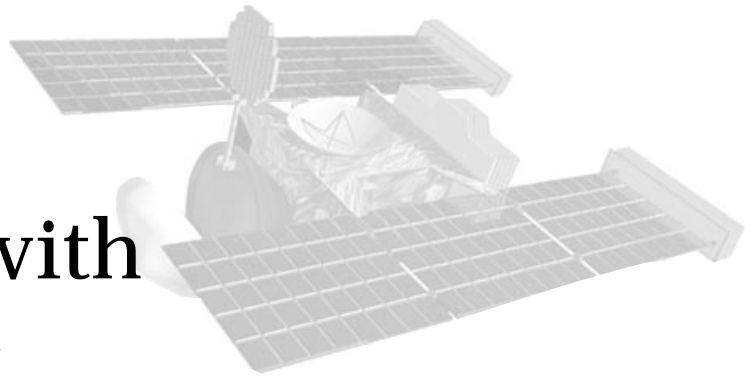# STARDUST's Rendezvous with Comet Wild 2

This section does NOT address orbital mechanics. Sending a spacecraft to encounter a comet, a planet, a moon, or an asteroid is a complicated process. Some targets are bigger than others, and they move at different speeds. In addition, Earth is spinning on its axis and moving along its orbit. The STARDUST spacecraft actually circles Earth twice for a gravity assist, which acts like a slingshot propelling the spacecraft to Comet Wild 2's orbit. That is all the mention orbital mechanics will receive in this activity guide.

As a spacecraft makes its final preparations to reach its destination, navigational communication plays an essential role. In this section, students will fly the STARDUST spacecraft to encounter Comet Wild 2 using simple grids and robotic toy cars. This will help to make the point that remote robotic communication and navigation face similar challenges.

❖ **Feedback Loop** - Challenges students to control a spacecraft (i.e., a robotic car) through remote commands (via walkie talkies) to perform required operations (knock over dominoes) to control the spacecraft.

❖ **Navigation Simulation** - Allows students at command center (the main room) to explore an offsite area (partitioned-off section of the room) using video cameras, walkie talkies, and a grid, and reach a destination (the comet).

Feedback Loops

Overview

Many navigational systems depend upon feedback loops. Controlling a robot requires a two-way flow of information between the robot and the controller. Information going from the robot to the controller is called *feedback*, and the flow of information moving both ways is called a *feedback loop*. STARDUST, a spacecraft that will rendezvous with Comet Wild 2 in 2004 to collect samples from its coma, will use feedback supplied by a camera to help it navigate towards the comet.

Objectives

✦ Remotely operate a vehicle.

✦ Use a feedback loop to modify the vehicle's movements.

Preparation

Well in advance of the activity, assemble enough remote-controlled cars so that each team has one to work with. If necessary, request that students bring personal remote control cars from home.

Management

Remote-controlled cars can be extremely exciting, especially for younger students. It may be wise to allow one recess period for students to play with the cars. This will hopefully serve dual purposes: it gives students unfamiliar with the toys a chance to experiment and discover, and at the same time reduces some of the energy associated with the novelty of the cars.

Materials Needed

For each group of students:

❑ Small, radio-controlled vehicle

❑ Ten dominoes or blocks

❑ Tape

❑ Meter stick

❑ Stopwatch

Procedure

PART 1 INTRODUCTION

1. Explain to students that the spacecraft's maneuverability depends upon feedback, or the transmission of signals between the spacecraft and its mission control. An array of sensors determines the spacecraft's exact location and relays this information to a navigational computer system. The computer processes this data and determines if the spacecraft is on course. Adjustments to the spacecraft's position are made automatically through the transmission of commands to the vehicle's thrusters.

2. Explain that in order to supervise the spacecraft's programmed navigation, the mission control operator closely monitors the information displayed by the spacecraft's sensors. This feedback information supplies the operator with precise details about the position and movement of the spacecraft.

3. The human operator can use a joystick to modify the programmed spacecraft path. But all human input, or supervisory control, must first be processed and integrated by the computer system. If the system "approves" of the course input, the new commands are transmitted to the thrusters.

PART 2 LESSON DEVELOPMENT

1. Assign students to cooperative groups. In each group of four, have Student A use a meter stick and tape to mark off a square area of the floor about 2 meters on each side. Explain that the taped area represents the spacecraft's field, or "envelope of operation."

2. Have Student B place 10 dominoes or blocks in a random pattern within the marked-off square.

3. Tell Student C that his or her role will be to knock over as many dominoes as possible with the radio-controlled vehicle. Give students time to examine the placement of dominoes. Then have Student B place the vehicle anywhere within the square.

4. Have Student C stand about a meter from the square facing away from the dominoes and the car. Students A and B should take positions on opposite sides of the square.

5. Student D will use a watch to keep time. On Student D's signal, Student C will use the controls to drive the car *without* watching its movement. (**NOTE:** If the car travels out of the square, Student A or Student B is to return it to its starting location.)

6. At the end of two minutes, Student D will stop the activity and students will count and record the number of fallen dominoes.

7. Now repeat steps 2 through 6. On this second run, however, permit operators to watch the movements of their radio-controlled vehicles.

8. Exchange roles so that every student gets a chance to control the car with and without a feedback loop mechanism (with and without watching and responding to its movements).

PART 3 CONCLUSION

1. Discuss the difference between the motion of the unwatched car and its purposeful movement when the operator is able to observe its course and make corrections. Explain that the second kind of operation illustrates a feedback loop-the operator provides data to the machine; the machine provides data (or feedback) to the observing operator; and the operator supplies more data (further feedback) in response. Without feedback it would be unlikely for the car to strike all ten dominoes within a short period of time.

Reflection Questions

1. How did watching the car while you controlled it change the outcome of the demonstration?

2. How would this situation change if the remote-controlled car were several million miles away?

3. Why haven't we sent astronauts to study a comet up close?

4. How does this exercise compare to navigating the STARDUST spacecraft to comet Wild 2?

Navigation Simulation

Overview

In the context of small bodies, the navigation camera on board the STARDUST spacecraft will allow scientists and engineers to steer the spacecraft within the coma of Comet Wild 2 in 2004. To adapt this activity to reflect this, have the students navigate a remote-controlled car (the spacecraft) across a grid that represents space and the parts of a comet. Students must seek out the comet, and more specifically its coma. Have them deploy a collection device and capture cometary particles, and later stow these particles within the spacecraft.

Objectives

- ❖ Construct a floor grid for tracking movements and discoveries.
- ❖ Simulate exploring space with the spacecraft, playing the roles of the control crew.
- ❖ Compare telepresence to the interaction of the spacecraft and the operator and to their own downlink site experience.

Preparation

Collect the materials necessary for this lesson well in advance. If walkie-talkies are unavailable at school, ask students to bring some from home.

Management

Be sure to assign the operation of the video camera to someone who is familiar with how they work. Alternatively, allow time before the activity for students to practice using the camera.

Timeline

1 to 2 classes

Key Question

How does telepresence affect a scientific mission?

Materials Needed

- ❑ Movable partition
- ❑ Copies of the Vent Field Grid, redrawn if necessary to fit space available, one for every student or team except the spacecraft operators
- ❑ Masking tape
- ❑ Meter sticks
- ❑ Index cards for floor grid location codes
- ❑ Video camera with display monitor and long connecting cable
- ❑ Walkie-talkie
- ❑ Traffic cones, funnels, or other items to simulate space features
- ❑ Bag to simulate a collection device
- ❑ Remote-controlled car

Procedure

PART 1 ROOM SETUP

Note: Room setup may be done with the assistance of students, or in advance by the teacher to save class time.

1. Partition classroom into two areas. One area will be the exploration area (EA) that the spacecraft explores; the other will be the mission control (MC).

2. Mark the floor of the exploration space with masking tape to form a grid of squares. Squares 0.5 meter x 0.5 meter are ideal. Use a 4-square x 6-square area as in the pattern on the field grid, or redraw the pattern to fit the space available. In either case, be sure the paper grid matches the floor grid. Label columns A, B, C, and D across, and 1, 2, 3, 4, 5, and 6 down. Each grid square now has a location code-A1, A2, and so on. Mark one index card with each location code and place a card in the lower right hand corner of each square so it can be observed by the camera.

3. Prepare the exploration area (EA). Furniture and objects should remain in the room, but rearranging the room so the explorers will encounter new objects or usual objects in unexpected places will heighten suspense and create more focused observation. Place cones or funnels and items representing organisms in one of the grids in such a way that the command center operators and observers will recognize them as a target of the exploration.

4. Set up the monitor on the command center. Be sure that students in this area cannot see into the exploration area. Divide students into teams of seven.

   ❖ **Site Coordinator** (MC): directs the command center

   ❖ **Assistant Site Coordinator** (MC): marks areas on the paper grid as they are explored

   ❖ **Command Operator** (MC): views the display screen and issues directions to the spacecraft over the walkie-talkie

   ❖ **Spacecraft** (EA): is controlled by operators and manipulators:
   Spacecraft's "Ears" Operator (EA): holds the other walkie-talkie so the spacecraft operator can respond to directions
   Spacecraft Manipulator 1 (EA): moves the spacecraft as directed by "Ears"
   Spacecraft Manipulator 2 (EA): walks behind the spacecraft and uses his/her arms and hands as the command center directs (This student should have a bag or box in one hand to store objects collected.)
   Spacecraft Camera Operator (EA): operates the video camera in close-up mode

   ❖ **Command Center Crew** (All remaining students-MC): mark locations of all objects on their vent field grids and trace the spacecraft's movements.

5. As the first team is navigating the course, distribute field grids to the remaining teams. Have each team design a course for one of the other teams to navigate.

PART 2 INTRODUCTION

Ask: How will the spacecraft be controlled? (The spacecraft's operator will direct its movements from the shipboard control panel by maneuvering a joystick for accelerating, tilting, and turning.) What will the operator have the spacecraft do when they find something of interest? What will the other scientists do? If they find something they want to see again, how will they know where to look or know where to tell someone else to look? (Students will learn the answers from this activity.)

PART 3 LESSON DEVELOPMENT

1. Instruct Spacecraft Manipulator 1 to begin anywhere on the vent field grid and turn on the camera. Command center turns on the display. Using the walkie-talkie, the Command Operator directs the spacecraft around the room. The Assistant Site Coordinator traces the spacecraft's movement on the paper grid and the command center team speculates on what they see and decides where the spacecraft should go next.

    If the Command Team members want the spacecraft to pick up something for closer observation or bring it back, they must direct the spacecraft's Ears and he or she must direct the manipulators: move right, move left, move up, close fingers, put in box, and so on. The simulation continues until the vents are found or only 10 minutes remain in the class period.

2. Reinforce the concept of *telepresence.* Observe the command center group and watch for a point at which the students get so involved in the task in the command area that they appear to feel more "present" in the vent field than at the command center. The control (changing the spacecraft's direction) and feedback (watching the picture change as the spacecraft is moved) begin to convey a sense of "being there," as the operator concentrates on taking part in the scene. Stimulate discussion of that sensation. It is what Dr. Ballard, founding chairman of the JASON Foundation for Education, calls *telepresence*, and what he hopes students will experience during their visit to the downlink site (http://www.jasonproject.org).

Reflection Questions

1. Discuss the simulation with the class. Ask: How was it similar to the STARDUST mission? How was it different? What kinds of improvements would have made it easier?

2. Tell students that the grid they used is similar to ones scientists use. What purpose does the grid serve? (Because the command center can view only a small area, it would be difficult to relate to the larger scene without a grid for reference. Imagine doing a 5,000 piece jigsaw puzzle without the picture on the box!)

3. What difficulties are introduced when the spacecraft you are navigating is several million miles away? How does this affect the speed of communication? How do you think that scientists compensate for this?

	A	B	C	D
1	A1	B1	C1	D1
2	A2	B2	C2	D2
3	A3	B3	C3	D3
4	A4	B4	C4	D4
5	A5	B5	C5	D5
6	A6	B6	C6	D6