COLLABORATIVE DECISION MAKING

NASA'S DEEP IMPACT MISSION

An Education Module
Grades 7-12

Featuring:

- ✯ Capture the Issue
- ✯ Timing is Everything
- ✯ Clarifying the Issues
- ✯ Refining the Issues
- ✯ The Decision

http://deepimpact.jpl.nasa.gov

Developed by: McREL Mid-continent Research for Education and Learning

Collaborative Decision Making: NASA's Deep Impact Mission

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Collaborative Decision Making is designed to engage students in grades 7–12 in activities that focus on collaboration and communication strategies. These activities will strengthen student understanding of and ability to use collaborative processes and communication practices to clarify, conceptualize, and make decisions. Students will compare the risks of varying courses of action that confront scientists and engineers. After the risks are identified, they will gather and convey evidence supporting and refuting the viability of these actions, and reach consensus. The module strategies rely primarily on student investigation into the background information that is necessary to support arguments; make quantitative risk analyses; engage in debate, role-playing, and persuasive writing/communication processes; and practice group decision-making procedures.

Once NASA funds a mission, there are still many challenges to solve. Check out this new module from McREL that covers the challenges of the A/B Phase (beginning phase) of the Deep Impact mission.

The following classroom materials are available in Portable Document Format (PDF) for your browsing and printing convenience. The files are print-optimized, and should be printed to achieve maximum resolution. Adobe's new Acrobat Reader 4.0 is required to view and/or print. To install the FREE reader, visit the Adobe Web site.

Module Planning Guide

Capture the Issue
- Teacher Guide
- Listening Notes Sheet
- Listening Notes Sheet Example

Interview Summary Sheet
- Michael A'Hearn

Captivate

In "Capture the Issue," students are introduced to a problem that mission planners dealt with during the planning phase of the mission. Students read about the problem, "How do we optimize our data collection?" from the perspective of the principal investigator. This introduction not only provides the "hook" for student interest, but will serve as a focus for the entire module. Students read a position statement from the Principal Investigator Dr. Michael F. A'Hearn, Department of Astronomy at the University of Maryland.

Timing is Everything
- Teacher Guide
- Student Planning Guide
- Building a Scenario

Earth-based Observatories
- Strategy Information Sheet

Earth Orbital Facilities
- Strategy Information Sheet

Deep Impact Spacecraft
- Strategy Information Sheet

Deep Impact Ephemeris Data
- Student Spreadsheet

Research

In the activities of this module, the teacher's primary role is Socratic. Through effective questioning, students should become aware of the different data collection methods for the Deep Impact mission.

Working individually, students will gather information on observing options (collecting data from spacecraft using the Deep Impact Spacecraft, Earth-based observatories, and the Hubble Space Telescope). Once students find out about each one, they then work in expert groups to compare the types of information they found. They will synthesize this information in order to make a recommendation to their home group. Students will work in their home groups to collect additional information about aspects of the collection mode they would like to emphasize. They will also identify lesser aspects and note which aspects of other strategies (given constraints) they would like to build into their response scenario. Students will need to defend their scenario based on cost, risk, scientific benefits, and data quality (meeting science objectives).

Student Mission

Student groups will use the information gathered from their research (collected in the second activity on their chosen strategy method) to prepare a presentation and defense that takes into account the risk, benefits, and quality of data (meeting science objectives). The case to be built by each group will include a specific plan with the following three components: 1) observing strategy, 2) specific details for implementing that method, and 3) advantages and disadvantages of that method.

Curriculum Connections
National Standards Addressed

Science Standards
Grades 5-8
Earth and Space Science
Earth in the Solar System

Grades 5-8, 9-12
Science as Inquiry
Understandings about scientific inquiry
Abilities necessary to do scientific inquiry

Science and Technology
Understandings about Science and Technology

History and Nature of Science
Science as a Human Endeavor
Nature of Science

Science in Personal and Social Perspectives
Science, Technology and Society
Risk and Benefits

Mathematics Standards
Grades 6-8, 9-12
Problem Solving

Data Analysis and Probability

Technology Standards

Technology Research Tools

Technology problem-solving and decision-making tools

Clarifying the Issues
- Teacher Guide

Defend This!
- Student Presentation Guide

What Goes Around Comes Around
- Student Text

Interview Summary Sheets
- Brian Muirhead
- John Marriott
- Karen Meech

Clarify

In "Clarifying the Issues," students read interview summaries from Dr. Karen J. Meech, University of Hawaii, who specializes in Earth-based observations, Brian Muirhead, project manager at the Jet Propulsion Laboratory, and John Marriott, engineer at Ball Aerospace & Technologies Corp. These individuals represent very different work institutions and thus, varying priorities, but must all work together to reach an agreement in order for the mission to be successful. Students build and present a case for a particular observation scenario that is to be used to inform and convince others. In the Student Text "What Goes Around Comes Around," students read about the reciprocal nature of science and technology using the development of the telescope as an example.

Refining the Issues
- Teacher Guide
- Public Forum Role Sheet

Communicating, Questioning, and Listening
- Student Text

Critiquing Ideas
- Assessment Guide

Refine

Students assume roles of various stakeholders of the mission including scientists, engineers, and the interested public including such as environmentalists, politicians, teachers, students, and others. General guidelines are provided for students to follow for each role, though they are encouraged to build the character of the person they are role-playing. Prior to the debate, students will view or listen to video or audio clips of some of the stakeholders in order to bring additional information into the mix. Students use the information from the presentations in order to prepare for a debate about the data collection methods at a public forum.

The Decision
- Teacher Guide
- Peer Review Checklist

Appendices

- Glossary
- Decision Making Process
- Rule-based Strategy

Decide

In the assessment activity, "The Decision," students prepare written statements for the data collection method with which they personally agree. On the same page, students will support a position statement that advocates other viewpoints. As a large group discussion, the class comes to an agreement on which combination of data collection is best at this time, knowing that as more information or circumstances come into play, this can change. Students determine the method for coming to a consensus, and one upon which all students can agree.

Curriculum Connections
National Standards Addressed

Assessment Standard B
- Achievement and Opportunity to Learn Science must be Assessed

Assessment Standard C
- Assessment Tasks Are Authentic

This science module, *Collaborative Decision Making: NASA's Deep Impact Mission*, was developed by educators at:

McREL

Mid-continent Research for Education and Learning

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Capture the Issue
TEACHER GUIDE

BACKGROUND INFORMATION
In this activity, students are introduced to the problem that mission planners dealt with during the planning phase of the Deep Impact Mission. The activity starts by having the students read the Deep Impact fact sheet. This is analogous to looking at the end of a good novel before one reads it. The next step is to look at the decision-making process, where students think about how they have made decisions in the past. "The Camera Controversy" then allows students a similar experience in making a decision about a controversial real-life problem. Students then hear a summary of an interview from the Principal Investigator, Dr. Michael A'Hearn. Dr. A'Hearn explains the problem, "How do we optimize our data collection?" This introduction not only provides the "hook" for student interest, but serves as a focus for the entire module.

The National Science Education Standards call for teachers of science to develop communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning. In doing so, teachers should display and demand respect for the diverse ideas, skills, and experiences of all students. This respect for diverse ideas is modeled in this opening activity in which students are exposed to different perspectives and then to an informal discussion based on a shared understanding of rules of scientific discourse.

The standards also call for teachers to engage in ongoing assessment of their teaching and of student learning in order to guide teaching. This activity begins with a short scenario that requires students to make a decision. Teachers can use this as a tool to see how students have made difficult decisions in the past.

NATIONAL SCIENCE STANDARDS ADDRESSED

Grades 5-8
Science As Inquiry
Abilities necessary to do scientific inquiry.
Identify questions that can be answered through scientific investigations.
Recognize and analyze alternative explanations and predictions.

Science and Technology
Understandings about science and technology.

Science in Personal and Social Perspectives
Science and technology in society.

History and Nature of Science
Science as a human endeavor.
Nature of science.

Grades 9-12
Science As Inquiry
Abilities necessary to do scientific inquiry.
Identify questions and concepts that guide scientific investigations.
Recognize and analyze alternative explanations and predictions.

Science and Technology
Understandings about science and technology.

Science in Personal and Social Perspectives

Environmental Quality.

Science and Technology in local, national, and global challenges.

History and Nature of Science

Science as a human endeavor.

Nature of scientific knowledge.

LANGUAGE ARTS STANDARDS

Listening and Speaking

Uses listening and speaking strategies for different purposes

Uses strategies to enhance listening comprehension.

Listens in order to understand topic, purpose, and perspective in spoken texts.

LIFE SKILLS STANDARDS

Thinking and Reasoning

Effectively uses mental processes that are based on identifying similarities and differences

Compares different sources of information for the same topic in terms of basic similarities and differences.

Applies decision-making techniques

Identifies situations in the community and in one's personal life in which a decision is required.

Secures factual information needed to evaluate alternatives.

MATERIALS

For the teacher:

- Listening Notes Example transparency

For each student:

- Deep Impact Mission fact sheet
- Deep Impact interview sheet:
  Dr. Michael F. A'Hearn
- Listening Notes sheet
- Highlighters (optional)
- Appendix G: Rule-Based Strategy (optional)

PROCEDURE

Begin this activity by asking students to read the Deep Impact fact sheet. This two-page document details the context for this entire mission.

1. The following is a procedure for using an inferential strategy with your students for reading the Deep Impact mission fact sheet.
   a. The teacher should analyze the content of the fact sheet for important ideas.
   b. Select three or four ideas that are important and might be difficult to understand. (For this fact sheet one idea might be what comets are and what they are made of.)
   c. Develop two questions for each idea identified in (b). The first should be about the background knowledge and the second should be a prediction question. (For this fact sheet and idea, a background question might be, “What do you know about comets?” or “Describe a time when you saw a comet in the nighttime sky.” A prediction question might be, “If you could send a spacecraft to visit a comet, what would you want to know?”

d. Discuss the responses to both the background and prediction questions BEFORE the students read the fact sheet.
e. After the discussion, assign the fact sheet to be read.
f. After reading, relate the prediction questions to what actually is being planned for the Deep Impact mission. Evaluate the ideas that motivated the background and prediction questions

2. Ask students to think about a time when they had to make a difficult decision. Ask them to relate the process they used to make that decision. Hold a class discussion about decision making. Ask students questions similar to the following:
   a. Why are some decisions easier to make than others?
   b. What is it that makes a decision difficult?
   c. In a difficult decision that you made in the past, what helped you to arrive at your conclusion?
   d. What are some things that you believe are critical in order to make an informed decision?
   e. After you make a difficult decision, what would you do if you needed to change your decision?

3. Explain to students that you are going to read an example of a controversy. As they listen to the story, ask them to think about both sides of the story, and whether additional information might be needed to make a decision. Read "The Camera Controversy" (located on the next page) aloud.

> **Alternate Strategy Tip**
> Use the "Rule-Based Strategy" in Appendix G to help students summarize this passage.

4. Ask students to list the process of how they would make this decision on a sheet of paper, and to add additional pieces of information that they would need to have before they could make this very difficult decision. Collect these sheets and read over the process and the types of information that the students would need to make this decision. You can use the student responses to provide a snapshot of how the students in your class make decisions. Explain to students that the module that they are about to begin is one about decision making based on a NASA mission called Deep Impact.

5. Explain to students that the rest of this module deals with the decision making process that the science team and mission planners used in DECIDING ON THE BEST TIME TO IMPACT COMET 9P/TEMPEL1 in order to get the best combination of data sources. Emphasize to students that they will be using information from interviews, data sheets, and the Internet to go through the same process as the mission planners. Also mention that although the mission planners have made a baseline decision, this decision could change prior to launch of the spacecraft.

6. Tell students that they are going to listen to an interview with the Principal Investigator Michael A'Hearn. Have one volunteer come forward to read the interview sheet. Give the volunteer the sheet and instruct him or her to read it silently. Tell the volunteer that they are going to read the sheet dramatically to the class.

> **Alternate Strategy Tip**
> Consider recording the oral readings from the student volunteers of the interviews. Students with learning disabilities could then listen to these tapes several times to meet individual needs.

7. While the volunteer is silently reading the interview sheet, distribute one Listening Notes sheet to the rest of the class. If they have never used listening notes before, give them the following instructions:
   a. Use the right side of the table for taking notes on what is said.
   b. Encourage students to use an indent or numbering system to categorize new ideas as they listen.
   c. Have the students put labels in the left-hand column and give them the chance to fill in gaps in the notes. This labeling should be done as soon as possible following the note taking.
   d. The main ideas and notes can then be used by the students to compare the interview and find areas that are similar and areas that are different.

> **Alternate Strategy Tip**
> Review the Deep Impact fact sheet a second time. This time, model the process for taking listening notes.

The Camera Controversy

Mariner 2 was the first space probe to visit a planet other than Earth. It was launched on August 27, 1962 in order to fly to Venus. The now famous astronomer Carl Sagan was immersed in a controversy about whether Mariner 2 should carry a camera. He and some of his colleagues argued for placing a camera onboard.

During the 1960's images from telescopes were hazy and not useful for scientists. Opponents to having a camera onboard maintained that a camera would only take up already-limited space and power resources on the space probe. Scientists who were opposed to the camera thought the space on board the probe would be better suited for "real" science instruments like the microwave radiometer, infrared radiometer, flux-gate magnetometer, ion chamber and Geiger-Mueller counters, cosmic dust detector, solar plasma detector—all of which were scheduled to fly on Mariner 2. These scientists preferred to make predictions about what would be found near a planet and then send specific instruments to test these predictions.

Sagan, on the other hand, expected to use cameras to "discover the unexpected." Sagan felt that cameras were important "precisely because they could answer questions we were too stupid to ask." Sagan thought these pictures would be valuable in their own right stating that they would help people to see Venus as more than the bright morning star, rather it being a complete world. In hindsight, images from other space probes have let the science community see a solar system that is much more complex than was thought previously.

Opponents countered with the fact that thick clouds on Venus would make it very difficult to see the "unexpected." Besides, are pictures real data? Many scientists preferred quantitative data that could be analyzed with their new computers.

Still, Sagan thought that if there was a break in the clouds, the camera could see evidence of possible life forms found in the cooler mountainous regions he thought were just below the clouds. These mountains, he thought might be cool enough to support life.

If you were on the panel at the Jet Propulsion Laboratory, what would you decide? Should a camera be flown on Mariner 2? What additional information about the benefits of the camera would you need to know before making the decision? What more should you know about the issues raised by the opponents?

8. Display the Listening Notes Example transparency to show students what their completed notes might look like. Once everyone is ready to start, ask the student volunteer to dramatically read the interview sheet to the class. You may want to have the volunteer read the interview twice; this will allow students to take more complete notes on the interview. Students who are taking notes should listen for information concerning the problem of determining the best time for impact of Comet 9P/Tempel 1. There are many variables that should inform this decision.

Teaching Tip
Provide key terms from the glossary to students before the presentation so they can listen for the main ideas.

9. Once the interview has been read, distribute the interview summary sheet to the class and instruct the class to label the main ideas of their notes in the left-hand column.

10. Divide the class into groups of three. This is now their home group and will be used during the research phase of the module in the next activity. Instruct the students to compare notes in this small home group for each person. You may want to pass out highlighters for students to color code

commonalties and differences in the opinions of the mission planners. A venn diagram is a useful tool for making comparisons and contrasts.

11. End this session by asking the student questions similar to the following:
    - Based on what you have heard so far, what questions do you now have?
    - What do you think would be appropriate next steps to answer these questions?

TEACHER RESOURCES

Publications

Davidson, Keay. (1999). *Carl Sagan: A Life.* John Wiley & Sons, Inc. New York, NY. Pp. 116-117.

Vacca and Vacca. (1993). *Content Area Reading.* Harper Collins College Publishers. New York, NY.

Web sites

http://fuse.pha.jhu.edu/overview/mission_ov.html
FUSE overview page

http://sci.esa.int/rosetta
ESA's Rosetta mission homepage

http://www.ball.com/aerospace/deepimpact.html
Ball Aerospace Deep Impact page

http://www.graphic.org/venbas.html
Venn Diagram information

http://www.jpl.nasa.gov/missions/past/mariner1-2.html
Information on Mariner 1 & 2 missions

http://www.psrd.hawaii.edu/Feb97/Hale-Bopp.html
Information about comets

Capture the Issue
SUMMARY INTERVIEW SHEET

Interview of: Dr. Michael A'Hearn
Job Title: Deep Impact Principal Investigator
Institution: University of Maryland
Interviewer: John Ristvey
Date: July 6, 2001
Conducted by phone at the University of Maryland in College Park, Maryland

My name is Michael A'Hearn. I am a professor of astronomy at the University of Maryland. My interest in comets goes back at least thirty years. The field has changed dramatically since then. There are now huge numbers of people studying comets. I am interested in all aspects of comets. The most unknown part of a comet is its nucleus. We know a great deal about the gas and dust that make up the head and the tail of the comet, but our knowledge of the nucleus is limited. The Deep Impact mission is intended to probe the interior of a comet's nucleus for the first time.

The final decision on the timing of the impacting Comet 9P/Tempel 1 has not been made. We have baseline data that we are working from now, but this decision is one that will be made just prior to launch. We will have data coming back from the spacecraft through the **Deep Space Network (DSN)**. In one sense, these data we get from the spacecraft are the most valuable. Because of this, we would like to use at least two antennas in the Deep Space Network, to make sure we get the data from the spacecraft.

On the other hand, the variety of data we get from the spacecraft is relatively small compared to the variety of data we can get from Earth-based facilities, both on the ground and in orbit around the Earth. We can get a much wider physical understanding of the characteristics of Comet 9P/Tempel 1 if we get a wide selection of data from Earth-based facilities, too.

Since it is not dark everywhere on Earth, the question that must be answered is, "From what observatories can we get the largest possible amount of data with the greatest diversity and the highest probability of success?" Some observatories are in locations where it is likely to be rainy, and others don't have the instrumentation in order to make a wide variety of measurements. So we must think very carefully about which ground-based observatories are the most important from the viewpoint of instrumentation and a probability of clear weather. This information is used for deciding the best time for impact. The two prime Earth-based sites with a large variety of instrumentation and telescopes are in Chile and in Hawaii.

The real choice is, how big of a priority is it to have two antennas in the Deep Space Network? Is it important to have two different sites, or is it adequate to have two antennas at the same site? This choice will also require an analysis of the instrumentation aboard the spacecraft. If these instruments are a lower reliability than the DSN, then perhaps it will be more valuable to get the Earth-based data than to have two antennas in the DSN.

Weather is not a factor for the Hubble Space Telescope (HST). We will have to make a small adjustment if we use the Hubble Space Telescope, because it is in a 90-minute orbit around the Earth, and if it is on the wrong side of the Earth, it will not be able to see the impact. We will need to be able to shift the impact time by plus or minus forty-five minutes to optimize the observability from the telescope. This is hard because the people who keep track of the space telescope do not know where it will be until two months in advance.

The science objectives of the Deep Impact mission are to understand as much as we can about the comet's nucleus. In order to do this, we need the widest possible selection of measurements of the material ejected from the impact crater, and the details of the outer layers of the comet's nucleus. The decisions we make for deciding the best scenario for optimizing our data collection will impact the extent to which we are able to meet these mission science objectives.

Capture the Issue
LISTENING NOTES SHEET

Interview of ____________________________________ Job title __________________________________

Institution ____

Main Ideas **Notes**

Capture the Issue

LISTENING NOTES SHEET EXAMPLE

Main Ideas	Notes
Introduction	All large telescopes built recently are reflector telescopes. Advances in technology have allowed them to be combined with instrumentation such as Charged Couple Device (CCD), which is used to make images that are studied. Astronomers rarely, if ever, use their eyes for direct observation.
Functions of the telescope	Telescopes gather light. Telescopes resolve fine detail. Telescopes magnify the image.

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.

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.

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 I nvestigate curriculum-related problems, issues, and information, and to develop solutions or products f or 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.

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

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.

LIFE SKILLS STANDARDS

Thinking and reasoning
Applies decision-making techniques
Secures factual information needed to evaluate alternatives.

MATERIALS

For each student:
Student planning guide
- Building a Scenario
- One of each strategy information sheet
    - Deep Impact Spacecraft
    - Earth-based Observatories
    - Earth Orbital Facilities
- Deep Impact Ephemeris Data student spreadsheet
- Computer with Internet connection
- Library
- Appendix F: Decision-making Process (optional)

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.

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)

> **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.

- 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 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.)

> **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.

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

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)

9. Ask the students to meet in expert groups (groups that have researched the same method) to compare the information they found on their strategy 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

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

Deep Impact Spacecraft
STRATEGY INFORMATION SHEET

BACKGROUND INFORMATION
The Deep Impact spacecraft is launched as a single spacecraft. About one day before the scheduled impact, the impactor is separated from the flyby spacecraft. Determining the timing of the impact is important to optimize the data that is obtained from Deep Impact. For this observation strategy, an important criterion for timing the impact is to do so such that the impact is made on the lighted side of the comet.

An onboard camera is used to target the impactor and to provide the highest resolution of the surface. The resulting crater is expected to form in 200 seconds after impact. The crater is expected to have a 120-meter diameter and be 28-meters deep. The flyby spacecraft has a number of instruments for making observations of the impact and resulting crater. High- and medium-resolution telescopes are mounted on the spacecraft's body. The spacecraft rotates in order to follow the nucleus and crater during the flyby. Other instruments include an optical imager and a near infrared mapping spectrometer.

The Deep Impact spacecraft observations must be carefully managed in order to stay within certain constraints. The spacecraft observational sequence must be designed to fit within the capabilities of the spacecraft memory and downlink data rate. Pictures that are taken must either be sent immediately to Earth over the telemetry link or stored in the spacecraft computer for later relay. Critical images might be sent immediately to Earth and stored in the spacecraft memory for backup. Since the survival of the flyby spacecraft through the orbital path of the comet, where dust and debris is concentrated, cannot be assured, it is planned to return as much data as possible before the spacecraft passes through this potentially dangerous region.

The Deep Space Network is an international network of antennas that supports interplanetary spacecraft missions. They conduct radio and radar astronomy observations for the exploration of the solar system and the universe. The network is a NASA facility and is managed and operated by the Jet Propulsion Laboratory. The Deep Space Network is used for all space missions is the largest and most sensitive scientific telecommunications system in the world. Three locations currently make up the network including: Goldstone in California's Mojave Desert; Madrid, Spain; and Canberra, Australia. These facilities are approximately 120 degrees apart on the globe. The placement of the network in these locations allows constant observation as the Earth rotates. However, many missions need to access the network during the impact. For more information about the Deep Space Network, visit the Web site at: http://deepspace.jpl.nasa.gov/dsn/

The downlink data rate is 175,000 bits per second using Deep Space Network's 70-meter antennas and 25,000 bits per second using the 34-meter antenna. A full frame image is about one megabyte. How long would it take to download one full frame picture using the 70-meter antennas? How long would it take to downlink one full frame picture with the 34-meter antennas? (One megabyte is equal to one million bytes and there are eight bits in one byte.) There are about 300 megabytes of memory in the spacecraft computer to store images. How many full frame images can be stored on the spacecraft? How does knowing this affect mission planning? (See Procedure #1 below.)

Determining the best time for impact will optimize the data collection during the following Deep Impact flight system objectives:

1. Hit nucleus of 9P/Tempel 1 with sufficient kinetic energy to form a crater with a depth greater than twenty meters.
2. Observe nucleus for more than 10 minutes following impact.
3. Image nucleus impact, crater development and inside of crater.
4. Obtain spectrometry of nucleus and inside of crater.
5. Acquire, store, format, and downlink imagery and spectrometry data.

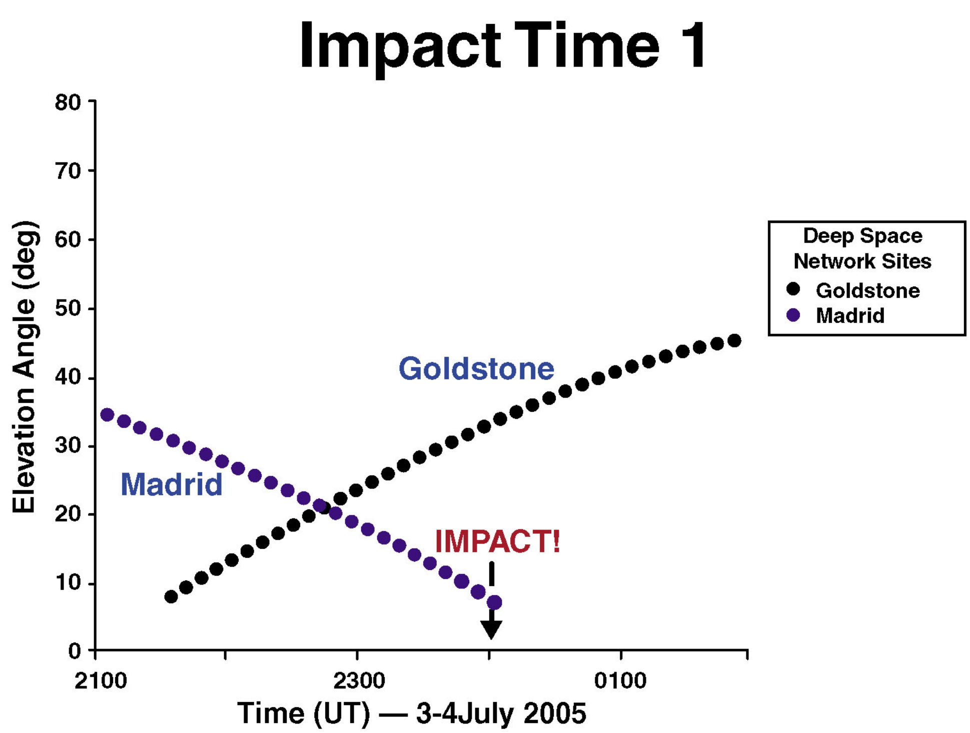
9P/Tempel 1 is in a 5.5-year orbit and next reaches its closest point to the Sun (perihelion) on July 5, 2005. The best date to reach the comet is when it is close to crossing the orbit plane of the Earth (the Ecliptic plane), which occurs on July 7, 2005**.** These events are fortuitously close together, so the Deep Impact mission first looked at days in early July 2005 for the impact date, since this minimizes the energy we need from the rocket that launches the spacecraft (the Delta II launch vehicle). Reducing the launch energy for the rocket allows it to carry the heaviest possible impactor in order to make a bigger crater.

PROCEDURE

1. Complete the calculations in the background section as noted above.
2. Your job in this expert group will be to analyze all of the possible times of impact and determine the best option for obtaining data from the flyby spacecraft. Read the information that follows and prepare a recommendation to your group. Which option would you recommend and why? Ideally, the impact should be planned to take place when two of the Deep Space Network antennas are covering that area of the sky. For the information below, the science value of Earth-based observing is shown as well.

Option1: Impact Time 1

This option has an impact time of 0000 UTC ON JULY 4, 2005. With this option, the impact time will be 5 p.m. Pacific Daylight time on the west coast on July 3, and 8 p.m. Eastern Daylight time on the east coast. During this time many people in the United States will be awake during the impact. This option involves Earth-based observing primarily from high-altitude sites in Chile, which are favored by the southern declination of the comet at impact, and DSN coverage through the Goldstone, California tracking site. Substantial functional redundancy for receiving data at Goldstone would be possible using multiple antennas (70 meter, and 34-meter array). However, this option does not provide DSN backup in case of bad weather (thunderstorm, winds) or a major power outage that would disable all of the antennas at Goldstone.

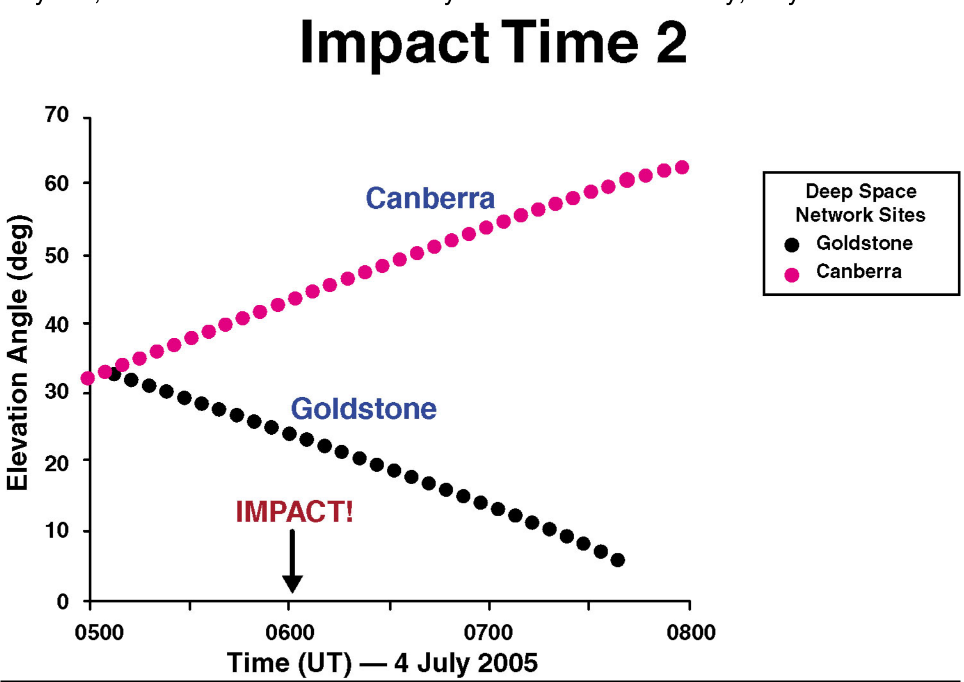


Option 2: Impact Time 2

The impact time for this option is set so that it will be first seen on the Earth at 0600 HOURS UNIVERSAL TIME ON MONDAY JULY 4TH, 2005. For people in the United States the time will be 11 p.m. Pacific Daylight Time on the west coast (actually Sunday, July 3rd) and 2 a.m. Eastern Daylight Time on the east coast.

0600 UTC puts the impact event in overlapping coverage between the DSN tracking stations at Goldstone, California and Canberra, Australia so that we have the highest confidence of receiving all the telemetry even if one tracking site has a problem, such as bad weather or a major power outage. This time represents some compromise in the observatory coverage of the impact event in order to maximize the probability of telemetry return. 0600 UTC puts the comet over the Pacific Ocean at impact, with overlapping coverage from the Mauna Kea, Hawaii observatories, just after sunset, and west coast observatories, primarily Palomar.

This scenario has the added benefit of similar public attention that was focused on the Pathfinder landing on July 4th, 1997. Most Americans will see the events before impact on TV on the evening of Sunday, July 3rd, but it should be the lead story in the news on Monday, July 4th.



Additional Information from the mission planners:

Not everything is perfect for the dates in early July 2005. A compromise must be made, choosing between several factors. The two primary factors are the launch energy and the approach phase angle, which determines what percent of the nucleus is illuminated as the flyby S/C and impactor are targeted for the encounter. July 4 is approximately the best encounter date when considering all the mission parameters, as it allows us to carry the most mass in the impactor. Later arrival dates don't provide much more mass, while the approach phase angle and Earth range are degraded. Earlier arrival dates provide a better approach phase angle and Earth range (for better telecom rates and Earth-based observing), but the mass capability falls off significantly and the encounter speed is increasing, producing more smear in the images. A large illumination or small phase angle is important because we need sunlight to image the impact.

The science team and, in particular, the principal investigator still want to review the implications of your decision. This is because some compromises have been made in the observations of the impact from astronomical observatories in order to maximize the probability of receiving all the radio telemetry from the flyby spacecraft with the most important images.

Earth-Based Observatories

STRATEGY INFORMATION SHEET

BACKGROUND INFORMATION

Earth-based observatories will be used for observations from Earth. The best case scenario would mean that the impact would take place when the comet is visible though the telescopes of more than one major observatory. Earth-based observing of the impact is a secondary source of data. Earth-based viewing allows scientists to observe the characteristics of the comet nucleus before impact. The types of observation from the Earth includes optical and infrared imaging, optical and infrared spectroscopy, and x-ray, optical, infrared and far infrared photometry.

The receipt of optical data from Earth-based observatories is constrained to night and only when the comet is above the horizon (i.e., in view). Clouds and bad weather can constrain ground observations. The Deep Impact mission design requires that impact occurs when more than one Deep Space Network antenna is in view of the comet.

Your group investigates the various possible observatories that may be involved with Earth-based observations of the impact by finding information about the observatories at various Web sites. Also, you will determine the locations of these observatories and the times at which the impact could be observed from these locations. Other factors like cost and requirements for the use of telescopes are considered.

Deep Impact astronomer Karen Meech describes the proposal process below:

> *One of the biggest challenges for this mission is to obtain as much observing time as we will need to fully characterize the target before we get there. In order to obtain telescope time at any observatory, scientists must submit a proposal justifying their need. At all of the national observatories the proposal process is very regimented. For example, they dictate the margin size and font to be used in the proposal. Proposals not meeting the specifications are not even read. There is usually one page of scientific justification, explaining why your proposal should be accepted. These proposals are read by astronomers, but many with a different specialty area. Not all astronomers understand the importance of determining the rotation of a dirty snowball in space. So, in this one short page we have to inform them of the necessary background of the request and excite them about why this is the best thing to be done with the telescope. Another page is dedicated to justifying the request for a particular telescope, and why your science cannot be done with a smaller telescope.*
>
> *A committee of our peers reads hundreds of proposals, judges them, grades them, and ranks them. After they have decided which proposals are awarded time, someone else schedules the proposals with the highest ranking proposals getting their first choice of dates. A high-profile NASA mission like Deep Impact will get special considerations when it gets closer to the time of impact. Amateur astronomers can take* **Charged-Coupled Device (CCD)** *images and measure the brightness of Comet 9P/Tempel 1 at different times. Their limitation, however, is that they cannot observe very faint objects. During the time when the comet is bright, we should have almost continuous coverage from an enthusiastic, interested public who want to contribute to a real mission.*

PROCEDURE

1. The following observatories are being considered for use by the Deep Impact team for Earth-based observations. Use an atlas/globe and the Web to find information about these observatories in order to fill in the chart on the next page. Under “general comments” you may want to comment on the amount of darkness at each observatory. The Earth at night can be viewed at http://antwrp.gsfc.nasa.gov/apod/ap001127.html

United States

- **Haleakala (Maui)**
  http://www.ifa.hawaii.edu/haleakala/
- **Mauna Kea Observatory, Hawaii (the big island)**
  http://www.ifa.hawaii.edu/88inch/88inch.html
- **Palomar Observatory (Southern California)**
  http://www.astro.caltech.edu/palomarpublic/
- **Chile**
- **Cerro Tololo Inter-American Observatory (Chile)**
  http://www.ctio.noao.edu
- **La Silla Observatory (Chile)**
  http://www.ls.eso.org/index.html
- **Paranal Observatory (Chile)**
  http://www.eso.org/paranal/

Observatory	Latitude/Longitude	Elevation	Weather Notes	General Comments
Haleakala, HI				
Mauna Kea, HI				
Palomar, CA				
Cerro Tololo, Chile				
La Silla, Chile				
Paranal, Chile				

2. There are certain pieces of information that are needed when requesting time for using telescopes at the various sites listed above. Look up some of the sites and make a list of some of the information that we would need to have in order to complete a research proposal. Include this information on a separate sheet of paper.

3. Use the European Southern Observatory Sky Calendar Tool to find the times that the impact could be observed from various observatories under consideration. That is, note the times of darkness and

moon location for July 4, 2005 in the chart below. The tool provides sunrise and sunset times at each site, astronomical twilights, in local time and moon rise and set times and phase for each night in the month. In order to obtain the information to fill out this chart, select the site, for year select 2005, from July to July. Convert all times to Universal Time, using a time zone converter. The following site offers this tool: http://www.timezoneconverter.com/index.shtml

Observatory	Sunset	Sunrise	Moonrise	Moonset	% moon illumination
Haleakala, HI					
Mauna Kea, HI					
Palomar, CA					
Cerro Tololo, Chile					
La Silla, Chile					
Paranal, Chile					

4. Use an **ephemeris** generator to find the right ascension and declination of Comet 9P/Tempel 1. The Solar System Dynamics Groups at the Jet Propulsion Laboratory has an online solar system data and ephemeris computation service that provides access to highly accurate **ephemerides** for solar system objects. An ephemeris table gives the position of celestial objects at different times and from different observing sites. Use the following procedure to find the **right ascension** and **declination** of Comet 9P/Tempel 1 at the time of impact.
   a. On a computer with Internet access, go to: http://ssd.jpl.nasa.gov/cgi-bin/eph
   b. Click on the button that says “Target Body.”
   c. Under “Select Small-Body,” enter “9P/Tempel 1,” then click “Search.” Choose “9P/Tempel 1 [2005.5]” from the drop-down menu, then click on “Use Selected Asteroid/Comet.”
   d. Click on “Observer Location.”
   e. Under “Lookup Named Location,” type in the name of the observatory. Then click on “Search.”
   f. Click on “Time Span.”
   g. Enter the start date and time as: “2005 – 07 – 04 - 00:00” for July 4, 2005.
   h. Enter the stop date and time as: “2005 – 07 – 04 – 23:50” for the end of the same day.
   i. Click on “Use Specific Settings.”
   j. Click on “Output Quantities and Format.”

k. Choose Number 1, “Astrometric RA and DEC,” and de-select all other check boxes.
l. Click on “Use Specific Settings.”
m. Click on “Generate Ephemeris.”
n. Fill in this table:

Comet 9P/Tempel 1 on July 5, 2005	Right Ascension	Declination
Observatory		
Haleakala, HI		
Mauna Kea, HI		
Palomar, CA		
Cerro Tololo, Chile		
La Silla, Chile		
Paranal, Chile		

The following is information provided to you from the Deep Impact mission planning team.

There are two scenarios for time of impact under consideration. The first is July 4, 2005 at 00:00 UT. In this scenario, the prime Earth-based observation locations include Lasilla, Cerro Tololo and Paranal in Chile. The second scenario is July 4, 2005 at 06:00 UT. In this scenario the prime Earth-based observation locations are Mauna Kea, and Haleakala in Hawaii, with Palomar as a backup.

a. From what site will the comet be above the horizon for the longest time?

b. How does the moon affect observing?

c. From the sunrise and sunset information in your chart, determine the dark times at different sites.

From this information, which two observatories would you recommend to your group for observing the impact from the ground? Include the reasons for your choices.

Earth Orbital Facilities

STRATEGY INFORMATION SHEET

BACKGROUND INFORMATION

The Hubble Space Telescope is another source of data for the Deep Impact mission. It has some advantages over Earth-based observatories as a source of data. The Hubble Space Telescope is a cooperative program of the European Space Agency and the National Aeronautics and Space Administration to operate a long-lived space-based observatory. The space telescope has many science instruments including three cameras, two spectrographs, and fine guidance sensors (used for astrometric observations). Because this telescope is above the Earth's atmosphere, its instruments can produce high-resolution images of celestial (sky) objects without interference from Earth's atmosphere, which blurs images. Hubble Space Telescope's resolution is about ten times better than ground-based telescopes. Hubble Space Telescope is not constrained by clouds or bad weather as the Earth-based telescopes are. Hubble must be in a position in its orbit around the Earth in which it can view the comet. To accommodate this, the Deep Impact spacecraft can be maneuvered sixty days before impact to adjust the impact time of the comet.

Even though Hubble operates around the clock, it is not used for observation all the time. When it is not used for observations, the Hubble Space Telescope is performing one of several "housekeeping" functions such as turning the telescope toward a new target, avoiding the Sun or moon, switching the communications antenna or receiving commands or downlinking data. When possible, two of Hubble's instruments are used simultaneously while observing a particular section of the sky. You read in "Earth-Based Observatories" that acquiring observation time is competitive, as only one in every ten proposals is accepted.

PROCEDURE

1. Read about the proposal process for obtaining observing time on the Hubble Space Telescope and summarize the process in your journal or notebook at the following Web site: http://www.stsci.edu/observing/proposal_process.html

2. Hubble Space Telescope observation time is measured in orbits. Hubble orbits the Earth every 96 minutes. Each orbit contains a certain amount of useful time when a target can be observed. This time is called the visibility period. The visibility period depends on the declination of the target. Orbits are grouped into larger units called visits. Because the orbit of Hubble is relatively low, most targets are blocked by the Earth for varying lengths of time during each orbit. The visibility period is the amount of unblocked time per orbit during which an observation can be made. The best visibility period, called the Continuous Viewing Zone, and includes targets lying within 24 degrees of the orbital poles and not blocked at all during the Hubble orbit. Low sky observations occur when Hubble's observation would be adversely affected by scattered light from earthshine or other **zodiacal light**. Observations are restricted when the Hubble Space Telescope is in the **Earth's shadow** during the **observation time**. Both low observations and shadow observations complicate scheduling and reduce Hubble's efficiency. Use table 6.1 in the Hubble primer book to indicate the orbit visibility of Comet 9P/Tempel 1 based on the declination of 9 degrees to find the number of minutes of regular visibility and number of minutes of low visibility during an orbit of the Hubble Space Telescope.

Target	Declination (degrees)	Regular Visibility (minutes)	Low Visibility (minutes)
Moving	Object near elliptic plane	53	48
Fixed	0-18°	52	47
Fixed	18-33°	53	48
Fixed	33-43°	54	48
Fixed	43-48°	55	45
Fixed	48-53°	56	45
Fixed	53-58°	57	45
Fixed	58-63°	56	46
Fixed	63-68°	57	45
Fixed	68-73°	58	43
Fixed	73-88°	59	42
Fixed	88-90°	60	41
Any	Any	25	Incompatible
Any	Any CVZ declination	96	Incompatible

3. When determining which information to include in a proposal for using the Hubble Space Telescope, target information is necessary. The Solar System Dynamics Group at the Jet Propulsion Laboratory has an online Solar System Data and **Ephemeris** Computation Service that provides access to highly accurate **ephemerides** for solar system objects. An ephemeris table gives the positions of celestial objects at different times and from different observing sites.

> **Helpful Hint**
> You may use the "Back" button on your browser to correct your input or start the procedure again.

4. Use the following procedure to find information about Comet 9P/Tempel 1 from the Hubble Space Telescope at the time of impact:
   a. A computer with Internet access, go to http://ssd.jpl.nasa.gov/cgi-bin/eph
   b. Click on the button that says "Target Body."
   c. Under Select Small-Body, type in "9P/Tempel 1", then choose "Search". Then choose "9P/Tempel 1 [2005.50]" and click on "Use Selected Asteroid/Comet."
   d. Click on "Observer Location."
   e. Under "Lookup Named Location", type in "Hubble Space Telesco", then click on "search."
   f. Click on "Time Span."
   g. Enter the start date and time as 2005 -07 - 04 - 00:00 for July 4, 2005.
   h. Enter the stop date and time as: 2005 - 07 - 04 - 23:50 for the end of the same day.
   i. Click on "Use Specified Settings."
   j. Click on "Output Quantities and Format."
   k. Choose the following settings: 1, 9, 10, 20, 21, 25, and 29. Be sure to de-select all other check-boxes.

l. Click on “Use Selected Settings.”
m. Click on “Generate Ephemeris.”

5. You may want to print the “Generate Ephemeris” page. Use the data on this page to find the following information. Remember this information is specific to the dates you input and the observer location of the Hubble Space Telescope. Record this information in your journal or notebook.

6. You may use the information at http://www.ii.metu.edu.tr/emkodtu/met204/lectures/section4/page1.html to help answer the questions below, but your responses have to be in your own words. Write your responses in your lab notebook or journal.
   a. What is the right ascension of the target?
   b. Describe what right ascension measures.
   c. What is the declination of the target?
   d. Describe what declination measures.
   e. What is the total magnitude of the target?
   f. Describe how the magnitude of celestial objects is measured?
   g. What is the nuclear magnitude of the target?
   h. Based on your answer for “f,” is the nuclear or total magnitude brighter?
   i. What fraction of the target’s circular disk does the Sun illuminate?
   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?
   k. What is the definition of an **astronomical unit (AU)**?
   l. How long does it take for light reflected from the target to reach the observer?
   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?
   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?
   o. Which constellation would one look to find the target? (Go to http://ircatalog.gsfc.nasa.gov/constel_names.html to find the name of the constellation based on the three-letter abbreviation.)

The following is information provided to you from the Deep Impact mission planning team.

There are two scenarios for time of impact under consideration. The first is July 4, 2005 at 00:00 UT. In this scenario, the Hubble Space Telescope window is about 45 minutes. The second scenario is July 4, 2005 at 06:00 UT. In this scenario the window is about 25 minutes. Based on the information you have found about the proposal process, the amount of time the target is visible from the Hubble Space Telescope and the information about the target found using the Ephemeris Generator, write a report to your group explaining the pros and cons of using the Hubble Space Telescope as a secondary data gathering method. Include your recommendation on whether or not this method should be included in your report and if so, which of the two times proposed would work best. For more information that will help you with this report, refer to the interview of astronomer Dr. Karen Meech in Appendix C. The last paragraph in this interview contains her thoughts about using the Hubble Space Telescope.

URL

http://oposite.stsci.edu/pubinfo/spacecraft/Primer/

General information about the Hubble space telescope.

Timing is Everything
STUDENT PLANNING GUIDE

BACKGROUND INFORMATION
Directions: Using the information gathered in your expert group, determine the requirements, benefits, and limitations of each type of observation strategy. This planning sheet will then be used by your group to build a scenario identifying exactly how the mission will be planned. In other words, how much importance, if any, will be given to the secondary collection methods?

The primary source of data is observing, using the instruments on the DEEP IMPACT SPACECRAFT and timing of the impact so that the most information is sent back and received by the Deep Space Network.

Deep Impact Spacecraft
Requirements:

Benefits (science value):

Limitations:

Another source of data is studying EARTH-BASED OBSERVATORIES for optical observations and timing such that the impact will take place when the comet is visible though the telescope of more than one major observatory.

Earth-Based Observatories
Requirements:

Benefits (science value):

Limitations:

EARTH ORBITAL FACILITIES, including the Hubble Space Telescope is another source of data that is not dependent on weather on Earth.

Earth Orbital Facilities
Requirements:

Benefits (science value):

Limitations:

Timing is Everything

BUILDING A SCENARIO GROUP SHEET

BACKGROUND INFORMATION

Use the Deep Impact Ephemeris Data Spreadsheet to create a line graph representation of the times that comet Tempel 1 will be at a viewable elevation from July 3-5, 2005 from various Earth-based telescopes as well as two of the Deep Space Network (DSN) sites. Use time in the x-axis and elevation in the y-axis.

Using this graph, find all of the times that the comet is viewable from both Madrid and Goldstone. This represents two DSN sites. Write the times below:

If having two DSN sites is not a priority, what would be the possible observatories that could be used during Madrid only as the DSN site? Write the observatories and times below:

If having two DSN sites is not a priority, what would be the possible observatories that could be used during Goldstone only as the DSN site? Write the observatories and times below:

In the space below describe the time of impact, DSN site, and observatories your team would recommend for the mission planners of Deep Impact.

In the space below describe the benefits of your scenario. Describe how your scenario meets the science objectives and why you have chosen this method.

In the space below describe the drawbacks and risks of your plan. These are potential weaknesses. Describe how your team would recommend that these weaknesses should be addressed by mission planners and how risks might be minimized.

Clarifying the Issues
TEACHER GUIDE

BACKGROUND INFORMATION
In this activity, students build and present a case for a particular observation scenario that is to be used to inform and convince others.

Student groups will use the research on their chosen observation method that they collected in the last activity to prepare a presentation and defense of their scenario that takes into account the risk, benefits, and quality (meeting science objectives). The case built by each group should include a specific plan for the observation method, specific details for implementing that method, as well as risks and benefits of that method.

The various perspectives that the students read about in this section include those of members of the Deep Impact science, management, and engineering teams. Students read position statements from Dr. Karen Meech, University of Hawaii, who specializes in Earth-based observations; Brian Muirhead, project manager at the Jet Propulsion Laboratory; and John Marriott, an engineer at Ball Aerospace Technologies Corporation. As you can see from the respective work roles, these individuals represent very different priorities, but must all work together and come to an agreement in order for the mission to be successful.

The National Science Education Standards call for students to develop descriptions, explanations, predictions and models using evidence. Throughout their preparation of the presentation, students must keep in mind the difference between explanation and description; their claims must be based on evidence and logical argument. It is therefore imperative that they have established a fair knowledge of subject matter in the previous activity. In developing their presentation package, students must decide carefully what evidence to use, and what evidence or anomalous data they should prepare to defend. Likewise, they will have to give considerable thought to the manner in which they will communicate the techniques and methods they used to generate, analyze, and draw conclusions from their evidence. Mathematics is an important aspect of this process of gathering, organizing, and presenting data, and should be brought into the presentation as support wherever possible. Varying stakeholders will emerge in the next activity. There are a myriad of scientists, engineers, technicians, and public citizens who will each pose different concerns and questions. At this stage, students should begin to understand that their solutions do indeed relate to human needs, desires, and opinions. Every data collection solution being prepared will have side effects, and it is the job of the student to best balance the costs and risks of their solution with the benefits that will be recognized. They learn to be systematic and objective in this portion of their preparation, and also attempt to use probability estimates to minimize risks when compared to benefits, including any social or personal benefits that can be derived. The advancement of science due to technology becomes apparent in this activity, as does the fact that technology can be driven to higher standards by science and a quest for better and higher quality data, even under constraints. The concept of building in back-up measures, thereby reducing the risk (never eliminating it) also is considered in preparation for the presentation. Finally, students' preparations must support creativity and insight, and the recognition that people, not scoring machinery, will determine the method of collection considered most worthy for the mission.

NATIONAL SCIENCE STANDARDS ADDRESSED

Grades 5-8
Science As Inquiry
Abilities Necessary to do scientific inquiry.
- Develop descriptions, explanations, predictions, and models using evidence.
- Think critically and logically to make the relationships between evidence and explanations.
- Communicate scientific procedures and explanations.
- Use mathematics in all aspects of scientific inquiry.

Science and Technology
Understandings about science and technology.

Science in Personal and Social Perspectives
Risks and benefits.
Science and technology in society.

History and Nature of Science
Science as a human endeavor.
Nature of science.

Grades 9-12
Science As Inquiry
Abilities Necessary to do scientific inquiry.
Formulate and revise explanations and models using logic and evidence.
Recognize and analyze alternative explanations and models.
Communicate and defend a scientific argument.

Science and Technology
Understandings about science and technology.

History and Nature of Science
Science as a human endeavor.
Nature of scientific knowledge.

LANGUAGE ARTS STANDARDS ADDRESSED

Standard: 8 Demonstrates competence in speaking and listening as tools for learning

Level III Grades 6-8
Listening and Speaking
Demonstrates competence in speaking and listening as tools for learning.
Conveys a clear main point when speaking to others and stays on the topic being discussed.
Presents simple prepared reports to the class.

Level IV Grades 9-12
Listening and Speaking
Adjusts message wording and delivery to particular audiences and for particular purposes (e.g., to defend a position, to entertain, to inform, to persuade).
Makes formal presentations to the class (e.g., includes definitions for clarity; supports main ideas using anecdotes, examples, statistics, analogies, and other evidence; uses visual aids or technology).
Responds to questions and feedback about own presentations (e.g., defends ideas, expands on a topic, uses logical arguments).

MATERIALS

For each student:

- Student Presentation Guide, "Defend This!"
- Completed observation Strategy Information Sheets (Deep Impact Spacecraft, Earth-based Observatories, and Earth Orbital Facilities)
- Deep Impact interview summary sheets:
- Dr. Karen J. Meech
- Brian Muirhead

- John Marriott
- Four Listening Notes sheets
- Student Text, "What Goes Around Comes Around"
- Presentation materials if necessary (poster board, computer disks, etc.)

PROCEDURE

1. Explain to students that they are going to listen to three more interviews using the same process that was used in the first activity, "Capture the Issue." This time, they are going to listen to three viewpoints from members of the Deep Impact science, management, and engineering teams. Ask for three volunteers to come forward and read the interview summary sheets. Give each volunteer a different sheet and instruct him or her to read it silently. Tell them that they are going to read the sheets dramatically to the class.

2. While the volunteers are silently reading the interview sheets, distribute three Listening Notes sheets to each person in the rest of the class. You may want to review the process for using these notes from Procedure 7 in the Teacher Guide to "Capture the Issue." Once everyone is ready, a student volunteer should read the interview summary as individuals take notes. A good strategy would be for the volunteer to read the summary twice. The first time, students should listen without taking notes, the second time students can take notes.

> **Alternate Strategy Tip**
> For advanced students, consider using the full interviews located in the Appendices.

3. Once the interview has been read a second time, distribute the interview summary sheet to the class and instruct them to include the main idea for their notes in the left-hand column. Students may work in their small groups on this part of the activity. Repeat Procedure 2 for the other interview summaries.

4. For students wanting more in-depth information about the interviews, provide the full-length interview located in the appendix.

5. Once everyone has had a chance to complete their Listening Notes, ask students to respond to questions similar to the following, in their home groups:
   - Based on what you have just heard, what new questions do you have?
   - In what ways have the interviews changed your group's thoughts about the scenario you have constructed? (You may spend time addressing these changes in your group scenario.)

6. Explain to students that they are now going to use the information they compiled through their research in the last activity in order to prepare their collected ideas on how to optimize data return for science team and public review. Tell them they will need to prepare a presentation that meets a multitude of requirements, and be prepared to defend their views as a result of this preparation.

> **Teaching Tip**
>
> It is difficult to assist groups for too long as an entire class. Students become acutely aware that they are preparing to meet a challenge from other groups. Arranging for sharing with these groups as well as open learning from each other can be delicate. A strategy that often works well is using a "debate scrimmage." As with any scrimmage, the agreement is to learn from each other. Two groups engage in a friendly exchange using any of a number of formats. They may choose to scrimmage early in the preparation, or later, on mutual agreement with their opposing "partner" group. It is suggested that these interactions be limited to two groups, and that groups have the choice of pairing off for a period of time. Groups that opt out of this activity may take the additional time to prepare within their own group. Groups should only be allowed one "scrimmage."

7. Allow students to move into their groups and distribute the student presentation guide and a copy of the meeting rules. It is important that all students understand that they must adhere to the meeting rules. These rules may even be posted in the room and used throughout the next activity, avoiding the need to distribute copies. Ask each group to first clearly state its scenario "case," including the description, primary subject matter evidence in support of that, and the "argument" or primary points they would like to make in support. Discuss the nature of these broadly focused ideas with students. The "description" (Item 1 on the Student Presentation Guide) should be thorough, yet easily understandable by those not completely informed about the specific content. The "evidence" (Item 2 on the Student Presentation Guide) should include that which is problematic as well as that which strengthens their group's claims. The "arguments" (Item 3 on the Student Presentation Guide) refers to the group's strategy for using the evidence in their presentation to convince the various stakeholders.

> **Teaching Tip**
>
> During final preparation of the presentation, an excellent opportunity is presented for students to learn to use presentation software. If only one computer is available, use a rotation schedule of student group use of the computer throughout the preparation phase. If plentiful, a computer may be assigned to each group for development of presentation slides, along with any other needs they may have. Microsoft PowerPoint, Hyperstudio, and Astound are all excellent choices. Students may even choose to develop a browser-based presentation, the construction of which would not greatly differ from that of a Web page. Note that if computers are used, you will need to provide a computer projector for the actual presentations in the next activity, or at a minimum provide students the means to print their slides on transparencies for use with an overhead projector. Take care not to engage students in preparation of materials that they can not properly use in the next activity.

8. Ask students to proceed with the remainder of their preparations, and provide assistance to each group as needed. Selecting appropriate methods for presenting their arguments (Item 4 on the Student Presentation Guide) and expressing a positive balance of benefit with risk will prove to be a mathematical challenge for many students. Be prepared to stop and provide large or small group instruction on basic probability calculations, or even computation and graphing. It is part of the value of the learning in this phase of the cycle, and should not be discarded. Student preparation for persuading various stakeholders (item 5 on the guide) will likely be quite enjoyable and valuable to students of all ages, especially if they are asked to role-play within their group. They could assume the role of one of the mission team members, a member of the public, or other role, and from that viewpoint attempt to find problems or holes in their own group's ideas. It is often effective to allow students to create their own characters in order to engage in the same effort to make their partners "defend this." Many students will have a very difficult time with understanding the mutual positive impact that can or will be recognized by their chosen data collection method. This is typically due, however, to a simple lack of understanding of the concept, and most problems can be remedied by providing each with the Student Text "What Goes Around Comes Around."

RESOURCE

National Research Council. (2000). *Inquiry and the National Science Education Standards.* National Academy Press. Washington, D.C.

Defend This!
STUDENT PRESENTATION GUIDE

BACKGROUND INFORMATION
In this activity, you and your group will build a case for a particular observation strategy, and a presentation that you will use to inform and convince others in the activity that follows.

Use your group's research on its chosen observation strategy from the last activity to prepare your presentation, as well as a defense that takes into account the cost, risk and benefits, and quality (meeting science objectives). Your group's presentation should include a specific plan that includes the observation strategy and arguments and evidence supporting the use of the strategy. You should give specific details for implementing that strategy, techniques and methods for communicating your group's assertions and ideas, as well as pros and cons (risks versus benefits) for that strategy.

Use the following guidelines to help prepare to "defend this!"

PRESENTATION PREPARATION GUIDELINES
- Provide a "description" of the observation strategy your group supports.

- What evidence supports your strategy? What evidence or data does not support your strategy, or possibly even directly opposes it? Use as much specific subject matter as possible in this section.

- What arguments, or logical reasoning, will you make to support your strategy? Use mathematics wherever possible – to organize evidence (spreadsheet sorting, tabular displays), and to analyze evidence (numerical formulas, graphical analyses, plotting data).

- What strategies will you use to present your arguments? Be prepared to present an explanation or illustration that clearly displays:
- How your group generated its evidence or data.
- What process your group used to analyze its evidence.
- How your group's analysis leads to the conclusion that this observation strategy is superior.
- Mathematical evidence in support of your strategy (any visual representations of the above, including use of poster boards, transparencies, computer graphics, etc.)

- How will your group satisfy the following stakeholders, considering that each will have different concerns and questions, and often these will depend on numerous human factors? For each person, anticipate what the representative group is most concerned with, and how they might react to different aspects of your plan. (Try to find at least one aspect that would prove disagreeable to each group.) How will your group satisfy or counter their question or concern?
- Mission Scientist
- Mission Engineer
- Space Agency Administrator
- Astronomer
- Environmentalist
- Public Citizen
- Education and Public Outreach Manager

- How does your observation strategy provide benefits in excess of the risks or costs? How does it minimize undesirable side effects? How does it minimize costs? What back-up measures will be built into your chosen method, thereby even further reducing the risk? (Remember that risk itself cannot ever be completely eliminated.) Be very systematic and objective in your approach, both in determining the positive balance your group hopes to portray, as well as considerate of the audiences you will address. Use mathematics (probability estimates, cost figures and analyses, successes, percentages, etc.) wherever possible.

- How will the technology inherent in your strategy lead to an advancement in the science, and vice-versa?

- What creative and interest-generating techniques and materials will your group use to make its presentation? (Remember that people, not scoring machinery, will determine the observation strategy considered most worthy for the mission.)

Clarifying the Issues
SUMMARY INTERVIEW SHEET

Question: Please tell us about your involvement with the Deep Impact mission and your thoughts about optimizing the data being received during the impact of Comet 9P/Tempel 1 in July of 2005.

Interview of: John Marriott
Job Title: Ball Aerospace, Deep Impact Program Manager
Institution: Ball Aerospace
Interviewer: John Ristvey
Date: July 5, 2001
Conducted by phone at Ball Aerospace in Boulder. Colorado

Ball Aerospace is responsible for the design and building of the Deep Impact flyby spacecraft, the impactor spacecraft, and three science instruments: a high-resolution imager, a medium-resolution imager, and the impact target sensor. The first two of these instruments are onboard the flyby spacecraft, and the last one is part of the impactor. As program manager, I oversee the development of this hardware and work with the Jet Propulsion Laboratory (JPL) and the University of Maryland to develop the mission operations and critical sequences of the Deep Impact mission.

The Deep Space Network (DSN) is the primary means of communications for robotic space missions. The principal investigator along with the mission planners at JPL are the primary people responsible for choosing the time of impact and which facilities will be used. We will need to work the actual mission sequences based on the current impact scenario. Since no one knows a whole lot about comets, we are going to be learning right up until launch. Other missions that are looking at comets will serve to inform our mission. This information could change the impact sequence of events up until shortly before the time of launch, in which case we would have to build a new sequence. The folks at Ball and JPL would get together and lay out exactly what the sequence needs to look like and then take this information to the software engineering group. The software group develops the new sequence, which is then tested, and verified. This software is then uploaded to the spacecraft through the DSN, causing the spacecraft to implement this new software at a particular time. This software is very complex, particularly with a spacecraft that does its own thinking. We have to be careful to develop comprehensive test programs for this software before it is uploaded to the spacecraft.

It is hard to tell at this point the other facilities that will be available during impact. We are looking very closely at the **Hubble Space Telescope (HST)**; we are looking at the Solar and Heliospheric Observatory (SIRTF), as well as the Chandra X-ray facility. We are evaluating the availability of observatories based on orbit patterns of space-based facilities, as well as the position of several ground-based facilities to determine where the best viewing is going to be. There are a lot of people right now working on exactly what the time sequence will be for the impact of the comet.

The data collection method itself is tried and true. The only thing that is different here is that we are using the latest and greatest software computers. The science team met recently at Ball and was delighted with the increased memory of this computer. However, the memory of the computer will fill up very quickly as we take more and more images. These computers are real enablers of science. The only concern I have is that as a deep space mission, Deep Impact has a rigid launch date. The comet is not going to wait for us. We have to make our deadlines. We have a lot of work to do in a short amount of time. Everything we have to do has been done before and done many times. But, we have to be there.

Clarifying the Issues
SUMMARY INTERVIEW SHEET

Question: Please tell us about your involvement with the Deep Impact mission and your thoughts about optimizing the data being received during the impact of Comet 9P/Tempel 1 in July of 2005.

Interview of: Dr. Karen J. Meech
Job Title: Astronomer
Institution: University of Hawaii-Honolulu Institute of Astronomy
Interviewer: John Ristvey
Date: July 10, 2001
Conducted by phone at her hotel in Washington, D.C.

My involvement with the Deep Impact mission is that I am the coordinator of all of the ground-based observing for the mission. We have been making observations of Comet 9P/Tempel 1 for Deep Impact ever since the mission was accepted. We had a huge observing campaign in 1999 and 2000. We used many ground-based observatories to get data about Comet 9P/Tempel 1 prior to impact.

One goal of these observations are to understand how much dust the comet puts out and when it starts to make this dust. This knowledge will be needed so we will be certain that the Deep Impact spacecraft will be safe when it passes near the comet. A second goal is the need to measure the chemical composition of the gasses coming from the nucleus prior to impact. Because the mission is going to create a large crater, we will measure the change in the types of gas after impact, in order to have a starting point for comparison. A third goal is to measure how fast the comet spins, which is important for targeting the impactor. We want to target the impact on the large side of the comet.

Much of this information that we are searching for prior to launch will help inform mission science and mission planning. There are many factors that we need to consider in deciding on a time of impact. If you think about public appeal, we would like to have as many people in the United States able to see the impact while the comet is above the horizon at night. This would provide the biggest "Ooh! Aah!" factor.

From a scientific point of view, we would like to have as many observatories in the world as possible to be looking at the event at the time of impact so we can maximize the science. Every observatory specializes in something different. We have a lot of telescopes in Chile that could be used. Since Chile is a little further east than Florida, it would be night time on the U.S. East coast at the same time as it would be night at Chile. We have a nice concentration of telescopes at Kitt Peak National Observatory in Arizona, and of course here in Hawaii. The question of which observatories to use boils down to two questions, "Do we pick having the impact during night time in Chile and get a huge amount of ground coverage? Or do we choose night time in Hawaii, where there are not as many telescopes, but it is a superb observing site?" Since the telescopes are spread out in Chile, we would have more options if the weather were bad in one location. If the spread of the telescopes was the only consideration, it would be an easy decision, but we also need to get data from the spacecraft via the **Deep Space Network (DSN)**. If we use Chile, we only are able to use one Deep Space Network site. If we use Hawaii, we would get an overlap of two DSN sites. There was a huge amount of discussion between scientists and engineers to which scenario to pick. With any decision, there will have to be a compromise somewhere.

Using orbiting telescopes like Hubble makes it even more difficult to schedule things, because Hubble has a 90-minute orbit and we would like to pick a time of impact when we can get as much of that 90-minute orbit as possible. There are certain periods when Hubble is not available. An advantage to using orbiting telescopes both prior to impact and during impact is that there are certain molecules, which emit light at wavelengths that are not accessible from the ground. Water is an example of a molecule that is not easily seen through our atmosphere. We will certainly use Hubble Space Telescope and other orbiting telescopes that we can.

So, we have a 90-minute time frame for Hubble, the need for two DSN sites, and the best ground-based viewing with sometime around July 4, 2005 for public viewing. It has been a challenge to mesh everything together to make sure it works when we want it to.

Clarifying the Issues
SUMMARY INTERVIEW SHEET

Question: Please tell us about your involvement with the Deep Impact mission and your thoughts about optimizing the data being received during the impact of Comet 9P/Tempel 1 in July of 2005.

Interview of: Brian Muirhead
Job Title: Deep Impact Project Manager
Institution: Jet Propulsion Laboratory
Interviewer: John Ristvey
Date: June 26, 2001
Conducted by phone at Jet Propulsion Laboratory in Pasadena, California

As project manager for Deep Impact, I am responsible for the development of the spacecraft and the design and operation of the mission. Together with the principal investigator, I am responsible for the overall success of the mission. I also manage the work that is done at the Jet Propulsion Laboratory (JPL) and Ball Aerospace so that the mission is on time and on budget. The most critical time of this mission is at the time of encounter with comet 9P/Tempel 1 on July 4, 2005. The quality of all our decisions will be measured then.

The Deep Impact mission is the first of its kind; impacting a comet has never been done before. I like working with people who get excited about these seemingly impossible mission projects. Deep Impact represents the most daring comet mission the United States has ever done.

One of the challenges of a deep space mission is returning data from the spacecraft to Earth. We have special radios onboard the spacecraft that transmit data at various data rates back to Earth. The **Deep Space Network (DSN)** antennas that are located around the world pick up the signal. We want to get as many pictures down from the spacecraft as fast as we can. A big challenge is that there may be only one chance to get these data after impact. With Deep Impact there is only one opportunity to send down data. If the Deep Impact spacecraft is hit with comet particles, we may not have the opportunity to send it down again.

Because it is so important for us to get this information down in a very short and critical time frame, we want to have two of our Deep Space Network stations able to receive data from Deep Impact. This will give us two chances to receive the data in the event that an electrical, mechanical, or weather problem occurs on one of the receivers. This is why at the time of impact and shortly thereafter, we are planning on having the spacecraft visible from two DSN stations.

Making a decision on which DSN stations and Earth-based observatories to use needs to be based on data about the location of the spacecraft and the location of the facilities on the ground. Mission planners take into consideration the past weather statistics for each location. Like many decisions, there is no crystal-clear answer; there are always conflicting factors. What we have to do is pick the optimal solution. The decision to use two DSN stations would limit some of the best Earth-based astronomical observatories. The principal investigator and I have determined at that at this time that having two ground stations is more important than having the most optimum Earth-based observatories. This decision is not final. We could change our strategy based on new evidence that would suggest that our initial decision was not the best.

The value of using the Hubble Space Telescope is that it can observe the impact without the problem of clouds or atmosphere. The quality of the cameras on board Hubble is outstanding, but I don't know how the resolution of Hubble compares with the best Earth-based observatories. One consideration for using orbiting telescopes is that scientists will have to make a proposal for access to Hubble that includes the object to be viewed, the viewing time, and the justification of the science objectives. There is no doubt that the science objectives of the Deep Impact mission would meet the requirements for using Hubble.

It is important to note that, as a result of the decisions we make here about timing the mission to get optimal data from the impact, there will be other decisions that will need to be made throughout this mission. There will be decisions made about what pictures, of what type, and how many of each we want to best meet our science objectives.

What Goes Around Comes Around

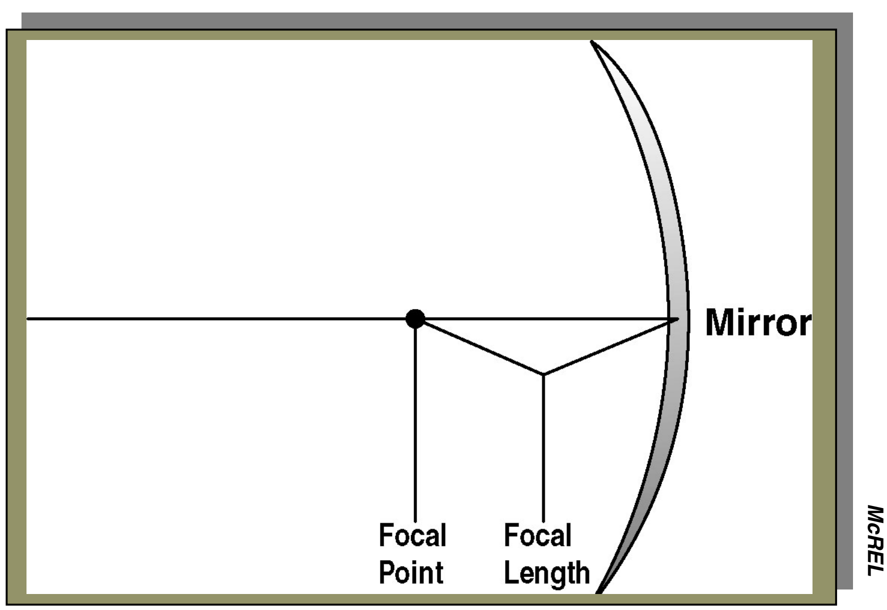
STUDENT TEXT

Science pushes technology, as scientists ask questions that demand more advanced instruments. Technology is essential to science. It provides instruments and techniques that offer observations of objects and events that are otherwise unobservable because of their quantity, distance, location, size, or speed.

The above statement, adapted from the National Science Education Standards, describes the reciprocal nature of science and technology. The more technology improves, the more science advances, and vice versa. This is a concept that is not often considered in many science classes. Modern science cannot be completed without the use of technology to enhance the human senses. As you have seen in the last two activities, it is not a matter of IF technology will be used, rather it is to WHAT EXTENT available technology will be used. The remainder of this text is a historical account of the reciprocal nature of science and technology using the telescope as an example. But, as is often the case in history, the question that is often asked is, “Which came first the chicken or the egg?”

In the case of the science of astronomy, it was the science that came first. From the dawn of time, humans have looked up at the sky in wonder. Babylonians around 1600 BC were keen observers of the nighttime sky and often recorded their observations of stars and planets on clay tablets. It was not until 3,000 years later that the telescope was first used to aid celestial observations. Scientists did not invent the telescope; rather, it was the product of craftsmen. For that reason, not much is known about the invention of the telescope since craftsmen were not often historically significant. The telescope was unveiled in the Netherlands. In October 1608, the government had patent applications from both Hans Lippershey and Jacob Metius for “seeing faraway things as though nearby.” The devices consisted of convex and concave lenses in a tube, which magnified objects three or four times. Lippershey charged his customers to use his new toy, so the telescope was first used to make money from curious people before it was even considered for science.

Although the telescope was first used for recreation and military use, it was not long before the telescope was applied to science. Galileo in 1610 used his telescope to look at the moon’s surface. He saw that it was not smooth and spherical as predicted; rather, it was rough with mountains and craters. Next, Galileo used the telescope to see that the Milky Way was made up of more stars than could be seen with the unaided eye. He also found that Jupiter and its moons resembled a mini solar system, though it was probably Kan Te of China who first saw “a bright red star” attached to Jupiter 2,000 years before Galileo “discovered” these four moons. Though Galileo made some enormous discoveries, it took other scientists several years to verify his findings since their telescopes were not adequate to do so.



It took hundreds of years and a lot of experimentation to get sharp images through telescopes. People were always trying to see farther into space, so the telescope was always being improved and even reinvented. For example Johannes Kepler proposed the use of two convex lenses in order to increase the astronomer's field of vision.

Not all improvements are from experimentation; sometimes technology advances by accident. “William Gascoigne, an amateur astronomer in England, was using a Kepler-style telescope when part of a spider's web found its way inside the telescope. One small web line happened to fall right at the focus point, so both the thin line and the image Gascoigne was viewing were magnified together. Gascoigne realized that he could more accurately point the telescope using the line as a guide, and he went on to invent the telescopic sight by purposefully placing wires at the focus point. This helped astronomers make more accurate observations and measurements of objects in space, using the thin wires as a reference point.” (JPL, 1998)

At the start of the 1600’s it was realized that increased magnification was achieved by increasing the **focal length** of the objective. The focal length is the distance from a lens or mirror to its focal point. The **focal point** is the place where parallel light rays converge after being reflected or refracted.

Beginning in the 1640s, the length of telescopes rose to lengths of 15 or 20 feet. A typical astronomical telescope of this era was the one made by Christiaan Huygens in 1656. His telescope was 23 feet long, magnified about 100 times, and was used to discover the rings of Saturn. Jean Dominique Cassini discovered many of the moons of Saturn. He used telescopes as long as 135 feet. It seemed that every time Cassini made a longer telescope, he discovered another moon! On March 13, 1781, William Herschel used a seven-foot telescope to discover a new planet, later called Uranus. As time passed, the reports of more discoveries thrilled people, who then wanted the latest telescope so they could see these new discoveries for themselves.

As mirror making and lens grinding began to improve, larger telescopes were made that needed to be housed in permanent buildings. At first, these observatories were built near large cities since that was where many scientists lived. However, it was discovered that the location of the telescope is as important as how big it is. Because of the lack of light pollution and factors such as clear skies and a thin atmosphere, many of the new observatories were built on mountaintops away from cities so that the best seeing could take place. The 200-inch Hale telescope located at Mount Palomar was completed in 1949. It revealed such wonders as the first quasars: star-like radio sources moving at incredible speeds at the edge of the visible universe. Once observatories on mountains became commonplace, scientists were interested in eliminating the effects of the atmosphere altogether.
The Gerard P. Kuiper Airborne Observatory (KAO) was a national facility operated by the National Aeronautics and Space Administration to support research in infrared astronomy since 1974. For over twenty years, the KAO was the world's only airborne telescope devoted exclusively to astronomical research. The plane was a converted C-141 military cargo plane that carried a 36-inch reflecting telescope. The KAO was the scene of many major discoveries, including the first sightings of the rings of Uranus and a definitive identification of an atmosphere on Pluto.

After the success of airborne observatories, the plan was to build an orbiting telescope that could be remotely controlled from Earth. The Hubble Space Telescope took eight years to build and was launched into orbit in 1990 by the space shuttle Atlantis. By observing 14,000 astronomical targets, Hubble has contributed significantly to our understanding of the universe from our solar system to the most distant galaxies. The Hubble Space Telescope has already outlasted its projected “life” and will retire by the end of 2010. The Next Generation Space Telescope scheduled to launch in 2009, will continue our quest to peer deeper into the far reaches of the universe.

As you can see from these examples, as the telescopes got bigger and better, the types of information that was learned increased causing the need for larger and more sophisticated instruments located at some exotic places. Science and technology are indeed reciprocal.

URL
http://www-isds.jpl.nasa.gov/cwo/cwo_54ga/html/cd/telescop.htm

Refining the Issues
TEACHER GUIDE

BACKGROUND INFORMATION

In this activity, students present a case for a particular data observation strategy scenario that is to be used to inform and convince others.

Student groups will use the materials prepared in the last activity to present and defend the cost, risk and benefits, and quality (meeting science objectives) of their chosen observation strategy. Students assume roles of various stakeholders of the mission including scientists, engineers, and the interested public such as environmentalists, politicians, teachers, students, and others. General guidelines are provided for students to follow for each role, though they are encouraged to build the position of the role they are portraying. Prior to the debate, students will study text profiles or audio clips of some of the stakeholders in order to bring additional information into the mix. Students use the information from the presentations in order to prepare for a debate about the data observation strategies at a public forum. The case built by each group includes the details on the observation strategy or combination of methods being advocated, specific details for implementing that method, and the pros and cons for that method.

The National Science Education Standards call for students to communicate scientific procedures and explanations. In the process, students describe and explain ideas and concepts, make predictions, and demonstrate processes and techniques using models. Throughout their delivery of the presentation, students must base the claims they present on evidence and logical argument. Therefore, it is important that in developing their presentation package, students have decided what evidence to use, and that they have prepared to defend certain evidence or anomalous data. During presentations and debate, students should demonstrate that they have given considerable thought to the manner they have chosen to use to communicate the techniques and methods they used to generate, analyze, and draw conclusions from their evidence. The various uses of mathematics they have employed should be demonstrated, as well as the processes they used to gather, organize, and present data. Students also learn to take the position of stakeholders that must learn what is required to make a rational and informed decision in the next activity. To do this, they use role guides that illustrate the positions of scientists, engineers, technicians, and public citizens who will each pose different concerns and questions.

Each group's solution relates to human needs, desires, and opinions, and these are a part of the debate in this activity, and a part of the decision-making process in which the students engage in the next activity. Every data collection solution being prepared will have side effects, and each student should pose questions around how well the group and their observation strategy balances costs and risks of their solution with the benefits that will be recognized. Students should also ask questions about how the science is possibly advanced due to technology advocated in the chosen method, and how the technology can in turn be driven to higher standards by the science that may be gained as a unique result of use of the method. Each group's back-up measures should be explained and thoroughly queried. This process exists in an effort to uncover any information necessary to select the method in the next activity that best reduces the risk, realizing elimination is not possible. Finally, students should demonstrate creativity and insight in their presentations, in the recognition that in the next activity it is people, not scoring machinery, who will determine the method of collection considered most worthy for the mission.

NATIONAL SCIENCE STANDARDS ADDRESSED

Grades 5-8
Science As Inquiry
- Abilities Necessary to do scientific inquiry.
  - Develop descriptions, explanations, predictions, and models using evidence.
  - Think critically and logically to make the relationships between evidence and explanations.
  - Communicate scientific procedures and explanations.
  - Use mathematics in all aspects of scientific inquiry.

Science and Technology

Understandings about science and technology.

Science in Personal and Social Perspectives

Risks and benefits.

Science and technology in society.

History and Nature of Science

Science as a human endeavor.

Nature of science.

Grades 9-12

Science As Inquiry

Abilities Necessary to do scientific inquiry.

Formulate and revise explanations and models using logic and evidence.

Recognize and analyze alternative explanations and models.

Communicate and defend a scientific argument.

Science and Technology

Understandings about science and technology.

History and Nature of Science

Science as a human endeavor.

Nature of scientific knowledge.

LANGUAGE ARTS STANDARDS ADDRESSED

Standard: 8

Demonstrates competence in speaking and listening as tools for learning.

Level III Grades 6-8

Listening and Speaking

Conveys a clear main point when speaking to others and stays on the topic being discussed.

Presents simple prepared reports to the class.

Level IV Grades 9-12

Listening and Speaking

Adjusts message wording and delivery to particular audiences and for particular purposes (e.g., to defend a position, to entertain, to inform, to persuade).

Makes formal presentations to the class (e.g., includes definitions for clarity; supports main ideas using anecdotes, examples, statistics, analogies, and other evidence; uses visual aids or technology).

Responds to questions and feedback about own presentations (e.g., defends ideas, expands on a topic, uses logical arguments).

MATERIALS

For each student:

- “Public Forum Role Sheets”
- Completed Student Presentation Guides, “Defend This!” (from last activity)
- Assessment Guide, “Critiquing Ideas”
- Student Text, “Communicating, Questioning, and Listening”
- Prepared presentation aids (poster board, computer disks, etc.)

PROCEDURE

1. Tell students that they are now going to use their group’s preparations from the last activity in order to present their observation strategy ideas for science team and public review. Tell them to move into their groups only when they are called upon to present. During the presentations by other groups, they will assume various roles in the public forum, and one representative of each role will be chosen to “officially” represent that role on a panel. Tell students that they each must play the role of a panel representative during at least one presentation. They will play each role at least once, and so will need to become familiar with each role for the stakeholders involved in the meeting. Tell students that they will have 10–15 minutes of the class period in their group at the start of the period in which they are to present to review the plans and procedures they will follow in their presentation. During that time, other students will work in a different group, comprised of those students who will assume a particular role in the audience, and the panel representative for that role.

> **Teaching Tip**
> Ask students to write additional roles on the Forum Role Sheets.

2. Ask students who are to present to move into their groups, and to go over their presentation quietly. Make sure they have all presentation aids, illustrations, data, notes and note cards, etc. ready, as well as the sequence in which they will present. The primary information they need should be on the completed student presentation guide from the last activity. They may be allowed to prepare the front of the classroom for their presentation. This could include posting any signage they wish (e.g., name of observation strategy, data or evidence charts, graphs, etc.), preparation of overhead projector and distance of projector from screen, organizing transparencies, computer and projector connections, and so forth. Distribute the “Public Forum Role Sheets” to each of the other students, and ask them to select the role they wish to play, or assign that role. If students choose, you may need to ask for volunteers to switch to another role for the day, as it is important to have a fairly equal number of representatives for each role during the presentation. Students should realize that they will play each role at least once anyway, so it should not be an issue. Ask them to move into groups with the other students who will assume that role and prepare their part for the day. Their preparation should include becoming familiar with the specific concerns for the audience roles they will represent, and the types of questions they may ask. The preparation of the exact questions to ask

> **Alternate Strategy Tip**
> For a writing extension, ask students to write additional role sheets that can be used during the debate. Examples could include, politicians, outside reviewer, teachers, students, media relations personnel, and others.

> **Teaching Tip**
>
> Students, especially those in middle school, often enjoy preparing for roles as specific people, with character traits and motivations specific to their character. You may wish to allow students to build upon their roles by incorporating a name for their character and/or a specific title. This could even lead to research on the various occupations and specialized careers available to students looking to the possibilities of a future in space science, astronomy, or even NASA. Some students might enjoy dressing the part of their role. Take care, however, to avoid stereotypes in extending the role-playing activity to this point.

cannot be entirely created prior to hearing the presentation, but students can be prepared to look for certain cues and areas their character would like to see addressed. Pass out the Student Text “Communication, Questioning, and Listening” to all students, and ask that they read through the strategies given to help them better attend to their roles during the presentation. At this time they should also choose their role’s panel representative.

> **Teaching Tip**
> As you preview the assessment guide with your students, you should help them define any words they may not understand.

3. Distribute a copy of the assessment guide, “Critiquing Ideas.” Explain to students what each category of the guide means, that the scores within each category represent a continuum, and that they should use the guide to assess on the continuum where each group falls as they make their presentation. Students should note that some categories provided deal specifically with the evidence and other information that supports or does not support their chosen data observation strategy. Other categories deal with delivery and presentation technique, preparedness, quality of visual aids, and so forth. Tell them you will also use a similar guide to assess each group. Note that the rubric contains space for you to add criteria of your own, if you choose to do so. You may even wish to design additional scoring criteria together with your students. Students should realize the importance of their responsiveness and participation in representing a particular audience and/or panel role. Now is also a good time to post the forum rules, or distribute copies for students to review.

> **Teaching Tip**
>
> It is difficult for students to effectively critique their classmates, but the critique is an essential part of the learning they derive from this stage of the cycle. To help prepare them to accomplish this task effectively, you may use a short video of a group or individual making a presentation that is intended to be persuasive. Ask them to evaluate the presentation using a modified version of the critique guide. It is not necessary for the presentation to specifically deal with observation strategies. Students should compare and students may discuss the reasons why they assigned a particular score. You may even use a particular group’s presentation from your own class if you see the need after the presentations have begun. Remember to acquire written permission from students prior to filming or using video or pictures of them for any purposes.

4. Ask a student group to conduct its presentation, and audience members to adhere to their roles during the presentation. Ask each student to complete their critique of the group’s performance and quality of its “case.” Conduct your own assessment of the group as well. Allow at least 5 minutes at the end of the presentation for completing the critique.

> **Teaching Tip**
> Consider conducting the presentations as a press conference. Videotape the press conference so that it can be reviewed later. Student should decide what information they want the public to know.
>
> Students should also choose graphics that would gain the public’s attention.

RESOURCE

National Research Council. (2000). *Inquiry and the National Science Education Standards.* National Academy Press. Washington, D.C.

Refining the Issues

PUBLIC FORUM ROLE SHEET

Mission Scientist

As a mission scientist, meeting the science objectives of the mission is the number one priority for you. These include:

1. Hit nucleus of 9P/Tempel 1 with sufficient kinetic energy to form a crater with a depth greater than twenty meters.
2. Observe nucleus for more than 10 minutes following impact.
3. Image nucleus impact, crater development, and inside of crater.
4. Obtain spectrometry of nucleus and inside of crater.
5. Acquire, store, format, and down link imagery and spectrometry data.

You have been interested in comets all of your life, and you see this as the best opportunity to make new discoveries about the inside of a comet. You are very open to availing yourself of all of the options for obtaining data for Deep Impact. You realize that much of the funding for this mission involves the use of onboard instruments that will image the impact and send the images to the Earth. Therefore the Deep Space Network is the primary collection method. Since various Earth-based observatories offer a different perspective of the comet, you are in favor of including as many large Earth-based observatories as possible. Telescopes above the Earth's atmosphere should also be used to obtain even more valuable data. You see this decision as being very important to the overall success of this mission, which will help scientists learn more about the small bodies of our solar system.

Mission Engineer

You have worked many space science missions in the past 20 years. You understand that it is critical to meet the science objectives for this mission. You have managed the design and construction of the spacecraft and most of the science instruments. You are confident that the instruments onboard are the best possible for imaging the impact of 9P/Tempel 1. You prefer to simply do everything possible to ensure a successful mission. Because of your experience with other missions, you believe that having redundant DSN sites available during the time of impact is the best way to ensure that data obtained from the spacecraft instruments will perform as designed. While you understand and respect the science team for wanting to use Earth-based observatories and the Deep Space Network, you often point out that timing the impact to use these facilities may compromise the redundancy of the Deep Space Network. At meetings you often point out that there are possibilities of weather issues and poor seeing conditions if Earth-based observatories are given priority. There is no mission without the use of the science instruments.

Space Agency Administrator

You have been a big advocate for this mission over the years. You know the principal investigator and many of the people on the science team personally. Your interest is that the mission is as successful as possible while maintaining fiscal responsibility. You have overseen past missions in which the spacecraft builder has provided instruments that provided success for these missions. You find it intriguing that there are so many options for obtaining data. You agree that having redundancy in the Deep Space Network would ensure mission success. Since the costs for adding the use of Earth-based and Earth-orbiting facilities are small compared to the science instruments onboard the spacecraft, you are not opposed to the mission planners pursuing these options. During a recent review, you gave the science team high marks for the comprehensive study of the comet by Earth-based observatories that have occurred thus far and will continue through the launch of the Deep Impact mission.

Astronomer

You have been observing far-away objects in our solar system for the last 30 years. You were the co-discoverer of several Kuiper belt objects during your time at a major observatory. Though you are not personally affiliated with any of observatories on the list, you have a strong interest in studying the images that will come from this mission after impact of Comet 9P/Tempel 1 in 2005. You hope to use the images to confirm your theories of the composition of comets, which will give us a better picture of the origin of our solar system. You are opposed to light pollution, which may be caused by people who use lighting fixtures that cause the light to shine into the sky. Light pollution makes it difficult for amateur astronomers to see objects in the nighttime sky. You are interested in working with amateur astronomers in getting images of the impact from the Deep Impact mission.

Environmentalist

You have been an environmentalist since the 1960's. You do not care for NASA or the missions that are funded. You believe the money that is used for space exploration should be used to make the environment clean for the next generation. You are personally concerned that this mission proposes to "impact a comet." You think that for years we have destroyed our own planet and that we should not destroy another world.

Public Citizen

You have been ambivalent to the space program, but enjoy watching science shows on the television. You discovered the Deep Impact mission while surfing the Internet. When you saw the mission homepage, you wanted to learn more about the mission. As a manager of a local business, you were intrigued with how the decisions that the science team and mission planner made in regard to the timing of impact closely resembled the process that you use everyday to make corporate decisions. You look forward to following this mission and watching about the impact on TV.

Education and Public Outreach Manager

As an education and public outreach manager, your job is to provide educators and the general public information and educational materials about the Deep Impact mission. Your goals are to increase public interest in space science as well as increase student awareness of space-related careers. You see the decision being made in the mission planning as a great example of the processes people need to make in their everyday lives. You think that the decision-making process is more important than the actual decision that is made.

Write your own roles here:

Critiquing Ideas
ASSESSMENT GUIDE

As students present a case for a data collection method, assess the quality of their work as thoroughly and as equitably as you possibly can. The following criteria can be used, along with additions that have been agreed upon in advance.

Collection Method Description			
1 Description of data collection method(s) not provided or addressed.	2 Description of data collection method(s) is provided, but not expressed in a manner that is clear and easily understandable.	3 Description of data collection method(s) is provided in clear and understandable manner, but lacks some thoroughness.	4 Description of data collection method(s) is clear, understandable, thorough, and reinforced throughout presentation.
Evidence and Argument			
1 Evidence is not provided.	2 Some evidence is provided, but not explained or shown to be supportive of data collection method chosen.	3 Evidence is explained, but not used as effectively as possible to support argument for collection method chosen.	4 Evidence is explained and used admirably throughout presentation to support data collection method chosen.
Main Points and Organization			
1 Main points are not provided.	2 Main points are provided, but not organized.	3 Main points are provided and organized, but sometimes lost in the presentation.	4 Main points are clear, concise, and supported throughout presentation.
Scientific Merit			
1 Method(s) does not provide data that answers fundamental mission questions.	2 Method(s) provides data that only partially answers fundamental mission questions.	3 Method(s) provides data that answers fundamental mission questions, but does not allow for comparison, ties existing data, or compliments, to future projects.	4 Method(s) will provide data that answers mission questions, can be tied to existing data, allows for comparisons, and complements future projects and research.
Technical Merit			
1 Method(s) does not use tested instrumentation, and shows no indication of cost-effectiveness or minimization of risk.	2 Method(s) uses partially tested instrumentation, and carries costs, risk of data loss, no stated or implied potential for added value of data.	3 Method(s) has heritage in that instrumentation is fairly well proven, but represents questionable cost, possible but not overwhelming potential for data loss, and unclear added potential value.	4 Method(s) uses tested and proven instrumentation, represents minimal cost and/or risk of data loss, and provides for efficient data archival and posting, and provides added data value.

Visual Aids			
1 Visual aids are not provided.	2 Visual aids are provided, but not illustrative of important concepts.	3 Visual aids are well-done, and illustrative of important concepts.	4 Visual aids are well-done, reinforce important concepts, and effectively reinforce the presentation.
Delivery			
1 Group does not appear prepared to speak.	2 Delivery is systematic, but with annoying mannerisms and no eye contact.	3 Delivery is clean and clear, with some eye contact and very few annoyances.	4 Delivery is exceptional and unique, with regular eye contact and no annoyances.
Public Support			
1 Method(s) portrays potential negative public impact, environmentally or otherwise, and no information is provided to allay this impression.	2 Public support is not directly sought, nor is the question of environmental impact raised or implied.	3 Desire for public support is implied but not cultivated with definitive information; simple statement is made regarding the lack of potential negative environmental impact.	4 Information is provided to promote public support, and relationship of method(s) and potential environmental impact are respectfully and positively described.
Credibility of Resources			
1 Resources were mostly non-scientific sources, like tabloid newspapers; or all sources were encyclopedias.	2 Some resources were questionable, non-scientific sources; the majority of sources were encyclopedias.	3 Most resources were reliable scientific sources; encyclopedias were used only as first sources for terminology.	4 All resources were reliable scientific sources.

Use this space to create additional scoring criteria.

Visual Aids			
1	2	3	4

Delivery			
1	2	3	4

Communicating, Questioning, and Listening
STUDENT TEXT

Communicating
Communicating clearly and effectively is an important part of any presentation. Through effective communication, a presenter is able to convey knowledge and understanding of a topic, and therefore solicit appropriate feedback, input, or questions as needed. Whether in a classroom, on the job, or in an interview, the importance of communicating informatively has become recognized worldwide. When asked later in their careers, many college graduates rank communication skills as most important to their jobs, regardless of the field. In preparing to communicate effectively, once your topic or the content of your presentation is selected, make sure that you organize your presentation, research the information you plan to present, illustrate certain key concepts, and deliver your message crisply and clearly.

Organize
It is essential to provide your audience with information in a highly- organized format. A good way to begin the organizing process is to identify the main point points that you want to cover. As most listeners cannot keep track of multiple main points, try to limit your points to between two and four. These main points comprise the central features of your presentation, and should be organized in the most appropriate order (chronologically, spatially, topically, etc.). An introduction should then be developed. The purpose of the introduction is to introduce the topic, list the main points of the presentation, and get the audience's interest and attention. Finally, you should develop a conclusion by creating a simple summation of the information revealed in the main points. The conclusion, of course, will signify the closure of the presentation.

Research
Your presentation should be based on research. Not only should each main point be researched, but also the items that surround and back up the main points. Collecting information for your presentation will provide helpful materials and ideas, useful ways of articulating or illustrating ideas, and so forth. A personal interview with someone who is an authority on the topic is a valuable resource. Gathering good materials serves a variety of purposes. Good information adds to the amount of evidence or data that can be revealed. It also enhances your credibility as a presenter. Good resources take the material presented beyond that of assumptions and offer good reasons why the presenter should be believed. It is important to remember, however, that resources that do not specifically offer additional insight or data that is germane to the presentation should not be used. If it seems like good information, but not fitting to the presentation at hand, set it aside. It is easier than throwing it away, and who knows? You may need it for another project one day.

Illustrate
When a visual aid supports a message in a presentation, it adds dramatic impact. Visual aids can be valuable tools for building interest and for helping you to get a certain point across. They can include models, charts, computer-generated graphics, drawings, graphs, objects, photographs, slides, videotapes, transparencies, or anything else that is appropriate for the presentation. Listed below are nine tips to assist you in the effective use of visual aids in your presentation:

- Practice with the visual aid in advance. Be sure that it functions correctly.
- Avoid presenting while using the chalkboard. Another group member may use an aid of this type, but the presenter of the moment does not want to turn his or her back on the audience.
- Explain the visual aid clearly. It is not enough to show the aid to the class; tell the audience what it means.
- Prepare the visual aid in advance. Early preparation will result in a quality piece of work, and the visual aid will be ready for you to use when you are practicing the presentation.
- Talk to the audience, not the visual aid.
- Be certain that the visual aid is large enough for the audience to see. A visual aid is useless if only those audience members seated in the front row can see it.

- Display visual aids only while they are being discussed. If kept in sight, they will serve as a distraction.
- Display visual aids where they can best be seen. You should determine the best placement of your visual aids prior to the presentation.
- Never pass visual aids among the audience members. At least three people in the audience will be more interested in the aid than they are in you – the last person who had it, the person who has it, and the person who will get it next.

Delivery
Well-delivered presentations feature presenters who are prepared and interested in their topic. They establish eye contact with members of the audience, and generally display a clear sense of purpose. Good presenters do not seek to draw attention to themselves. For this reason, most will avoid conspicuous dress on the day they present. They will also avoid distracting mannerisms, such as chewing gum, staring or gazing, mumbling or talking in a monotone, or moving about too much or too frequently. The audience should be tuned in to your words, not you. Use the proper volume. The best presentation falls on deaf ears if it cannot be heard. Speaking rate, vocal variety, good articulation, and well-placed pauses are also important for a well-delivered presentation. You should practice presenting—at home in front of the mirror, in the car with family, or at a friend's house. The more familiar you are with the presentation itself, the more at ease you will feel when you approach the front of a room to make the final presentation to your audience.

Questioning
The ability to ask the right type of question, and the way you respond to the answers you receive, often determines whether or not you are able to determine what you need to know in order to proceed with any investigation. It is also important to help you determine if another investigation or theory is headed in the right direction.

THREE CATEGORIES OF QUESTIONS

There are numerous types of questions that may be asked. Along with other types, some questions may be designed to obtain differentiation, support, or clarification. The following is a description of each of these three potential categories of questions, and possible examples of each.

Differentiation
These types of questions call for those responding to apply a certain concept or set of circumstances to another situation, or to describe different processes they may have used to do the same thing. Examples include:
What would happen if…?
In what other ways could you…?

Support
These types of questions call for those responding to provide reasons or information to back up a statement, claim, or belief they have made. Examples include:
Why do you think this is true for all…?
What makes you say…?

Clarification
These types of questions call for those responding to rephrase a statement, or to provide further description, details, extensions, or applications. Examples include:
If that is the case, then how does this…?
How would this apply to…?

QUESTIONING IN ORDER TO LEARN

One of the most obvious reasons for asking a question is to extend or engage the thinking of an individual. There are several ways to do this effectively. When asking questions, try to:

- Paraphrase rather than praise. Open scientific discussion should not encourage conformity by praising the mundane. Paraphrasing and/or rephrasing signifies that you've heard and understand what has been said, without necessarily indicating that any judgments or opinions have yet been formed. Asking others to rephrase will also ensure that they understand what you have said.
- Use precise, not abstract, language. You've probably heard the saying, "If you can't dazzle them with brilliance, puzzle them with baloney." Don't believe it. If it works once, it certainly won't twice, not with anyone worth "puzzling" anyway. Be simple and straightforward with your questions, and say exactly what you mean, in as few words as possible.
- Question randomly, and acknowledge all responses. If you restrict your learning to only a few people, you don't learn nearly as much. If you only ask questions of a few people, you are restricting your learning to those few. If those to whom you ask questions have potentially valuable information to share, their questions should be acknowledged accordingly, and accepted. "Valuing" a response does not mean you have to agree, but helps you make sure that person continues to respond, so that you can continue to learn.
- Ask open-ended questions. "Yes" or "no" responses do not provide the depth of information you need.
- Base questions on responses. Keep detailed notes of discussions and who says what, and refer to that person or point in other questions. It will accomplish several things. For example, it makes everyone aware that when they speak, people are listening very closely. It also calls attention to conflicting comments from individuals who are supposedly taking the same point of view, or purporting the same claim.

Listening
Listening attentively is an important part of participating in any presentation. If you are being asked to respond to information you are provided in the presentation, or if you are being asked to give input, whether in the form of questions, ideas, or additional information, it is especially critical. Learning to listen effectively and clearly is an often-overlooked way to improve communication skills. The best communicators, in fact, are usually the best listeners. Though we live in an age of rapid communication—facsimiles, e-mail, Web sites—the truth is that face-to-face communication is still alive and well. Have you ever seen the floor of the New York Stock Exchange when trading is in a flurry? What if everyone talked instead of listening? What if no one listened closely? One mistake could cost millions of dollars. Additionally, it is not just in dollars that high prices are paid. Think about the consequences of testimony given in error on the witness stand as a result of poor listening. Costly mistakes can happen in the corporate world, in the court room, at the negotiating table, and in an interview—all as a result of poor listening. According to listening experts like Dr. Lyman K. Steil of the University of Minnesota, Americans spend most of their communication time in listening, followed by speaking, then reading, and last, by writing. Yet, poor listening is all too prevalent. Poor listening skills often result in a lack of comprehension, which affects a person's ability to conceptualize, analyze, and consider solutions. In short, the inability to listen effectively directly impacts critical thinking skills.

Scientists often search for ways to engage with each other in critical thinking exercises. Expanded critical thinking skills invite effective questioning, which in turn opens the door to engaging debates. The end result is the creation of an environment that is conducive to learning. Participants find out that they can offer their own ideas, concepts, questions, and perspectives in an environment that respects individual opinions. And most importantly, they learn the benefit of listening—to their peers, to other experts, and even to the public.

TIPS FOR EFFECTIVE LISTENING

There are strategies for becoming a better listener, but they all require work and practice. Listed below are six tips on effective listening.

- **Listen for main points.** It is important to listen for content. Watch for signals from the presenter's eyes, body, face, voice, and gestures. Pay attention to visual materials.
- **Listen for evidence.** Resist the temptation to form a conclusion early in the discussion. Let the presenter complete his or her thought and then evaluate the evidence by distinguishing the specifics vs. the generalities, the believable vs. the incredible, etc.
- **Develop note-taking skills.** Listening is not exclusively memory related. Part of developing good listening skills is learning to write down the important part of the discussion.
- **Resist distractions.** Clear your mind if someone is presenting. This will help you to be more receptive to what they are saying.
- **Suspend judgement.** Never assume that you have heard correctly because the first few words have taken you in one direction. Some people only hear the first few words of a sentence, finish the sentence in their own minds, and miss the second half. These people represent most of the listening mistakes.

Don't be diverted by appearance or delivery. Don't tune out a speaker just because you don't like his or her looks, voice, or general mannerisms. Pride yourself on remaining open to new ideas and information

The Decision
TEACHER GUIDE

BACKGROUND INFORMATION
In a written forum, students prepare written statements for the data observation strategy they personally agree with. On the same page, students will support a position statement that advocates additional viewpoints. As a large group discussion, the class comes to an agreement on which observation strategy is best at this time, knowing that as more information or circumstances come into play, this can change. Students determine the method for coming to a consensus.

The National Science Education Assessment standards call for achievement data to focus on the science content that is most important for students to learn. Over the course of this module, students have been given opportunities to reason scientifically, use science to make decisions and take positions on issues, and communicate effectively about science. The standards go on to say that assessment processes include all outcomes for student achievement and should probe the extent and organization of this achievement. The statements that students write not only support the "knowledge" that they have learned, but also take into consideration how the students have utilized the knowledge and decision-making processes. The final activity of this module will allow for students to demonstrate their full understanding and ability as well as reflect on their experiences and how they might apply these processes in the future.

NATIONAL SCIENCE STANDARDS ADDRESSED

Grades 5-8
Science As Inquiry
Abilities Necessary to do scientific inquiry.
Think critically and logically to make the relationships between evidence and explanations.
Recognize and analyze alternative explanations and predictions.
Communicate scientific procedures and explanations.
Use mathematics in all aspects of scientific inquiry.

Science and Technology
Understandings about science and technology.

Science in Personal and Social Perspectives
Risks and benefits.
Science and technology in society.

History and Nature of Science
Science as a human endeavor.
Nature of science.

Grades 9-12
Science As Inquiry
Abilities Necessary to do scientific inquiry.
Formulate and revise scientific explanations using logic and evidence.
Recognize and analyze alternative explanations and models.
Communicate and defend a scientific argument.

Science and Technology
Understandings about science and technology.

History and Nature of Science
Nature of scientific knowledge.

LIFE SKILLS STANDARDS

Thinking and Reasoning

Applies decision-making techniques

Secures factual information needed to evaluate alternatives.

Predicts the consequences of selecting each alternative.

Makes decisions based on the data obtained and the criteria identified.

LANGUAGE ARTS STANDARDS

Writing

Uses the general skills and strategies of the writing process

Drafting and Revising: Uses a variety of strategies to draft and revise written work.

MATERIALS

For each student:

- Peer Review Checklist

Teaching Tip

In using a peer review process, you may want to have the students place a distinguishing symbol in place of their name, so that the compositions can be reviewed anonymously and returned to the writer.

PROCEDURE

1. Tell students that this assessment is a written composition in which they need to decide which combination of observation strategies they most agree with, based on the evidence collected during the research phase and the information presented. Give the following general instructions:
   - The length of your statement should be between 1-3 pages.
   - Introduce your position on the collection combination that represents the best use of resources while meeting the science objectives of the Deep Impact mission.
   - Provide one or more reasons for your position.
   - Provide support for the reasons—evidence from the research and debates.
   - Write a conclusion that drives home the point you are making.

2. Once students have completed their written composition, collect the papers for use as a peer review. Distribute the peer review checklist to be used by the peer reviewers. Have the peer reviewers write their name at the top of the checklist and staple the checklist to the composition to be returned to the teacher and then the author.

Teaching Tip

Explain to students that the number of checked items: per category does not indicate that the category is more important than others. Communicate to students which items are most important.

3. Allow time for the original writers to read the comments and respond to them. This may necessitate some re-writing of the material. In some cases the original writers may disagree with the comments and not want to include them. This is fine as long as they can justify this on their paper.

4. Have the students repeat this process by having the students write another composition that supports a position statement that advocates other viewpoints. This should have the same requirements as those stated above in procedure 1.

5. Repeat the peer review process, allowing time for the students to react to peers’ comments before submitting the final draft of both compositions to the teacher.

6. Explain to students that after the mission planners have completed their research, listened to opposing viewpoints, and considered alternatives, a decision on how to move forward must be made. Instruct students to work in their small groups to generate a short summary of the different scenarios that have been written about in the first part of this lesson. Once groups have had a chance to develop their summary, have a representative share the scenario summaries. During this sharing out time, have a volunteer record these summaries onto the board or overhead. As a large group, synthesize the list such that commonalties from all of the various scenarios are combined until there is a workable list of 3-5 to choose from.

7. Hold a discussion with your class to determine how this decision should be made. Provide the following list of possibilities:
   - The principal investigator makes the decision.
   - The science team makes the decision.
   - The engineering team makes the decision.
   - The mission planners take a vote and the outcome is the position of a simple majority of the voters.
   - The mission planners take a vote and the outcome is the position of a predetermined majority of the voters.
   - The mission planners vote to eliminate all but the top two choices; a second vote is taken, and the outcome is the position of the majority.
   - The decision must be unanimous.
   - A group is elected or appointed to represent the mission planners; this group uses one of the above methods.

8. Ask the class if any of these possibilities need clarification. If so, provide this before asking the small groups to discuss each of the above decision-making strategies. On a sheet of paper they should list the strengths and weaknesses of each of these methods and determine which one should be used.

9. Once each group has completed a list and has made a decision about how to decide, hold a vote with each group registering one vote for one of the decision-making methods.

10. Based on this decision, make the decision on how to move forward for this mission. Your students may be interested in learning how the Deep Impact team made this decision and following the mission as progresses toward Comet 9P/Tempel 1.

RESOURCES

http://www.cgocable.net/~rayser/peereval.txt
Peer editing check sheet by Lynne Cattafi

http://www.cgocable.net/~rayser/writing.htm
Lesson Plans: Literature, Writing, Poetry & Library Skills, Outta Ray's Head

The Decision

PEER REVIEW CHECKLIST

BACKGROUND INFORMATION

Use this checklist as you review a peer's composition. Answer the following questions in detail. Use complete sentences when answering.

Content

- Does the composition use good and accurate information from the research?
- Is the writer's argument convincing? Do you buy the writer's argument?
- Does the writer use evidence from the research and presentations?
- Is the composition interesting to read?

Style

- Does the paragraph contain misspellings? If so, circle them in the paragraph.
- Does the paragraph contain run-on sentences or fragments? If so, point them out.
- Does the writer use transition words effectively?
- Does the writer use adverbs and adjectives effectively? If not, suggest some ways he or she can do so.

- Does the paragraph contain frequent errors? If so, point them out.

- Does the paragraph contain errors in capitalization? If so, point them out.

- Does the paragraph contain punctuation errors? If so, point them out.

- Does the writer repeat him- or herself? If so, indicate where this occurs.

Conclusion

- Does the conclusion show the importance of the composition?

- Does the conclusion simply summarize the paragraph? (It should not do this). If so, point this out to the writer.

Miscellaneous

- What one or two things did the writer do very well in this paragraph?

- What one or two things does the writer need to do better/change?

What is your overall impression of the paragraph?

GLOSSARY
APPENDIX E

Astronomical Unit (AU) - Standard unit for measuring distance within the solar system. One AU is equal to the average distance between the Sun and Earth or about 93 million miles.

Charge-Coupled Device (CCD) - Charge-coupled devices (CCDs). Technological instruments that contain light-sensitive silicon chips with an arrangement of light-sensitive spots called pixels.

Coma (or the comet's head) - The comet's coma or head is the fuzzy haze that surrounds the comet's true nucleus. The coma (and tail) are really all that we see from Earth.

Declination (DEC) - Declination is measured in degrees, and refers to how far above the imaginary "celestial equator" an object is (like latitude on the Earth).

Deep Space Network (DSN) - An international network of antennas that supports interplanetary spacecraft missions and radio and radar astronomy observations for the exploration of the solar system and the universe.

Earth's Shadow - The unlit side of the Earth.

Ecliptic - From the Earth, the apparent yearly path on the celestial sphere of the Sun with respect to the stars; also, the plane of the Earth's orbit.

Ejecta - Material expelled from the impact site during a crater formation.

Ephemeris (Ephemerides; plural) - A table that gives the positions of objects in the sky at various times.

Focal Length - The distance from a lens or mirror to its focal point.

Focal Point - The point at which parallel light rays, incident on a mirror, are focused after reflecting. For concave mirrors, the focal point is on the same side of the mirror as the source.

Hubble Space Telescope (HST) - A space telescope launched in 1990 by the U.S. space shuttle into a low-earth orbit; with a 2.4 meter mirror, HST can observe faint objects with high resolution, especially in the ultraviolet.

Observation Time - The time that a scientist plans to make an astronomical observation.

Nucleus of a comet - The center of the coma (head) of a comet. The true nucleus of a comet has only been seen once from a spacecraft. From the ground, the star-like nucleus always includes a cloud of dust and gas around the true nucleus.

Redundancy - More than one of something in order to ensure that results are not hampered by a failure. For this mission, having more than one Deep Space Network antenna used to receive data from the Deep Impact spacecraft.

Right ascension (RA) - Right ascension is measured in hours of time. It is similar to longitude on the Earth. Astronomers have chosen the Vernal Equinox to define the starting point for the measurement of right ascension. The Vernal Equinox is the point where the Sun appears to cross the Celestial Equator at the beginning of spring. It is therefore one of the two points where the Ecliptic intersects the Celestial Equator.

Selection Phase - The time at which a mission is being considered for funding.

Spectra - Plural of spectrum.

Spectroscopy - The study of spectra.

Spectrum - The distribution of energy from a radiant source, arranged in order of wavelengths.

Superordinate (umbrella term) - A word whose meaning encompasses the meaning of another, more specific word.

Zodiacal light - Sunlight reflected from dust in the plane of the ecliptic.

Decision Making Process

APPENDIX F

KEY POINTS

1. Help students understand how important it is to generate clear criteria that accurately identify the conditions that the selected alternatives need to meet.
2. Hold students accountable for rigorously applying criteria to alternatives.
3. Vary the way that you use decision making to maximize its potential for encouraging students to use the knowledge they are gaining in a unit of study.

DEFINITION OF DECISION MAKING:

The process of generating and applying criteria to select from, among seemingly equal alternatives.

Using the table on the following page:

1. Identify a decision you wish to make and the alternatives you are considering.
2. Identify the criteria you consider important.
3. Assign each criterion an importance score.
4. Determine the extent to which each alternative possesses criterion.
5. Multiply the criterion scores by the alternative scores to determine which alternative has the highest total points.
6. Based on your reaction to the selected alternative, determine if you want to change importance scores or add or drop criteria.

REFERENCE:

Klinger & Vaughn (1999) *Promoting Reading Comprehension, Learning, and English Acquisition through Collaborative Strategic Reading (CSR).*

Marzano, Pickering, et. al. (2001) *Dimensions of Learning Teacher's Manual (2nd Edition)* Association for Supervision and Curriculum Development (ASCD) Alexandria, VA.

Swanson & De La Paz (1998) *Teaching Effective Comprehension Strategies to Students with Learning and Reading Disabilities.*

Criteria	Alternatives					
TOTALS						

Rule-Based Strategy
APPENDIX G

PROCEDURE
1. Present students with a "rule-based" strategy.
One summarizing strategy developed by Brown, Campione, and Day (1981) is referred to as a rule-based summary strategy. It has been tested with students of various ages. The rules in the strategy are as follows:

- Delete trivial material that is unnecessary to understanding;
- Delete redundant material;
- Substitute superordinate terms for lists (e.g., "flowers" for "daisies, tulips, and roses"); and
- Select a topic sentence, or invent one if it is missing.

To make these rules "come alive" for students, a teacher might initially demonstrate them in some detail. For example, the teacher might present students with a passage such as the one in Exhibit 3.2.

Exhibit 3.2 Sample Passage for Rule-Based Summary Strategy

Why Does Studying Solar Wind Help Us Learn About the Origin of Our Solar System?
Most scientists believe our solar system was formed 4.6 billion years ago, with the gravitational collapse of the solar nebula, a cloud of interstellar gas, dust, and ice created from previous generations of stars. As time went on, the grains of ice and dust bumped into and stuck to one another, eventually forming the planets, moons, comets, and asteroids as we know them today.

How this transition form the solar nebula to planets took place has both fascinated and mystified scientists. Why did some planets, such as Venus, develop thick, poisonous atmospheres, while others, such as Earth, become hospitable to life? Partial answers are available from the study of the chemical composition of the solar system bodies, which scientists find are significantly different from one another. Although this information helps scientists model various processes form planet formation, they are still hampered by one major question: What was the original solar nebula made of?

Our Sun may contain the answer. It contains over 99 percent of all the material in the solar system, and, although its interior has been modified by nuclear reactions, its outer layers are believed to be composed of the same material as the original solar nebula. By collecting and studying solar wind - the material flung from the Sun - scientists may find more answers to this mysterious puzzle.

Excerpted form "What's Genesis All about?" on the Genesis, Search for Origins Web site (www.genesismission.org/mission/index.html).

EXAMPLE
The teacher asks the students to read the passage silently. Then she explains that she is going to demonstrate the "rule-based strategy" for summarizing information that she had introduced the previous day. She talks them through the process as follows:

"I'm going to think aloud as I apply the rules of this strategy. See if my thinking makes sense to you. "The rules say to 'delete trivial material, to delete redundant material, and to substitute superordinate terms for lists.' The first paragraph is almost all background, but it doesn't seem trivial. There are, however, a couple of lists. Let's see. For 'interstellar gas, dust, and ice,' I'll substitute 'interstellar material'. for 'planets, moons, comets, and asteroids,' I'll substitute 'heavenly bodies.' Also, I see something redundant: The ‘solar nebula’ and the ‘cloud of interstellar material created from previous generations of stars’ are the same thing, so I’ll delete one of them. And come to think of it, the expression ‘bumped into’ seems somewhat trivial. I think I’ll take it out, too!”

REFERENCES

Klinger & Vaughn (1999) *Promoting Reading Comprehension, Learning, and English Acquisition through Collaborative Strategic Reading (CSR).*

Marzano, Pickering, & Pollock (2001) *Classroom Instruction that Works* Association for Supervision and Curriculum Development (ASCD) Alexandria, VA.

Swanson & De La Paz (1998) *Teaching Effective Comprehension Strategies to Students with Learning and Reading Disabilities.*