Crater Capture

EXPLORER GUIDE

Developed for Stardust-NExT mission by Dr. Martin Horejsi

PICTURE THIS.

- A comet racing around the Sun in its elliptical orbit.
- Its first mission complete, a spacecraft stalking the comet with the little fuel it has left.
- The spacecraft's mission? To photograph not only the comet nucleus, but a very special crater on its surface, created by yet another spacecraft.
- The comet nucleus is spinning, and there are only a few seonds to take the pictures!

WHAT DO YOU DO?

BACKGROUND INFORMATION: THE CRATER THAT GOT AWAY!

DEEP IMPACT MISSION: Glimpse into the heart of a comet

Mission art: Deep Impact impactor spacecraft approaching comet Tempel 1. Image courtesy NASA

In 2005 a NASA Discovery mission named *Deep Impact* traveled into the path of comet Tempel 1 with one simple objective: to learn about the internal characteristics of a comet by blowing a crater in the surface.

The Deep Impact spacecraft had two components, one a flyby spacecraft, and the other a 360 kg (820 lbs) impactor. The plan was that the flyby spacecraft would release the impactor into the path of the comet. Sort of like a small boulder falling off an embankment in front of a giant truck zooming along a mountain highway, comet Tempel 1 would slam into the impactor. Speeding along on a divergent frontage road, the flyby spacecraft would snap pictures of the whole thing! The thought was that a crater would form on the comet surface, allowing scientists to peer inside the nucleus—similar to how you can see inside parts of truck after an accident.

The mission was picture perfect, executed exactly as planned…except for one thing. The impact hurled up a great deal of dust and debris, more than expected. So while the images were spectacular, the scientists were unable to see into the crater. Rats!

Comet Tempel 1 after Deep Impact's impact! Image courtesy NASA/JPL

BUT ALONG CAME STARDUST!

NASA calls Stardust-NExT a Discovery "Mission of Opportunity," and is it ever! In another part of the solar system (but not too far away!), yet another comet mission had completed its work. The Stardust spacecraft successfully returned a sample of comet Wild 2's coma dust, dropping a collector capsule gently to scientists waiting catch it in the Utah desert in 2006. Since then, Stardust had been in an orbit around the Sun close to Earth's, just hanging out. Scientists and engineers saw a rare opportunity! In NASA lingo, the Stardust spacecraft was re-commissioned, renamed, and sent on its way in a new trajectory to comet Tempel 1.

WHAT NEXT? Stardust-NExT!

The revisiting of comet Tempel 1 alone is an incredible opportunity. We believe comets change with every passage around the Sun, as you would if made of ice, but never before have we been able to revisit a comet nucleus to see for ourselves. And since the Stardust spacecraft was originally designed to study a comet (though the data focus was different, dust collecting rather than image collecting), the new mission was in great shape to study another. Happily, several of the instruments on Stardust-NExT are the same as were on Deep Impact spacecraft, so powerful comparisons can be made between the before, during and after data from Comet Tempel 1.

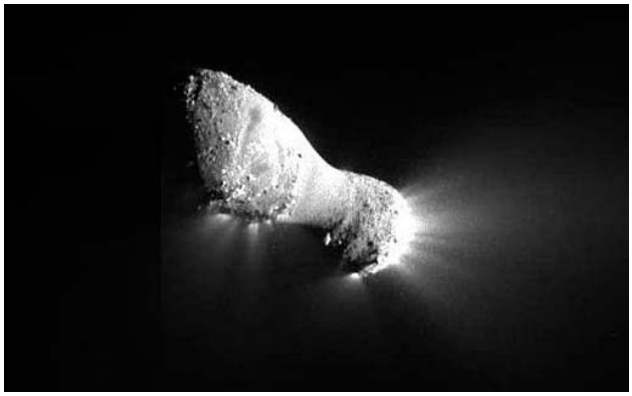
And don't forget that crater! There are many unknowns about the crater's size and position that are challenging to factor in. When a comet nucleus orbits close to the Sun heating up the ices, they sublime creating bursts and fans off the surface. As the gas expands, it pushes on the comet constantly, changing its rotation speed and direction. The Stardust-NExT mission team cannot help but hope to get a picture of the crater created by Deep Impact, but a picture of it will be icing on the Stardust-NExT cake.

Want to see those jets modeled? Go to the comet interactive on this website:
http://stardustnext.jpl.nasa.gov/multimedia/comet_interactive/index.html

Image This!

Stardust-NExT will be zooming at speeds of over 10.9 km/second while Tempel 1 itself is no slouch, careening in its elliptical path around the Sun at 15.6 km/s. To top it off, Tempel 1 is rotating on its axis. But that rotation is inconsistent for several reasons, including the outgassing jets on its surface. Outgassing jets? That's right. Just like little random rocket engines, or teakettle spouts.

Comet Tempel 1 is a conglomeration of ices and dark and rocky organic goo. Kind of like if you scrubbed off a barbeque with soapy water in the middle of winter. Pretty soon you would have frozen mess of sooty black grease and ice. When the comet comes close to the Sun, the icy components of the comet sublime off the surface, turning directly from a solid into a gas and creating those jets.



Comet Hartley 2's outgassing jets.
Courtesy NASA/JPL

MISSION MODELING:

Your mission? Develop a model that simulates a comet rotating along in its elliptical orbit, Stardust-NExT's camera imaging the nucleus as it flies by, and the science and engineering team planning the timing of the event, hoping to capture a picture of a comet's crater.

Activity Objectives:

You will get to

- Model a real engineering problem that applies to current space science by:
  - Make a scale model of a cratered comet
  - Determining the position of the comet and the location of its crater at a given place in the comet's trajectory (orbit around the Sun)
  - Testing the model of encounter with the "spacecraft" camera
  - Evaluating the model in terms of accuracy

Materials (per team):

- Regulation men's basketball
- US quarter coin
- Metric ruler
- Duct tape
- two meter sticks
- chalk or masking tape
- large flat openspace (gymnasium, hallway, playground)
- measuring wheel, tape measure, or bicycle wheel (to use for measuring)
- Digital camera, cell phone, etc.
- Further Data
  - Visit the Stardust-NExT website: http://stardustnext.jpl.nasa.gov/index.html and mission pages: http://stardustnext.jpl.nasa.gov/mission/sci_objectives.html for more information on Stardust-NExT's primary mission objectives.
  - Other resources
    - *Comet Chronicle* (grades 7-12)
    - Comet Fun Facts (grades 6- 8)

Image This!

Stardust-NExT will flyby by comet Tempel 1 in approximately 70 seconds and hopes to take one image per second!

Helpful formulas	
Surface area of a sphere $A = 4\pi r^2 = \pi d^2.$	Length of circumference $c = 2\pi r$ $c = \pi d.$
area of a circle $Area = \pi r^2.$	

Gathering Information:

1.
2. On what date will the Stardust-NExT spacecraft flyby Comet Tempel 1?

3. What are two primary science objectives of the Stardust NExT mission (URL above)?

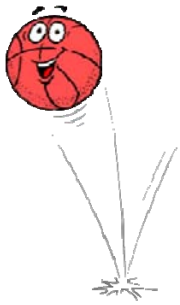
   a.

   b.

4. During encounter, the distance between the spacecraft and the comet nucleus will be about 200km. What city or landmark is about 200km (125 miles) from your school or home?

   - Imagine trying to take a picture of a football field on a moving comet while 200km away from it!

PROCEDURE



Scientists use models to simulate many different situations. Applying mathematics to the modeling is critical whether using a computer model or a physical one. For the modeling in this activity you and your mission team will be use a basketball to model comet Tempel 1's nucleus and a mark on its surface to represent the crater.

Comet Team:

A. Modeling the comet and crater:

Using the Simulated Comet and Crater image (page 8),

1. Measure the diameter of the comet nucleus the nearest millimeter.
2. Measure the predicted diameter of the impact crater to the nearest millimeter.
3. Calculate the proportion of the diameter of the nucleus to the crater by dividing the comet nucleus diameter by the crater diameter.

Image of the Comet and Crater	
Diameter of nucleus in mm:	
Diameter of impact crater in mm:	
Proportion	

Using the basketball and quarter, verify the model

1. Measure the circumference of your basketball.

2. Calculate the diameter of your basketball.
3. Measure the diameter of a quarter.
4. Calculate the proportion of the diameter of the basketball to the quarter by dividing the basketball diameter by the quarter diameter.

Model of the Comet and Crater	
Circumference of the basketball in mm.	
Diameter of the basketball (representing the comet nucleus)	
Diameter of quarter (representing the crater)	
Proportion	

5. How do the proportion's compare? Though an approximation, this is the general proportion we will use to make model crater on the model comet nucleus.
    - There is a chance that the diameter of the Deep Impact crater on comet Tempel 1 could be larger then our model, or 10 or even 100 times smaller.
    - Not unless Stardust-NexT is able to image the crater will we know its size with certainty.

Creating the crater.

1. If you are allowed to draw on the basketball use the coin for scale and draw a circle around it. If not, then place the quarter on the sticky side of a small piece of duct tape.
2. Cut around the quarter and peel tape off
3. Place the tape "crater" on the basketball.
4. The "comet" is now ready to roll.

B. Modeling the comet's motion

Important: In our model, each rotation of the rolling ball will represent one rotation of the comet nucleus. In reality the comet is not rolling along a surface, but rotating in space. The distance our comet travels will be a calculation of the number of rotations, allowing us to predict the best place for the spacecraft to encounter the comet with the crater facing the camera.

1. Since each rotation of the basketball simulates one rotation of the comet nucleus in space, it is important to practice rolling the ball in a straight line between the Launch Line and the Encounter Line.
2. When you model the encounter, the basketball is placed crater face-up on the Launch Line and rolled toward the Encounter Line. A successful image is one where the crater is face-up as the comet crosses the Encounter Line.

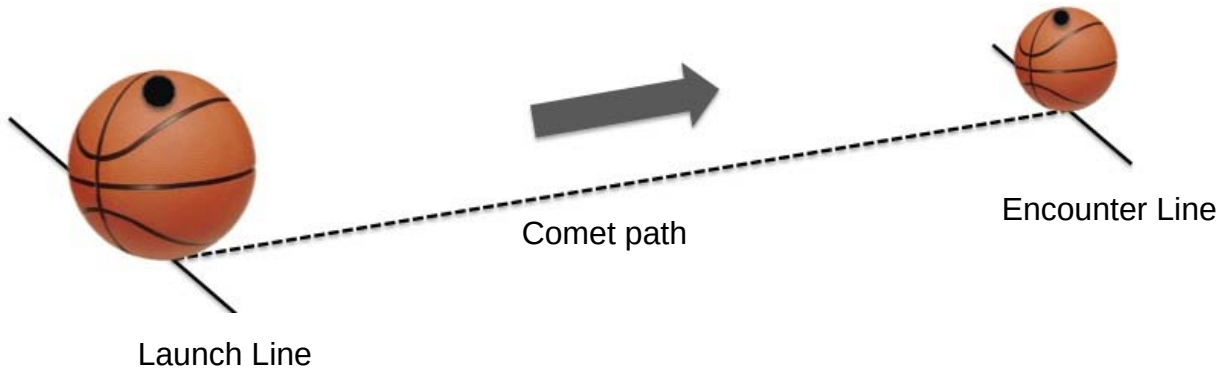
C. Modeling Comet, Crater and Spacecraft Positions:

1. Select a location for your team. Make sure your comet's path will not cross that of another team. You can roll the comet downhill as long as it travels in a straight line.
2. Mark the **launch line** for your team using chalk, tape, or a convenient crack.
3. Identify the number of rotations the basketball must make to simulate the number of rotations the comet Tempel 1 nucleus will make prior to encounter.
    - Use 20 rotations if no other information is available.
4. Multiply the number of rotations by the basketball's circumference.
    - This is the exact distance you need between your launch line and your **encounter line**.
5. Accurately measure and mark the distance your encounter line must be you're your launch line using a meter stick or other tool.
    - Since the distance may be greater than you can easily measure with a meter stick, you may want to measure the curcumference of a bicycle wheel by rolling it along a meter stick or two (see above).
6. Clearly mark encounter lines using either chalk or tape.

Use a wheel!

Since the distance may be greater than you can easily measure with a meter stick or tape measure, you may want to measure the curcumference of a bicycle wheel by rolling it along a tape measure or pair of meter sticks. The bicycle wheel can then be used as a measuring device. The wheel works best when.

1. the same person who rolled it during calibration rolls it during measurement
2. the path the wheel rolls is as straight as possible, and
3. the wheel is only used for complete rotation measurements.



D. Modeling the Encounter Mission

The Stardust-NExT encouter with the comet is of extremely short durtation, as flybys usually are. In our model, depending on the camera, the encounter will last from less than a second to a couple seconds depending on the speed of the ball.

To prepare for the mission: Practice, practice, practice…

- Putting the comet (basketball) into orbit (rolling it on its trajectory to meet up with the spacecraft
  - Rolling the ball straight,
  - At an appropriate speed, and
  - Launching from the correct starting position with the crater up.
- Taking a picture of the basketball-comet as it rolls across the encounter line.
  - Note the delay between when the camera's button is depressed and when the camera actually takes the picture Tip:
    - be ready with the button half way pushed,
    - depress it the rest of the way when you want to take the picture.
  - If video is used, the video can record the entire motion of the comet from start to finish with the target zone line being used to measure success.
    - It helps to make sure you are pointing the camera directly down when the basketball crosses the encounter line.

In all, about 70 images will be taken by the real Stardust-NExT spacecraft, improving the odds of a usable image. Half the pictures will be taken as the optimum position approaches, and the other half will be taken as the comet moves away from optimum position.

E. Launch!

When you are ready, announce to the other groups to watch your main encounter.

- Make one final roll of the model and see if you can *Capture the Crater*.

F. Mission Results

Evaluate your model, first as a team, and then in your science notebook or log.

1. What about your model was an accurate representation of the Stardust-NExT mission?

2. What about your model was an inaccurate representation of the Stardust-NExT mission?

3. Now that you've tried this model, how would you revise it? What new characteristics would you wish to model?

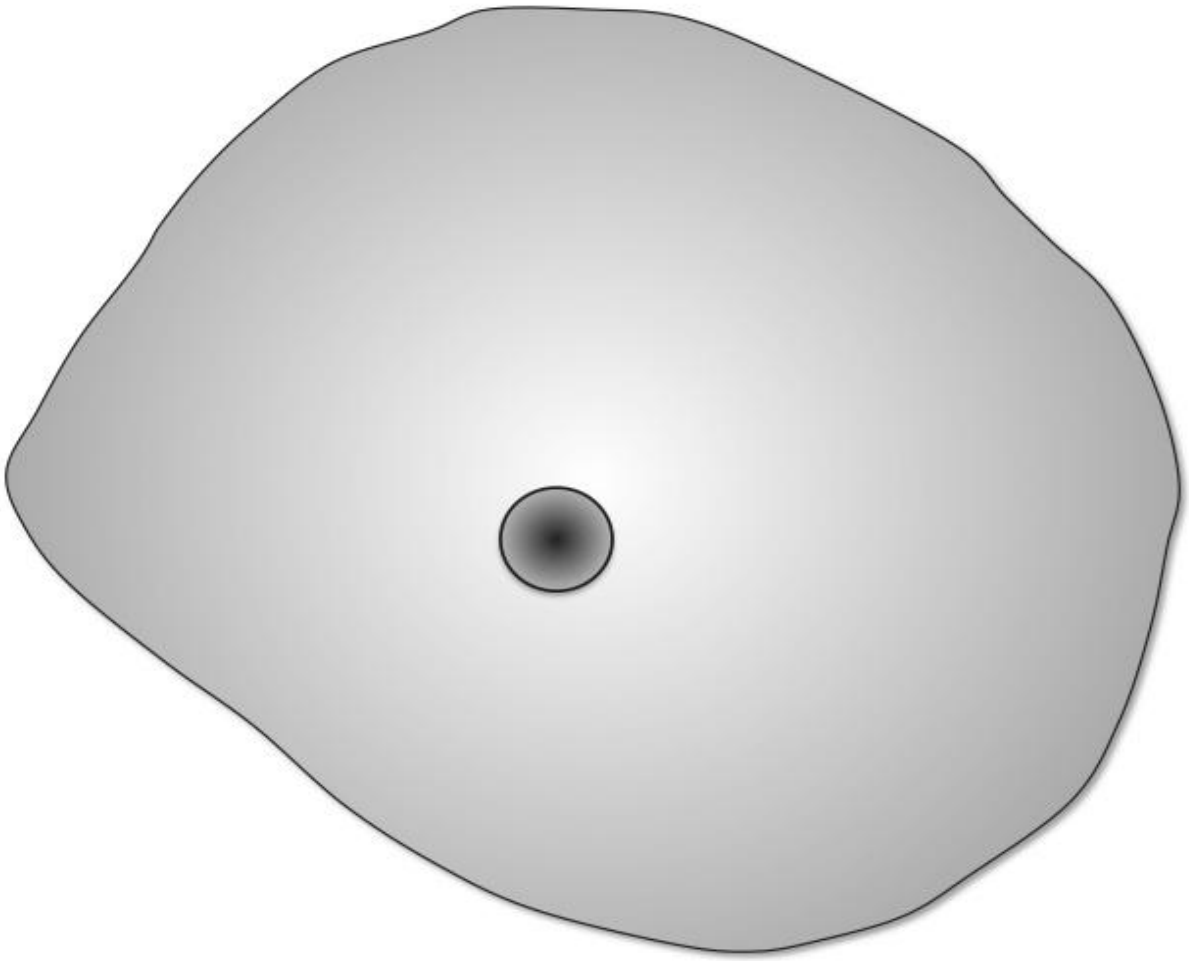
Telling Shadows?

Stardust-NExT spacecraft will attempt to image the crater at an angle of 20 degrees off-center. This is because the position of the Sun and the depth of the crater are also factored into the position of the camera to enhance the information gleaned from the imaging.

Extensions:
By changing some one or more parameters of the Stardust-NExT's mission to comet Tempel 1 you can increase the challenge of Capturing the Crater. For example, you could:

- Model a much smaller crater.
- Make comet nucleus a shape not a sphere – use a football or other non-spherical objects to see how observations might change (the different shapes might surprise you!).
- The basketball could roll or bounce over some small objects altering its rotation. This challenge will introduce errors into the calculations that could be compensated for with further measurements.
- Try using the camera's flash.
- See how far away you can place the encounter line and still have a useful image.
- Consider the lighting angle the actual mission will be using – how might you model that?

Design your next Mission investigation!



Simulated Image of comet Tempel 1 and its crater