Extreme Navigation

EDUCATOR GUIDE

Created for the EPOXI, Deep Impact and Stardust-NExT Missions
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Adapted by Stardust-NExT Education and Public Outreach

Activity Description:

"Extreme Navigation" is designed for students in grades 5-8. In this activity, students take on the roles of a navigation team, spacecraft, comet, Earth, and Sun to simulate how mission planners design a spacecraft/comet rendezvous.

Parallels in Engineering:

Mission designers use sophisticated mathematics and communication to plan and execute how a spacecraft travels along a trajectory in order to meet up with an object in space. Emphasize with your class the importance of math in planning an encounter to a comet and explain the value of doing well in mathematics. All students, particularly those interested in a career in engineering, should learn and experience applied mathematics as frequently as possible throughout their time in school.

National Science Education Standards addressed:

Grades 5-8

Earth and Space Science

- Earth in the Solar System
    - Most objects in the solar system are in regular and predictable motion.

Physical Science

- Motion and Forces
    - The motion of an object can be described by its position, direction of motion, and speed.
    - That motion can be measured and represented on a graph.

Science and Technology

- Abilities of Technological Design
    - Identify appropriate problems for technological design
    - Design a solution or product
    - Implement a proposed design
    - Evaluate completed technological designs products

Objectives:

Students will

- plan a mission to rendezvous with a comet
- simulate the Sun, Earth, spacecraft, and comet

Materials:

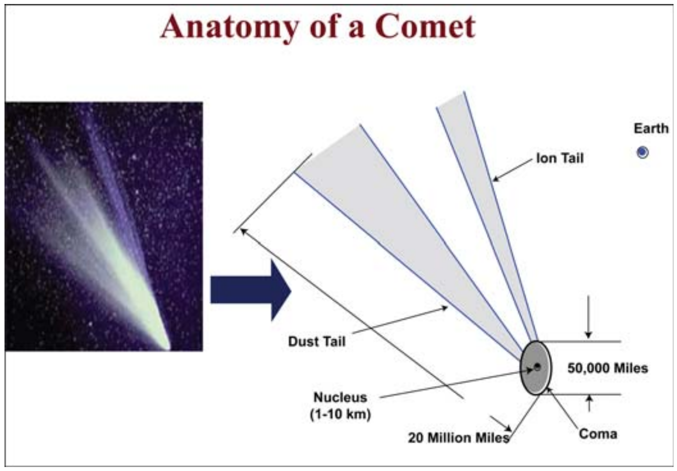
- A minimum of 60 meters of string to make your comet's orbit and spacecraft path.
    - Cut the string in half. Roll each string separately onto an empty paper towel tube so they don't become entangled.
- Two marker pens to mark half meter lengths on both strings.

- Pieces of duct tape, stickers or labels to mark the meeting point on the spacecraft path string with each calculation and to label the launch "trial" number at the Earth end.
- Scissors to cut the string.
- Clipboards and pencils/pens for each student
- Student Role Sheets (one set per group)

Advanced Preparation:

- Place duct tape or other marks at every half meter interval on the string
- Select an open area with ample room for students to move around
- Use the length of string to represent the path your spacecraft will need to take in order to get to the comet, and then cross in front of it. Use another string to represent your comet's orbit path. (The path comets follow as they circle around the Sun). Each will represent the same length of time, from launch to comet encounter.
- This activity requires at least four active participants

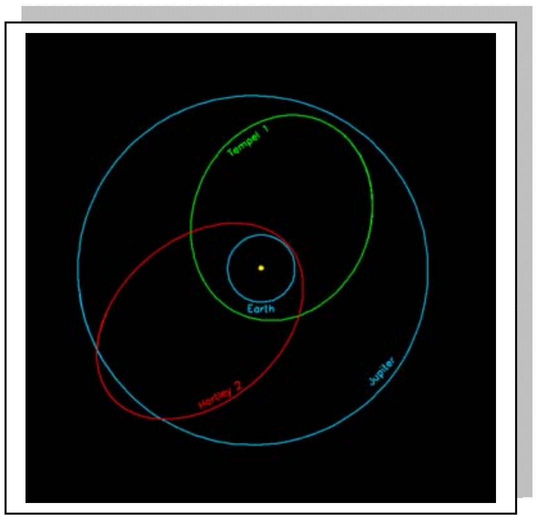
Procedure:



1. As a class, discuss what is they think they might know about comets. Use the diagram at right to explain the basic anatomy of a comet.
2. Use PowerPoint slides to provide some mission context for both the Stardust-NExT and EPOXI missions.
3. Show the slide that depicts the orbits planets and the orbits of Comet Tempel 1 and Hartley 2 (shown at right). Ask students to explain the similarities and differences in these orbits. (Students might indicate that in both cases, the bodies orbit the Sun. Most students will notice that the comets' orbits are more "oval" in shape).
4. Read the following statement to your students. This will serve as their "briefing."

    - *NASA has funded your team to encounter a comet to see what it is made of and how it has changed since last visited. EPOXI will encounter comet Hartley 2 in late 2010 and Stardust-NExT will meet up with Tempel 1 in early 2011. One question you need to ask yourself is "What is the best way to get to the comet?" The mission teams of both the EPOXI and Stardust-NExT spacecrafts have to answer that very question. We will play a game you can try to see how you would get a spacecraft to a comet.*

    The mission engineers have determined that the comet and spacecraft must meet at the end of your comet orbit string in order to achieve closest approach.



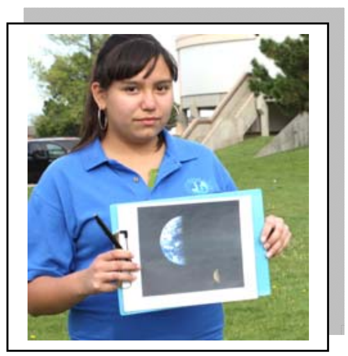
Comet orbits are ellipses (Hartley 2 and Tempel 1). Planet orbits are more circular (Earth and Jupiter).

- *When you launch your spacecraft, you must launch it in a counter clockwise direction (This is the way Earth rotates as seen from the North Pole and we use Earth's rotation to assist spacecraft into orbit.).*

- *We are only using this exercise to bring the comet and a spacecraft together and determine a safe distance while the comet approaches.*

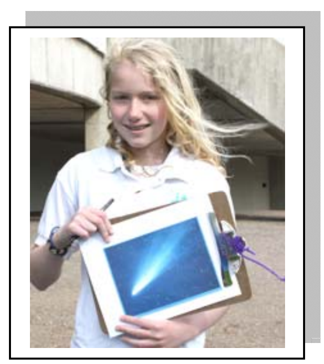
5. Explain to students that they will take on different roles and that each group will be able to complete the simulation at least once. Distribute a different role sheet to each student in the group (if you choose to have groups larger than four students per group, you can have multiple mission planners). Have students read over the directions on the role sheets. While the first group participates in the simulation, other students should watch and learn from what happens in order to make improvements when it is their turn.

6. Set the position of the Sun and Earth in your solar system. Set the position of the comet orbit string on the ground in an arc so that it orbits the Sun. The navigation team should use the second string and plan the trajectory of the spacecraft. The Navigation team should lay out a piece of string to represent the spacecraft path in an arc between Earth and a place they calculate will cross over the comet path so that the comet and spacecraft meet at the same time. Once ready, the spacecraft, mission planners should all be near the Earth ready for "launch."


From left: Sun, Earth, and Navigation Team

Navigation Team members plan the spacecraft's trajectory so that it intersects the orbit of the comet



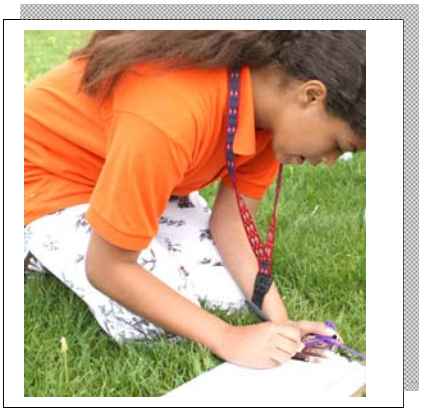
The student representing the comet should start on one end of the orbit and walk counter-clockwise around the Sun

7. Place a student at the furthest end of the comet orbit path to be the traveling comet and place one student next to the Earth who will travel the spacecraft path. Each student will begin from these points and take half meter steps according to the markings on the string with the toe of their shoe hitting the mark.
8. Explain that after the countdown, each second will represent two-weeks of time.

9. Give a 5 second launch countdown to give the comet and spacecraft students their timing. Have a student count in a loud voice. On one, the students representing the Earth, Spacecraft, and Comet should take their first step.
   a. They should be move around the Sun in a counter-clockwise direction.
   b. The comet/student is allowed to take one step for each two seconds.
   c. The spacecraft/student begins at Earth and is allowed to take one step only every other second, which results in moving half as far per beat as the comet which takes a step every two week beat.
10. Both the spacecraft and comet keep moving on the beats until they get to the place where the strings cross (or intersect). Did the spacecraft and comet meet together at the same time? Did the spacecraft get in front of the comet?

Spacecraft encounters a comet!

Spacecraft takes off from Earth



Student responds to questions on role sheet

11. If they did not, have the class decide how to change the time of launch to make up for the difference and try it again. Then try your other two locations for the Earth at launch. Mark each trial with a label at the intersecting point and mark each location for Earth with the corresponding number. Have students answer the questions on their role sheets.
12. Once the first group has completed the simulation, allow the next group to take their turn. Allow all groups a chance to simulate the extreme navigation before engaging the students in debriefing questions that follow.

Debrief Questions:

1. Describe the comet's orbit. (Students should describe it as an ellipse.)
2. What is the trajectory of the spacecraft? (The planned path that the spacecraft travels toward its destination.)
3. What made this simulation challenging? (Many students will state that figuring out where the comet will be when the spacecraft arrives was challenging. Others might say that because the comet and spacecraft were moving at different speeds.)
4. What could have made this simulation more challenging? (Accept student responses. State that a comet speeds up relative to the Sun as it reaches the place in its orbit where it is closest to the sun [perihelion].)
5. How did you make improvements after your first trial?
6. How was math important in planning a trajectory?
7. What did you learn about trying to encounter a comet in space? Why can't you aim for where the object is at the time of launch? (The comet will have moved) Where did you have to aim? (Where the comet will be when the spacecraft arrives.)

8. If you were near the simulated Earth at the beginning of the activity, how did you feel after the spacecraft launched? (Many students on the Navigation Team may have felt out of control. You may also want to state that sometimes the navigation team can vary the approach of the spacecraft by conducting "trajectory correction maneuvers.")
9. What did you notice about the motion of the bodies in the solar system? (Students should state that the bodies all moved all the time. Students should state that the motion was regular and predictable. You may want to point out that the Sun rotates and that the entire system revolves around the center of the Milky Way galaxy. Explain that to simulate this, the entire simulation would have to be conducted while on a large platform that moved around the school which would represent the galaxy.)

Challenge: moving our spacecraft/comet flyby model closer to the real thing

1. Calculate the length of comet string needed to intersect based on the different walking speed of the comet and spacecraft. You will need to measure the length of the comet string and make a mathematical plan to calculate the length of the spacecraft string needed. Since the comet travels twice the speed of the spacecraft in this formula, they will need to calculate not only the length but also the curve to make the encounter. Have the students place a label on their meeting place. In this exercise, label the intersection point before laying it out on the floor.
2. The spacecraft string must arc toward the comet so the spacecraft can intersect with the end of the comet string. Have the students try to make the comet and spacecraft meet with the length they have labeled. Run the exercise with the timer.
3. When the correct length of the spacecraft path has been found and a successful encounter point is established, move the placement of the Earth around the Sun and "launch" the spacecraft again. Use the same timing for the steps. Moving the Earth around the Sun is a good exercise for understanding why there is an ideal time to launch and why other times of the year would not be as efficient. Have students discuss what new issues are raised as they have to re-calculate their trajectory.