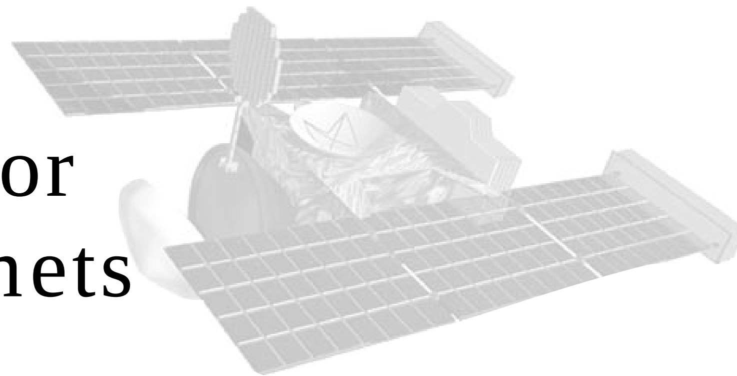
Technology For Studying Comets

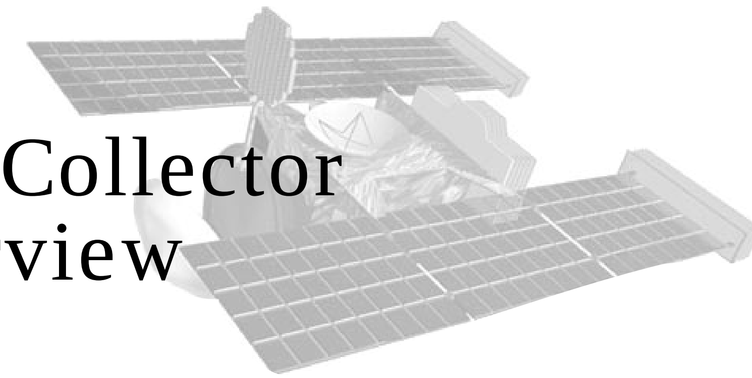


The instruments on board the STARDUST spacecraft will analyze particles during the mission, take images using the navigation camera, and most exciting of all, capture particles to bring back to Earth for analysis. This section contains two activities that focus on the technology that allows astronomers to study Comet Wild 2 in depth.

Aerogel Clay Collector - Investigates how to capture a high-speed particle (a large clay ball, thrown) without damaging it by using various materials. Teams design a capture device, write up experiment directions, and seek to reproduce experimental results.

Paint By the Numbers - Explores how an image is turned into data, transmitted to mission control and reassembled into an image back on Earth.

Aerogel Clay Collector Activity Overview



Overview

This activity offers a simple approach for "experiencing" aerogel. Aerogel is an amazing feat of technology that will be used by the STARDUST spacecraft to capture high-velocity interstellar dust and particles from the coma of comet Wild 2. Students design and conduct an experiment to capture a fast-moving particle of of clay without changing its shape or composition.

Part 1 Students investigate the characteristics of clay, examining what happens to a ball of clay that they drop under different conditions. The teacher then associates investigating falling clay to capturing a particle from a comet.

Part 2 The teacher reviews parts of the comet and introduces the STARDUST mission.

Part 3 This demonstration uses gelatin and lead pellets to show how the spacecraft's aerogel collector will capture comet particles.

Part 4 Student teams examine mediums to capture a falling clay ball without changing it and then design a collection device. They also write the directions for conducting the experiment using this device.

Part 5 Teams evaluate each other's directions based on set criteria.

Part 6 Finally, teams test the highest scoring direction design by doing the experiment and then share their findings with the class using visual aids.

Time Line

Part 1 = one class

Part 2 = one to three classes depending on variations

Part 3 = one class

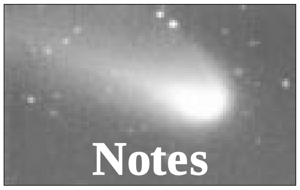
Part 4 = one to three classes each depending on the depth of exploration desired.

Part 5 = one class

Part 6 = two classes

Objectives

1. To tie experimental design into a real-world context using aerogel from the upcoming STARDUST mission.
2. To design a device that captures a falling clay ball without changing its characteristics while exercising good practices for conducting an experiment.
3. To apply principles of the scientific process by planning an experiment and communicating it by writing directions.
4. To use a peer review process to evaluate an experimental design based on criteria.
5. To conduct the experiment and verify the results through replication.
6. To present the findings using written and oral communication skills.



Preparation

Students should be familiar with parts of a comet, the way they move through the Solar System, the scientific process, and controlling variables. We recommend doing the activity *Cookin' Up a Comet* before doing this lesson.

Key Question

How do you capture a fast-moving object without changing its characteristics?

Materials Needed

Part 1: Characteristics of Falling Clay

Teams of 3-4 students need:

- ❑ Paper towels or newspaper to cover the floor
- ❑ A golf ball-size clay ball (use modeling clay)
- ❑ Powdered seltzer tablets (optional - See Management for Older Students)
- ❑ Student worksheets entitled "Clay Impacts"

Part 2: Introduction to Comets & STARDUST Mission

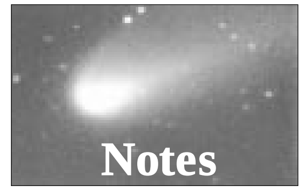
Use some combination of these materials:

- ❑ The Comet Fact Sheet
- ❑ If available from NASA CORE, show the videotape *STARDUST Bringing Cosmic History to Earth*.

Part 3: Aerogel

For the aerogel-lo demonstration you will need:

- ❑ 1 packet unflavored gelatin
- ❑ Hot water
- ❑ Two clear plastic cups (NOT the soft, opaque plastic ones)
- ❑ A spoon
- ❑ A plastic straw
- ❑ A scrap of clean pantyhose and tape to secure it (optional)
- ❑ Lead pellets (available at sporting goods stores)
- ❑ Safety goggles for you and all students
- ❑ Aerogel Fact Sheet



Part 4: Design Collector & Create Experiment Directions

Teams will need:

- ❑ Clay ball
- ❑ Newspaper or paper towels
- ❑ Assorted materials for collector (See management section for details.)
- ❑ Worksheets entitled Design Collector and Create Experiment Directions

Part 5: Evaluate Experimental Designs

Teams will need:

- ❑ Copies of other team's directions
- ❑ Experiment score sheet

Part 6: Design Testing & Findings Presentations

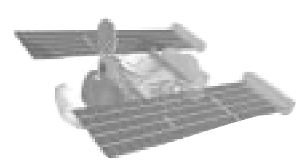
Each team will need:

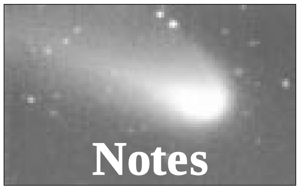
- ❑ A set of directions for the chosen experiment
- ❑ Materials listed for the experiment
- ❑ Posterboard
- ❑ Markers
- ❑ Rulers

Management

The activity designers assume that the teacher will use this activity to introduce STARDUST to students. If the teacher will be doing other STARDUST activities with the class, then Part 2 may be unnecessary. We leave it to the teacher's discretion as to which parts to skip and which to include. Check the beginning of each part for tips on how to modify the section for younger or older students.

Completion time for the aerogel activity can be scaled back to one class for younger students or increased to five classes so older students can really delve into experiment design and testing.





Part 1:
Characteristics of Falling Clay

Part 1 is the hook of the activity. Here students explore the characteristics of clay when it falls. They identify and control variables and use the results to develop a "profile" on falling clay that they will use in parts 3-4.

Materials Needed

Teams of 3-4 students need:

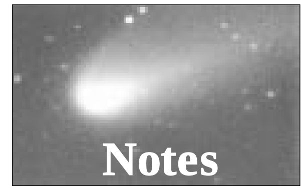
- ❑ Paper towels or newspaper to cover the floor
- ❑ A golf ball-size clay ball (use modeling clay)
- ❑ Powdered seltzer tablets (optional - See Management for Older Students)
- ❑ Student worksheets entitled "Clay Impacts"

Procedure

1. Explain to the class that they will conduct a scientific investigation of a moving object to determine its characteristics. Show the ball of clay. Their task is to carefully observe and record what happens to a falling ball of clay under different conditions.
2. Have the class review how to make careful observations by describing characteristics of the clay ball. Responses should describe factors like:
   - shape
   - size (like a golfball, estimate diameter)
   - color
   - weight (light/heavy, estimate grams)
   - temperature (warm or cold)
   - texture (soft and malleable or hard)
3. Part of the object's characteristics has to do with what happens to it when it hits the ground. Students will work in teams of 3 or 4 to test what happens to the ball under different conditions and make careful observations.

   They need to identify and control variables so they can write a profile on clay. For example students can drop the clay from different heights, at different speeds, on different surfaces, at different temperatures. It is up to the students to test only one variable at a time and provide detailed descriptions of their results. The worksheet will help teams record their results.

   Teams will use their results to design a device that can capture the ball without altering it in any way.



4. Have students form teams of 3 or 4 and arrange desks accordingly. Each member has a role with specific responsibilities listed on their worksheets. Have teams send one member to get materials.
5. Allow teams to conduct their investigations. Float between teams, observing how carefully they control variables. Encourage students to ask their teammates questions first before coming to you.
6. Have teams clean up the experiment.
7. Use the last ten minutes of class to have each team's reporter share their profile on the nature of falling clay based on their experiments.

   Students' profile on what happens to falling clay should conclude that clay is *malleable*. It changes shape easily. The faster the clay hits the ground, the more the shape changes. This has to do with the energy converted from dropping the clay.

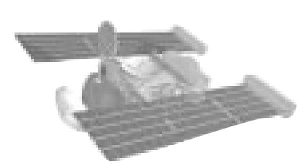
Reflection Questions

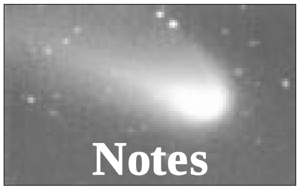
1. How do you describe the characteristics of your falling object?
2. What precautions did teams take to control variables in their experiments?
3. What was difficult about controlling variables?
4. What would your team do differently?
5. If more time was available, what would you like to try next?
6. What did you learn from doing this activity?
7. How does this activity relate to what scientists do?
8. If an asteroid or comet hit Earth, how do you think its characteristics would change?

Wrap Up

If a small delicate object travels at very high speeds and hits something, what happens? Do its characteristics change? How could you capture it?

This is what the NASA mission called STARDUST will do. In the next class we will discuss this mission and how it will capture particles from a comet without damaging them. Then teams will design a device to capture a falling ball of clay without changing it in any way to simulate how aerogel will capture particles during the STARDUST mission.





Part 2:
Introduction to Comets & the STARDUST Mission

Now that the students are hooked, it is time to relate the clay to comet particles. To do so, review the subject of comets with them. Progress to the STARDUST mission, and introduce the kind of technology needed to capture moving particles.

Materials Needed

Use some combination of these materials:

- ❑ The Comet Fact Sheet
- ❑ If available from NASA CORE, show the videotape *STARDUST Bringing Cosmic History to Earth*.

Procedure

COMETS

1. Find out what students know about comets and how they travel through the Solar System. Do the students hold any misconceptions?
2. Discuss parts of the comet and the manner in which they travel through the Solar System. See the Comet Fact Sheet for details.

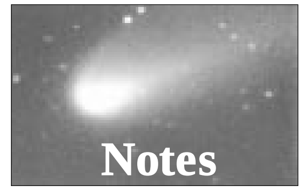
   Once in the inner Solar System, the comet's nucleus begins to sublimate, ejecting vast quantities of particles of dust and gas. Ices normally turn to liquid. From a liquid state a substance can turn to a gas. This is known as evaporation. When a solid turns directly to a gas, this is known as sublimation.

   This forms a coma around the nucleus. Charged particles from the Sun push the coma into two tails - a gas tail and a dust tail - that stream away from the Sun. These gas and dust particles in the tail are very small - smaller than grains of sand - and move at high speeds.
3. Ask the students how much they think scientists know about comets.

   The truth is, our understanding of comets is not as detailed as you might think, because comets are difficult objects to study. Comets can have huge orbits. Some spend hundreds of years past the outermost planets. During this time comets are commonly hard to see because they are small and dark. Compared to planets comets are small - generally less than the size of a city. Comets usually grow tails when they are in the inner Solar System because they are closer to the Sun's heating rays, making them easier to see.

   Much of what we know about comets comes from ground-based observations. We know something about the parts of comets and we can predict their orbital motions. We have even witnessed a comet (Shoemaker-Levy 9) hitting Jupiter back in July 1994. However, spacecraft have only studied one comet (Comet Halley) and

that was back in 1987. Many theories about comets exist, including the debate over whether or not a comet's nucleus is solid. Scientists seek more information on this subject since future missions are proposing to land a probe on a comet. An ideal way to learn about the composition of comets is to capture particles from a comet and return them to Earth for study.



4. Ask students why studying comets is important.

   Comets are important because they:

   - Provide clues as to how our Solar System formed. They are the oldest, most primitive bodies in the Solar System, dating back to its formation.
   - Possibly act as building blocks of planetary systems around the stars.
   - Bring volatile elements (ices) to planets that may play a part in the formation of oceans and atmospheres.
   - Contain organic materials that may play a role in the origin of life on Earth or other planets.
   - Can cause major changes in climate and ecosystems if they hit Earth (they might have led to the extinction of the dinosaurs and other types of life).

STARDUST

1. Discuss the STARDUST mission with students.

   STARDUST launched in 1999. It will get a gravity assist by looping around Earth to slingshot toward the comet. En route the spacecraft will go around the Sun twice, collecting interstellar dust. In 2004 STARDUST will fly through the coma of comet Wild 2 where gas and dust spew forth. The comet is named Wild 2 because it was the second comet discovered by the Swiss astronomer Paul Wild. Professor Wild's name is actually pronounced "Vilt" in his native language (German). Within 100 kilometers of the comet's nucleus, STARDUST will collect particles and take pictures of the comet's surface features.

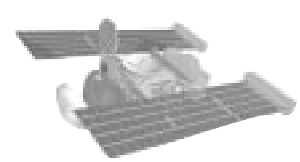
   On the return trip, the samples stored in a return capsule will separate from the main body of the spacecraft. In 2006 the capsule will re-enter Earth's atmosphere, deploy a parachute to slow its descent, and land in a dry Utah lakebed, making history.

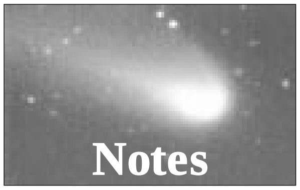
   Option: If a copy of the videotape "STARDUST Bringing Cosmic History Home to Earth" is available, it is a great addition to a classroom discussion. The video is less than 10 minutes long and contains exciting information that captures the attention of the audience.

2. Show images of the spacecraft downloaded from the STARDUST website.
3. Have students write a journal entry using the worksheet provided.

Reflection Questions

1. Which part of the comet will STARDUST fly through?
2. Why was Comet Wild-2 chosen for the STARDUST mission?
3. How will the spacecraft collect particles?
4. Why do scientists want to study these particles?
5. What were you surprised to learn about?





Part 3:
Aerogel

Preparation

This demonstration uses gelatin and pellets to show how STARDUST's aerogel collector will capture comet particles. The gelatin is referred to as "aerogel-lo." For a successful demonstration, the gelatin must have the right consistency. Follow the directions on the gelatin packet to achieve the desired consistency. Pour the gelatin into two glasses, one for class, one for practice. Be sure to prepare the gelatin before doing the activity in class. This does two things; first it allows enough time for the gelatin to set. Second, you have time to test the gelatin and make another batch if it does not have the right consistency.

To test the consistency, attach a clean scrap of pantyhose over one end of the straw using tape. This precaution is to keep you from inhaling a lead pellet by mistake. Place a piece of lead pellet in the straw. Tip the straw so the lead slides to the covered end. Pinch the straw, trapping the lead pellet at the top of the covered end. Blow the lead pellet into the gelatin with a quick, sharp blow.

Gelatin has the right consistency if the lead pellet enters the gelatin easily, the gelatin stops the lead pellet, and the track from the lead pellet remains visible. If the lead pellet bounces off the bottom of the container, the gelatin is too watery. Make another batch of gelatin using less water. If the lead pellet bounces off the surface of the gelatin or hardly penetrates it, add more water to the next batch.

CAUTION

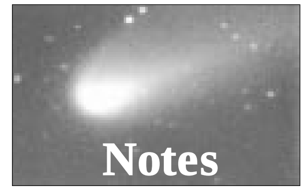
This demonstration can be dangerous if not done correctly. Have your students wear safety goggles and follow the safety procedures.

Materials Needed

For the aerogel-lo demonstration you will need:

- ❑ 1 packet unflavored gelatin
- ❑ Hot water
- ❑ Two clear plastic cups (NOT the soft, opaque plastic ones)
- ❑ A spoon
- ❑ A plastic straw
- ❑ A scrap of clean pantyhose and (optional) tape to secure it
- ❑ Lead pellets (available at sporting goods stores)
- ❑ Safety goggles for you and all students
- ❑ Aerogel Fact Sheet

Procedure



1. Ask students how they could capture particles from a comet.

   Would a huge net work? Well, the particles are microscopic. How about sticky fly paper? They travel so fast that they would tear through the thin paper. How about buckets of syrup or water? Syrup or water would freeze in the vacuum of space or evaporate from the heat of the Sun. The scientists really had a problem—challenge — to find a good collecting device.

2. Collecting materials from a comet's coma is no easy feat!

   The impact velocity of the particles as they are captured will be up to 6 times the speed of a bullet fired from a rifle. These particles are smaller than grains of sand. High-speed capture could alter their shape and chemical composition or vaporize them entirely.

3. Scientists needed something that would capture very tiny delicate particles without damaging the shape. The substance had to be strong to survive the launch into space, lightweight to keep liftoff costs low, and not melt or freeze in the extreme temperatures of space. Also the substance needed to be relatively see-through so the particle could be found easily.

4. Put on safety goggles and take out the cup of gelatin, straw, and lead pellets.

5. Place a lead pellet in the straw. Tip the straw so the lead slides to the covered end. Pinch the straw, trapping the lead pellet at the top of the covered end.

6. Hold the cup so students can see it or pass the cup around the room.

7. Take a big breath and at the same time, stop pinching the straw and blow the lead pellet into the aerogel-lo with a quick, sharp blow. Shoot several pieces into the cup.

8. Point out the track mark to the lead pellet. If possible, show the image of the track from the STARDUST website at: http://stardust.jpl.nasa.gov/spacecraft/aerogel.html

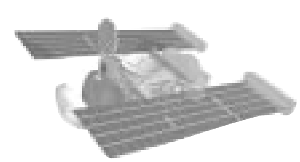
9. What is aerogel?

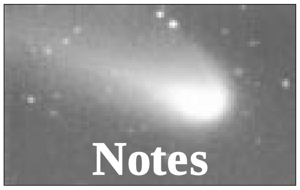
   Aerogel is mostly transparent. Scientists refer to it as blue smoke. It is a silicon-based solid that is 1,000 times less dense than glass with a sponge-like structure, in which 99% of the volume is empty space. An inch thickness of aerogel has the insulating power of six inches of fiberglass.

   Show students images of aerogel downloaded from the STARDUST website http://stardust.jpl.nasa.gov/spacecraft/aerogel.html

10. When was aerogel developed?

    Aerogel was discovered in the late 1930's, but it was not until the late 70's that it could be prepared in a reasonable amount of time - less than several weeks. In the early 80's, advances in making aerogel maintained its structural integrity and eliminated some safety concerns, such as working with toxic compounds and explosion hazards, in manufacturing it. Other advances in aerogel





formation during that time included a decrease in the amount of time that it took to create aerogel and the ability to form gels that were lighter, containing more air per volume.

11. How does aerogel act as a mechanism of capture?

    When a particle hits the aerogel, it buries itself in the material, creating a carrot-shaped track up to 200 times its own length as it slows down and comes to a stop. Scientists will find the particle at the end of this track.

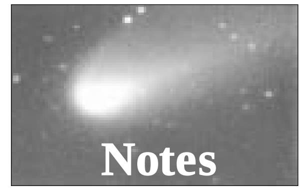
12. Have students compare the similarities between gelatin and aerogel as a capturing media for moving particles. Like aerogel, aerogel-lo stops the moving particle and holds on to it, leaving a trail, at the end of which lays the particle.

13. Discuss the limitation of the aerogel-lo model.

    Models represent certain characteristics of the thing they represent, often falling short in other ways. The aerogel-lo is far more dense than real aerogel. It lacks properties needed for stopping a high velocity particle. It would not travel well in space, which has temperature extremes, due to its high water content. The weight of the gelatin is far greater than aerogel, which is 99% air.

Reflection Questions

1. What makes aerogel special?
2. How does aerogel stop a particle from a comet?
3. Why don’t we insulate our houses with aerogel?
4. What did scientists and engineers have to consider when picking a material to capture comet particles?



Part 4:
Design Collector & Create Experiment Directions

Teams test materials and devise a collector to safely catch a clay ball without changing it. For younger students, try limiting the materials only to cotton balls. Have teams determine how many cotton balls and the best container shape to catch the clay ball without changing its shape.

Tell the students which materials to use. Try baking soda, water, cotton, marbles, dry beans (like split peas or lentils), or candy sprinkles to catch the clay ball. Limit the collection device to something shallow and something deep. Try either a shallow pie pan, a margarine tub, or a bucket.

For older students, teachers can use their judgment as to how much leeway to grant students for designing a capturing device in terms of materials and development time. Be sure to set limits for expense and safety issues.

A fun twist to this experiment is to add powdered seltzer tablets to the clay. The challenge is then not only to capture the ball without changing the shape, but to keep the capturing substance from changing the composition of the ball. If students use water to stop the ball, it will fizz.

Another twist is to challenge students to find a medium that will capture and hold the clay ball so it cannot escape.

Materials Needed

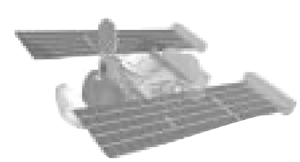
Teams will need:

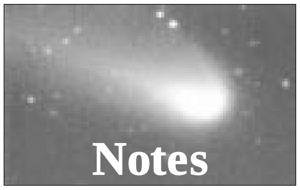
- ❑ Clay ball
- ❑ Newspaper or paper towels
- ❑ Assorted materials for collector (See management section for details.)
- ❑ Worksheets entitled Design Collector and Create Experiment Directions

Procedure

Material Testing

1. Particles from the coma of the comet are traveling 6 times faster than the speed of a bullet fired from a rifle. This is too fast and dangerous to replicate in the classroom, but students can imagine the clay ball traveling this speed and how flattened the shape would be on impact. The particles from the comet are actually smaller than a grain of sand, and the particles are delicate, especially traveling at high speeds.





2. Have students work in teams of 3 or 4 students to test materials for a capturing device. The device should keep the clay's shape intact. Students need to pick a material to stop the clay ball and decide on the shape and material of the container used to hold the collection substance. Have teams use the worksheet to walk them through this process.
3. Discuss what materials and containers work best, and which worked poorly.

   Have the teams characterize the material as a good particle capturer if it keeps shape intact and stops the falling ball (the material not the container). Is the material:

   - Thin or thick
   - Solid or liquid
   - Strong or weak
   - Transparent or opaque
   - Light or heavy
   - Expensive or inexpensive
4. Discuss how these criteria relate to aerogel.
5. Teams will then decide which material to use in their collection device and bring in any materials from home that are not available in the classroom.

Collector Device Design

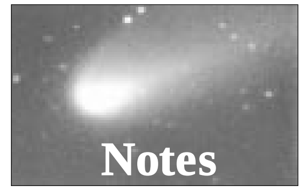
1. Based on what teams found out about the materials and containers for the collector device in the last part, they will refine the design of their collector devices using the Design Collector and Create Experiment Directions worksheets.
2. Before teams begin, discuss how engineers approach design changes in systematic steps, controlling variables, and alternatively skipping steps when they can infer that it is appropriate.
3. Once teams develop a collector device that works, they are ready to write the directions for their experiment using the criteria listed on the worksheet. Discuss the criteria in detail.

   This exercise is important. For an experiment to be considered scientifically sound, others should be able to replicate the experiment and achieve the same results.
4. Have teams write directions for conducting their experiments. Have them attach a cover sheet with the title for their experiment and the name of the team members. These names should not appear on the direction page. (The peer review process should not be biased by the name of team members.)

Reflection Questions

1. What materials are good at catching the clay without changing it?
2. What characteristics do these materials have?
3. What properties does the container need to work well?
4. How does your collection device differ from aerogel?
5. What was difficult about finding a good material to use? Container?
6. What did you learn from designing a collector?
7. What did you learn about the scientific process by writing directions?

Part 5:
Evaluate Experimental Designs



In this part, experiments go through a peer review process where each team will score the experiment against set criteria. By committee the class will decide which experiment to test and all of the teams will then conduct the experiment to verify the results in the next class.

Materials Needed

Teams will need:

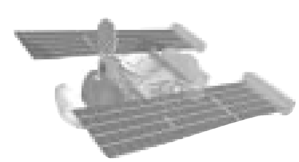
- ❑ Copies of other team's directions
- ❑ Experiment score sheet

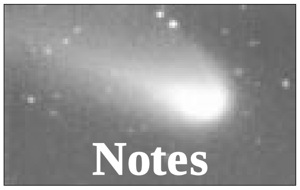
Procedure

1. Add a title page to each set of directions that reads, "Experiment # ____." Give each experiment a number. Be sure the directions do not include the name of the team members. Make copies of all sets of directions and the Experiment Score Sheet.
2. Discuss how to use the Experiment Score Sheet with the class.
3. Pass out the sets of directions. Be sure no team gets a copy of their own directions.
4. Have teams secretively score each set of directions.
5. Share the results as a class. Discuss the merits of each team's directions and the collector design.
6. Have the class decide which experiment to replicate.
7. Give teams the option to revise their directions to improve their score. After all, writing directions is a skill best perfected with practice.

Reflection Questions

1. What was the difference between the good directions and the excellent directions?
2. With which criteria did most groups have trouble?
3. How did criteria help you "grade" directions?
4. Why is peer review important to the scientific process?





Part 6:
Design Testing & Findings Presentations

The final part of the aerogel activity stresses the importance of other scientists being able to take an experiment, do it themselves and get the same result. An experiment is not scientifically sound otherwise.

Materials Needed

Each team will need:

- ❑ A set of directions for the chosen experiment
- ❑ Materials listed for the experiment
- ❑ Posterboard
- ❑ Markers
- ❑ Rulers

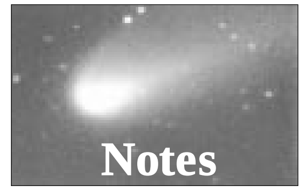
Procedure

1. Have teams gather materials and set them up. The team whose experiment design was chosen floats between teams acting as consultants, answering questions.
2. Conduct the experiment.
3. Clean up.
4. Have teams write a report summarizing their findings. Teams need to present their results with a visual aid, like a poster with a graph.
5. Have teams present their findings on how well the experiment was able to be replicated. Discuss problem areas that may have influenced the outcome of each team's experiments and how to address them.
6. Tie the process the class went through in developing a collector with the challenge engineers faced when designing the aerogel collector for the STARDUST mission.

Reflection Questions

1. What happened when teams replicated each other's experiments?
2. Were the experiments well designed?
3. What problems can affect the outcome of an experiment?
4. How does this part tie into the scientific process?
5. Do you think every experiment a scientist publishes in scientific journals works?
6. Why is it important for experiments to consistently yield the same result?

Characteristics of Falling Clay



Name____ Date________________

Before beginning this worksheet, do the following:

- Find three other students to be on your team and find an area of the classroom to sit together.
- Send one student to get clay and newspaper or paper towels.
- Roll the clay into a ball.
- Place the newspaper or paper towels on the floor.

1. Write the name next to the role each team member chooses.

_______________ **Journalist** - Writes down the group's answers on the worksheet.

_______________ **Public Affairs Officer** - Presents team's findings to the class.

_______________ **Engineer** - Drops the clay ball and controls variables.

_______________ **Materials Specialist** - Collects and returns materials.

2. Find out what happens to clay when it falls under different conditions. Name some types of conditions, or variables, you can test when dropping the clay ball. *(For example, you can drop the clay from different heights.)*

____

____

____

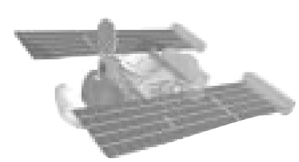
3. Pick a variable you want to test. Design two ways to test this variable. (For example, drop the ball from two different heights.) Fill in the results in the chart below.

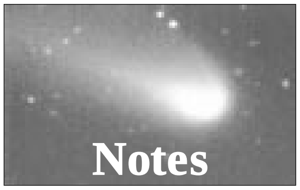
Describe Test 1: ____

What Happened: ____

Describe Test 2: ____

What Happened: ____





4. Pick another variable to test. Design two ways to test it and describe the results in the chart below.

   Desribe Test 1: ______________________________

   What Happened: ______________________________

   Describe Test 2: ______________________________

   What Happened: ______________________________

5. What did you learn about falling clay? Write a profile describing what happens to falling clay under different conditions.

   ____

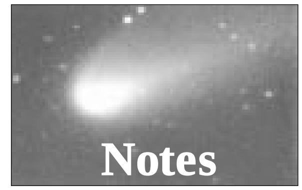
   ____

   ____

   ____

   ____

Student Journal



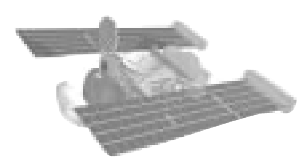
Finish the following sentence starters.

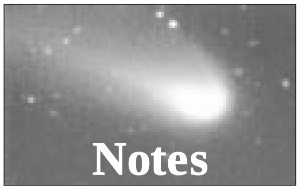
1. One thing I found interesting about comets is . . .

2. One thing scientists say about comets that surprised me is . . .

3. STARDUST is a "cool" mission because . . .

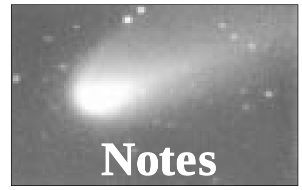
4. Another thing I would like to learn about the STARDUST mission is . . .





	Shape	Texture	Temperature	State: Clean/Dirty	Surface: (Wet/Dry/Sticky)
Material 1					
Material 2					
Material 3					
Material 4					

Materials Testing



Name ______________________________ Date __________

Before beginning this worksheet, do the following:

- Find three other students to be on your team and find an area of the classroom to sit together.
- Send one student to get clay and newspaper or paper towels.
- Roll the clay into a ball.
- Place the newspaper or paper towels on the floor.

1. Write the name next to the role each team member chooses.

   ____________ **Recorder** - Writes down the group's answers on the worksheet.

   ____________ **Reporter** - Presents team's findings to the class.

   ____________ **Engineer** - Drops the clay ball and controls variables.

   ____________ **Materials Specialist** - Collects and returns materials.

2. Pick four materials to catch the clay ball without changing it.
   List the materials below.

   ____________________ ____________________

   ____________________ ____________________

3. Drop the ball from the same height for each material. What happens?

   Material 1 ______________________________

   Result ______________________________

   Material 2 ______________________________

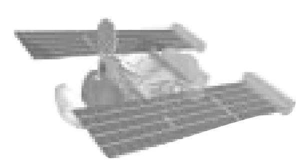
   Result ______________________________

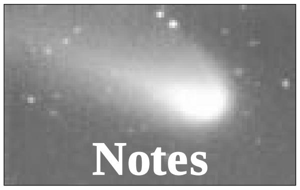
   Material 3 ______________________________

   Result ______________________________

   Material 4 ______________________________

   Result ______________________________





Collector	Result
Include the amount of material, and the size and type of container.	Describe in detail.
1. ______________________	______________________
2. ______________________	______________________
3. ______________________	______________________
4. ______________________	______________________
5. ______________________	______________________

4. Did the materials you use affect the ball in the following ways?

5. What materials worked best? What properties does the material have that make it work the best?

____

____

____

____

6. What other materials might work better than the ones you tried?

____

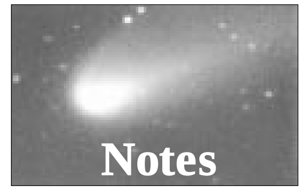
____

____

____

____

Collector Design



Name ______________________ Date __________

Before beginning this worksheet, do the following:

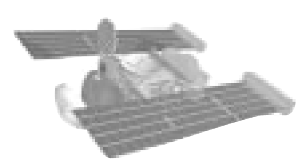
- Sit with your team.
- Take out the Materials Testing worksheet

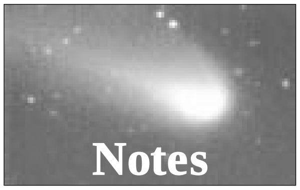
1. Based on the Materials Testing worksheet, design a container to hold the material of your choice.

2. Discuss ways to modify your collector device so the clay ball does not change shape when dropped from shoulder height.

3. Gather newspaper, a clay ball, and the materials you need for your collector device. Modify your design until it works. You may not need to fill in the entire chart.

4. What characteristics of the collector device were the most important in preventing the ball from changing shape?





Create Experiment Directions

Name________________________________ Date____________

Before beginning this worksheet, do the following:

- Sit with your team.
- Take out the Design Collector worksheet.

An experiment is not scientifically sound if it cannot be replicated. Others should be able to do the same experiment and get the same result you did. Your task is to write step-by-step directions so anyone can do your experiment.

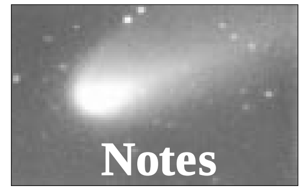
1. Before you begin writing directions, make a list of variables - those elements you can change that can affect the outcome of the experiment.

   For example, the type of clay someone uses might be harder or softer than the clay you used.

2. Write the directions for conducting your experiment on a separate piece of paper. Clear directions meet the following *criteria*.
   - Tells the purpose of the experiment and why it is important.
   - Collection device seems functional and creative.
   - Collection device is inexpensive and safe.
   - Lists the materials needed and includes exact amounts.
   - Explains tasks one step at a time.
   - Steps are detailed, make sense, and are easy to follow.
   - Steps are in order.
   - Uses drawings when needed.
   - Uses complete sentences.
   - Has good grammar and proper punctuation.

   Use the space below for notes before you begin writing the directions.

Experiment Score Sheet



Evaluate each experiment using the criteria below. Use the point system below. Add points up and convert to a percentage for a score.

Point System

2 points . . Directions fully meet criteria.

1 point . . . . Directions partially meet criteria.

0 points . . Directions do NOT meet criteria.

1. _____Tells the purpose of the experiment and why it is important.
   Comments: ______________________________

2. _____Collection device seems functional and creative.
   Comments: ______________________________

3. _____Collection device is inexpensive and safe.
   Comments: ______________________________

4. _____Lists the materials needed and includes exact amounts.
   Comments: ______________________________

5. _____Explains tasks one step at a time.
   Comments: ______________________________

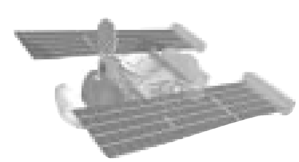
6. _____Steps are detailed, make sense, and are easy to follow.
   Comments: ______________________________

7. _____Steps are in order.
   Comments: ______________________________

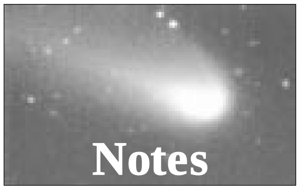
8. _____Uses drawings when needed.
   Comments: ______________________________

9. _____Uses complete sentences.
   Comments: ______________________________

10. _____Has good grammar and proper punctuation.
    Comments: ______________________________



_____ Total Points X 5 = _____ %



Paint by the Numbers

Timeline

1 class

Key Question

How do spacecraft convert images into bits of data and then convert them back to images?

Overview

A pencil and paper activity demonstrates how astronomical spacecraft and computers create images of objects in space. It simulates how light collected from a space object converts into binary data and reconverts into an image of the object. STARDUST will use the same principles to transmit images of the comet's coma to scientists on Earth.

Objectives

- ❖ Convert an image into binary code.
- ❖ Reconvert binary code into an image.

Preparation

Make enough copies of the transparent grid, the paper grid, and the picture of the house for each pair of students

Materials Needed

For each pair of Students

- ❑ Transparent grid
- ❑ Student A: You are the Spacecraft Worksheet
- ❑ Student B: You are Mission Control Worksheet
- ❑ Pencil
- ❑ Tape

Management

Older students can make the exercise more complex using a finer grid. The finer the grid, the greater the detail the final image has. However, this also means that the process is more tedious. Likewise, younger students can use a larger grid with a less detailed image as a result.

Procedure

1. Divide students into pairs.
2. Give one student (A) in each pair the Student A Worksheet and a transparent grid. Give the other student (B) the Student B Worksheet. Instruct student A not to reveal the picture to student B.
3. Explain that the picture is an object being observed at a great distance. It will be scanned by an optical device like those found on some astronomical satellites and an image will be created on the paper.

4. Have student A place the grid over the picture. Student A should look at the brightness of each square defined by the grid lines and assign it a number according to the chart above the picture. Student A will then call out the number to student B. If a particular square covers an area of the picture that is both light and dark, student A should estimate its total brightness and assign an intermediate value to the square such as a 1 or a 2.

   Note: The letters and numbers on two sides of the grid can assist the receiving student in finding the location of each square to be shaded.

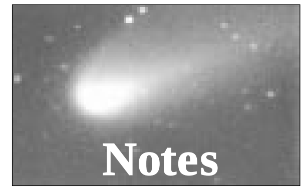
5. After receiving a number from student A, student B will shade the corresponding square on the grid. If the number is 0, the square should be shaded black. If it is 3, the square should be left as it is.
6. Compare the original picture with the image sketched on the paper.
7. Use the following information to discuss with students the context of this activity.

   The image created with this activity is a crude representation of the original picture (see house 2 at right). The reason for this is that the initial grid contains only 64 squares. If there were many more squares, each square would be smaller and the image would show finer detail (see houses 3 and 4 at right). You may wish to repeat this activity with a grid consisting of 256 squares. However, increasing the number of squares will require more class time.

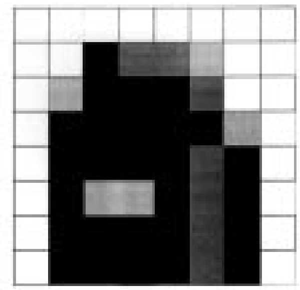
   This activity shows how astronomical satellites such as the Hubble Space Telescope (HST) produce simple black and white images. Pixel stands for “picture element” and refers to one of the squares in the grid. With the HST, the grid consists of more than 2.5 million pixels and they are shaded in 256 possible shading variations to create the image.

   Color images of an object are created by the HST with color filters. The spacecraft observes the object through a red filter, a blue filter, and then a green one. Each filter creates a separate image, containing different information. These images are then colored and combined.

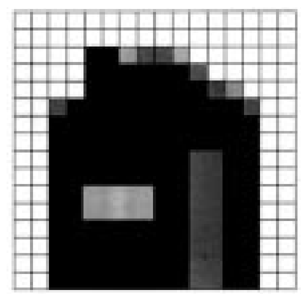
8. Conclude the lesson with Reflection Questions.



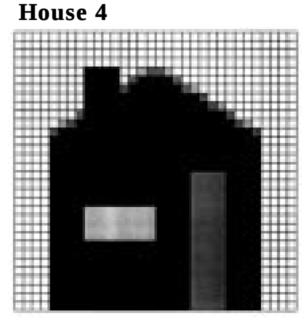
House 2



House 3

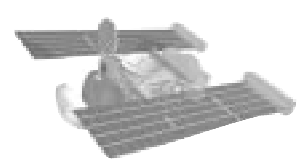


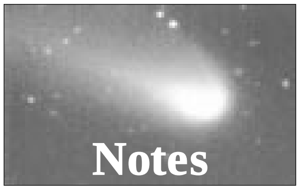
House 4



Reflection Questions

1. How did the transmitted image change from the original picture?
2. What do you think would happen if the grid squares were bigger? Smaller?
3. How does making the grid squares smaller make it more difficult for scientists and engineers to transmit information?
4. What does it mean if a rectangular section of an astronomical image appears black?
5. What other factors besides number of pixels per area can affect the detail of an image?





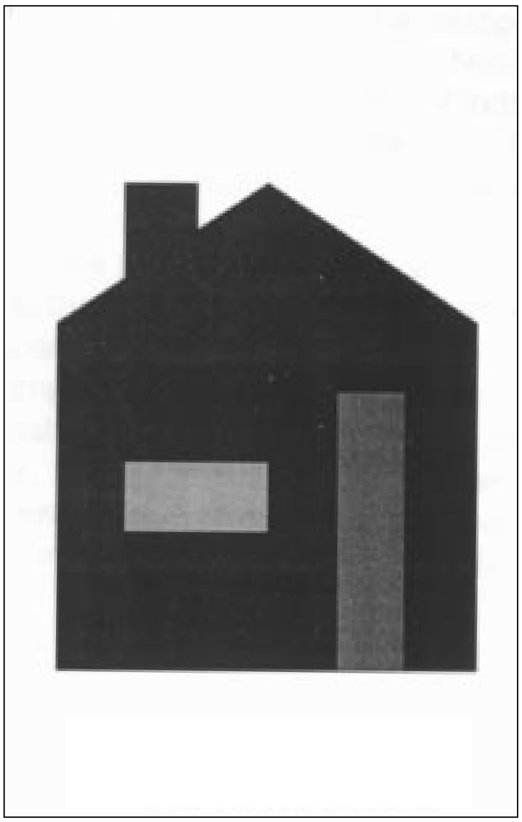
Student A: You are the Spacecraft.

Your job is to change the image into data and transmit it to Mission Control (your partner).

1. Lay the transparency of the grid on top of the picture. Tape it in place.
2. Find Row A Square 1. Decide which value this square has.
3. Send this information to Mission Control. Tell your Mission Control Partner:

Row ___ Square ___ Value ___

4. Repeat this process for each square of the grid.



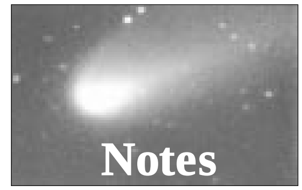
Image

0 1 2 3

Shading Values

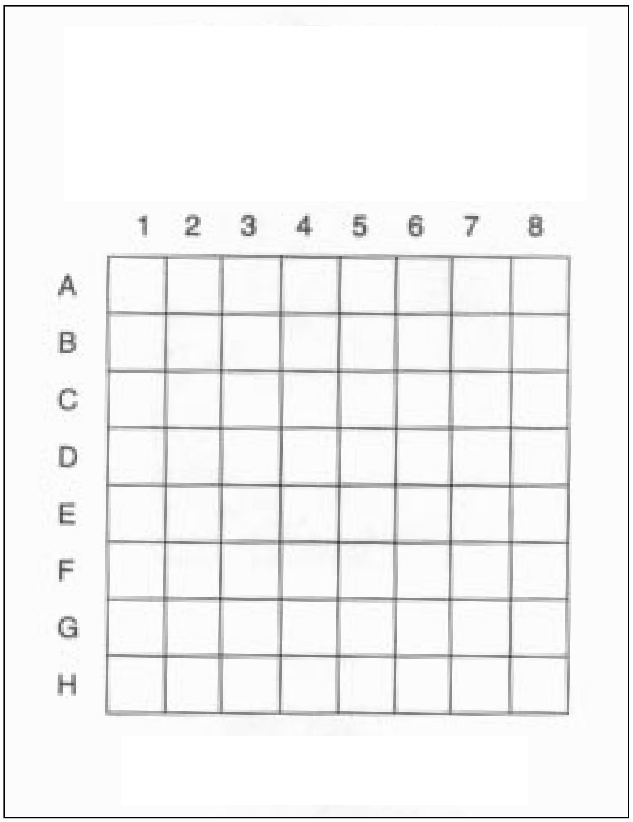
(Don't tell what the picture is!)

Student B: You are Mission Control.

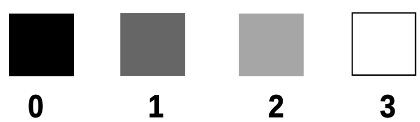


Your job is to assemble the data the spacecraft (your partner) sends you and turn it into an image.

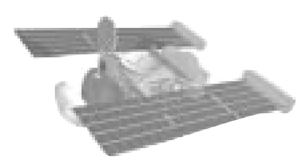
1. Find the square identified by your partner.
2. Color it in to match the Shading Value.
3. What picture did the spacecraft send?

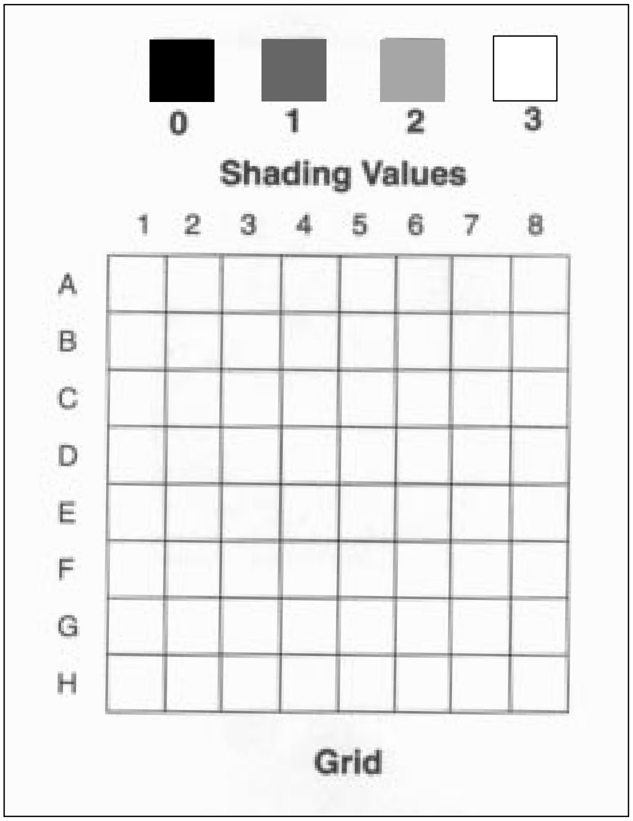


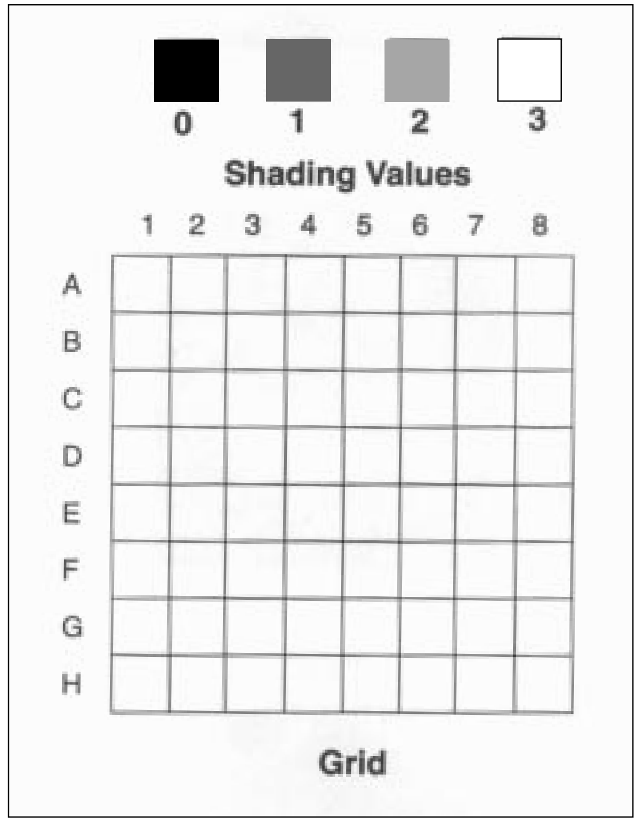
Grid



Shading Values




0
1
2
3
Shading Values
1 2 3 4 5 6 7 8
A
B
C
D
E
F
G
H
Grid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Shading Values
1 2 3 4 5 6 7 8
A
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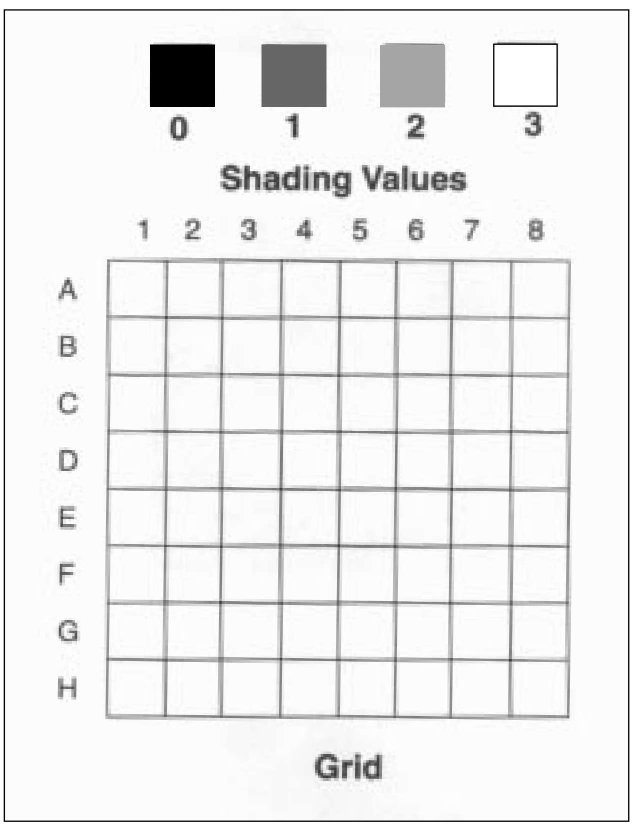
Grid


0
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Shading Values
1 2 3 4 5 6 7 8
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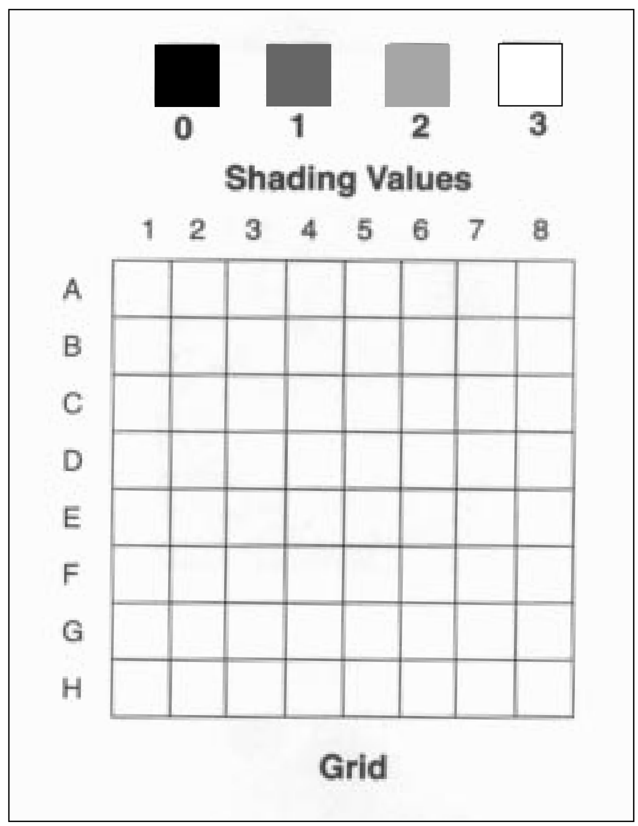
0
1
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Shading Values
1 2 3 4 5 6 7 8
A
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