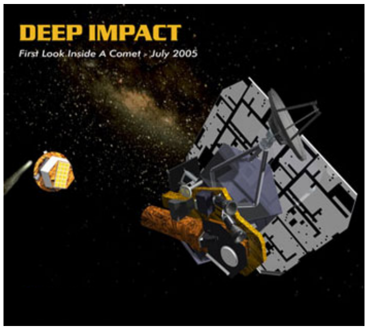


Exploring Comets and Modeling for Mission Success

National Science Education Standards Alignment

Created for Deep Impact, A NASA Discovery mission

Maura Rountree-Brown and Art Hammon
Educator-Enrichment

Grades 5 – 8

Science as Inquiry

Abilities necessary to do scientific inquiry

- Identify questions that can be answered through scientific investigations.
  - *Exploring Comets: Reflections on comets, missions and modeling*
- Develop descriptions, explanations, predictions, and models using evidence.
  - *Make a Comet and Eat It!, Chemistry and Thermodynamics of Ice Cream, Comet on a Stick, Paper Comet with a Deep Impact, and Comet Models Based on the Deep Impact Mission*
- Think critically and logically to make the relationships between evidence and explanations.
  - *Make a Comet and Eat It!, Comet on a Stick, Paper Comet with a Deep Impact, and Comet Models Based on the Deep Impact Mission*
- Communicate scientific procedures and explanations.
  - *Make a Comet and Eat It!*

Understandings about scientific inquiry

- Different kinds of questions suggest different kinds of scientific investigations. Some investigations involve observing and describing objects, or events; some involve experiments; some involve seeking more information; some involve discovery of new objects and phenomena; and some involve making models.
  - *Make a Comet and Eat It!, Chemistry and Thermodynamics of Ice Cream, Comet on a Stick, Paper Comet with a Deep Impact, Comet Models Based on the Deep Impact Mission, and Deep Impact Comet Modeling*
- Current scientific knowledge and understanding guide scientific investigations. Different scientific domains employ different methods, core theories, and standards to advance scientific knowledge and understanding.
  - *A Comet's Place in the Solar System, Exploring Comets: Reflections on comets, missions and modeling, Deep Impact Comet Modeling, Deep Impact: Interesting Comet Facts, and Small Bodies Missions*

- Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories. The scientific community accepts and uses such explanations until displaced by better scientific ones. When such displacement occurs, science advances.
  - *Consider This!, A Comet's Place in the Solar System, Deep Impact Comet Modeling*
- Scientific investigations sometimes result in new ideas and phenomena for study, generate new methods or procedures for an investigation, or develop new technologies to improve the collection of data. All of these results can lead to new investigations.
  - *Exploring Comets: Reflections on comets, missions and modeling, A Comet's Place in the Solar System*

Physical Science

Properties and changes of properties in matter

- A mixture of substances often can be separated into the original substances using one or more of the characteristic properties.
  - *Make a Comet and Eat It!, Chemistry and Thermodynamics of Ice Cream*
- Substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristic properties. In chemical reactions, the total mass is conserved.
  - *Chemistry and Thermodynamics of Ice Cream*

Motions and forces

- The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.
  - *Comet on a Stick, Paper Comet with a Deep Impact*
- Unbalanced forces will cause changes in the speed or direction of an object's motion.
  - *Comet on a Stick, Paper Comet with a Deep Impact*

Transfer of energy

- Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.
  - *Chemistry and Thermodynamics of Ice Cream*
- Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature.
  - *Chemistry and Thermodynamics of Ice Cream*
- In most chemical and nuclear reactions, energy is transferred into or out of a system. Heat, light, mechanical motion, or electricity might all be involved in such transfers.
  - *Chemistry and Thermodynamics of Ice Cream*

Earth and Space Science

Earth in the solar system

- The earth is the third planet from the sun in a system that includes the moon, the sun, eight other planets and their moons, and smaller objects, such as asteroids and comets. The sun, an average star, is the central and largest body in the solar system.
  - *Small Bodies Missions, A Comet's Place in the Solar System, Ten Important Comet Facts, The Deep Impact Comet Acrostic, Comet on a Stick, Paper Comet with a Deep Impact*
- Most objects in the solar system are in regular and predictable motion.
  - *A Comet's Place in the Solar System, Ten Important Comet Facts, The Deep Impact Comet Acrostic, Comet on a Stick, Paper Comet with a Deep Impact*
- Gravity is the force that keeps planets in orbit around the sun and governs the rest of the motion in the solar system.
  - *A Comet's Place in the Solar System*

Science and Technology

Abilities of technological design

- Design a solution or product.
  - *Comet on a Stick, Paper Comet with a Deep Impact, and Comet Models Based on the Deep Impact Mission*
- Implement a proposed design.
  - *Comet on a Stick, Paper Comet with a Deep Impact, and Comet Models Based on the Deep Impact Mission*
- Evaluate completed technological designs or products.
  - *Comet on a Stick, Paper Comet with a Deep Impact, and Comet Models Based on the Deep Impact Mission*

Understandings about science and technology

- Scientific inquiry and technological design have similarities and differences. Scientists propose explanations for questions about the natural world, and engineers propose solutions relating to human problems, needs, and aspirations.
  - *Consider This!, A Comet's Place in the Solar System*
- Many different people in different cultures have made and continue to make contributions to science and technology.
  - *Consider This!, Small Bodies Missions*
- Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable due to factors such as quantity, distance, location, size, and speed. Technology also provides tools for investigations, inquiry, and analysis.

- *A Comet's Place in the Solar System, Small Bodies Missions*
- Perfectly designed solutions do not exist.
  - *Comet on a Stick, Paper Comet with a Deep Impact*

Science in Personal and Social Perspectives

Personal health

- Natural hazards include possible impacts of asteroids.
  - *Briefly addressed in Consider This! And Ten Important Comet Facts*

Science and technology in society

- Science and technology have advanced through contributions of many different people, in different cultures, at different times in history.
  - *Consider This!, A Comet's Place in the Solar System*

History and Nature of Science

Nature of science

- Scientists formulate and test their explanations of nature using observation.
  - *A Comet's Place in the Solar System, Deep Impact Comet Modeling*

Unifying Concepts and Processes (K-12)

Evidence, models, and explanation

- *Make a Comet and Eat It!, Comet on a Stick, Paper Comet with a Deep Impact, and Comet Models Based on the Deep Impact Mission*

Grades K-4

Science as Inquiry

Abilities necessary to do scientific inquiry

- Plan and conduct a simple investigation.
  - *Make a Comet and Eat It!, Comet on a Stick, Paper Comet with a Deep Impact, and Comet Models Based on the Deep Impact Mission*
- Use data to construct a reasonable explanation.
  - *Make a Comet and Eat It!, Comet on a Stick, Paper Comet with a Deep Impact, and Comet Models Based on the Deep Impact Mission*
- Communicate investigations and explanations.
  - *Make a Comet and Eat It!*

Understandings about scientific inquiry

- Scientific investigations involve asking and answering a question and comparing the answer with what scientists already know about the world.
  - *Make a Comet and Eat It!, Comet on a Stick, Paper Comet with a Deep Impact, Comet Models Based on the Deep Impact Mission, and Deep Impact Comet Modeling*

- Scientists use different kinds of investigations depending on the questions they are trying to answer. Types of investigations include describing objects, events, and organisms; classifying them; and doing a fair test (experimenting).
    - *Make a Comet and Eat It!, Comet on a Stick, Paper Comet with a Deep Impact, Comet Models Based on the Deep Impact Mission, and Deep Impact Comet Modeling*
- Scientists develop explanations using observations (evidence) and what they already know about the world (scientific knowledge). Good explanations are based on evidence from investigations.
    - *Consider This!, A Comet's Place in the Solar System, Deep Impact Comet Modeling*

Physical Science

Properties of objects and materials

- Objects have many observable properties, including size, weight, shape, color, temperature, and the ability to react with other substances.
    - *Make a Comet and Eat It!*
- Materials can exist in different states--solid, liquid, and gas. Some common materials, such as water, can be changed from one state to another by heating or cooling.
    - *Make a Comet and Eat It!*

Position and motion of objects

- The position of an object can be described by locating it relative to another object or the background.
    - *Comet on a Stick, Paper Comet with a Deep Impact*
- An object's motion can be described by tracing and measuring its position over time.
    - *Comet on a Stick, Paper Comet with a Deep Impact*

Earth and Space Science

Changes in the earth and sky

- Objects in the sky have patterns of movement.
    - *A Comet's Place in the Solar System, Ten Important Comet Facts, The Deep Impact Comet Acrostic, Comet on a Stick, Paper Comet with a Deep Impact*

Science and Technology

Understanding about science and technology

- People have always had questions about their world. Science is one way of answering questions and explaining the natural world.
    - *Consider This!, Small Bodies Missions*
- People have always had problems and invented tools and techniques (ways of doing something) to solve problems.
    - *Small Bodies Missions*
- Tools help scientists see, measure, and do things that they could not otherwise see, measure, and do.
    - *A Comet's Place in the Solar System, Small Bodies Missions*

Grades 9-12

Science as Inquiry

Understandings about scientific inquiry

- Scientists usually inquire about how physical, living, or designed systems function. Conceptual principles and knowledge guide scientific inquiries. Historical and current scientific knowledge influence the design and interpretation of investigations and the evaluation of proposed explanations made by other scientists.
  - *Make a Comet and Eat It!, Chemistry and Thermodynamics of Ice Cream, Comet on a Stick, Paper Comet with a Deep Impact, Comet Models Based on the Deep Impact Mission, Deep Impact Comet Modeling, Small Bodies Missions*
- Scientists conduct investigations for a wide variety of reasons.
  - *Exploring Comets: Reflections on comets, missions and modeling, Small Bodies Missions*
- Scientists rely on technology to enhance the gathering and manipulation of data. New techniques and tools provide new evidence to guide inquiry and new methods to gather data, thereby contributing to the advance of science. The accuracy and precision of the data, and therefore the quality of the exploration, depends on the technology used.
  - *Small Bodies Missions*

Physical Science

Structure and properties of matter

- Atoms interact with one another by transferring or sharing electrons that are furthest from the nucleus.
  - *Chemistry and Thermodynamics of Ice Cream*
- An element is composed of a single type of atom.
  - *Chemistry and Thermodynamics of Ice Cream*
- Bonds between atoms are created when electrons are paired up by being transferred or shared. A substance composed of a single kind of atom is called an element. The atoms may be bonded together into molecules or crystalline solids. A compound is formed when two or more kinds of atoms bind together chemically.
  - *Chemistry and Thermodynamics of Ice Cream*
- The physical properties of compounds reflect the nature of the interactions among its molecules. These interactions are determined by the structure of the molecule, including the constituent atoms and the distances and angles between them.
  - *Chemistry and Thermodynamics of Ice Cream*

- Carbon atoms can bond to one another in chains, rings, and branching networks to form a variety of structures, including synthetic polymers, oils, and the large molecules essential to life.
    - *Chemistry and Thermodynamics of Ice Cream*

Motions and forces

- Gravitation is a universal force that each mass exerts on any other mass.
    - *A Comet's Place in the Solar System*

Conservation of energy and the increase in disorder

- In all energy transfers, the overall effect is that the energy is spread out uniformly.
    - *Make a Comet and Eat It!, Chemistry and Thermodynamics of Ice Cream*

Earth and Space Science

The origin and evolution of the earth system

- The sun, the earth, and the rest of the solar system formed from a nebular cloud of dust and gas 4.6 billion years ago.
    - *Consider This! Ten Important Comet Facts*

Science and Technology

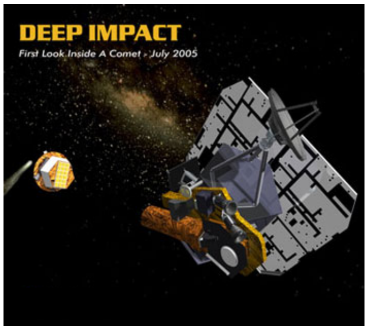
Understandings about science and technology

- Science often advances with the introduction of new technologies. Solving technological problems often results in new scientific knowledge. New technologies often extend the current levels of scientific understanding and introduce new areas of research.
    - *A Comet's Place in the Solar System, Small Bodies Missions*

History and Nature of Science

Science as a human endeavor

- Individuals and teams have contributed and will continue to contribute to the scientific enterprise.
    - *Small Bodies Missions*



Exploring Comets and Modeling for Mission Success

Overview and Goals

Created for Deep Impact, A NASA Discovery mission

Maura Rountree-Brown and Art Hammon
Educator-Enrichment

Age group: This activity is best suited for grades 5 - 9 but some components of the module have been successfully used for grades 2 - 12 such as *Comet on a Stick* and *Make a Comet and Eat It.*

Standards alignment: Standards for this educational activity can be found at (David - please link to and include the document on Standards Alignment which is a new addition to this activity)

Purpose: The purpose of this activity is to give educators information and activities surrounding the basics of comet science. Students get the opportunity to follow the path science has taken throughout history to explore comets. They'll also learn about how we are currently exploring comets and why mission teams perform modeling exercises on Earth in order to assure mission success in space. Students learn the physical and chemical properties of comets, as we presently understand them.

More background on the mission: Educators can get more background on the mission at:

Pre-Encounter: http://deepimpact.umd.edu/mission/factsheet2-bw.pdf

Post Encounter: http://deepimpact.umd.edu/mission/factsheet-postencounter.pdf

Introduce background on the mission to students prior to using "*Interesting Comet Facts"*

GOALS

Students:

- Have the chance to interact with the rest of the class discussing theories on the formation and structure of comets
- Add and eliminate comet theories as they incorporate experiment and inquiry
- Make an ice cream model to visualize comet formation and the technologies used in a comet space mission
- Progress from talking about comets to creating models to test their own space designs and comet theories
- Begin with questions and perceptions about comets and progress to building their

own solid base of comet knowledge

Educators:

- Enhance their information about comets in general and the Deep Impact mission in particular
- Integrate historical information into classroom lessons that give people a personal connection with comets
- Employ comet modeling activities that use common household items: One that simulates comet formation and composition using ice cream, and another simulation that uses recyclable materials to give students experience with a common mission practice – evaluating and modifying models
- Encourage communication among students using prompts about comet characteristics, composition and formation
- Use resources that encourage thinking, discussion and writing about comet structure and behavior
- Better understand the mechanics of ice crystal formation and micro-crystal formation in ice cream

Program Description: Comets have engaged the attention of many cultures from earliest recorded history. Students duplicate the sequential path scientists have taken throughout history to research comets.

Scientists:

- Formed questions by looking up at the sky and through the drawings of others. They theorized about what might be true of comets.
- Expanded knowledge through the use of math, science and eventually emerging technologies. Using these technologies, they began to understand more about comets.
- Develop space exploration and ground observation. Robotic spacecraft visit comets. Mission teams model comets while the spacecraft is still on Earth to test and solve challenges to their mission design.

There are many reasons to explore comets both for knowledge and for future resource and protection of the Earth. The underlying goal for this activity is to lead the student from casual observation to an involvement and ownership in comet science.

Students Objectives:

- Elicit #1 - Think how they would initially define a comet based on their current knowledge and possible misconceptions
- Elicit #2 - Model an "ice cream comet" to learn about some of the elements that make up a comet and add to their base of knowledge through new information
- Elicit #3 – Discuss why scientists explore comets and what value they might have to us in the future
- Elicit #4 – Choose the information they might investigate about comets and

design the mission they would use
- Elicit #5 – Discuss modeling for the success of a mission and create models for their mission design and comet environment
- Elicit #6 – Research current comet space missions and their technologies

Web Materials for the Educator: The following materials are provided:

- "Exploring Comets - Overview and Goals"
- "Comet Activity Overview" (activity outline, order of activity)
- "Make a Comet Model and Eat It!" – Educator page
- "Deep Impact's Comet on a Stick!" – Educator page
- "Questions from Past Workshops" – Discussion or student test
- "Make a Comet Model and Eat It!" Activity

Web materials for Students and Educators:

- "Consider This" history page
- "A Comet's Place in the Solar System"
- "Chemistry of Ice Cream Activity"
- "Ten Important Comet Facts" – Facts about comets
- "Deep Impact's Comet on a Stick" Activity
- "Paper Comet with a Deep Impact" – Optional Activity
- "Deep Impact Fact Sheet" - Background information on the mission

Web materials for Students:

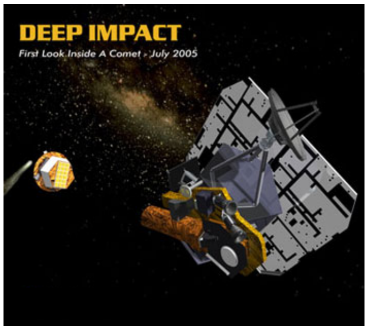
- "Exploring Comets" – Student reflection page
- "Make a comet model and eat it" – Student Data Sheet
- "C-O-M-E-T-S – Acrostic" – Facts about comets
- "Comet Models based on the Deep Impact Mission" Activity
- "Deep Impact – Interesting Facts" – mission background

Additional materials you will need to provide:

- Materials for the "Make a Comet and Eat It!", "Comet on a Stick", or other activities you choose from this package
- Household or arts and crafts items to make comet models
- Poster board and pens or enough blackboard space to retain several class discussion lists
- Computer to look up mission web sites for research
- The Deep Impact web site: http://deepimpact.umd.edu

Questions?

Contact Maura Rountree-Brown Maura.Rountree-Brown@jpl.nasa.gov or Art Hammon – Pre-College Education Specialist, JPL ahammon@jpl.nasa.gov



Exploring Comets and Modeling for Mission Success

Activity Overview for Educators

Created for Deep Impact, A NASA Discovery mission
Maura Rountree-Brown and Art Hammon
Educator-Enrichment

A. FIRST, TELL THEM A LITTLE AND FIND OUT WHAT THEY KNOW.

1. Past Beliefs - Consider This!
What did people think about comets throughout history and in different cultures? Show a picture of a comet. You'll find one on our Why Study Comets? page.

Use the "Consider This" page. Educators may want to look at the Science and Mission Results portions of the Deep Impact web site for more updated information on comet science discoveries. You can use the Deep Impact Questions included with this activity to get your students started.

2. Where are comets in the Solar System?
Find a picture of the Solar System and see where the Kuiper Belt and Oort Cloud are in relationship to all the other bodies. Use the "A Comet's Place in the Solar System" page.

3. Elicit #1 - What are your ideas about comets?
Use the "Exploring Comets" page to discuss questions and ideas about the composition and behavior of comets. Record students' answers on a list to re-check later. You might also encourage your students to record their thoughts as journals, graphics or other written reflection on a separate handout.

B. ADD TO THEIR KNOWLEDGE OF COMETS.

1. Activity - Make a Comet and Eat it!
Build a representation of a comet with ice cream and candy "debris" using "Make a Comet and Eat it!" Page. Discuss with students what is taking place as the ice cream forms.
Extension: Stardust's "Cookin' up a Comet", Deep Impact's "Chemistry of Ice Cream"

2. Explore More - Discussion:
Educator input: Discuss results of student "data" testing. Gather visuals of comets from web sites. Begin with less detailed visuals of comets and then show

those with more detail (a picture of a comet, a comet with an ion tail, Shoemaker Levy 9 breaking apart, Giotto views of Borrelly and Stardust views of Wild 2). Finish with the images from the Deep Impact encounter. Make a drawing as a group showing components of a comet the students now recognize. It should have a nucleus, coma and tail. Use "Ten Important Comet Facts" and "C-O-M-E-T-S".

3. Student Elicit #2 - What new ideas do you have about comets, their origin and their composition?
Return to the list of original comet theories and questions the students recorded in Elicit #1. Confirm or modify their original ideas. Add new information. Which ideas are still questions within the science community?

4. Student Elicit #3 - What ideas do you have about why scientists explore comets? What effect could comets have for and against us in the future? What questions do you still have about comets?

C. NOW IT'S THEIR TURN TO WORK WITH SCIENCE THEORIES FOR THE DESIGN OF A MISSION.

1. Think about modeling for the success of a mission:
Elicit #4 - Pick one thing scientists don't know about comets and design a model around finding the answer.
As a group or individually, pick one goal for a mission and discuss how it might be met. Have students describe how the mission would work and what kind of real or imagined technology they would use in their design.

Use the introduction to modeling "Deep Impact Comet Models". Why do mission teams have to prepare models of cometary environment on Earth in order to assure the success of their mission in space?

2. Activity: Comet on a Stick!
Make and evaluate the comet on a stick from the beginning of the Comet on a Stick activity. Ask students how it succeeds as a comet model. Ask them how they would improve it? How would they make a whole new model? Do the rest of the activity with the class.

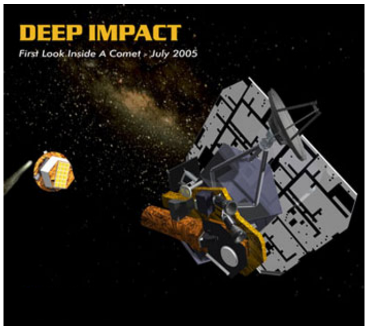
Additional extension activities: "Paper Comet with a Deep Impact" (option to "Comet on a Stick") or "Comet Models based on the Deep Impact Mission".

3. Elicit #5 - What kind of modeling can you do to test a mission's design and the comet's possible environment?
Have students discuss what they would need to know about cometary environment in order to continue design on their mission. What kind of model can they make here on Earth to test both the mission and the cometary environment?

4. Elicit #6 - What kinds of comet missions is NASA funding?
Use Deep Impact - Interesting Facts. What kinds of technologies are comet

missions using? Why? Check out the Deep Impact and Stardust websites. Use "Questions from Past Workshops" as discussion or testing tool for students.

Further information about comets: "Maura Rountree-Brown" Maura.Rountree-Brown@jpl.nasa.gov
Classroom concerns: "Art Hammon" Virgil.A.Hammon@jpl.nasa.gov



Consider This
Consider the "impact" comets have had throughout history.

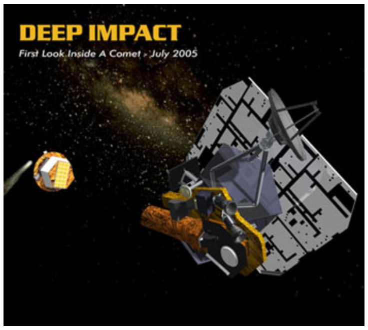
Created for the Deep Impact Mission, A NASA Discovery Mission

Maura Rountree-Brown and Art Hammon
Student - Enrichment

Historical
- Because comets appear suddenly and look different from other celestial bodies, some historical cultures fear them while others revere them.
- Some cultures thought comets predicted coming events. Some Native American cultures used them as count markers to show seasonal change.
- Comets were believed to foretell the death of kings, the demise of great empires and the creation of plagues.
- The appearance of Halley's comet in 1066 was believed to foretell the loss at the Battle of Hastings.
- In 1910, when spectroscopy was new to the world of science, toxic gases were found in Halley's comet. When Earth passed through the comet's tail, some people encouraged the sale of "comet insurance policies" and special medicines for "Comet Fever".

Scientific
- There is the theory that comet impacts on Earth provided both the water and possibly the carbon-based molecules necessary for life.
- About 40,000 tons of dust particles from comets and asteroids fall to Earth every year.
- Comets are both a potential threat and a potential resource. Comets have hit Earth in the past. At some point in the future we will need to know how to draw from their resources and also to protect ourselves against their impacts.
- As the primitive, leftover building blocks of the outer solar system's formation process, comets offer deep within them, clues to the chemical mixture from which the giant planets formed about 4.5 billion years ago.
- See Comets in Ancient Cultures for more information.

But how do we find out more???



A Comet's Place In The Solar System

Created for Deep Impact, A NASA Discovery Mission
Art Hammon
Educator/Student - Enrichment

Our solar system has four rocky inner planets and four giant gas outer planets. In addition, there are other "small bodies" in the solar system. Comets make up a portion of those small bodies and contain a large percentage of ice since they come from a very cold area. Scientists aren't sure whether comets are more like snowy dirtballs or dirty snowballs depending on the amount of rocky debris mixed with the icy material. Comets seem to be found in two places: some far beyond the edge of the solar system called the Oort Cloud, and some beyond Neptune in a region called the Kuiper Belt. The Oort Cloud may contain a trillion icy comets. The Kuiper Belt comets replenish the population of short period comets (comets that orbit the Sun every 20 years or less).

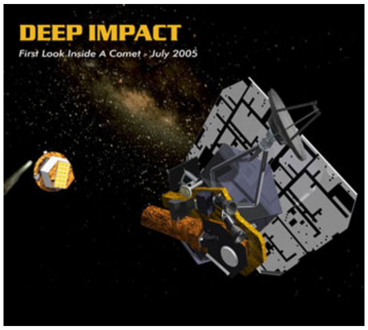
Comets may be an important part of the recipe for making planets and may be material left over from solar system formation. Some comets may have crashed into forming planets adding to their water and rock, while other comets escaped to establish their own orbits around the sun. Some believe that cometary material may have brought water to Earth through impacts.

The orbits of planets (called ecliptic) line up primarily on one plane like rings on a target. Comet orbits can be different from that of planets. They may arrive in the inner solar system from "above" or "below" the plane of the planets and they travel very far from the Sun. Sometimes, there is a stirring in the Oort Cloud, possibly from the gravity of nearby stars or dark matter bodies that pass through the cloud. That stirring can cause a comet to head from the Oort Cloud into the inner solar system.

The earliest observers who noticed comets in the sky could only learn from looking up just like a person looks at a picture of a comet in a book. Later, observers began to notice that comets moved from night to night in the sky based on their position against the stars. Using what they knew about math, they were able to begin tracking comet orbits. As technologies were developed, scientists could begin observing in a new way to discover the makeup of these icy bodies. Comets may have within them the last pristine clues to the beginning of solar system formation. Scientists want to find evidence of some of those early compounds deep within a comet's interior. Scientists believe the solar system may have formed in this way. As gas and dust swirled around the condensed Sun, molecules came together forming compounds. Water and carbon dioxide are two examples of volatiles/ices while olivine and CH-O-N molecules are dust or refractory compounds. Gravity brings the molecules together in clumps that eventually grow to larger and larger cometesimals. Rather than a solid ice cube, comets may be made of many smaller ice crystals with other organic molecules mixed in. To see what the Deep

Impact science team learned about the composition of comet Tempel 1, see science results.

A modeling exercise like making ice cream filled with different foods to represent "debris" can be a good example of the formation of a dirty snowball "comet". See the Make a Comet and Eat It activity.



Exploring Comets

Reflections on comets, missions and modeling

Created for Deep Impact, A NASA Discovery Mission
Maura Rountree-Brown and Art Hammon
Student - Reflection

1. What are your ideas about comets?
What are comets? Where did they first originate? What components make up a comet? What don't we know about comets? Draw a diagram of what a comet might look like.

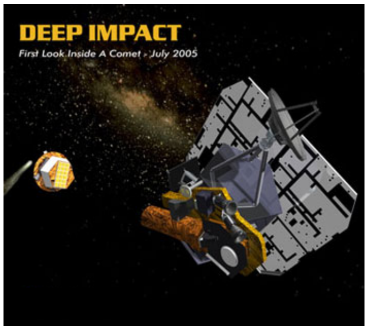
2. After doing some research, what new ideas do you have about comets, their origin and composition? What are the physical parts of a comet?
Compare your new information with the list that you built as a class. Draw a diagram of a comet as you now understand it.

3. What ideas do you have about why scientists explore comets?
Why do they want to know about them? Why would more information make a difference to them?

4. Pick one of the questions scientists had about comets and decide what kind of mission might find the answer.
How would you investigate a comet? What kind of a mission would you put together? What kind of real or imagined technology would you use? What would you need to know first?

5. What kind of "model" would you build to test the details of your design and show your comet's possible environment?

6. Research to see what real comet space missions exist and what kinds of technologies they are using. Other Small Bodies Missions



Make a Comet Model and Eat it!
Instructor Page

Created for Deep Impact, A NASA Discovery Mission
Student – Inquiry
Maura Rountree-Brown and Art Hammon

The "Make a Comet and Eat it" activity can be used with a wide age range. Younger students will come away with three important ideas: Comets are cold, they have debris from the early solar system and we still don't know everything about what is in them or how they behave. After this activity, older students will be able to discuss their own theories about what we found out about Comet Tempel 1 when we made a crater inside it in July 2005. They can compare their current theories with our results. Background on the Deep Impact mission can be found on our Science Objectives page. Some of our results can be found on our Mission Results page.

The Activity:

- "Make a Comet and Eat it!" - The activity
- "Make a Comet and Eat it!" - Student Data Sheet - The student work sheet

Background material:

- Consider This - This page shows the history of perceptions about comets.
- A Comet's Place in the Solar System - A little history about where comets came from
- Ten Important Comet Facts - A quick review of comet facts
- C-O-M-E-T-S - A comet acrostic. Good for younger students or comet quick fact reference
- Deep Impact - Interesting Mission Facts - Some fun facts about our mission
- Small Bodies Missions - Learn more about Deep Impact and about other missions to comets and asteroids through their web sites.

Learn more about the chemistry behind this activity (optional)

- The Chemistry of Ice Cream - Learn more about the chemistry of ice cream and how it freezes.
- Building a Butterfat Molecule - Gum drops and toothpicks are all you'll need for this one.

Classroom Management:

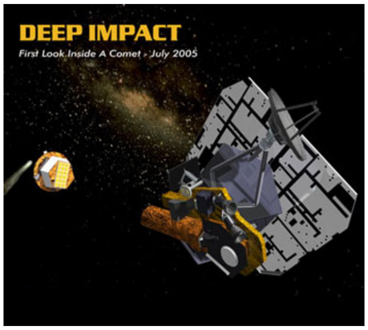
A. Materials need to be purchased fresh and kept in store-bought containers. Anything that is used to measure, hold or eat with should never have been used for any classroom or laboratory chemical use.

B. A mop and sponge is very helpful for desks or floor areas where measuring is done. You may choose to pre-load cream bags and salt bags at home unless you would like the students to perform the measurements.

C. The ice needs to be either freshly bought or well frozen in storage. The container for transporting and storing the ice should be pre-cooled if possible or very efficient. If the ice has "warmed", it will be difficult to get the milk/cream to solidify.

D. A list of materials for the activity are found on the Make a Comet and Eat It page.

Questions: Maura Rountree-Brown at Maura.Rountree-Brown@jpl.nasa.gov



Make a Comet Model and Eat it!

Created for Deep Impact, A NASA Discovery Mission
Student – Inquiry
Maura Rountree-Brown and Art Hammon
Questions?? – Contact Maura.Rountree-Brown@jpl.nasa.gov

Comets have sometimes been described as dirty snowballs, snowy dirtballs or something in between. But what does that really mean? It means that these they are believed to be a cold mixture of frozen water, dry ice (frozen carbon dioxide), and other sandy/rocky materials left over from the early formation of our solar system. In this activity, we are going to develop a comet model that you can eat. Once your team has made your comet, you'll trade a sample of it with another team. Once traded, you will use your different senses to demonstrate the filters on an instrument called a spectrometer that will collect data on the Deep Impact spacecraft. A spectrometer analyzes the structure and composition of comets by using nine different filters. You will use four of your senses individually to decide what is in the ice cream. Most of the ingredients can be found in your home.

Comet connection: Discuss the following ingredients to be added to the ice cream to represent dust (Black/brown cookies in fine and large chunks), rocks (peanuts), carbon dioxide (coconut flakes). Then have the students begin to add ingredients. Make sure they are also adding some ingredients to represent what we might find in a comet. Possibilities are: peppermint, toffee or other ingredients to represent new discoveries. Remember to choose food that will not dissolve while the ice cream is setting. Each team should make their own choice of ingredients. Now close the bags carefully.

Form small research groups of 2 - 4 students. Make sure no one has any allergies (milk, peanuts, etc) that are used for this activity. You'll need to gather the following materials for each group:

- One sandwich size re-closable plastic bag per team of 2 - 4
- One Gallon size re-closable plastic bag per team of 2 - 4
- Small cups for eating ice cream - one for each person on the team. Two additional cups are needed to trade with another team - one to "feel only" and one to "taste, smell and look at".
- Plastic spoons for everyone
- Pairs of rubber kitchen gloves, oven mitts or have them use cloths or sweaters (The comet bags get cold!!)
- Ice (enough to fill a gallon size bag 1/2 full per team) - or bring in fresh snow from outside.

- Chunky cookies in black or brown, crushed candies (like toffee or peppermint), gummy bears, coconut flakes and peanuts
- Whole milk (2% won't work)
- Sugar
- Vanilla extract
- Evaporated milk
- Salt
- Can opener
- Something to use to crush cookies and other additives

To begin: Wash hands! You may choose to use food gloves.

HINT: One person should hold the bag while another pours ingredients into the bag. To cut the activity time, you can pre-mix the milk, evaporated milk, sugar and vanilla in the small bags and pre-measure the salt into the large bags. Make enough sandwich bags of ice cream mix for each team to have one. Squeeze the air out as much as possible and seal the sandwich bags carefully each time they are opened to add ingredients.

STEP #1:
Mix into the sandwich size bag
One-third cup evaporated milk (or cream)
Two-thirds cup whole milk
5 level spoonfuls of sugar
Less than ¼ tsp of vanilla

Each team adds the ingredients they feel should be in their "comet" and records those ingredients for confirmation later.

HINT: Squeeze any extra air out of the sandwich bag and close it. Be sure it cannot leak. [Turn it upside down to check.]

SUGGESTIONS FOR LARGER GROUPS: For a class of 20 (10 groups of 2)

- 3 - 4 cans - 12 fl oz each
- 1 gallon of milk (you'll have some left over)
- 20 cookies
- 1/4 lb of sugar
- 1 bag of peanuts and 1 bag of coconut flakes
- 1/4 bottle of vanilla or leave this ingredient out
- 10 sandwich size re-closable bags (but best to make a couple extra)

- 10-gallon size re-closable bags
- 2 - 3 containers of table salt (you'll have some left over)

STEP #2
Place the sandwich bag into the bottom of the gallon bag. Put in approximately 10 heaping spoonfuls of salt if you did not pre-load the salt earlier. You can pre-load salt into the bags at home.

STEP #3
Fill the gallon bag (containing sandwich bag) at least 1/3 full of ice.

STEP #4

1. Close the larger bag tightly to remove as much air as possible. Check for leaks.
2. Gently shake and roll the bag while keeping it in constant motion for approximately 6 - 10 minutes or until half the bag has turned to water. [SUGGESTION: Rubber gloves, mitts, cloth towels or other thick fabric may be needed to hold the bag because it will get extremely cold. Start with bare hands so students can feel the temperature change].
3. Gently feel the sandwich bag through the icy mixture. When the milk/sugar mixture in the sandwich bag has hardened into soft ice cream, open the gallon bag and remove the sandwich bag containing the ice cream. Carefully and briefly rinse the outside of the sandwich bag to get the salt/ice mixture off or the ice cream will carry the taste. Scoop the ice cream into one cup for each member of the team. Fill two cups to trade with another team - one they will only feel and one from which they will all get one bite. Put your own ice cream cup aside for the moment.

STEP #5
Once each team has received a cup to "feel" and a cup to "taste" everyone is ready to research a sample "comet."

A spectrometer takes different kinds of data through different filters. Pretend that your eyes, hands and taste buds are filters on a spectrometer taking data from your "comet". Record the following on a data sheet:

- Look at the "comet" and see what you can observe **visually**. Record it on a data page.
- Take the "feel only" cup and have each team member **feel** the contents with their fingers. Record any new data discovered.
- **Smell** the ice cream and record any additional data.
- Each team member can **taste** one bite of ice cream and record any final information about its contents.

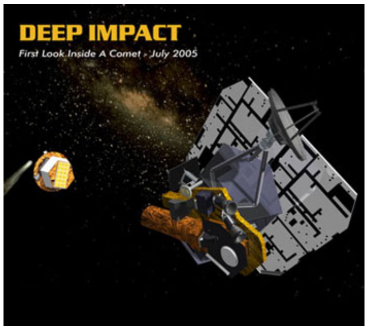
STEP #6

Compare your results with the team who made the ice cream you tasted and see how close you came to being correct. Now teams can eat the ice cream that they made themselves.

- Share your conclusions about your comet with your class.
- Optional extension for older students: Learn more about spectrometers.

SOME TIPS FOR THE TEACHER:

- If the students toss the bags back and forth or bang them against a surface while freezing the ice cream, they may break.
- Bring dishtowels, cloths or other insulator for hands to guard against discomfort while they are turning their bags over and over.
- Have a mop available for dripping water or do the activity outside.
- Limit the amount of any material students put into their ice cream to one plastic spoonful so supplies last.
- Mark one of your serving cups to the amount of sugar and salt measurements to pre-load bags faster. Mix all ingredients in class if you want your students to work on measurements, percentages and fractions.
- Older students can use The Chemistry and Thermodynamics of Ice Cream after this activity.



Make A Comet Model And Eat It!!

Student Research Data Sheet

Created for Deep Impact, A NASA Discovery Mission
Maura Rountree-Brown and Art Hammon
Student - Reflection

Throughout history, scientists have used different methods of observation and testing to find out more about comets. First, they used their eyes to look into the sky. Over time, they applied what they knew about math, science and finally technology to further study these icy travelers. Now we have the ability to visit comets. Scientists are always careful to record their observations and data. They use this research to build models to test and confirm their theories about comets. Deep Impact will use a spectrometer with a series of filters each of which will collect a different kind of data about a comet. Although spectrometer filters are not senses, you can collect data on your ice cream comet by using your sight, touch, smell and taste "filters" separately and then learning from all the data gathered together?

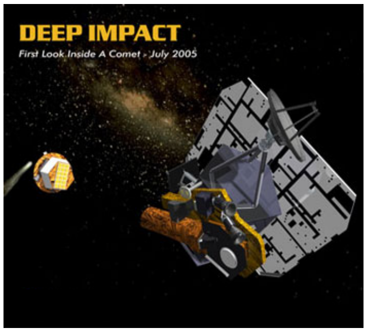
What visual observations do you make about your ice cream comet? Diagrams can be drawn also.

Take the "feel only" cup. Don't taste this one. What are you able to tell by using your fingers to feel the ice cream comet?

What are you able to tell about your sample comet using only your sense of smell?

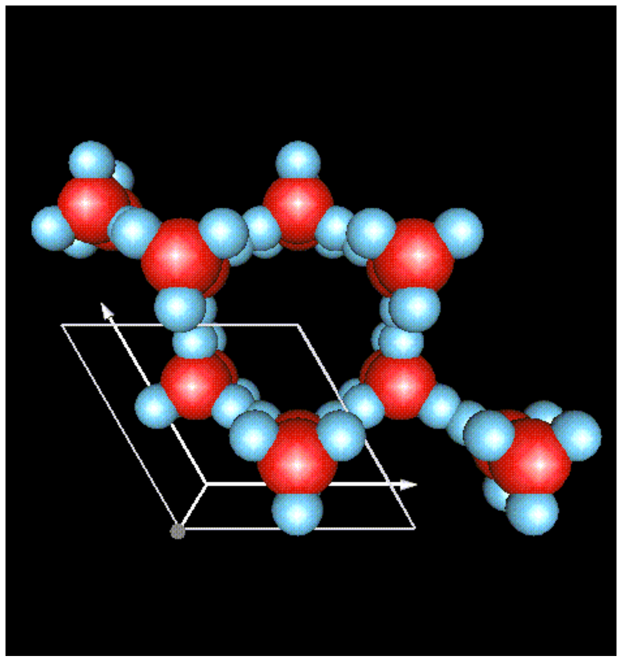
What are you able to tell about your sample comet adding your sense of taste?

What explanations do you draw about the composition of your comet?



The Chemistry and Thermodynamics of Ice Cream

Created for the Deep Impact Mission, A NASA Discovery Mission
Maura Rountree-Brown and Art Hammon
Educator/Student - Enrichment



"The Reason for the Seasons:" - Snowflake Shapes

The picture above was created at the Institut Laue-Langevin an international research centre and world leader in neutron science and technology. It is based in Grenoble in the South-East of France. It shows an ice crystal. The crystal is made of many molecules of water (H_2O). The atoms are shown by different colors. The darker atoms are oxygen. The lighter atoms are hydrogen. The hydrogen atoms are attached at an angle near 120 degrees. The hydrogen atoms are attracted to each other and form hexagonal rings in all directions.

As ice crystals or snowflakes grow, they expand by attaching new water molecules to each other. Looking at them with a hand lens or microscope tells us about how they join together. The angles are always the same so the designs always have six sides. Whether ice crystals or snowflakes, observing the shape under "atomic microscopes" reveals a shape that is always hexagonal.

If the angle had been different, the shape would have been different. Salt crystals (NaCl) are made of two elements, sodium (Na) and chlorine (Cl) which join at 90 degree angles. Under a hand lens or microscope, the crystals of salt appear as little dice or cubes. The shape of the crystal is determined by the angle of chemical bonding (joining together).

What does "ice" have to do with "ice cream"?

Below is a typical triglyceride butterfat molecule from which ice cream is made. Ice cream is formed when many tiny ice crystals form between the "arms" of the triglyceride butterfat molecule.

$$
\begin{array}{l}
\qquad\quad \mathbf{O} \\
\qquad\quad \| \\
\mathbf{CH_2\text{-}O\text{-}C\text{-}(CH_2)_7CH{=}CH(CH_2)_7CH_3} \\
| \\
| \qquad \mathbf{O} \\
| \qquad \| \\
\mathbf{CH\text{-}O\text{-}C\text{-}} \\
\mathbf{(CH_2)_7CH{=}CHCH_2CH{=}CHCH_2CH{=}CHCH_2CH_3} \\
| \\
| \qquad \mathbf{O} \\
| \qquad \| \\
\mathbf{CH_2\text{-}O\text{-}C\text{-}(CH_2)_7{=}CHCH_2CH{=}CH(CH_2)_4CH_3}
\end{array}
$$

Typical molecule of butterfat, a triglyceride, found in ice cream.

Extensions: Chemistry, Crystals and Calories

A. Look at the drawing of the butterfat molecule. The letters stand for chemical elements, joined together in long chains. You can make a "MODEL" of the molecules with gum drops and toothpicks

B. You can make up a code…which element (gumdrop) is which color:
The elements are:
Carbon (C) Color______________
Oxygen (O) Color______________
Hydrogen (H) Color______________

C. Build the molecule with groups assembling a part of a chain. Connect them with toothpicks (chemical bonds…the glue that holds elements together in molecules). . The symbols "=" or "||" mean use two toothpicks. These are called double bonds in chemistry. Then lay them out and connect the whole butterfat molecule on the floor or table.

D. At the same time, make lots of water molecules (H_2O- Oxygen in middle, Hydrogens on each side like a boomerang) and oxygen molecules (O_2). Lay the water molecules between the long chains of the butterfat. Now “freeze” them by connecting three boomerang shaped water molecules together in a hexagon shape, touching the hydrogen atoms together.

E. Why does ice cream make people gain weight? After you eat ice cream, the only way to get rid of it is to “burn” it out of your body. That involves the same idea as burning a match…fuel and oxygen…except this burning is flameless. The ice cream is the fuel and the air you breathe gives you oxygen.

F. “Burn” the ice cream by using the oxygen molecules you made. Oxygen breaks ice cream apart by attacking and breaking the toothpicks and carrying away the Hydrogen and Carbon. Here is the formula:
$C + O_2$ makes one CO_2 (carbon dioxide you breath out)
H + H+O makes one H_2O (water) which you breath out (cold morning breath?)

G. How many oxygens does it take to carry away the butterfat molecule? This is why “Aerobics” is a good idea for weight loss…makes you fill your body with lots of Oxygen to “burn” the butterfat, releasing “heat” measured in calories (a way of measuring energy content).

The Thermodynamics and Chemistry of Ice Cream
(Where is the heat going and what happens to ice cream after you eat it?)

What is going on in the bags?

A. The inside of the ice is very cold, -10^o to –20^o F. But when you hold an ice cube, the exterior, in contact with air and your hand is +32^o F, cold water. Clean, pure water cannot be a liquid below +32^o F. It becomes ice.

B. Salt Mysteries- The mixture of salt and water can be liquid below +32^o F. It can be a liquid down to –20^o F. So adding salt does not “melt ice”. It makes a mixture of water and salt that has a low temperature… “Salt gives water permission to freeze at a lower temperature”.

C. The very cold salt water surrounds the baggie with the milk (which is 30% water) and “steals” heat from the milk. The temperature of the milk becomes so cold that the water in the milk begins to form tiny ice crystals. The butterfat does not form crystals. The shaking keeps the milk from forming one big ice cube.

D. What is a comet - ice cube or ice cream? Deep Impact will help us find out. The data from Deep Impact will tell us a little about how the comet formed…blob of water or snowball of crystals that came together.

Art Hammon, Pre-college Education Specialist, JPL
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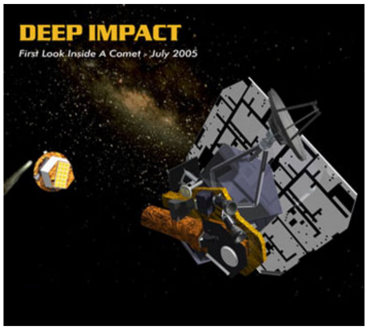


Ten Important Comet Facts

Created for Deep Impact Mission, A NASA Discovery Mission
Maura Rountree-Brown
Educator/Student - Enrichment

1. Comets are in orbit around the Sun as are our planets.

2. Comets are composed of ices, dust and rocky debris carried from the early formation of the solar system about 4.5 billion years ago.

3. Comets are remnants from the cold, outer regions of the solar system. They are generally thought to come from two areas - the Oort Cloud and the Kuiper Belt. Both of these are areas where materials left over from the formation of our solar system have condensed into icy objects. Both regions extend beyond the orbits of Neptune and Pluto but are still part of our solar system and much closer to us than the closest star.

4. Comet orbits are elliptical. It brings them close to the sun and takes them far away.

5. Short period comets orbit the Sun every 20 years or less. Long period comets orbit the Sun every 200 years or longer. Those comets with orbits in between are called Halley-type comets.

6. Comets have three parts: the nucleus, the coma and the tails. The nucleus is the solid center component made of ice, gas and rocky debris. The coma is the gas and dust atmosphere around the nucleus, which results when heat from the Sun warms the surface of the nucleus so that gas and dust spew forth in all directions and are driven from the comet's surface. The tails are formed when energy from the Sun turns the coma so that it flows around the nucleus and forms a fanned out tail behind it extending millions of miles through space.

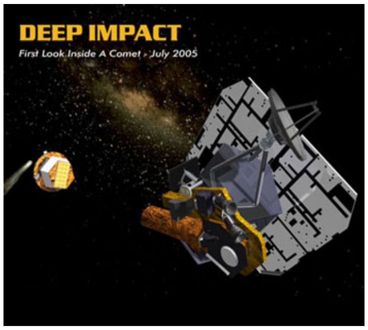
7. We see a comet's coma and tail because sunlight reflects off the dust (in the coma and dust tail) and because the energy from the Sun excites some molecules so that they glow and form a bluish tail called an ion tail and a yellow one made of neutral sodium atoms.

8. Scientists have seen comets range in size from less than 1 km diameter to as much as 300 km, although the 300km (called Chiron) does not travel into the inner solar

system.

9. We know a comet could impact Earth and that it is important to understand the nature of comets so we can design better methods to protect ourselves from them should one be on a collision path with Earth.

10. A comet nucleus has a dark, sometimes mottled surface but we don't know if it has an outer crust or if it is layered inside. We don't really know what comets are like beneath their surface and that's why we need a mission like Deep Impact.



The Deep Impact Comet Acrostic

Created for Deep Impact Mission, A NASA Discovery Mission

Maura Rountree-Brown
Educator/Student - Enrichment

C

ARE COLD AND ICY
HAVE COMA
DO THEY HAVE A CRUST?

O

OUTGAS ICE AND DUST
COME FROM THE OORT CLOUD OR KUIPER BELT

M

MIDDLE CALLED A NUCLEUS
MILLIONS OF MILES OF TAIL

E

FROM THE EARLY SOLAR SYSTEM
HAVE ELLIPTICAL ORBITS

T

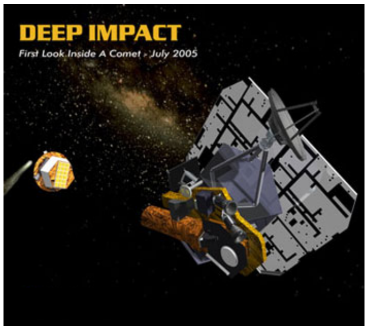
THREE TAILS – DUST, ION AND NEUTRAL SODIUM

S

THE SUN HEATS COMETS TO CAUSE OUTGASSING, REFLECTION OF DUST, MOVING THE COMA BACK TO FORM A TAIL. COMETS ARE SNOWY DIRTBALLS OR DIRTY SNOWBALLS – WHICH ONE??

ALSO: The appearance of the nucleus is very dark and sometimes mottled or spotted in appearance because some of the material from a comet's jets settles back down and clings to the surface. They hold important clues to the formation of the solar system and could potentially offer natural resources for us if we ever live in space. A comet that takes 200 years or more to pass around the Sun is a ***long period comet*** while ***short period comets*** come more often, every 20 years or less. Comets with orbit periods in between are called ***Halley-type comets***. Want to know more?

Check out the **Deep Impact mission to a comet at**:
http://deepimpact.umd.edu
Find out about more NASA comet missions at:
http://deepimpact.umd.edu/science/smallbodies.html



"Deep Impact Comet on a Stick"
Educator Page

Created for Deep Impact, A NASA Discovery Mission
Maura Rountree-Brown and Art Hammon
Educator - Enrichment

The "Comet on a Stick" activity can be used with a wide age range. Students will see that modeling is continuous on a NASA mission as is evaluation of those models. Younger students will learn the basic characteristics of a comet. Older students will practice evaluation and improvement of the comet model shown. The importance of this activity is not the initial model or its exercise, but the fact that it will put students in the position of emulating a process that scientists and engineers follow on all missions.

The activity:
"Comet on a Stick" - Activity for students
Supplies are shown within the activity. Gather household and art supplies for the students to improve or build new models.

Background materials for this activity:
Background on the Deep Impact mission
Consider This - This page shows the history of perceptions about comets.
A Comet's Place in the Solar System - A little history about where comets came from
Ten Important Comet Facts - A quick review of comet facts
C-O-M-E-T-S - A comet acrostic - Good for younger students or comet quick fact reference
Deep Impact - Interesting Mission Facts - Some fun facts about the Deep Impact mission
Small Bodies Missions - Learn more about Deep Impact and about other missions to comets and asteroids.

National Science Education Standards related to this activity:
Science as Inquiry:

- Identify questions that can be answered through scientific investigations
- Think critically and logically to make the relationships between evidence explanations
- Develop descriptions, explanations, predictions and models using evidence
- Recognize and analyze alternative explanations and predictions

Tips for materials to improve or build comet models:

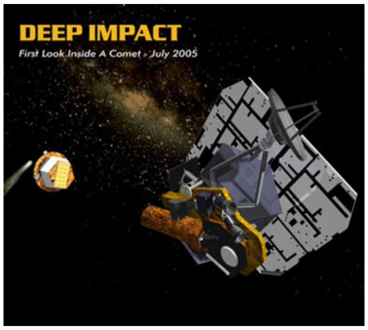
- Find fruits and vegetables that might look like a comet nucleus.
- Get different "surface" coverings like chocolate cake mix or icing, chocolate shell (you'll need to freeze the object you cover
- Paper or streamer of different kinds
- Paints or other coloring solutions
- Any kind of textured covering that you think would be useful
- Netting or other fabrics
- Bulk cushion stuffing fiber or cotton balls
- Tin foil
- See what else you can come up with

Tips for the Teacher:

1. A hairdryer only sends heat from one side while the Sun would be sending out solar wind from all sides.

2. This model does form a tail with the solar wind but it fails to show that the material that outgases from the comet mostly shoots forward. This is why we see the nucleus area of the comet glow but do not directly see the nucleus of the comet which is hidden further back inside the comet's coma.
3. The Deep Impact observing spacecraft must maintain a path beneath the comet, as the nucleus passes overhead. This helps the spacecraft to avoid coma debris from the comet tail as it passes. Coma debris is the dust, gas and rocky material that burst from the comet nucleus in jets as its surface is heated by the Sun.
4. This model does not show that the tail of a comet appears curved because in space we see a "history of the tail". At any point in time, particles move directly away from the Sun (as in this model). Over time, as the comet curves around the Sun on its orbit path, the particles leave a tail that is curved (not shown in this model).
5. As the comet moves away from the Sun, the model tail droops. In space, the particles and debris continue to be swept away from the nucleus, but the production rate of debris decreases. Note that the tail does not shoot out from the nucleus but is the trail that is left behind much like that of a jet plane.
6. Comets are not white since the rock and debris being out gassed clings to the surface of the comet in a crust that is blacker than toner for a copy machine or charcoal. Comets also appear in different irregular shapes and are not round "balls". They are shaped more like potatoes. Scientists are not sure how rough or smooth the surface of a comet might be and will get that information from the missions currently planned by NASA.
7. Comets can have three tails although scientists usually only talk about the dust and ion tail: the largest is the dust tail produced by radiation light pressure from the Sun and it carries most of the debris and gas and is easiest to see. The ion tail, produced by "solar wind" can show as a bluish glow and a neutral sodium tail produced by solar wind is very hard to see.

Questions: Maura Rountree-Brown at Maura.Rountree-Brown@jpl.nasa.gov



Deep Impact Comet Modeling

Created for Deep Impact Mission, A NASA Discovery Mission
Maura Rountree-Brown
Educator/Student - Enrichment
Questions? Contact: Maura.Rountree-Brown@jpl.nasa.gov

Modeling is an important part of any space mission and begins earlier than most people think. Before any piece of hardware is built or software is designed, in fact, before anyone begins to make calculations for the size and shape of the spacecraft, intensive research must be done and certain questions must be asked.

- What do we want to find out?
- Where should we go in space to find this information?
- In the case of the Deep Impact mission, what do we know about Comet Tempel 1?
- Learn more about the Deep Impact mission.

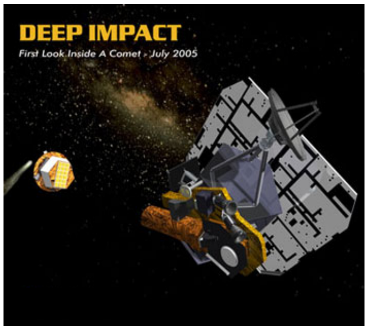
Obviously, it isn't possible to visit Tempel 1 to get all the information we need in order to design a mission so scientists and engineers perform exercises to "model" our comet. They ask themselves questions like:

- What other comets do we have information on?
- What has that information told us?
- If we build a model for a comet we know better, will it tell us what we need to know about the one we will visit?

The Deep Impact mission has used images of Halley's comet as well as the more recently collected images of comet Borrelly and Wild 2. Using what we know about those comets, and combining that information with images of Comet Tempel 1 taken from Earth, the Deep Impact team has created models for researching the following challenges:

- How fast is our comet rotating and is that rotation slow enough to allow us to see the crater we make?
- When sunlight falls unevenly on the comet, can we design software that will help our impactor find the best lit area to target?
- Based on what we know about cometary dust environments, will our impactor and spacecraft arrive safely to impact? How large a dust particle can the twin spacecraft survive before the images they are collecting are blurred or the spacecraft themselves are damaged?

Questions for students: If you were building a model of a comet out of odds and ends around the house, what two characteristics about a comet would you choose to show and what materials would you find to build it? If you were designing a mission, how would you use your comet model to test some of your challenges and bring them to solutions?



"Deep Impact Comet on a Stick"

Student Activity

Created for Deep Impact, A NASA Discovery Mission
Maura Rountree-Brown and Richard Shope
Advisors: Bill Smythe (science)
Student - Inquiry
Questions?? Contact Maura.Rountree-Brown@jpl.nasa.gov

Purpose:
Develop a model of a comet and use the same thought processes as a science and engineering team do to design and build missions. Use it to test your theories about comets and then evaluate the strengths and weaknesses of your comet model. The importance of the activity is not the initial model, but the model you improve or design and your evaluation of the initial model. During the second part of the activity, you will work with a team to decide what kind of new model you would like to build.

Project:
The **Deep Impact** mission launched in 2004 and encountered Comet Tempel 1 on July 4th of 2005. Before launch, scientists and engineers used modeling to research and test some of their theories about comets. They also used modeling to find solutions to some of their mission challenges. Modeling takes place throughout the life of a mission as challenges arise. You can try modeling by making a "Comet on a Stick." Use it to test the influence of the Sun on these small bodies. Discuss as a class some theories about comets. Then try to communicate them with the stick comet. This is a good model for some of the attributes of a comet. For others, it is not. During the activity, you will have the opportunity to decide the strengths and weaknesses of this comet model. You will also get to improve this model or build an entirely new one. If you need to know more about comets, visit http://deepimpact.umd.edu to learn more about the Deep Impact mission.

Before you start:
As a class, discuss what is or might be true about comets. Build one list. Add to that list the things you wonder about comets or don't know. Build a model to study the following question: If you have to send a spacecraft to a comet, what will you need to consider about the way the Sun affects a comet? Now, build a "Comet on a Stick".

Materials:
One 2" styrofoam or other ball or an 8 ½ X 11 piece of paper
Two 1 - 2 ft lengths of mylar gift strips, raffia or ribbon
One 5" strip of tape
One wooden skewer (shish kabob type)
An electric hairdryer/electrical power available
One marker pen
Gather household or art supplies for students to use to design their own comet models.

Directions:
1. Make a tiny hole in the ball so it can be mounted on the skewer (the fit of the skewer should be tight). Mount the ball on the skewer. If you use paper instead, mold it to the shape you believe should represent your comet nucleus.
2. Place the mylar strips on top of the ball or paper nucleus so the two pieces cross each other in an "X" and the lengths of all sides of the strips hang down evenly. You can also use light ribbon.
3. Attach the strips to the ball or paper with the 5" strip of tape or narrow masking tape wrapped over the strips and around the circumference of the nucleus.
4. With a marker pen, assign a "front" for your comet and represent it with the letter "H" for head. On the opposite side, mark the letter "T" for tail of the comet.

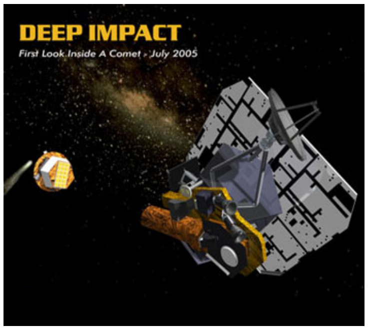
<u>Here's what you do:</u>

Use a hairdryer to simulate a portion of the Sun's solar energy as it meets the comet. The heat from the Sun warms the surface of the comet nucleus. This causes gas, ice, particles and rocky debris of various sizes to burst from the comet in all directions (called coma) and the solar wind causes these substances to flow back behind the nucleus to form a "tail" behind the comet. Have someone be the "Sun" and stand in place with the hairdryer. The hairdryer simulates the solar wind causing the comet "tail" to form and trail behind the comet. Aim the hairdryer at the comet and keep it trained on the comet as it approaches and as it moves away. Have a second person hold the comet by the stick and walk in an elliptical (elongated or oval) orbit around the Sun. As the comet gets closer to the Sun, the Sun's solar influence affects the comet so that the gas and debris forms a tail that is pushed toward the back of the nucleus. This tail flows in opposition to the Sun so that the nucleus is between the Sun and the tail. As it travels away, the lost influence of the Sun causes the tail to diminish or in this case, fall. The solar wind from the Sun, which is made of electrically-charged particles, uses electrostatic attraction and electrical transfer to form the comet's gas and debris into a tail.

<u>Questions:</u> Use the materials you gathered to have students improve or build new models.

1. What are the strengths of this model for showing the influence of the Sun on a comet?
2. What are the weaknesses of this model for showing the proper influence of the Sun?
3. What other facts or theories about a comet can be seen using this model?
4. Which facts or theories of a comet are not well shown by this model?
5. Can you improve the model by changing it or making an entirely new model?
6. Can you build a model that shows what a comet does in space as opposed to what it is?
7. The Deep Impact mission makes a crater in the nucleus of Comet Tempel 1 with a copper projectile. A sister spacecraft nearby takes optical and spectrometer data during the encounter and for 14 minutes after impact. What do they need to consider about a comet in order to successfully gather their data?
8. Form teams and choose three facts, theories or characteristics about comets you would like to show through modeling. Make a new model or improve your current model.
9. Or, as a team, decide what kind of comet mission you would design. Take one of the challenges you will face and try to create a model that will help you find a solution for your challenge.
10. Once your team has designed your comet model, show it to the other teams without explanation. See if they can identify what you were trying to show about a comet. How well did you collaborate as a team to build a clear and accurate model?

Questions? Contact: Maura.Rountree-Brown@jpl.nasa.gov



"Paper Comet Model With a Deep Impact"

An option to the "Comet on a Stick"

Created for Deep Impact, A NASA Discovery Mission
Maura Rountree-Brown and Art Hammon
Student - Inquiry

Purpose:
The Paper Comet is an option to "Comet on a Stick" using instead an 8 ½ X 11 piece of paper which is less expensive than the Styrofoam version. Develop a model of a comet and use the same thought processes as a science and engineering team do to design and build missions. Use it to test your theories about comets and then evaluate the strengths and weaknesses of your comet model. The importance of the activity is not the initial model, but the model you improve or design and your evaluation of the initial model. During the second part of the activity, you will work with a team to decide what kind of new model you would like to build.

Project:
The **Deep Impact** mission launched in 2004 and encountered Comet Tempel 1 on July 4th of 2005. Before launch, scientists and engineers used modeling to research and test some of their theories about comets. They also used modeling to find solutions to some of their mission challenges. Modeling takes place throughout the life of a mission as challenges arise. You can try modeling by making a "Comet on a Stick." Use it to test the influence of the Sun on these small bodies. Discuss as a class some theories about comets. Then try to communicate them with the stick comet. This is a good model for some of the attributes of a comet. For others, it is not. During the activity, you will have the opportunity to decide the strengths and weaknesses of this comet model. You will also get to improve this model or build an entirely new one. If you need to know more about comets, visit http://deepimpact.umd.edu to learn more about the Deep Impact mission.

Before you start:
As a class, discuss what is or might be true about comets. Build one list. Add to that list the things you wonder about comets or don't know. Build a model to study the following question: If you have to send a spacecraft to a comet, what will you need to consider about the way the Sun affects a comet? Now, build a "Comet on a Stick".

Materials:
One 8 ½ X 11 piece of paper
Two 1 - 2 ft lengths of mylar gift strips, raffia or ribbon
One 5" strip of tape
One wooden skewer (shish kabob type)
An electric hairdryer/electrical power available
One marker pen
Gather household or art supplies for students to use to design their own comet models.

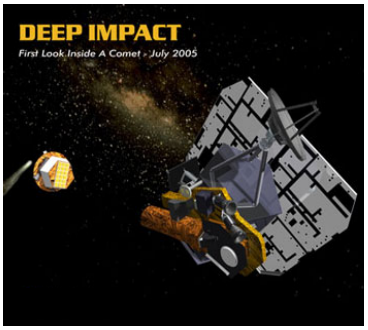
Directions:
1. Mold the sheet of paper into the shape your team believes should represent your comet nucleus and attach it to the top of the wooden skewer or straw.
2. Place the mylar strips on top of the paper nucleus so the two pieces cross each other in an "X" and the lengths of all sides of the strips hang down evenly. You can also use light ribbon.
3. Attach the strips to the paper with the 5" strip of tape or narrow masking tape wrapped over the strips and around the circumference of the nucleus.
4. With a marker pen, assign a "front" for your comet and represent it with the letter "H" for head. On the opposite side, mark the letter "T" for tail of the comet.

<u>Here's what you do:</u>
Use a hairdryer to simulate a portion of the Sun's solar energy as it meets the comet. The heat from the Sun warms the surface of the comet nucleus. This causes gas, ice, particles and rocky debris of various sizes to burst from the comet in all directions (called coma) and the solar wind causes these substances to flow back behind the nucleus to form a "tail" behind the comet. Have someone be the "Sun" and stand in place with the hairdryer. The hairdryer simulates the solar wind causing the comet "tail" to form and trail behind the comet. Aim the hairdryer at the comet and keep it trained on the comet as it approaches and as it moves away. Have a second person hold the comet by the stick and walk in an elliptical (elongated or oval) orbit around the Sun. As the comet gets closer to the Sun, the Sun's solar influence affects the comet so that the gas and debris forms a tail that is pushed toward the back of the nucleus. This tail flows in opposition to the Sun so that the nucleus is between the Sun and the tail. As it travels away, the lost influence of the Sun causes the tail to diminish or in this case, fall. The solar wind from the Sun, which is made of electrically-charged particles, uses electrostatic attraction and electrical transfer to form the comet's gas and debris into a tail.

<u>Questions:</u> Use the materials you gathered to have the students improve or build new models.

1. What are the strengths of this model for showing the influence of the Sun on a comet?
2. What are the weaknesses of this model for showing the proper influence of the Sun?
3. What other facts or theories about a comet can be seen using this model?
4. Which facts or theories of a comet are not well shown by this model?
5. Can you improve the model by changing it or making an entirely new model?
6. Can you build a model that shows what a comet does in space as opposed to what it is?
7. The Deep Impact mission makes a crater in the nucleus of Comet Tempel 1 with a copper projectile. A sister spacecraft nearby takes optical and spectrometer data during the encounter and for 14 minutes after impact. What do they need to consider about a comet in order to successfully gather their data?
8. Form teams and choose three facts, theories or characteristics about comets you would like to show through modeling. Make a new model or improve your current model.
9. Or, as a team, decide what kind of comet mission you would design. Take one of the challenges you will face and try to create a model that will help you find a solution for your challenge.
10. Once your team has designed your comet model, show it to the other teams without explanation. See if they can identify what you were trying to show about a comet. How well did you collaborate as a team to build a clear and accurate model?

Questions? Contact: Maura.Rountree-Brown@jpl.nasa.gov



Comet Models

Based on the Deep Impact Mission

Created for Deep Impact, A NASA Discovery Mission
Maura Rountree-Brown and Art Hammon
Educator/Student - Inquiry
Questions?? Contact Maura.Rountree-Brown@jpl.nasa.gov

Here are some comet models you can try to build. Then design your own model. You can also use these models to explore some of the facts, theories and concepts about comet science.

Comets have a dark surface we can’t see through. From what is it made?

Make several ice cream balls or use baking potatoes and cover them with different materials:

- Is it a hard crust? – Use chocolate shell. (hardens into a layer)
- Is it a slushy crust? – Use chocolate syrup
- Is it powdery – Use cocoa powder or cake mix
- Is it rough and thick – Use broken cookies

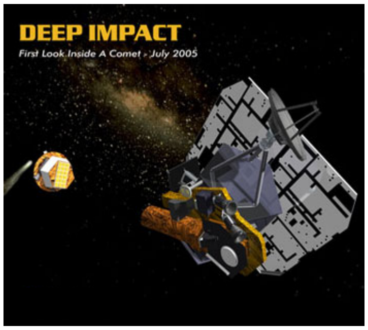
Cover the surface of your “comet” so that the inner contents can’t be observed. (The Deep Impact Mission will create a crater on the surface of a comet and visually observe how the impact is made to the surface of the crust to learn more about its makeup.) Try to have another team design an experiment to see what is beneath the surface of your comet? Which kind of surface do you think we will find on a comet and why?

What do you think we will find beneath the surface of a comet?

Look for a candy bar that you believe might show what it is like beneath the surface of a comet. Is it dark or light? Is it smooth or full of “debris” – peanuts, candy etc? Are there layers beneath the surface or not, and is it delicate or firmer in composition? Why do you think you have picked a good model?

How will you build and evaluate your own model?

Bring materials from home and have your team decide on a mission design, comet theory or comet question you would like to communicate. Design a model to communicate your question about a comet. Build it and design a test to try to confirm your theory or answer your question. Was it a good model and can you improve it? If there is time, work on an improved designed based on evaluation of the first model.



Deep Impact

Interesting Mission Facts

Created for Deep Impact, A NASA Discovery Mission
Maura Rountree-Brown
Educator/Student - Enrichment

1. The term “comet” comes from the Greek “kometes” meaning long hair, referring to the tail.

2. The Deep Impact flyby (observing) spacecraft is about the size of a Volkswagen Bus.

3. The Deep Impact impactor (projectile) spacecraft is about 3 X 3 feet, about the size of a desk and weighs 370 Kg (820 lbs).

4. The entire combined spacecraft weighs about 1 ton.

5. The closing speed of the comet to the impactor is 10 times faster than a speeding bullet.

6. The size of the crater is expected to range in diameter from that of a house to that of a football stadium and to be several stories deep.

7. The ejecta curtain (sprays of ice and rock) coming out of the crater might look like what you see when you throw a rock into a can of paint (funnel shaped spray).

8. If you view the impact of Comet Tempel 1 from Earth with a large telescope it might look like a bright flash followed by a glowing stream. It would take a couple of minutes after the flash for the "stream" to separate from the center of the comet.

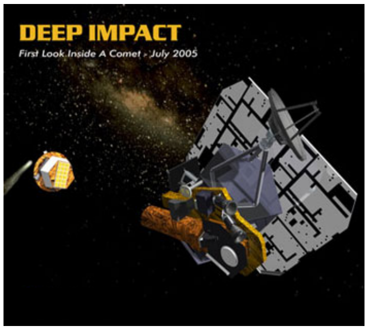
9. The impact will not knock the comet out of its orbit because the force of the collision between the impactor and the comet is less than that of a moving truck hitting a BB. It does not affect speed or direction to any noticeable degree.

10. It takes 7 1/2 minutes for the flyby spacecraft signal to reach Earth. Once the mission is within its last hour, there is no time for the team on Earth to communicate effectively with the twin spacecraft. That is one of the reasons auto navigation systems are being built into the flight plan.

11. The communication time between the flyby spacecraft and the impactor takes less than one second.

12. The impactor does not actually speed toward the comet. The impactor aims to place itself in the path of the approaching comet and it is actually the comet that hits the impactor and vaporizes it. The flyby spacecraft has moved away and below the comet path to observe the impact. After the impact, the comet passes over the top of the observing flyby spacecraft and continues on its orbit around the Sun.

13. For more information, see our Fact Sheet.



Deep Impact Questions

Created for the Deep Impact Mission, A NASA Discovery Mission
Maura Rountree-Brown and Art Hammon
Student - Inquiry

These are the questions that Elicit #1 "What are your ideas about comets?" has brought. You can use these questions for discussion or as an evaluation tool with your students.

- Where do comets come from?
- What are comets made of?
- How do they get from their origin to near Earth?
- What is inside them?
- Where are they now?
- How do you tell the difference between a comet and a shooting star?
- How many are there?
- What is the tail made of?
- Do they all travel the same direction?
- What makes them fly?
- Are they hot and burning?
- Is the tail dangerous?
- What is the life span for a comet?
- Is a comet a ball of gas?
- Is it ice?
- Is it a rock?
- Is it a ball of fire?
- Is it like a shooting star?
- What activates comets?
- Why was Halley's Comet so popular?
- Can they be re-routed?
- How close do they come to Earth?
- Do they have a head and a tail?
- Are they from deep in outer space?
- Are they from the black hole?
- What is "periodic"?
- What keeps them going? Do they have something like a jetpack?
- Why are new ones discovered?
- How do you distinguish one comet from another?

For additional facts about comets, look in Science and Mission Results.

Small Bodies Missions

Deep Impact joins a suite of missions that will travel to other comets and asteroids and learn more about our solar system.

Ephemerides for each of the following missions

Comet Missions

STARDUST
Launch Date: 7 February 1999
Destination: Comet Wild 2
Encounter: January 2004
Sample Return: 2006
Objective: Collect comet dust and interstellar dust particles for return to earth
Description: This was the first mission to collect samples from a comet and return them to earth. Stardust made three loops around the sun before its closest approach to the comet. Samples were captured in a special material called aerogel and the collector retracted into a sample return capsule. The capsule was returned to earth during a soft landing at the U.S. Air Force's Utah Test and Training Range.
Web site: http://stardust.jpl.nasa.gov

CONTOUR
Launch Date: 3 July 2002
Contact Lost: 15 August 2002
NOTE: *Contact with the CONTOUR spacecraft was lost after an engine burn that was intended to send it out of Earth orbit. Evidence suggests the spacecraft split into several pieces and so far all efforts to make contact with CONTOUR have failed. The last attempt to contact the spacecraft was December 20, 2002 without a signal from the spacecraft. No further contact with the silent probe will be made.*
Objective: Encounter and study at least two comets by taking high-resolution pictures
Description: The Comet Nucleus Tour (CONTOUR) was scheduled to encounter at least two comets during their visit to the inner solar system. The spacecraft was to encounter each comet during its peak of activity close to the sun and take high-resolution pictures. The spacecraft was to rendezvous Comet Encke on Nov. 12, 2003 and Comet Schwassmann-Wachmann 3 on June 18, 2006.

ROSETTA
Launch Date: 2 March 2004
Destination: 67P/Churyumov-Gerasimenko
Encounter: 2014
Objective: Travel to and land upon the surface of the comet to study its nucleus.
Description: The International Rosetta Mission was approved in November 1993 by ESA's Science Programme Committee as the Planetary Cornerstone Mission in ESA's long-term space science programme. The mission goal was initially set for a rendezvous with comet 46 P/Wirtanen. After its launch postponement it will now aim at Comet 67P/Churyumov-Gerasimenko. On its 10 year journey to the comet, the spacecraft will pass by at least one asteroid. This mission is designed and managed by the European Space Agency (ESA).
Web site: http://sci.esa.int/rosetta

NEAR SHOEMAKER
Launch Date: 17 February 1996
Destination: Asteroid Eros
Encounter: 14 February 2000
Objective: Orbit asteroid Eros for a period of one year
Description: The NEAR spacecraft entered the orbit around Eros in February of 2000 to determine its

structure, geology, mass, composition, gravity and magnetic field. Having successfully completed its mission objectives, the project team took on an extended objective to land the spacecraft on the surface of Eros. The Near spacecraft touched down on February 12, 2001 transmitting 69 close-up images as it descended.
Web site: http://near.jhuapl.edu

DEEP SPACE 1

Launch Date: 24 October 1998
Destination: Comet Braille, Comet 19P/Borelly
Encounter: July 1999, September 2001
Objective: Test new technologies in space to fly by a comet
Description: The thorough testing of new technologies meant flying them on missions with a strong resemblance to missions of the future. The DS1 mission has successfully tested 12 new technologies in space including:

- An ion drive rocket engine
- A new solar panel design that concentrates sunlight
- An autonomous navigation system that guides the spacecraft using established positions of asteroids

On its way to Comet Borelly, the DS1 spacecraft flew past asteroid (9969) Braille in July 1999.
Web site: http://nmp.jpl.nasa.gov/ds1

DEEP IMPACT

Launch Date: 12 January 2005
Destination: Comet Tempel 1
Encounter: 4 July 2005
Objective: Impact the surface of a comet with a 370 kg impactor creating a crater that exposes fresh material from the interior, study crater formation and composition of the interior.
Description: Deep Impact was the first mission to look beneath the surface of a comet by making a crater that exposed fresh material from its interior and observing the chemistry of materials beneath. The dual spacecraft mission collected images and spectra of the impact and its aftermath from the impactor, the flyby spacecraft and from ground and space based observatories. The flyby spacecraft had approximately 14 minutes to observe before the comet passed over it. After turning, the spacecraft observed the comet for another 24 hours.
Web site: http://deepimpact.umd.edu

Asteroid Missions

DAWN

Launch Date: June 2007
Destination: Vesta & Ceres
Encounter: Vesta July 2010 - July 2011, Ceres Aug 2014 - July 2015
Objective: Orbit two of the largest asteroids in the asteroid belt
Description: Dawn will orbit Ceres and Vesta, two of the largest asteroids in the asteroid belt, for 11 months each in order to characterize the conditions and processes of the solar system's earliest epoch. The top level question that the mission addresses is the role of size and water in determining the evolution of the planets. Ceres and Vesta are the right two bodies with which to address this question, as they are the most massive of the protoplanets, baby planets whose growth was interrupted by the formation of Jupiter.
Web site: http://dawn.jpl.nasa.gov/

Hayabusa

Launch Date: 9 May 2003
Destination: Asteroid 1998 SF36

Encounter: September 2005
Sample Return: June 2007
Objective: Collect up to three asteroid surface samples for return to Earth
Description: Hayabusa will arrive at asteroid 1998 SF36 and collect up to three surface samples before returning them to earth. The Japanese Institute for Space and Astronautical Sciences (ISAS) is managing the mission with some technical assistance provided by NASA.
Web site: http://www.isas.ac.jp/e/enterp/missions/hayabusa/index.shtml

Ephemeris for Tempel 1