missions. The International Space Station will serve as a test-bed for research and development for human exploration techniques and technology, and a new spacecraft will be developed and flown with a crew by 2014. Human missions to the Moon will begin between 2015 and 2020, serving as a preliminary preparation source for further human and robotic exploration. NASA will research ways to "live off the land," making the most of resources found on other worlds. Robotic spacecraft will continue to explore other worlds in our solar system, increasing efforts to find planets like our own in other stellar systems.

As NASA's newest mission directorate, many of the exact tasks the office will undertake have yet to be established. However, some of its duties are already underway. ESMD will be responsible for the Crew Exploration Vehicle (CEV). This vehicle, the next generation of NASA's crewed spacecraft, will be the core of the system that will carry astronauts back to the Moon and later to Mars. The CEV will be a modular system that can adapt to meet the requirements of several missions, from ferrying astronauts back and forth from the Earth's orbit to carrying them out into the solar system. ESMD is currently looking at the future of the Hubble Space Telescope, researching ways to robotically service and repair it in orbit. ESMD is also responsible for the Jupiter Icy Moons Orbiter, a nuclear-powered spacecraft that will explore some of our solar system's most fascinating worlds.

ESMD will also oversee NASA's new Centennial Challenges program, an innovative approach to encouraging the development of new technology. Through Centennial Challenges, NASA will identify important technological goals and offer prizes to those who can accomplish them. The program is designed to maximize the return on investment for both NASA and researchers.

In his speech announcing the Vision, President Bush made a statement that summarizes the Exploration Systems mission: "As our knowledge improves, we'll develop new power generation propulsion, life support, and other systems that can support more distant travels. We do not know where this journey will end, yet we know this: human beings are headed into the cosmos."

Visit to a Tiny Planet
NASAexplores article, February 14, 2001
http://www.nasaexplores.com/show2_articlea.php?id=01-010

If you want an interplanetary rags-to-riches story, look no farther than the asteroids that clutter the solar system.

For most of the 20th century they were ignored. If they had atmospheres, their hills and valleys might echo with the call that "There's gold in them thar hills — and platinum and palladium and rare earth elements."

Don't look for a gold rush any time soon. But when mankind does start expanding across the solar system — these '49ers could be the 2049ers — asteroids could help out with the finances. They might even serve as a training mission before humans make the first big jump to Mars.

Most of NASA's research on asteroids is sponsored by the Science Mission Directorate. No human missions to asteroids are planned, but NASA's Exploration Systems Mission Directorate is studying these along with human missions to Mars.

It's quite a measure of respect and interest for a class of bodies that was largely ignored by scientists for decades.

"As late as 10 years ago we hadn't seen one up close," said Dan Britt in the Department of Geological Sciences at the University of Tennessee in Knoxville. "We still haven't seen many of them."

Britt was a co-investigator on the Imager for Mars Pathfinder spacecraft that landed in 1994. He is also a member of the science team for the Deep Space 1 spacecraft that flew past asteroid 9969 Braille on July 29, 1999 and past comet p/19 Borrelly on Sept. 22, 2001 .

Asteroids belong to a broad group if bodies called planetesimals, objects ranging from the size of baseballs to a third the diameter of our Moon. Because most of the early asteroids were discovered in region between Mars and Jupiter, they were thought to reside in an "asteroid belt." In truth, asteroids are scattered throughout the solar system with a variety of shapes and orbits.

The modern awareness of asteroids is due to Eleanor Helin of the Jet Propulsion Laboratory in Pasadena, Calif. Until the 1970s, most astronomers considered

Visit to a Tiny Planet (Continued)

asteroids to be "vermin of the skies," which cluttered their photographic plates by leaving streaks across star field images as they move rapidly with respect to the star background. The discovery of all asteroids is the result of this movement.

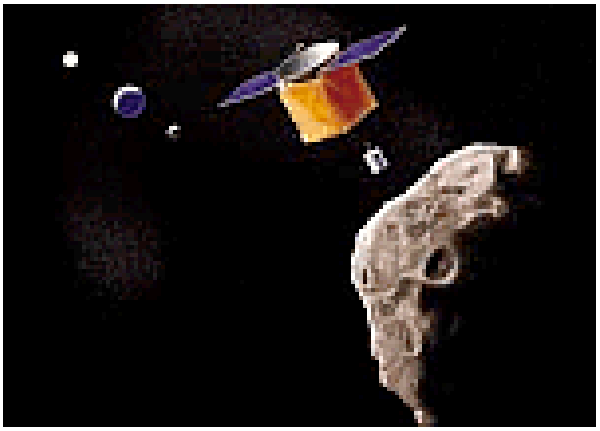
"Gradually I became aware of these intriguing objects and was struck by the lack of any recent work to study or survey them," Helin said. While asteroids had been the rage for a while in the early 1800s, their popularity waned and most were discovered by accident on star fields taken for other purposes. Helin and the late Eugene Shoemaker, one of the fathers of planetary geology, started the Palomar Planet-Crossing Asteroid Search (PCAS) in 1973.

By its conclusion in June 1995, she had cataloged several dozen asteroids (including asteroid Braille); most new, some "recovered" from incomplete observations made decades earlier. Helin's work earned her NASA's Exceptional Service Medal and her own asteroid, 3267 Glo, her nickname.

As principal investigator of the Near-Earth Asteroid Tracking program, she and her colleagues have detected 18,344 asteroids and numerous comets and other small bodies, of which 5,254 were previously unknown, by using a telescope atop Maui's Haleakala volcano. Of these asteroids, 53 have orbits that eventually might target them for Earth; 30 are larger than one kilometer in diameter.

While this makes for good ticket sales at the movie box office, the possibility of an impact remains remote. The real money might be in mining asteroids.

"I've never been convinced that we want to go into space to mine these bodies for materials to be returned to Earth, but rather, to use these resources in space," Helin said. "But we will want to use these raw materials for manufacturing purposes: construction of space colonies in space and use the asteroids and their by-products as stepping stones to venture deeper into the solar system."



What can you get from orbiting rocks?

"Most of the asteroids were composed of pretty much the same stuff," Britt said. Some asteroids, probably through radioactive decay of short-lived elements like aluminum-26, melted and differentiated. Just like the planets, they developed a rocky crust and mantle along with a metallic core. Later collisions have "stripped off" the rocky parts

Visit to a Tiny Planet (Continued)

exposing the most iron cores. These remnant cores are probably the source for many of the iron meteorites that fall to Earth.

"Now an iron meteorite would be considered ore-grade material in almost any gold mine," he continued. In addition to gold, many are rich in platinum, palladium, and "rare Earth elements." All are highly valuable in an advanced industrial economy.

The high cost of space transportation is all that stops this gold rush.

"That's what stops most gold rushes," Britt said. "The cost of getting there and the cost of living there."

But once you are of a mind to move across the solar system, asteroids increase in value for manufacturing spacecraft to help you explore further.

Virtually anything on an asteroid could be used: water ice (if trapped there) could be used for life support or rocket propellant, aluminum and even iron could be made into large structure and silicon into solar cell arrays. Even the soil on the surfaces could be baked down to capture traces of helium-3, a valuable candidate fuel for nuclear fusion, blasted into the regolith by eons of solar wind. (Regolith literally means stone rug or carpet. It's the loose stuff atop the solid core or mantle.)

Shoemaker Near Earth Asteroid Rendezvous (NEAR) observations of 433 Eros and Galileo's observations of Gaspea and Ida have rewritten much of what we though we knew about asteroid. For example, they were once believed to be bare rock. Now they are known to have thick regoliths.

"Mining this stuff is an attractive possibility," Britt continued. Besides being in ore-grade concentrations, "it's not at the bottom of a deep gravity well," so moving it about would be easier than lifting large systems from Earth. In fact, extra caution would have to be taken to ensure that equipment and people were not accidentally boosted away from the asteroid's weak gravity field.

They do have gravity, strong enough to keep the Shoemaker NEAR's spacecraft in orbit around 433 Eros and to make a few boulders roll downhill. (One asteroid even has its own tiny moon).

"A landslide would be more glacial than anything else," Britt suggested. "You'd have plenty of time to get out of the way." Landing a spacecraft would be more like docking with a space station.

Now space planners have started to take seriously proposals made as far back as the 1970s to use asteroids as way stations and resources. One possibility was mentioned at the 36th annual Joint Propulsion Conference held July 2000 in Huntsville, Ala.

Visit to a Tiny Planet (Continued)

Stanley Borowski, a nuclear engineer managing nuclear rocket studies at NASA's Glenn Research Center, said that a future Mars ship could be sent on a one-year asteroid mission to test all the major systems before committing to a Mars mission lasting three years or more. It would be similar to the Apollo 8 mission that circled the Moon in 1968. The asteroid mission could return valuable samples and scientific data.

The most economically feasible mission targets are a number of asteroids that are relatively close to the Earth in energy terms.

"There are accessible targets out there that would serve our needs logistically and economically, and very nicely," Helin agreed. "With about 500 near-Earth asteroids, we have a smorgasbord of possibilities.

Student Sheets

Objective
To develop skills needed to effectively communicate instructions in verbal and written form.

Materials
Robot obstacle course (set up by your teacher)
Commanding a Robot Worksheet

Introduction
Most robots used for exploration of other planets, asteroids, or comets rely on receiving instructions from Earth to accomplish tasks. For these robots, there is a delay between the time that controllers send instructions and the time that the robot receives the instructions. For a robot on Mars, this delay can be as much as 20 minutes. Therefore, it is important that the instructions sent be very well written. In this exercise, you will work in a group with several of your classmates to develop instructions for a robot.

Procedure
1. Read the “Tiny Planet” article and the NASA Exploration Systems Mission Directorate.
2. Select one person to play the part of the robot. Everyone else in the group will play the part of controllers back on Earth. Make sure that you take turns playing the robot, so everyone gets a chance.
3. Your teacher should have set up a course for you to navigate. The controllers will give instructions to the robot for navigating the course.
4. Have each member of your group be the robot and try to navigate through the course using only the instructions given by the other group members.
5. Once all group members have played the part of the robot, find your “Writing a Program” Student Sheet.
6. Write out instructions that would guide a robot successfully through the obstacle course.
7. Have a robot test out your written instructions.

Student Sheets (Continued)

Special Instructions

Robot

As the robot, you only know a few things:

1. You DO know how to move forward in a straight line.
2. You DO know how to stop.
3. You DO know how to turn using the degrees of a circle.
4. You DO know how to keep yourself away from danger.
5. You DO know how to follow commands that have been “programmed” into your memory (see below).
6. You DO NOT know where the end of the course is.
7. You DO NOT know where the correct path is.
8. You DO NOT know how to think for yourself – but only how to follow the directions that are given to you.

Because you do not know where the end of the course is, you must follow the commands of the controllers to get there. They can give you commands such as “move three steps forward,” or “turn 90 degrees to the right.” Or, they can “program” you. As a group, you can decide that, for example, the command “Right” will mean that the robot should turn 90 degrees to the right, take two steps forward, and turn 90 degrees to the left. But, remember, you can only follow commands that the robot knows how to do, and, you must never follow a command that would allow the robot to get hurt.

Controllers

As a controller, you must navigate the robot through the course. Remember that a robot cannot make decisions for itself very well. The robot only knows how to propel itself and how to turn using the degrees of the circle. If you try to give it the command, “Go to the end of the course,” the robot won’t know what to do. You must guide the robot, telling it only to do things that it knows how to do.

Student Sheets (Continued)

Defining Commands
Write down any words that you want to "program" into the robot. This is like a vocabulary list for the robot.

Command	Meaning
TURN RIGHT	Turn 90 degrees to the right
TURN LEFT	Turn 90 degrees to the left
______________	____
______________	____
______________	____
______________	____
______________	____
______________	____

Student Sheets (Continued)

Writing a Program

Using what you have learned from the activity, write out a series of instructions for sending the robot through the course, from beginning to end. Once the instructions have been written, you will send all of the instructions to your robot at once. If the instructions are written well, your robot should be able to find its own way through the course.

REMEMBER: The robot will only follow the instructions written on the paper. Once the robot begins to navigate the course, it cannot stop and no changes can be made to the directions.

Step # Command ______________________________

Step #1 ______________________________

Step #2 ______________________________

Step #3 ______________________________

Step #4 ______________________________

Step #5 ______________________________

Step #6 ______________________________

Step #7 ______________________________

Step #8 ______________________________

Step #9 ______________________________

Step #10 ______________________________

Step #11 ______________________________

Step #12 ______________________________

Step #13 ______________________________

Step #14 ______________________________

Step #15 ______________________________

(*Use the back of this sheet if more steps are needed.)*