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ABSTRACT

The Challenger Center for Space Science Education is a not-for-profit educational organization founded in 1986 following the Challenger 51-L space shuttle tragedy. This packet contains a variety of separate sheets and brochures providing information about the activities of the Challenger Center. Challenger Learning Centers provide hands-on, realistic space flight simulations for students and teachers. The Center also conducts teacher workshops on a regular basis, and produces science curricula that include space exploration and colonization simulation projects, and integrated activities centered around space science topics. This packet contains sample activities on the characteristics of light, aerogel technology as a means of capturing interstellar debris, and data transfer and compression in space exploration technology. (WRM)

This is CHALLENGER CENTER... CHANGING the Way Teachers TEACH and Students LEARN Now!

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FAIRFAX NETWORK
Electronic Field Trip Registrar
4414 Holborn Avenue
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the Quest in the Question

the Quest in the Question

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Embrace Space

Made Possible by

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Send in video questions from your students!

(see opposite page)

Beyond Every Question Lies a Great Adventure.

The Quest in the Question, a free Electronic Field Trip that will be broadcast nationwide on Space Day '99 (May 6, 1999), will introduce students to the excitement and adventure of scientific discovery. Through the experiences of space scientists, engineers, and explorers, students will see how science is like the greatest adventure stories—full of courageous pioneers, unexpected challenges, and priceless rewards. Science isn't merely a process—it's a quest!

It all begins with a question.

"Why does the Moon look different from night to night?"

"Why do astronauts float in space?"

The Quest in the Question will showcase students from across the country asking thoughtful questions about space and space exploration, and getting clear answers from experienced scientists, engineers, and explorers.

In addition, the Electronic Field Trip will feature:

- A creative look at the scientific method that goes beyond traditional models and shows the creative—and inherently human side—of science.
- Profiles of the people and events that have pioneered space exploration, in celebration of NASA's 40th anniversary, as well as the questions that inspired them to explore.
- Engaging explanations of some commonly held misconceptions about the Earth and space.

The Quest in the Question and its supporting teacher's guide are aimed at students in grades 4 to 6. Not only are the classroom activities aligned with the National Research Council's National Science Education Standards the underlying story of *The Quest in the Question* embraces the true spirit of the science standards.

Poster Images (clockwise from top):
Cone Nebula by David Malin, copyright Anglo-Australian Observatory; Spiral galaxy NGC 4314 from the Hubble Space Telescope; Zarya and Unity, the first two modules of the International Space Station, from space shuttle Endeavor; Earth and Moon, both from the Galileo orbiter.

Electronic Lesson Broadcast, April 22, 2-2:45 p.m. EDT

To provide teachers with an exceptional educational tool, a special broadcast will be made two weeks prior to the live event. Three 15-minute electronic lessons will tackle the more challenging topics that students will be exposed to in the live event, such as moon phases, microgravity, and the information we receive from light. Although these lessons effectively stand alone and can be used in your classroom for years to come, we strongly encourage teachers to use them and *The Quest in the Question* Teacher's Guide (which is mailed in March 1999 upon registration) in preparation for the live event.

Live Satellite Broadcast, May 6, 1999, 1-2 p.m. EDT

Challenger Center for Space Science Education, the Fairfax Network, and Lockheed Martin invite you to join millions of students throughout the nation on May 6 as they explore *The Quest in the Question*. The satellite broadcast will challenge students not only to ask questions, but to follow their questions and seek answers.

Other Space Day Events

Broadcast as part of the CyberSpace Day activities, *The Quest in the Question* is only one dimension of the learning opportunities available for students participating in Space Day '99. A live interactive webcast is being planned in conjunction with the Electronic Field Trip broadcast to allow students to ask questions via email of leading scientists, engineers, and space celebrities...and to watch and listen to their answers with live audio and video on the Internet. More information about the webcast and other exciting Space Day activities can be found at ***www.spaceday.com***.

What's on Your Mind?

Challenger Center for Space Science Education is currently soliciting questions from students in grades 4 to 6 around the country on the topics described below. If selected, students will have the opportunity to see their questions aired nationwide during the live, nationwide event on May 6, or as a part of a series of electronic lessons that will be aired two weeks prior. Some questions may also be used during the web chats immediately preceding and following the live satellite broadcast on Space Day. Leading scientists and explorers will answer as many questions as we can squeeze in, all within the context of space exploration. Last year, students shared their questions with millions of their peers around the nation.

Tapes *must* be received by March 15 to be considered for use in the field trip. Please review and follow our submission criteria to increase your students' chances of being selected. You can find the criteria at ***www.challenger.org/quest***, or simply email your name and school address to quest@challenger.org and we'll mail you a copy.

Question Topics

- The Moon
- Gravity
- Humans in Space
- Rockets & Robotics
- The Earth-Sun-Moon Connection
- What Does It Mean to Be a Scientist?

Accessing "The Quest in the Question"

The easiest way to access this free Electronic Field Trip is by tuning your satellite dish to the coordinates provided in the Teacher's Guide to all registered participants. Many statewide and district media service centers have the ability to pull down the broadcast and make it available to schools on their local networks. Check with your local provider.

TCI

To make sure *The Quest in the Question* is available to as many schools as possible, Challenger Center has also been encouraging cable companies across the country to make the broadcast available on local community channels. Space Day partners include Cable in the Classroom, Comcast Cablevision, Falcon Cable TV, TCI Communications, Time Warner Cable, Turner Learning and USA Network's Sci-Fi Channel. TCI Cable has agreed to encourage their local sites to make *The Quest in the Question* available to schools.

To ask your local cable company to broadcast the Electronic Field Trip, visit Cable in the Classroom at ***www.ciconline.com/whohom.htm*** to get the name and number of your local contact. Encourage the contact to call or email the Fairfax Network for broadcast specifications using the registration information below.

REGISTRATION

The Electronic Field Trip is ***FREE***. To register and receive satellite coordinates and a teacher's guide, use the form below and mail, email, or fax your request to the Fairfax Network or register online at ***www.fcps.k12.va.us/FairfaxNetwork/quest*** or ***www.challenger.org/quest***.

Name _____ *School* _____

School District _____

School Address _____

City, State, ZIP _____

Phone _____ *Fax* _____ *Email* _____

How many schools will participate in this Electronic Field Trip? _____

How many students will view the Electronic Field Trip? _____

Describe Your Institution

(Check all that apply to your institution.)

__ *Public* __ *Private* __ *Elementary School* __ *Intermediate or Middle School*

__ *Secondary or High School* __ *Regional Media Center* __ *Cable or Television System* __ *Other* _____

Mail

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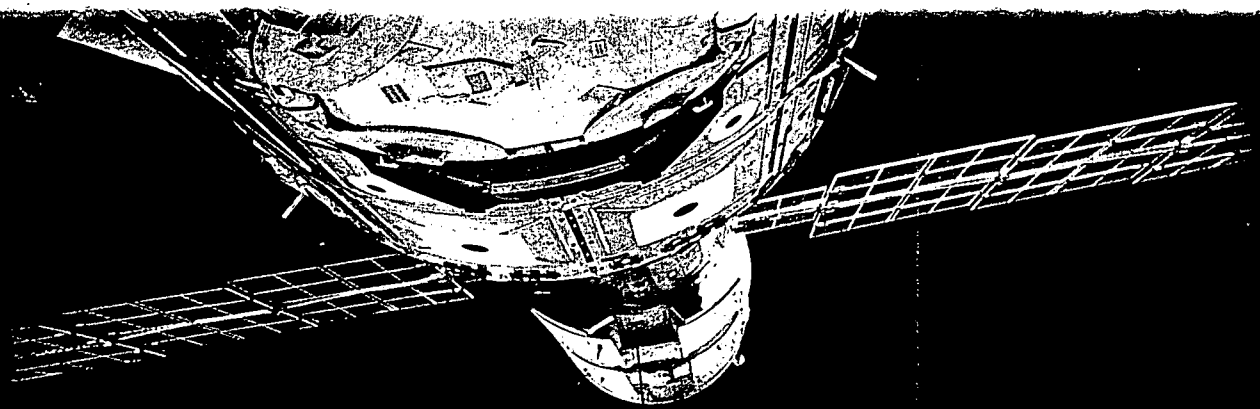
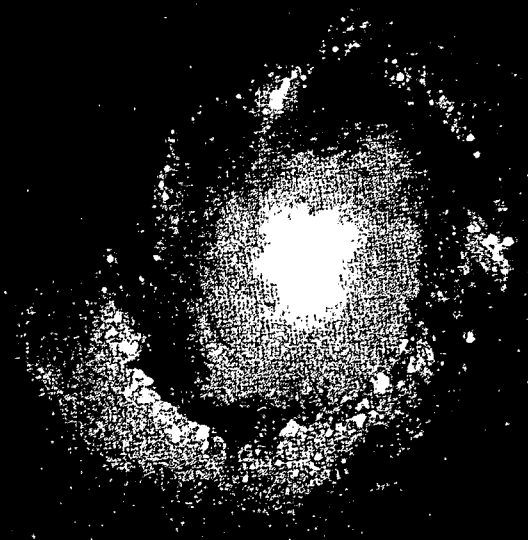
Electronic Field Trip Registrar

4414 Holborn Avenue
Annandale, VA 22003

Email FFXNetwork@chapelsq.fcps.k12.va.us
Fax 703.503.7501, Phone 703.503.7492





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Space

Space Day '99

Free Electronic Field Trip

May 6, 1999
1 p.m. EDT

the Quest in the Question

Beyond Every Question Lies a Great Adventure

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Challenger Learning Center

The Challenger Learning Center Network

Challenger Center for Space Science Education is the not-for-profit educational organization founded in 1986 following the Challenger 51-L space shuttle tragedy. Established by the families of the crew, which included America's first teacher in space, Challenger Center is backed by partnerships with nationally renowned educational and science organizations. Each Challenger Learning Center is designed to support America's goals of dramatically improving math and science education.

More than 300,000 students and teachers across the United States and Canada will experience the excitement of space exploration this year as part of a Challenger Learning Center simulation program. Using a youngster's natural fascination with space, Challenger Learning Centers foster a love of learning through hands-on, realistic space flight simulations.

The Challenger Learning Center Experience

Challenger Learning Centers offer students the next best thing to actual space flight with a mission control room designed after NASA Johnson Space Center and a room on board a space station. In this dynamic environment, students use principles of science and mathematics and technology to complete their tasks. As far as the students are concerned they are not in a classroom. Everything around them resembles a realistic Mission Control and Space Station - computer consoles, communication headsets, continuous messages on the loud speakers, electronic messages, teammates they can only see on video monitors and hands-on activities at science stations. Challenger Center specifically designed its simulation program to provide students with an authentic encounter with science and technology.

Embedded throughout the simulations are opportunities for students to use multiple process skills, including manipulation, procedural, and critical thinking skills. It provides students with an opportunity to apply the skills they've learned in the classroom. The experience creates a cooperative learning atmosphere underscored by teamwork, communication, problem-solving and decision-making.

Regardless of a student's cultural background, economic situation, gender, learning style or academic level every Challenger Center simulation provides students with an opportunity to succeed. Every mission is successful! Students have a renewed spirit of camaraderie and boosted self-esteem.

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Classroom Programs

A not-for-profit educational organization, Challenger Center for Space Science Education continues to explore new teaching techniques, learning environments and instructional programs. The result has been innovative programs that change how teachers teach and students learn. Challenger Center's educational programs are based on an acclaimed instructional model promoting communication, teamwork, problem-solving and decision-making.

Marsville: The Cosmic Village®

Marsville is a classroom based project that allows students to create a prototype habitat for Mars. Students create their own living environment using a multitude of interdisciplinary skills. The program culminates with a link-up day when all the classes rendezvous at one site to construct their cosmic village and share the experience of creating a settlement on Mars.

Marsville lends itself to use by multiple classes within a school and facilitates mentoring between grade levels as students learn to work together to solve the problems of every day life on Mars. The program was designed, however, to allow multiple schools within a school district or region to work together in a true spirit of cooperative learning to develop their Martian settlement.

Mars City Alpha®

Mars City Alpha is an exciting classroom simulation that transforms students into scientists and engineers launching an international effort to design a settlement on Mars. Students work in teams to prepare for their endeavor, which crosses the educational spectrum from technology to social studies to the arts. The culmination of this multiweek learning simulation has the students building a tabletop model of a futuristic human habitat on Mars. ***Mars City Alpha*** received Learning Magazine's coveted Teachers Choice Award in 1994.

Cosmic EdVentures: Exploring Earth's Neighborhood™

Designed as a multi-disciplinary program with lots of language arts, geography, social studies and art, ***Cosmic EdVentures*** also provides solid support for teachers to integrate the National Science Standards into their classroom instruction. During the program, students in grades 3-6 will explore such topics as:

- names, characteristics and order of bodies in the Solar System;
- the scale of the Planets and the vast distances between them;
- the phases of the Moon;
- the Earth's place in the Solar System;
- the Sun's place among the stars;
- the connection between Earth's axis and the four seasons; and
- some of the more fascinating features in the Solar System.

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Educator Workshops

Since its inception, Challenger Center for Space Science Education, a not-for-profit organization, has been committed to changing the way teachers teach and students learn. In 1987 NASA's Teacher-in-Space finalists joined the Challenger Center team creating a powerful International Faculty of master teachers dedicated to helping educators achieve that goal. Through the educator workshops offered by Challenger Center and led by this International Faculty, more than 25,000 classrooms throughout North America are now using Challenger Center's acclaimed instructional model promoting communication, teamwork, problem-solving and decision-making.

Touching the Future:
Linking the Classroom with Space™

Touching the Future is a day long workshop for 20-30 teachers designed to provide educators with opportunities to incorporate "space" into the classroom as a catalyst for learning. The program introduces participants to Challenger Center's materials and methodology to stimulate student interest in various subjects.

The ***Touching the Future*** workshop provides hands-on activities which demonstrate how space science can be used to teach skills in every discipline. The program targets upper elementary and middle school science, math and technology curriculum but may be adapted to any discipline or grade level.

EdVentures in Simulation:
A Great START for the 21st Century™

Designed for teachers who want to see their classrooms come alive with engaged learners, the ***EdVentures in Simulation*** workshop is a one-day, hands-on program stressing the theory and practice of simulation strategies for the classroom. Participants will be introduced to the current concepts of Multiple Intelligence and Situated Cognition and how the application of these constructs is facilitated by the use of simulation as a teaching tool.

The workshop comes with an easy to use workbook with templates, sample lesson plans and activities. Educators will be given a step by step model for transforming any activity into a powerful classroom simulation.

Classroom Program Training Workshops

Through its International Faculty, training programs for Challenger Center's award winning Classroom Programs, Mars City Alpha and Marsville the Cosmic Village are offered throughout the year.

For dates and locations for all of Challenger Center's Educator Workshops check Challenger Center OnLine at www.challenger.org or call 1-800-98 STARS.

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Launch Your Internet Exploration of Space at Challenger Center OnLine www.challenger.org

Whether you're going to a Challenger Center space simulation or just exploring the universe, make Challenger Center OnLine your first stop for:

- **Teacher Resources**
- **Educational Activities**
- **Space News**

Education Resources

Challenger Center OnLine aims to please teachers with the latest, greatest, fun and exciting news, space activities, clip art, and the neatest space-related Internet sites we can find.

Because Challenger Center programs focus on Comets, Mars, Earth, and the Moon, we place a special emphasis on providing resources for these topics.

This way teachers taking students to a Challenger Learning Center, or doing one of our classroom simulations, can find materials to use before and after their experience.

You'll notice that we cover a wide variety of space topics as well:

- **Comets**
- **Earth**
- **Mars**
- **Moon**
- **Astronomy**
- **International Space Station**
- **Shuttle**
- **Educational Sites**
- **Space "Clip Art"**
- **General Space**

Challenger Center OnLine features what teachers want...

Publications like Lesson Launchers, that contain resource pages, teacher notes and student worksheets.

Current news, like the NASA Press Release Kit for recent Mars Missions that contains quick facts, Mars at a glance, historical Mars missions, "Why Mars?", and spacecraft illustrations.

Challenger Center OnLine provides teachers and students with a wealth of activities and resources to facilitate the learning process at any grade level. Activities are provided in downloadable formats so that they may be directly reproduced for use in the classroom. In addition, a series of Lesson Launchers® are provided for some of the most popular activities from NASA's homepages. Challenger Center OnLine is your one stop for space science educational materials. Access Challenger Center OnLine at www.challenger.org and let the fun begin.

Inspiring. Exploring. Learning...
It's Our Mission!

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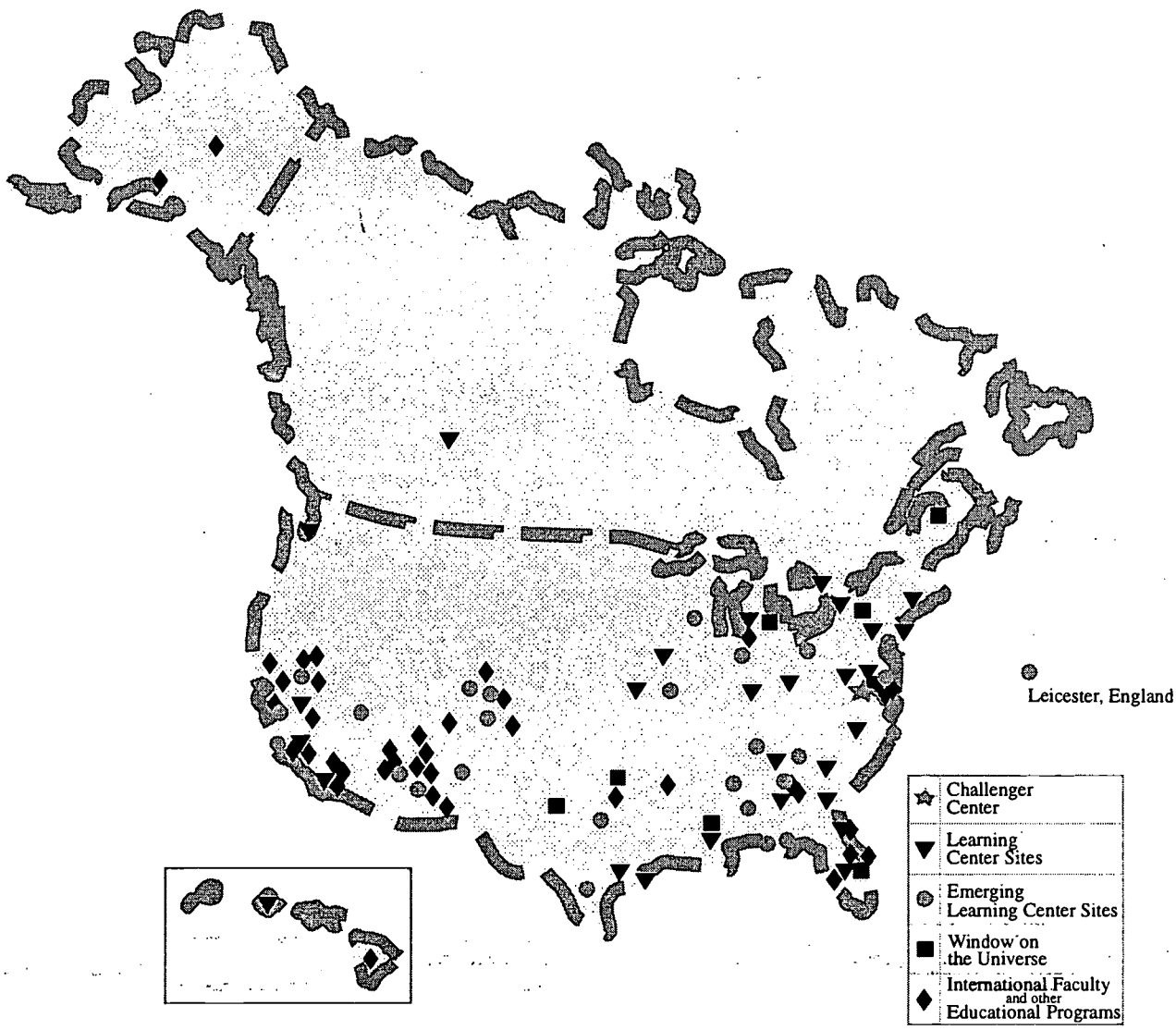

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STARDUST Educator Fellowship Activity

This activity is from the STARDUST Educator Fellowship Activity Guide. The STARDUST Educator Fellowship Program is a cooperative effort between Challenger Center for Space Sciene Education and NASA's Jet Propulsion Laboratory, targeting grades 5-8, encouraging everyone to THINK SMALL... in a very BIG way! Comets and asteroids made a BIG impact in early 1999. During January-February 1999, three "small body" NASA missions reached key milestones: Deep Space-1 flew by the asteroids 1992 KD; NEAR arrived at asteroid Eros in Feb. '99; and STARDUST, the first-ever cometary material return mission, launched in Feb. '99. Although small and often overlooked during Solar System lessons, comets and asteroids provide captivating topics for students.

The complete Activity Guide and more information on this exciting project can be found at **http://stardust.jpl.nasa.gov/education/activities.html.**

Challenger Center believes exploration is the essence of learning, and that imagination is just as important as knowledge. Using an irresistible combination of education and adventure to create Challenger Learning EdVentures™, our programs have inspired students and their teachers all around the world. For more information on Challenger Center, a not-for-profit organization headquartered in metropolitan Washington D.C., visit our web site at **http://www.challenger.org.**

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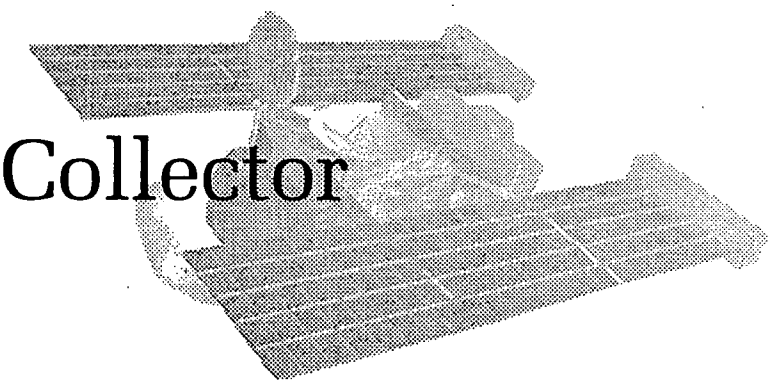
Aerogel Clay Collector



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.

This activity was developed by Challenger Center For Space Science Education based on the Aerogel-lo activity from Kirkpatrick Science and Air Space Museum at Omniplex. The original activity has been modified as a demonstration in Part 3.

Time Line

Part 1 = one class

Part 2 = one to three classes depending on variations

Part 3 = one class

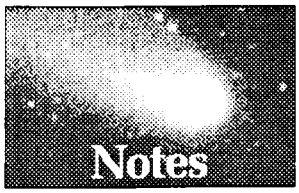
Part 4 = one to three classes each depending on the depth of exploration desired.

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?

Management

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 Characteristics of Falling Clay

PART 2: INTRODUCTION TO COMETS & STARDUST MISSION

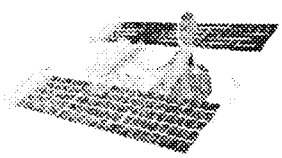
Use some combination of these materials:

- ❑ 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 Materials Testing, Collector Design, and Create Experiment Directions

Part 5: Evaluate Experimental Designs

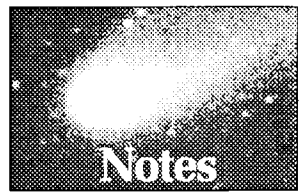
Teams will need:

- ❑ Copies of other team's directions
- ❑ Experiment Score Sheet

Part 6: Design Testing & Findings Presentations

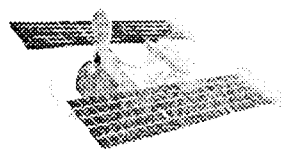
Each team will need:

- ❑ A set of directions for the chosen experiment
- ❑ Materials listed for the experiment
- ❑ Posterboard
- ❑ Markers
- ❑ Rulers
- ❑ Worksheet entitled Student Journal



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.



Notes

Part 1: Characteristics of Falling Clay

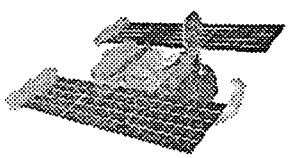
Part 1 is the hook of the activity. Here students explore the characteristics of clay when it falls. They identify and control variables and use the results to develop a "profile" on falling clay that they will use in parts 3-4.

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), and
   - 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.

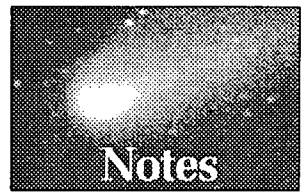
   They need to identify and control variables so they can write a profile on clay. For example students can drop the clay from different heights, at different speeds, on different surfaces, at different temperatures. It is up to the students to test only one variable at a time and provide detailed descriptions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



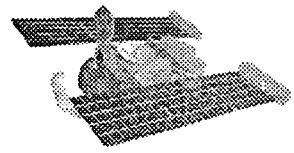
Reflection Questions

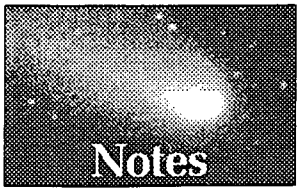
1. How do you describe the characteristics of your falling object?
2. What precautions did teams take to control variables in their experiments?
3. What was difficult about controlling variables?
4. What would your team do differently?
5. If more time was available, what would you like to try next?
6. 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 an upcoming 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: Comets & STARDUST Mission Overview

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.

Procedure

COMETS

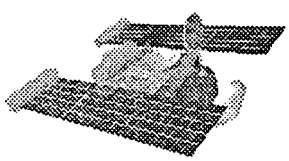
1. Find out what students know about comets and how they travel through the Solar System. Do the students hold any misconceptions?
2. Discuss parts of the comet and the manner in which they travel through the Solar System. See the Comet Fact Sheet for details.

   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.

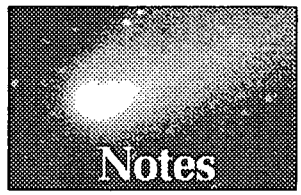
   This forms a coma around the nucleus. Charged particles from the Sun push the coma into two tails - a gas tail and a dust tail - that stream away from the Sun. These gas and dust particles in the tail are very small - smaller than grains of sand - and move at high speeds.
3. Ask the students how much 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 1993. However, spacecraft have only studied one comet (Comet Halley) and that was back in 1987. Today scientists have a lot of theories about comets, but they want to know more. Some scientists think comets are like dirty snowballs. Others think some comets are actually fluffy. If this is the case, it would be difficult to land a probe on a comet, which scientists are proposing to do for future missions. 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.
   - 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 (perhaps leading to the extinction of the dinosaurs and other types of life).



STARDUST

1. Discuss the STARDUST mission with students.

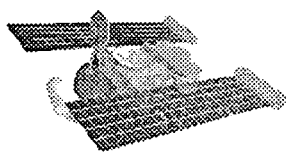
   STARDUST launches in 1999. It will get a gravity assist by looping around Earth to slingshot toward the comet. Enroute the spacecraft will go around the Sun twice, collecting interstellar dust. In 2004 STARDUST will fly through the coma of comet Wild 2 where gas and dust spew forth. The comet is named 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 you can get a copy of the videotape STARDUST Bringing Cosmic History to Earth, show it! This video is less than 10 minutes long and it is snazzy.
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?



Notes

Part 3:
Aerogel-lo Demonstration

This demonstration is based on Kirkpatrick Science and Air Space Museum at Omniplex's creation of "Aerogel-lo" from their Frozen Smoke Activity from *Grasping STARDUST.*

CAUTION

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

Preparation

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 aerogel-lo 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 gellatin 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.

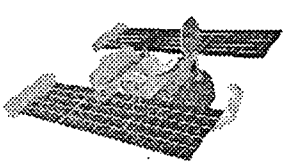
Procedure

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 10 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?

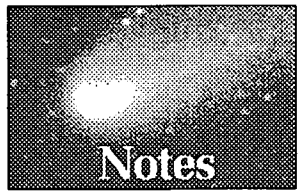
   Aerogel is mostly transparent. Scientists refer to it as blue smoke. It is a silicon-based solid that is 1,000 times less dense than glass with a sponge-like structure, in which 99% of the volume is empty space. An inch thickness of aerogel has the insulating power of six inches of fiberglass.

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

    Aerogel has been around since the 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 in manufacturing it.
11. How does aerogel act as a mechanism of capture?

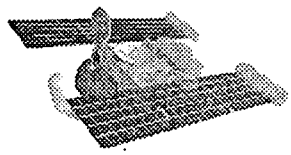
    When a particle hits the aerogel, it buries itself in the material, creating a carrot-shaped track up to 200 times its own length as it slows down and comes to a stop. Scientists will find the particle at the end of this track.
12. Have students compare the similarities between gelatin and aerogel as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



GEM Educator Fellowship Activity

This activity is from the Galileo Europa Mission (GEM) Educator Fellowship Activity Guide. The GEM Educator Fellowship Program is a cooperative effort between Challenger Center for Space Science Education and NASA's Jet Propulsion Laboratory, targeting grades K-12 and focusing on grades 6-12. The GEM mission is a follow-on of the Galileo Prime Mission. It is exploring the scientific topics of ice, water and fire as they relate to Jupiter and the Jovian system, most specifically to the moons Io and Europa. This dramatic two-year mission, from December 1997-1999, will highlight the many features on the icy moon Europa, examine the volcanoes of Io and even take a look at the thunderstorms on Jupiter.

The complete Activity Guide and more information on this exciting project can be found at **http://www.jpl.nasa.gov/galileo/activities.html.**

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Challenger CENTER

1029 North Royal Street, Suite 300 • Alexandria, Virginia 22314
(703) 683-9740 • 1-800-98STARS

Getting the Data Back

Grade Level: 5-12*

Approximate length: 2-3 class periods

SCIENCE STANDARDS:

5-8	9-12
• Evidence, models, and explanation • Abilities of technological design • Understanding about science and technology	• Evidence, models, and explanation • Abilities of technological design • Understanding about science and technology

MATHEMATICS STANDARDS:

5-8	9-12
• Patterns and functions • Mathematical connections	• Mathematical connections

Overview

This lesson contains an explanation and application of data transfer and compression, as well as image compression. After *Galileo's* High Gain Antenna failed to open, data compression became critical to salvaging the mission and its scientific objectives. Seventy percent of the original mission objectives were met as a result.

*Varies from activity to activity

Galileo

Bringing Jupiter To Earth

Getting the Data Back

Contents:

Data Transfer and Codes: BASE 2

Resource used: Curriculum Module #1

Activity description: Here is one suggestion for expanding the curriculum module into a math unit that shows that all this base 2 addition isn't just busywork:

It's 20 years in the future, and, instead of having to carry textbooks back and forth to class, students read them on their home computers. This means that at the start of each class, or at home you don't keep the entire book stored on your computer (it takes up too much room, and crowds off the games), but instead, you "download" just the chapters that you're working on.

The computer can only communicate in a limited fashion: it can only recognize something as being a "on" or "off" (much like Morse code, which recognized short "dots" and long "dashes"). So, we have to come up with a "code" that will tell the computer "this is an a" or whatever. However, we want to be able to send the data back and forth as quickly as possible, so we also want to minimize the number of "ons" and "offs" that have to be sent.

Have the students come up with a code that will cover each letter. For example,

a = (on)
b = (on)(on)
c = (on)(on)(on)
etc.

with "off" signifying the end of a letter.

Spell out the words "zebra" and "milk" in your code. How many bits of information does this take?

zebra = 26 + 5 + 2 + 18 + 1 + 5 offs = 57 bits
milk = 13 + 9 + 12 + 11 + 4 offs = 49 bits

How many bits of information, on average, will it take to identify each letter? (14)

Is there any way to minimize the number of bits that will get used on average? (some letters occur more frequently (e.g. e, s, t); assign those letters to a smaller number of "ons")

Also, we must account for capital letters, punctuation, and numerals. How many characters total do we need?

a-z = 26
A-Z = 26
numbers, punctuation, etc. (count keys on keyboard) = 42
94 characters needed, total.

Having to write out 94 (on)s is going to get tedious! Let's try another possibility. Make each letter exactly 7 bits of information long. Then, you could have (for example)

a = (off) (off) (off) (off) (off) (off) (off)
b = (off) (off) (off) (off) (off) (off) (ON)
c = (off) (off) (off) (off) (off) (ON) (off)
d = (off) (off) (off) (off) (off) (ON) (ON)

and so on; moving from the right, we keep turning on little switches. This scheme has some nice advantages: every letter or bit of punctuation only takes up seven bits of data.

Why seven bits?

If we had a code that said that each letter can only be one bit long, the computer would only receive two possible letters: (on) would be one letter, and (off) would be the other letter. If your entire vocabulary consists of the word "og," this is no problem, but it would definitely hinder conversation in English.

If each letter could be 2 bits long, then we would have these possibilities:

(on)(on)
(on)(off)
(off)(on)
(off)(off) = 2 possibilities x 2 possibilities = 4 possible letters

If letters could be 3 bits long, what would the possibilities be?

(on)(on)(on)
(on)(on)(off)
(on)(off)(on)
(on)(off)(off)
(off)(on)(on)
(off)(on)(off)
(off)(off)(on)
(off)(off)(off) = 2 possibilities x 2 possibilities x 2 possibilities = 8 possible letters

If we allow each letter to be 7 bits long, 2 x 2 x 2 x 2 x 2 x 2 = 128 possibilities, more than we really need (but 2 x 2 x 2 x 2 x 2 x 2 = 64, which is too few). Actually, computers assume 8 bits per letter: this allows for additional characters that aren't used in all languages (such as the British pound symbol).

Instead of writing (on) and (off), let's write 1 and 0. In this type of shorthand, the thirteenth number, for example, is written as 1101, where each "place" further from the right side increases by a factor of 2, compared with the numbers we're used to writing (where each place increases by a factor of 10). This is why we call normal numbers "base 10" and the other system "base 2;" we also see here that systems other than base 10 can have real-world uses (base 16 is also used for computer purposes, as is base 8).

What is meant by "bit rate?"

Have students come up with a list of different ways to send a message to a friend living 50 miles away (e.g. smoke signals, pony express, letter, telegraph, phone call, fax). Which ways are fastest? Which are slowest? How can we measure how fast each of these sends the data?

Spacecraft engineers (and computer engineers, too), talk about "bit rate," which measures how many bits of information can get sent by the computer each second. A home modem can easily send over 14,000 bits per second (bps). Let's see what bit rate really means:

a) Pick out a book, and count the words on one page. Have one student read the page out loud at "normal" speed while another student acts as timer. Try doing this as fast as possible, too, while making sure that the other person can actually understand WHAT you're saying. How fast can YOU read and still be understandable? (one JPL engineer, trying this, got out 4.4 words per second.).

Change this to a bit rate. Assume that there are 5 letters per word, and 8 bits per letter, so there are 40 bits per word. If you can read 4.4 words per second, that's 176 bits per second.

How long would it take you to read the entire book?

Now, let's make the problem harder. Go outside on a noisy street (or in front of a loud fan, or in the middle of a lunchroom), and, once again, read the page out loud. Notice how, if you read very quickly, the words get lost in the noise--you have to be careful and make sure that each word is clearly pronounced, which makes you slow down. What is your bit rate now? How low does your bit rate drop if you move 10 feet away from the person who is listening to you?

Just as your "bit rate" drops when you get further away, or when other noise interferes with your "signal," so too Galileo's bit rate drops when its signal weakens with distance, or when it has to overcome interference (such as when its signal has to pass near the Sun, which can generate a great deal of radio noise). Galileo will be communicating back to earth at a top rate of 160 bits per second. How long would it take Galileo to read the book?

Compression: Huffman codes

Compressing the data before sending it back allows us to make the most of our limited spacecraft-to-Earth bit rate. Here is one example of using "minimal encoding schemes" to decrease the size of a file. Called "Huffman codes," this is the basis for Galileo's compression process.

In this activity, we will demonstrate how these codes reduce the number of bits that it takes to encode a file by assigning fewer bits to the most frequently used letters.

Using the standard encoding scheme (introduced in the previous activity on Base 2), each letter of the alphabet requires the same number of bits. Suppose we have a message which uses that "normal" encoding scheme. The message contains only the letters E, I, N, P, S, and T. To represent this six-letter alphabet with a standard encoding scheme (which, as you may recall, uses the same number of bits per letter), we would need three bits per letter. (Two bits is not enough because $2^2 = 4$. But $2^3 = 8$, which is enough.[1])

In that message, there are twenty-nine E's, five I's, seven N's, twelve P's, four S's, and eight T's.

Letter	Code	Number of times it appears in the file	Total bits required
E	000	29	87
I	001	5	15
N	010	7	21
P	011	12	36
S	100	4	12
T	101	8	24
Total:		*65*	*195*

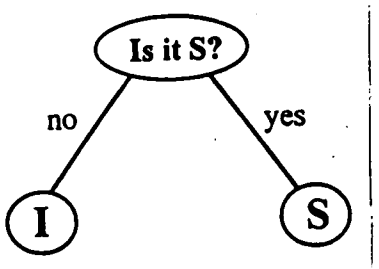
In real life, files can be quite large -- much larger than 195 bits or 65 letters. Furthermore, in many files, there is a significant gap between the highest and lowest frequencies of letters. For example, many large data files have a huge number of digits but very few x's and q's.

Huffman codes take advantage of that property by assigning fewer bits to the most frequently used letters in exchange for requiring more bits for less frequently used letters. So, to create a Huffman encoding scheme, first sort the frequencies into increasing order:

[1] Using a standard encoding scheme, the minimum number of bits required to represent an alphabet of size X is $\lceil \log_2 X \rceil$.

Letter	Number of times it appears in the file
S	4
I	5
N	7
T	8
P	12
E	29
Total:	*65*

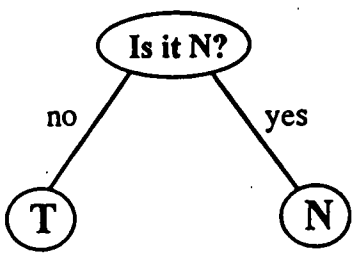
Then, choose the smallest two values from the table -- in this case, S and I. Combine them into a flowchart, or "decision tree"[2]:



Now combine S and I in the table above, sort it into increasing order again, and you have:

Letter (s)	Number of times it/ they appear in the file
N	7
T	8
I & S	5+4 = 9
P	12
E	29
Total:	*65*

Once again, pick the smallest two values from the table -- this time, N and T. Combine them into anther decision tree:

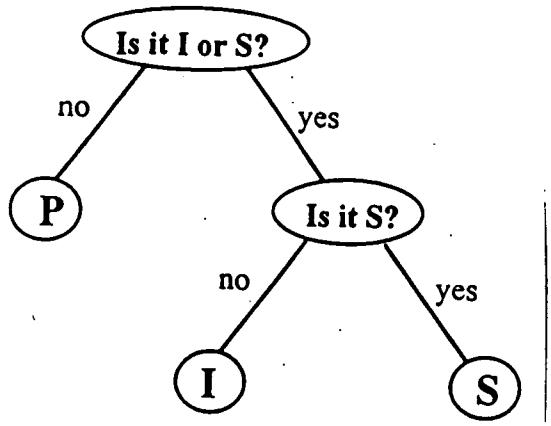


[2] In this tree, the letter with the lower frequency is made into the question ("Is it __?"), the left branch is the negative answer, and the right branch is the affirmative answer. That order is arbitrary, and it doesn't have to be done in the same order for the rest of the trees constructed. However, it is convenient to follow a consistent pattern, and we will do so here.

Now merge N and T into the table and sort it once more:

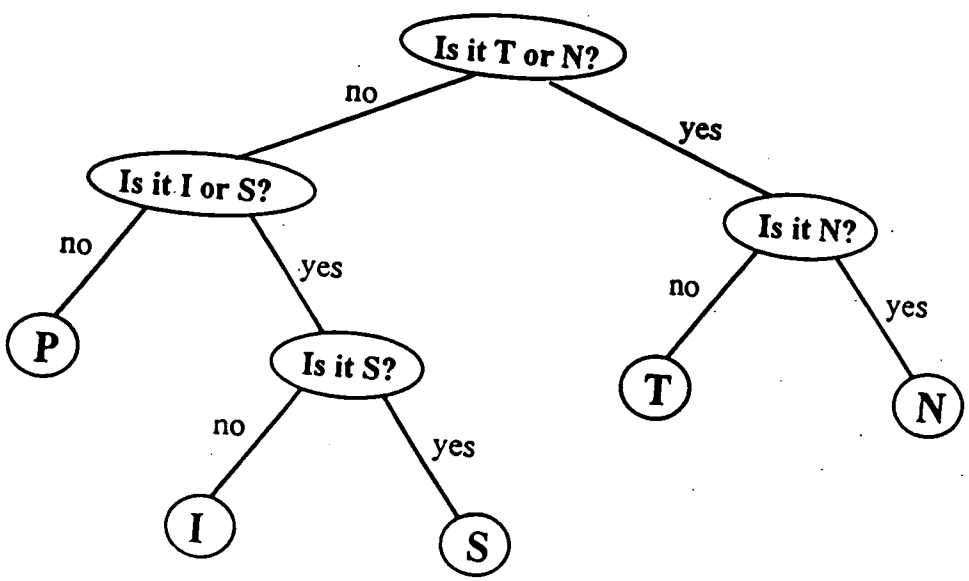
Letter (s)	Number of times it/ they appear in the file
I & S	5+4 = 9
P	12
T & N	8 + 7 = 15
E	29
Total:	*65*

The third time around, the two smallest values in the table include a pair that has already been combined. But that's not a problem; just do the same as before -- pick the smallest two values, put them into a decision tree, combine the frequency values in the table, and sort the table:



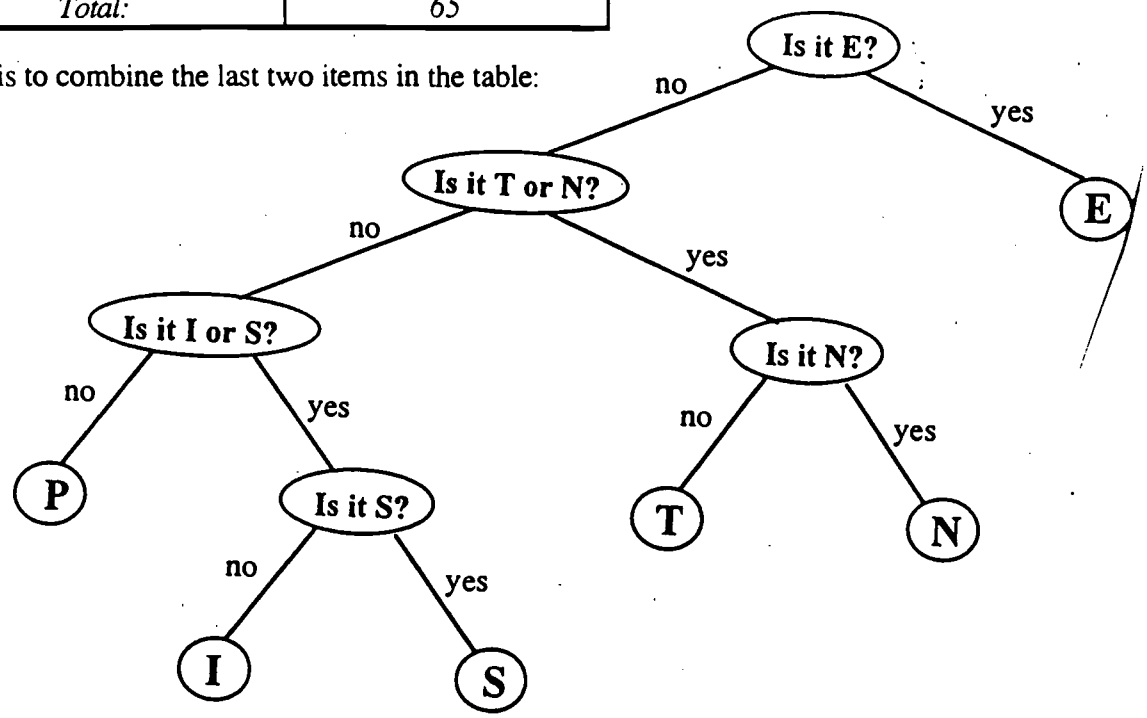
Letter (s)	Number of times it/ they appear in the file
T & N	8 + 7 = 15
P & (I & S)	12 + 9 = 21
E	29
Total:	*65*

The next time, both of the things to be combined are decision trees. Again, follow the same procedure of taking the smallest two frequency values from the table, putting them into a decision tree, inserting the new (combined) value back into the table, and re-sorting the table.



Letter (s)	Number of times it/ they appear in the file
[P & (I & S)] & (T & N)	21 + 15 = 36
E	29
Total:	*65*

The last step is to combine the last two items in the table:

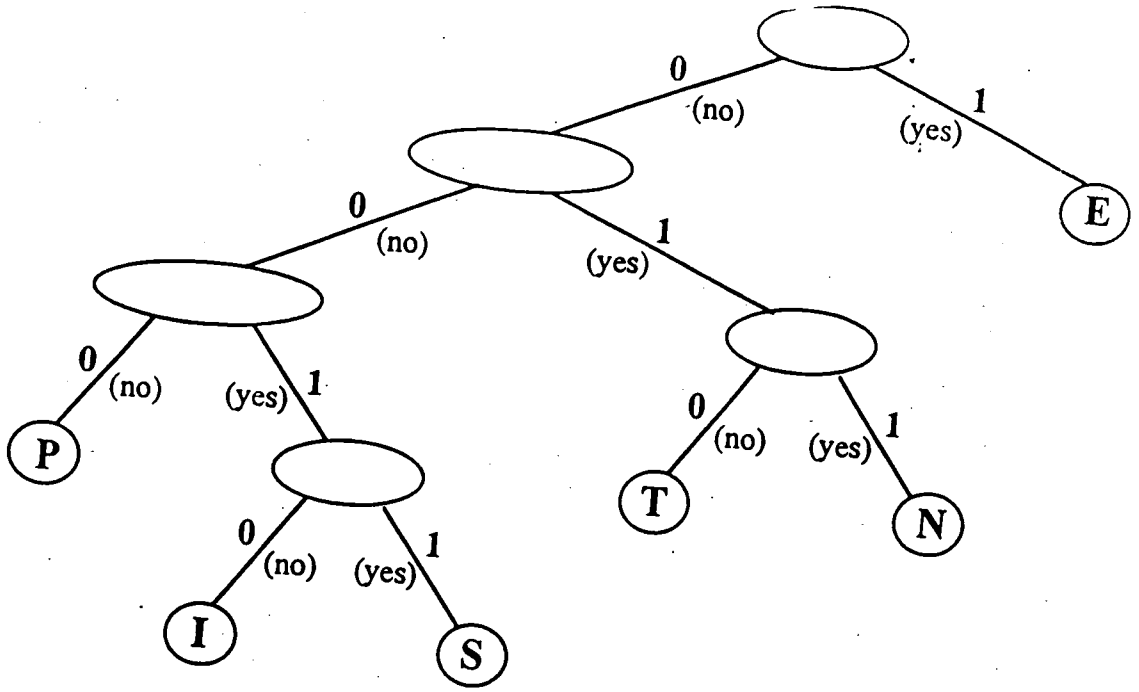


The resulting decision tree is more than just a nice diagram. Take a look at the original chart of letters and frequencies:

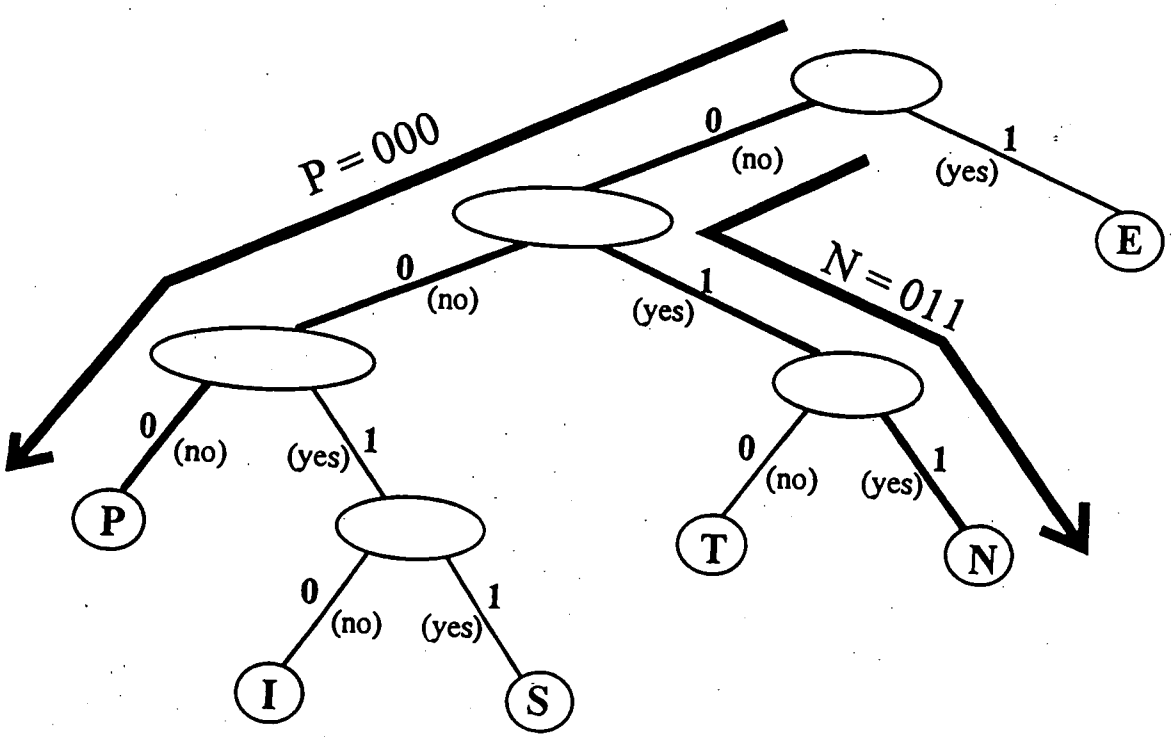
Letter	Number of times it appears in the file
S	4
I	5
N	7
T	8
P	12
E	29
Total:	*65*

How many questions does it take to reach the most frequently occurring letter? How many questions does it take to represent the least frequently occurring letter?

The decision tree that we have just constructed requires fewer questions, and therefore fewer "yes" or "no" branches, to reach the letters that occur more frequently. If we replace the "yes"es and "no"s with 1's and 0's respectively -- we can remove the questions, too -- what we get is an efficient way (a Huffman encoding) to represent our 6-letter alphabet:



The encoding of a letter consists of the 0's and 1's that are passed by on the path to that letter. For example, P is represented by the bit string 000 and N by the string 011:



The letter E is represented by the single bit 1, and the word "SENT" would be coded as 00111011010.

Now we have:

Letter	Code	Number of times it appears in the file	Total bits required
S	0011	4	16
I	0010	5	20
N	011	7	21
T	010	8	24
P	000	12	36
E	1	29	29
Total:		*65*	*146*

In two cases (S and I), the total number of bits required increased, but the number of bits required for the most frequently occurring letter dropped dramatically -- from 87 to 29! If the file had been encoded in the "normal way" (using 3 bits for each letter), it would have required 195 bits. Using these new codes, the message requires 146 bits -- a savings of 49 bits.

Codes such as these can be constructed for entire languages by using the average frequency counts for the letters. They can also be used in files of data, which may have different frequency counts (more digits and few letters, for example).

Huffman codes are called *prefix* encoding. As soon as a 1 is read as the first digit, you know it is an E. 0010 is an I -- you do not need to see any more bits. The codes have this feature because a code for one letter is never the first part of a code for another letter.

In addition, because they do not cause any information to be lost, Huffman codes are what is called a *lossless* compression. Other compression algorithms are *lossy* but can give better compression ratios. (For an example of lossy compression, see the activity entitled "Data Handling Techniques," which appears on page 12 of the Galileo Curriculum Module.)

By itself, Huffman codes reduce the size of the Galileo data down to as small as 50% of the size of the uncompressed data. For an even better rate of compression, Huffman codes can be applied to sets of data that are already compressed. On Galileo, data that is "lossy" compressed and then Huffman-encoded can be reduced down to 5-10% of its original size!

This description of Huffman codes was based on a description written by Karen Van Houten., a professor of computer science at the University of Idaho. You can find her original description at: *http://www.cs.uidaho.edu/~karenv/cs213/useful.pages/huffman.html.*

Questions:

1. a) Using the encoding scheme introduced in this activity, how would you encode the word "SEEN"? Using the original encoding scheme (with 3 bits for each letter), how would you encode the same word? Which encoding is shorter? How many bits do you save?

b) Answer the questions in part (a) for the word "PENS".

c) Answer the questions in part (a) for the word "PINS".

d) Compare the savings for individual words with the savings for the file on which the encoding scheme was based. What can you conclude about the savings for individual words compared to the savings for an entire file?

2. Construct a Huffman encoding for the following file:

Letter	Original Code	Number of times it appears in the file	Total bits required
A	000	9	27
E	001	15	45
O	010	5	15
P	011	8	24
S	100	14	42
T	101	12	36
Total:		*73*	*189*

Analyze the savings using the Huffman codes both for the file and a whole and for indivual words that the file could contain.

3. Computers represent the spaces in-between words the same way they represent letters -- with a series of bits. In this question, the notation "*<space>*" is used to represent a space.

Suppose that you use the following regular encoding scheme to send the message "MEET ME AT TEN" to a friend. Fill in the table with frequencies of the letters and the bits required to represent them.

Letter	Code	Number of times it appears in the message	Total bits required
M	000		
E	001		
T	010		
<space>	011		
A	100		
N	101		
Total:	---		

Now, construct a Huffman encoding for the same message. Compare the total number of bits required for each letter using the two different encodings. How many bits do you save overall by using the Huffman codes? What portion of the bits in the original encoded message is that?

When you encode the message using the Huffman scheme, how do you know where the code for one letter begins and the one for the next letter begins? Is there any other message that could be represented by the same series of bits?

Image compression

An interesting activity that illustrates ways in which images are compressed can be found on page 12 of the Galileo Curriculum Module.

Reconstructing the image

When Galileo's camera takes a picture, it doesn't actually take a single color image. It's able to record the amount, or intensity, of light that it receives in each pixel, but not what wavelength of light it is. In fact, any single image taken by Galileo's camera will be black and white and shades of grey.

How, then, do we get those stunning color images of Jupiter and its moons? The answer is: Use filters! Placing a filter in the camera that allows only green wavelengths to pass through, for example, will produce an image that shows *only* the green components of things. It will still be black and white, but black means "no green," and white means "bright green." In visible light, there are three primary colors -- red, green, and blue -- that combine in different ways to produce all the other colors. To produce a color image that represents how a scene would look to our eyes, we must combine the images taken through each of these three primary color filters, and "colorize" the pixels of each individual image.

To simulate the combination of the primary colors of light, purchase cellophane paper that is as close as you can get to each of the primary colors. If you buy colors that are somewhat different from those, your experiment will not work properly. Next, you'll need 3 flashlights that have about the same beam size and intensity, so that when their light projected on top of each other, they won't wash the others out. Cover each flashlight with the primary color cellophane. You may need to put several layers to make the color balance come out right.

Start with the green light and red lights. Point them at a white wall so the beams are side by side and study their colors. Then slowly overlap the beams and watch what happens to the color. Its yellow! Light of red and green wavelengths together appears as yellow to our eyes. Now try the same with the other combinations. You'll find the colors red and blue together form magenta, and blue and green form a greenish-blue called cyan. What do you get when you combine all three colors?

Imagine these beams are from one pixel of an image, each from a different filter. A bright pixel in the red filter will combine with a bright pixel in the green to make a yellow pixel when we put the images from those filters together. Add the pixel from the blue filter - if its bright, you'll end up with a white pixel (because you'll have all the primary colors present; if its dark, the pixel will remain yellow.

Picture	Red Light	Green Light	Blue Light	Apparent Color to Human Eye
1	n	n	n	black
2	y	n	n	red
3	n	n	y	blue
4	n	y	n	green
5	y	n	y	magenta
6	y	y	n	yellow

7	n	y	y	cyan
8	y	y	y	white

This represents a *very* simple camera on a spacecraft that captures pictures of moons: for each color (a single wavelength) that the camera could detect, it would be either "present" or "not present" -- no variations in intensity could be recorded.

Our eye can literally perceive and distinguish a spectrum of colors, which the simple spacecraft camera cannot record and hence the cellophane display cannot reproduce. The filters in Galileo's camera allow through wavelengths over a wider range than that represented by the cellophane, so more colors can be recorded with it. Also, the cellophane camera only represents two intensities of light (present or not present), whereas Galileo's camera can represent 256 different intensities (shades of gray). In order to reproduce so many different colors and intensities, we use computers rather than combining cellophane paper to process the images when they are returned.

It's interesting to note that the filters used in Galileo's camera to represent what our eye would see ("true" color) are slightly different from what the camera on Voyager used (basically, Voyager used an orange filter instead of red). Thus, true color images from Galileo are closer to how they'd look to us than those from Voyager. These are especially evident in images ith a lot of red in them, like those of Io or Jupiter.

The Galileo camera and other instruments (such as NIMS, which observes the Near-Infrared wavelengths) can also look at other wavelengths that our eye cannot see. By assigning arbitrary colors to these other wavelengths, we produce a "false color" image.

For a description of how light is combined to produce diffferent colors on a television screen or computer monitor, take a look at the section entitled "Television Set" in David Macaulay's book "The Way Things Work."

Computer Image Processing

If you have access to a full-featured image processing program such as Photoshop, you can give a much more realistic demonstration of image processing by splitting the red, green, and blue channels. Here's how to do it in Photoshop 3.0:

1) Open an electronic image (the more colorful, the better) from within Photoshop.
2) Select RGB mode: Click on Mode(from the menu bar) -> select RGB Mode. (For an explanation of these modes, refer to the Photoshop user's guide.)
3) Display the channels: Click on Window (from the menu bar) -> Palettes -> Show Channels.
4) Separate the red, green, and blue channels: On the toolbar that shows the channels, click on the arrow in the upper right hand corner to reveal a menu. Choose "Split Channels." The three new grayscale images that will appear represent the intensity throughout the image of red, green, and blue. For example, in the red channel, black represents no red and white represents the most intense red. Each pixel represents a numerical value which is the intensity of the color detected through that particular filter.

5) Merge the channels: From the channels toolbar again, click on the arrow in the upper right corner; this time select "Merge Channels" and click "OK" twice. Combining the channels represents the step in image processing in which the images from each filter are combined to form a full-color image. When combining the images taken through the different filters on a spacecraft's camera, the images must be lined up first because they are not necessarily in the same part of the frame due to the spacecraft's constant motion.

mission log

Student Investigator

the Quest in the Question

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mission log

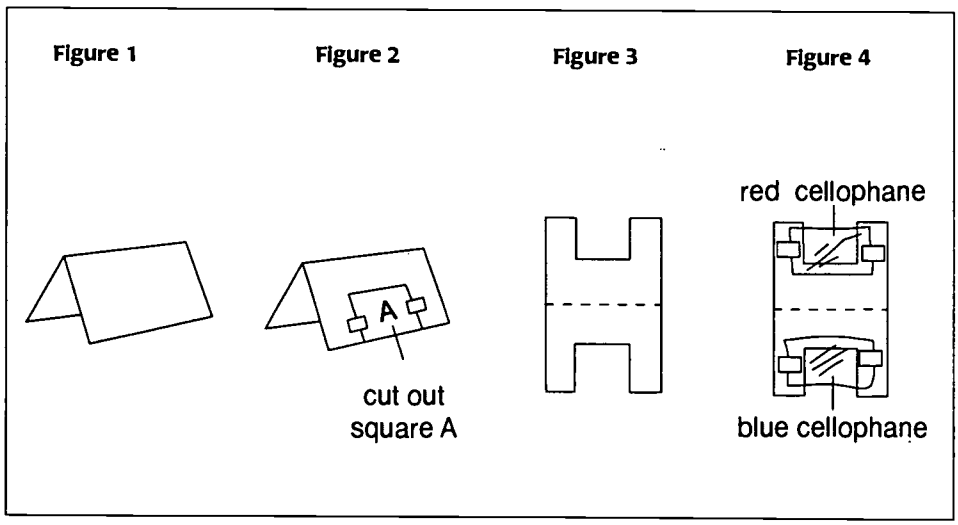
How Can Certain Colors of Light Be Removed From the Light We See?

Light Experiment 2

1. Fold an index card in half. (Figure 1)
2. Cut out the rectangle template below.
3. Tape template A to the folded index card. (Figure 2)
4. Now cut through both halves of the index card, while cutting around the template. Open card. (Figure 3)
5. Tape the red cellophane to one side of your instrument so that it covers one of the rectangular holes. (Figure 4)
6. Use a red Sharpie® pen and color the red cellophane to make it darker red. This is your red filter.
7. Tape the blue cellophane to one side of your instrument so that it covers the other rectangular hole.
8. Use a blue Sharpie® pen and color the blue cellophane to make it darker blue. This is your blue filter.
9. Use crayons to color the image on the next page.
10. Predict what you think will happen to each color when you observe the color through the red filter. Write this in the chart.
11. Predict what you think will happen to each color when you observe the color through the blue filter. Write this in the chart.
12. View the image with the blue side and then the red side of your instrument.
13. Record your color observations.

Now, using what you have learned, design your own hidden image.

	Red Filter Prediction	Results	Blue Filter Prediction	Results
red				
orange				
yellow				
green				
blue				
indigo				
violet				



Cut out and tape to the folded index card.

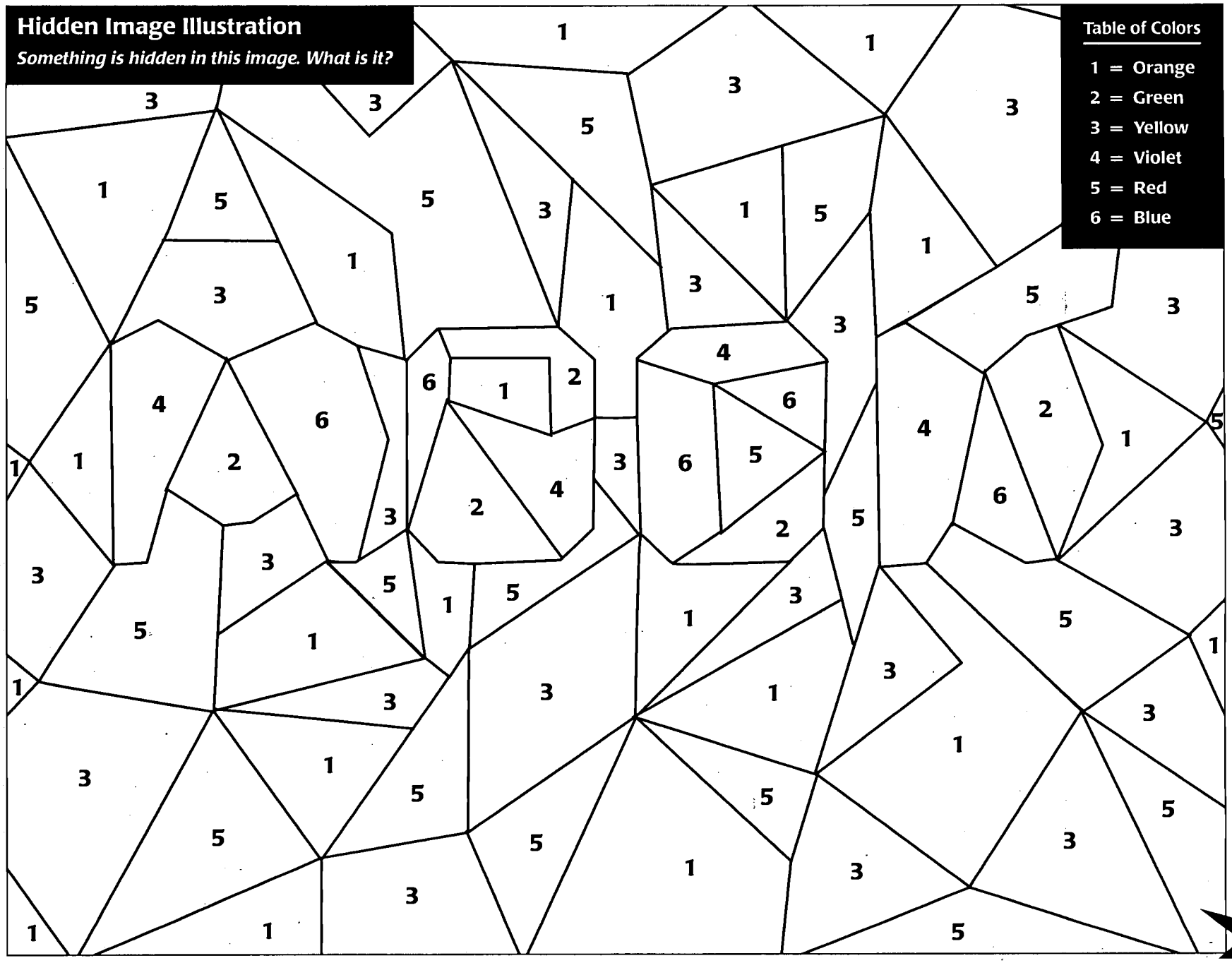
Template A

Hidden Image Illustration

Something is hidden in this image. What is it?

Table of Colors

1 = Orange
2 = Green
3 = Yellow
4 = Violet
5 = Red
6 = Blue



S.5

mission log

How Do Light Filters Help Space Scientists Study Objects in Space?

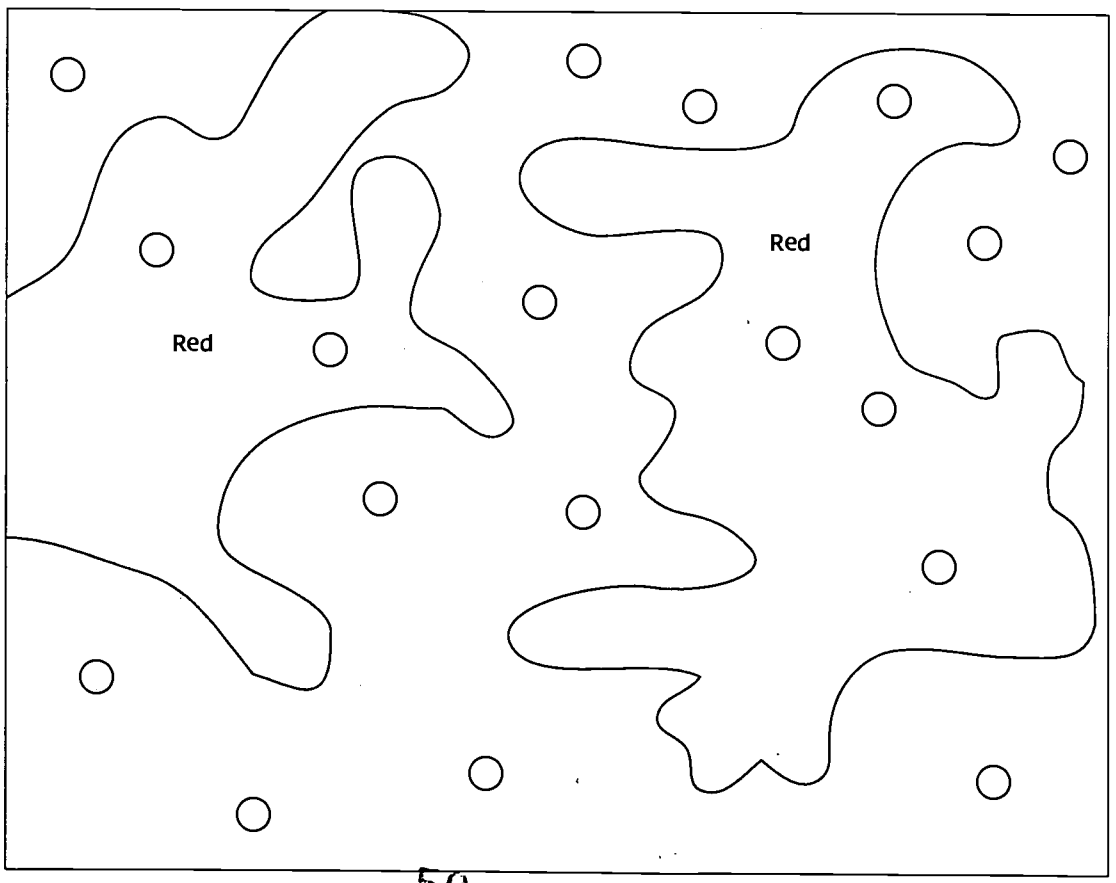
Light Activity

1. Look at an image of an emission nebula. Your teacher may provide you with one or you can go online at www.challenger.org/quest or you can buy the June edition of *Astronomy* magazine.
2. Observe your image using your blue and red filters.
3. Draw what you see through each filter.

How are these images different?

If you do not have the opportunity to see a photograph of a nebula, color the image below. The red are nebulae. The small white circles are stars. Color the background black, color the nebulae red, and leave the circles white.

A nebula is a vast cloud of dust or gas in space. This picture contains an emission nebula. It is made of gas and dust. Emission nebulae give off their own light because the bright stars near them are giving them energy.



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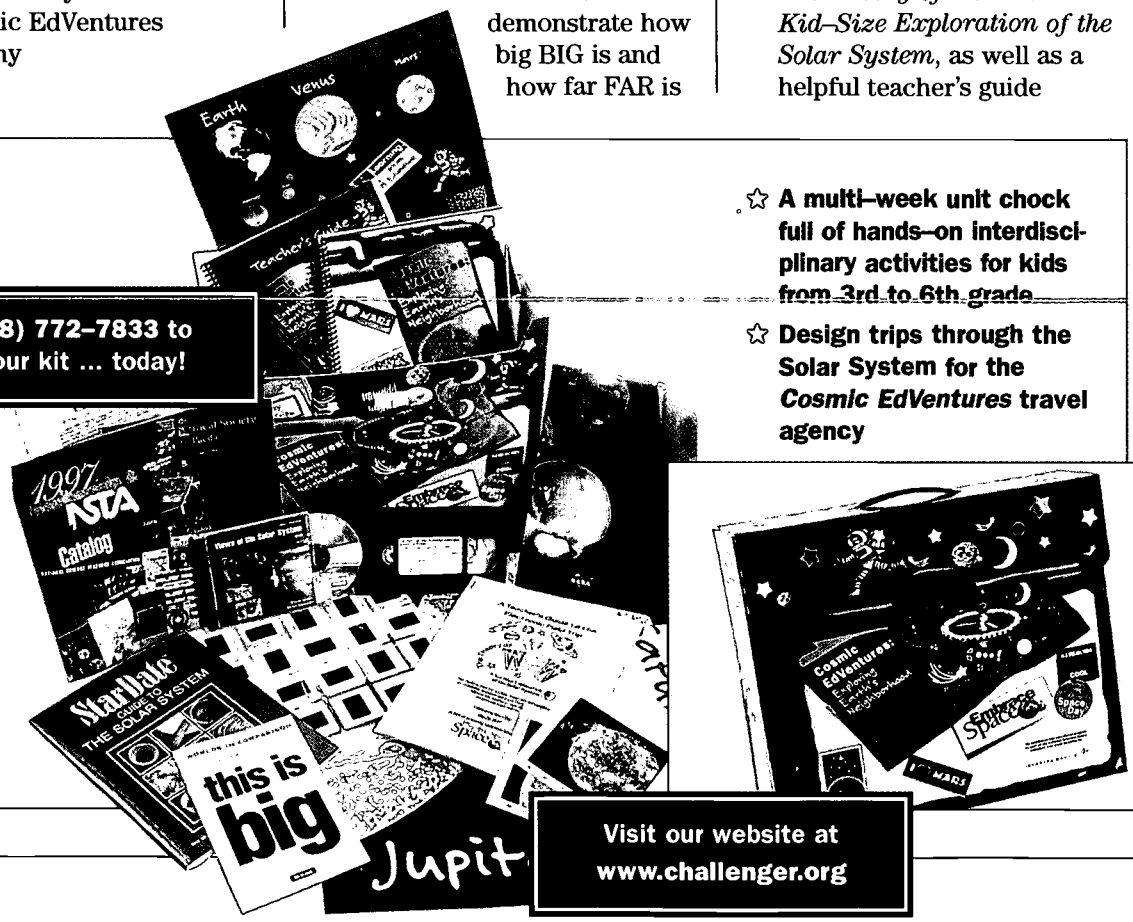

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