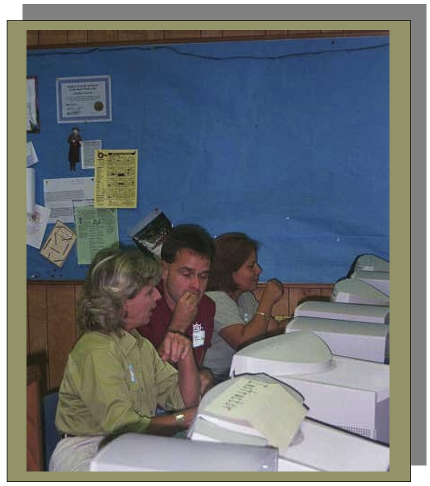
NASA's Deep Impact Mission: Decision Making

Timing is Everything

TEACHER GUIDE

BACKGROUND INFORMATION



Working individually, students will gather information on each of the science data collection options (using the Deep Space Network, Earth-based observatories and the Hubble Space Telescope). Once students find out about each one, they then work together in expert groups and compare the types of information they found. They will synthesize this information in order to make a recommendation to their home group, made up of individuals who worked in different areas. Students will work in their home groups to collect additional information around aspects of the observation strategy that they would like to emphasize and aspects they would like to lessen. They will also gather information regarding constraint aspects of other methods they would like to build into their scenario. Students will need to defend their scenario based on cost, risk and benefits, and quality (meeting science objectives.)

There are a number of resources listed at the end of this teacher guide. One resource that might be useful for the entire class is the online *Basics of Space Flight Training Module*. You should refer students to this tutorial as they start asking questions about telemetry or the Deep Space Network.

The National Science Education Standards call for teachers to design and manage learning environments that provide students with the time, space, and resources needed for learning science. During the research phase of this module, teachers should be careful not to rush this process. Research often takes a good amount of time, and is not finished at the end of the day. To that end, teachers should encourage students to continually refine their findings throughout the activities that follow this research phase. The standards go on to state that teachers should make time for students to work in varied groupings—alone, in pairs, in small groups, as a whole class—on varied tasks, such as reading, conducting experiments, reflecting, writing, and discussing. For this research component to be successful, teachers should also make materials, technology, and media available to students. Students should learn how to access information from books, periodicals, videos, databases, and the Internet. Students should also learn to evaluate and interpret the information that is acquired through these resources and to apply critical pieces to new situations.

NATIONAL SCIENCE STANDARDS ADDRESSED

Grades 5-8

Science As Inquiry

Abilities to do scientific inquiry.

Use appropriate tools and techniques to gather, analyze and interpret data.

Understandings about scientific inquiry.

Earth and Space Science

Earth in the solar system.

(View a full text of the National Science Education Standards.)

Grades 9-12

Science As Inquiry

Abilities to do scientific inquiry.

Use technology and mathematics to improve investigations and communications.

PRINCIPLES AND STANDARDS FOR SCHOOL MATHEMATICS GRADES 6-8, 9-12

Problem Solving

Solve problems that arise in mathematics and in other contexts.

Apply and adapt a variety of appropriate strategies to solve problems.

Data Analysis and Probability

Formulate questions that can be addressed with data and collect, organize and display relevant data to answer them.

Develop and evaluate inferences and predictions that are based on data.

(View a full text of the Principles and Standards for School Mathematics

NATIONAL EDUCATIONAL TECHNOLOGY STANDARDS GRADES K-12

Standard 5: Technology Research Tools

Students use technology to locate, evaluate, and collect information from a variety of sources.

Standard 6: Technology problem-solving and decision-making tools

Students use technology resources for solving problems and making informed decisions.

Students employ technology in the development of strategies for solving problems in the real world.

Grades 6-8

Standard 7

Collaborate with peers, experts, and others using telecommunications, and collaborative tools to investigate curriculum-related problems, issues, and information, and to develop solutions or products for audiences inside and outside the classroom.

Standard 10

Research and evaluate the accuracy, relevance, appropriateness, comprehensiveness, and bias of electronic information sources concerning real-world problems.

(View a full text of the National Education Technology Standards.)

LANGUAGE ARTS STANDARDS

Writing

Gathers and uses information for research purposes

Uses card catalogs and computer databases to locate sources for research topics.

Uses a variety of resource materials to gather information for research topics.

Determines the appropriateness of an information source for a research topic.

LIFE SKILLS STANDARDS

Thinking and reasoning

Applies decision-making techniques

Secures factual information needed to evaluate alternatives.

(View a full text of the McREL Compendium of Standards and Benchmarks for K-12 Education.)

MATERIALS

For each student:

- Student planning sheets
- Scenario construction guide
- One collection method information sheet
    - - Deep Impact Spacecraft
    - - Earth-based Observatories
    - - Earth Orbital Facilities
- Deep Impact Ephemeris Data student spreadsheet
- Computer with Internet connection
- Library
- Impact Time Graphs
- Appendix F: Decision-making Process (optional)

Teacher Tip
This activity uses the cooperative learning technique called "jigsawing". In this method, students begin in groups of three (the home group). They do their information gathering individually and then compare information with students that searched for similar information (expert groups). Finally, they share back in their home groups.

PROCEDURE

1. Begin with students in small groups of three students per group. Explain to the groups that each member of the group is to be responsible for gathering information on the various observation strategies that are available to the Deep Impact science team. Describe the different observation strategies and make sure students have a general understanding of each of these as each person decides which method they would like to research.
    - **Deep Impact spacecraft and timing** of the impact so that the most information is sent back and received by the Deep Space Network. This is the primary source of data.
    - **Earth-based observatories** for optical observations and timing such that the impact will take place when the comet is visible, after sunset, through the telescope of more than one major observatory. This is a potential secondary source of data.
    - **Earth orbital facilities** uses the Hubble Space Telescope as a secondary source of data that is not dependent on optimum weather and provides high resolution images not degraded by Earth's atmosphere.

2. Explain to students that each person in their group will research one of the above observation strategies.

3. Distribute one of each of the observation strategy information sheets to the student groups. Within each group, students should decide which of the strategies they are going to research. Ask students to read over the information on their sheets and ask questions before proceeding to the library and/or the Internet for research. Instruct students to write out the questions that they are going to research. Suggest that they write one question on each sheet.

4. Allow students time to complete the observation strategy information sheet individually. Circulate around to each person and offer assistance as required. Explain to students that they will first work on this individually and then with people who are working on the same problems before reporting back to their base group. Inform the students as they work together to write their recommendations clearly and in a way that can be easily communicated to people who have done similar research and to the people in their home group.

Alternate Strategy Tip
Special need students and second language learners may prefer to be paired with another student during the completion of the collection method information sheet.

5. Encourage the Earth-based observation group to fill in the tables as completely as possible. For the second question dealing with research proposal requirements, look for responses similar to the requirements from Mauna Kea. (Information about the principal investigator, program titles and

abstracts, telescope time requested including instruments, nights, lunar phase, optimum, acceptable and unacceptable dates, collaborators, prior telescope time awarded to the principal investigator, a list of publications by the principal investigator, scientific and technical justifications, and the object to be studied along with right ascension, declination, and magnitude of the object) For the second table in the ground-based observation group, explain that converting from local time to universal time can be calculated by using the information at http://tycho.usno.navy.mil/cgi-bin/timer.pl on the US. Naval Observatory Master Clock.

6. Instruct the Deep Impact spacecraft timing group to read the background information carefully. In the fourth paragraph there are some problems that the students should solve. Provide help as needed for the students to answer these. For students who may need help on these, explain the first one and ask them to try the second one on their own. This is a good application of unit analysis. For the first problem, "How long would it take to download one full frame picture using the 70 meter antenna?" tell students that one way to start would be to determine how many bits in a megabyte (8 million bits equals one megabyte).

   - If the 70 meter antenna has a downlink rate of 175,000 bits per second and we want to find out how many seconds 8 million bits will take to download, we simply divide 8 million bits by the rate. (8 million bits / 175,000 bits per second = about 46 seconds)

   - If the 34 meter antenna has a downlink rate of 25,000 bits per second, and we want to find out how long would it take to downlink one full frame picture with the 34-meter antenna, we simply divide 8 million bits by the rate.
     (8 million bits / 25,000 bits per second = 320 seconds or just over 5 minutes)

   - How many full frame images can be stored on the spacecraft?
     (300 images)

   - How does knowing this affect mission planning?
     (Answers will vary, but should include the fact that the most important images should be stored as back up and also sent to Earth via the Deep Space Network later.)

7. The students in the Earth orbital facilities group start by reading and summarizing the proposal process for acquiring time to use the Hubble Space Telescope. This exercise makes students aware of the competitive nature and forethought that is needed for acquiring precious time using Hubble. Next, this group uses an online Ephemeris generator for finding out the position and condition of 9P/Tempel 1 from the Hubble Space Telescope at the time of impact. The student activity sheet provides step-by-step instructions for inputting information into the generator. Encourage interested students to conduct similar research on the SIRTF and Chandra X-ray observatories mentioned on the interview sheets.

> **Teaching Tip**
> Teacher Tip: You may want to practice using this table yourself prior to the class so that you are able to anticipate questions that the students may have. Alternately, for students who may have difficulty inputting the information as instructed, you may print out the resulting information from the generator and provide this to the students.

8. Answers to the questions for student procedure 4 are in parenthesis for Comet 9P/Tempel 1 from the Hubble Space Telescope at the time of impact:
   a. What is the right ascension of the target? (13 hours, 37 minutes, 24 seconds)
   b. Describe what right ascension measures. (The distance on the celestial sphere measured eastward along the celestial equator.)
   c. What is the declination of the target? (-9.46604 degrees)
   d. Describe what declination measures. (The distance on the

> **Teaching Tip**
> As students start asking questions about vocabulary terms such as "right ascension" and "declination," refer them to the URL dealing with the Astronomical Coordinate System. From here, students can begin to construct meaning to these terms.

celestial sphere north or south of the celestial equator.)

e. What is the total magnitude of the target? (9.92)
f. Describe how the magnitude of celestial objects is measured? (The higher the number the lower the magnitude.)
g. What is the nuclear magnitude of the target? (15.03)
h. Based on your answer for “f”, is the nuclear or total magnitude brighter? (Total magnitude, the nuclear magnitude is included in the total magnitude.)
i. What is the fraction of the target’s circular disk illuminated by the Sun? (87.8%)
j. What is the apparent range of the target from the observer? How does this compare to the average distance of the Earth to the Sun? (0.8927908869 AU, the target is closer to Earth than the Sun.)
k. What is the definition of an astronomical unit (AU)? (The average distance between the Earth and the Sun.)
l. How long does it take for light reflected from the target to reach the observer? (7.425115 minutes)
m. What is the apparent lunar elongation angle between the target body center and the center of the moon? Will the target center be behind the moon on this date and from this location? (131.7 degrees; no it will not.)
n. What fraction of the lunar disk will be illuminated by the Sun? Why is it better to be a smaller percent rather than a large percent? (6.0 %, the more the moon is illuminated, the more scattered light exists and the more difficult it will be to “see” the target.)
o. Which constellation would one look at to find the target? (Virgo)

> **Teaching Tip**
> Discuss the importance of significant digits with students. Explain that they may round answers to the nearest hundredth.

9. Ask the students to meet in expert groups (groups that have researched the same method) to compare the information they found on their collection method information sheets. Since there are only three groups meeting during this time, the groups will be quite large. You may want to have the students meet in pairs to compare notes. Have them rotate several times within these expert groups before moving onto the next procedure. This is a time for students to talk with others who researched the same method. They should examine the strengths and weaknesses of their method. They should decide the best way to present the information back to their home groups.

10. Students should report back to their home groups. Allow time for them to familiarize each other with the observation strategy that each member of the group researched. Students should take notes on the findings of the other people in their group. This will allow them to complete the student planning sheet as homework.

11. Distribute the student planning sheets for each person in the class. Explain that this sheet should be completed individually and will be used for the groups to build their scenario. This sheet could be done as a homework assignment, but must be done prior to the next session.

12. Once everyone in the home group has completed their student planning sheet, distribute one scenario construction guide per group. As a technology application, an Excel spreadsheet is available for students to use with Ephemeris data for comet 9P/Tempel 1 from July 3-5, 2005 from various DSN and potential observatory sites. Students can use this spreadsheet to make a line graph with time for the x-axis and elevation in the y-axis. The resulting graph is essential for a tool to determine the best time of impact utilizing various sites. Everyone in the group should use their student planning sheets to inform the group as they build the scenario. Each home group should prepare a visual presentation representing their scenario using PowerPoint or another type of presentation software. Each home group should come to consensus about how the scenario is defined. The basic outcome of the scenario will be the extent to which the various observation strategies are used. The core of the scenario is for students to choose a time for impact such that the Deep Space Network and other observation strategies cover the event as completely as possible.

> **Teaching Tip**
> Students may select Chart 1 at the bottom of the spreadsheet to view the data in a graph format.

13. Once the group scenario has been constructed, use the “Decision-Making” process in Appendix F as a potential technique for students to use in making this decision. Collect the scenarios from each group. Look the scenarios over and provide feedback as appropriate. This scenario will then be used in the next activity building and presenting the case.

TEACHER RESOURCES

Web sites

http://deepimpact.jpl.nasa.gov/mission/quickfacts.html
Names of constellations and abbreviations

http://deepspace.jpl.nasa.gov/dsn/
The Deep Space Network

http://hubble.stsci.edu/
Space Telescope Science Institute (Hubble Space Telescope)

http://ssd.jpl.nasa.gov/cgi-bin/eph
Jet Propulsion Laboratory on-line Solar System Data and Ephemeris Computation Service

http://www.astro.caltech.edu/palomarpublic/
Palomar Observatory, California

http://www.astro.uiuc.edu/~kaler/sow/const.html
Names of constellations and abbreviations

http://www.ctio.noao.edu/
Cerro Tololo, Chile

http://www.deepimpact.jpl.nasa.gov/
Deep Impact Home Page

http://www.eso.org/observing/skycalc.html
European Southern Observatory Sky Calendar Tool

http://www.eso.org/paranal/
Las Capanas Observatory, Chile

http://www.iac.es/ot/
Observatory, in Izaña (Tenerife)(Canaries)

http://www.ifa.hawaii.edu/88inch/
Mauna Kea Observatory, Hawaii

http://www.ifa.hawaii.edu/haleakala/
Haleakala Observatory, Hawaii

http://www.ii.metu.edu.tr/emkodtu/met204/lectures/section4/
Astronomical Coordinate System

http://www.jpl.nasa.gov/basics/
Basics of Space Flight Training Module

http://www.skypub.com/tips/basics/coordinates.html
Information about coordinates

http://www.stsci.edu/observing/proposal_process.html
Hubble Space Telescope proposal process