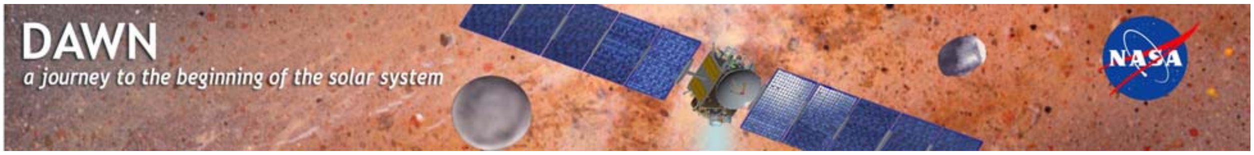

History and Discovery of Asteroids

Journey to the Beginning of the Solar System

TEACHER GUIDE—BRIEFING

BACKGROUND

Welcome to the *History and Discovery of Asteroids* module. This module is intended for middle and high school students who are enrolled in Earth/space science or astronomy. This module could also be used in a social studies class. Students will explore scientific discoveries and technology development as a sequence of events that led eventually to the Dawn mission. Guiding questions may include: *How and why have views of the solar system changed over time? After the discovery of Ceres, why were asteroids identified as being important in our solar system? How do advances in technology enable scientists to investigate the solar system?* This module engages students in a number of experiences that allow the teacher to activate students' prior knowledge and assess student understanding in order to inform instruction.

When students hear the phrase "solar system," they often think of the names of the planets that they may have memorized. Students sometimes forget about the minor planets or asteroids that also orbit around the sun. Asteroids are irregular, rocky bodies that are small in size compared to the planets. Yet, asteroids help scientists understand more about the formation of the solar system. Thus, the Dawn mission will send a spacecraft to visit two large asteroids in the main asteroid belt (the region lying between the orbits of Mars and Jupiter, containing the majority of the asteroids).

Just like a mission briefing for the press, the purpose of this section of the module is to provide students with some background information about the Dawn mission and the need for a spacecraft to travel to new worlds. This lesson begins by having students view a PowerPoint presentation that describes the Dawn mission.

The first student text develops students' recognition of space travel as the next logical step in the progression of asteroid discoveries. Written in the style of a timely news article, "Dawn Spacecraft Poised for Flight to Asteroid Belt" takes students to the launch pad and provides a retrospective of the science, technology, and history leading up to this momentous journey.

TEACHER GUIDE APPENDICES

- Main Ideas and Leading Questions (with answers) that accompany the news article (**Appendix A)**.
- A list of standards addressed in this section of the module (**Appendix B)**.
- Additional background resources—both online and print—for this module are provided in the Resource Section.
- Visit the Dawn Dictionary for a list of terms and definitions for this module.

MATERIALS

- Briefing PowerPoint
- News article, "Dawn Spacecraft Poised for Flight to Asteroid Belt"
- Projector

PROCEDURE

Part 1: The Solar System

1. Begin this activity by asking students to list all of the bodies that can be found in our solar system. Allow time for students to work on this individually. Walk around the room and check students' lists. Students might include planets, the sun, moons, comets, asteroids, gas, and dust.

2. Ask students to check their list to see if they included asteroids or minor planets. For the students that did not list asteroids, ask them why they did not include them. For students who did include the asteroids in their list, ask them to explain briefly what they know about asteroids, including their location in the solar system.

3. Ask students to think about how asteroids have been studied in the past. As a large group, list the methods of asteroid study on the board. (Some answers might include: with the naked eye, through telescopes, and with photographs.) Ask students if they think that a human spacecraft has ever visited and studied an asteroid. (Accept all student answers).

4. Tell students that they are about to embark on a journey back in time to learn about the history of asteroid discovery. Explain that there is a mystery to be solved and that they will need to collect evidence (information) from different periods of time throughout history in order to completely understand what is known about asteroids and their place in our solar system. Ask students to write a list of questions that they have about the history of asteroid discovery. Throughout this module, students should begin to answer these questions and then develop new questions as they explore.

Part 2: Briefing PowerPoint

1. Explain to students that before they start answering these questions, they will be learning a little bit about NASA's Dawn mission. The latest step that scientists are taking to understand cosmic beginnings is the study of asteroids that have not changed much since the dawn of our solar system.

2. Set up the projector and the PowerPoint presentation for students to view. You may want to print student handouts for students to take notes during this presentation. The presentation notes on the PowerPoint should be used when presenting to students, as they contain more detailed information. Augment the notes by asking students follow-up questions.

3. Presentation Notes:

   Slide One: Dawn is the ninth mission in NASA's Discovery Program. http://discovery.nasa.gov/. This site contains information and links of all Discovery Program missions.

   Slide Two: Exploring a new frontier, the Dawn mission will journey back in time over 4.5 billion years to the beginning of our solar system. How is this "time travel" possible?

Slide Three: Many hundreds of thousands of small bodies orbit the sun in the asteroid belt—a large region between the orbits of Mars and Jupiter. They formed at the same time and in similar environments as the bodies that grew to be the rocky planets (Mercury, Venus, Earth, and Mars). Although at one time asteroids were budding planets, scientists theorize that they were never given the opportunity to grow, because of the gravitational effect of the massive planet, Jupiter.

Jupiter causes significant gravitational perturbation or disturbances in the solar system. We think that most of the asteroids were **planetesimals** just like those that formed the planets, but something happened that caused their orbits to tilt and elongate. Because their collision velocities probably approached 5 km/sec, the asteroids fragmented each other rather than accumulating into a single body. The current total mass of these asteroids is probably less than half of the Earth's moon, which is 7.35×10^{22} kg or about 0.0123 of the Earth's mass.

Sometimes called minor planets, asteroids contain clues that reveal the conditions and processes acting during the solar system's earliest epoch.

Slide Four: By investigating two very different asteroids, **Ceres** and **Vesta**, the Dawn mission hopes to unlock some of the mysteries of planetary formation, including the building blocks and the processes leading to their state today.

All of what we now know about Vesta and Ceres comes from ground-based and Earth-orbiting telescopes like NASA's Hubble Space Telescope (HST). This evidence is revealed by electromagnetic radiation reflected from the surface of the asteroids in the ultraviolet, visible, and near-infrared regions, and by emitted radiation in the far-infrared and microwave regions.

Although Vesta is about the size of Arizona, from the Hubble Space Telescope it appears to be the size of a potato suspended from one goal post and viewed from the other end of the football field. Vesta rotates once every 5 hours, 20.5 minutes on its short axis. Scientists think that some **howardite, eucrite, and diogenite (**HED) meteorites have come from Vesta.

Ceres' physical characteristics have remained a mystery even though it was the first asteroid discovered 200 years ago. It is about as big as Texas and is located further from the sun than Vesta. We have found no meteorites on Earth that can be identified as having come from Ceres.

Slide Five: We have reached the limit of what can be observed about these asteroids using Earth-bound technology. In this slide, NASA's Dawn spacecraft is depicted atop the Boeing Delta II rocket at the Cape Canaveral Air Force Station in Florida.

Slide Six: *Current Trajectory:* Launching from Cape Canaveral on September 27, 2007, the Dawn spacecraft encounters Vesta four years later, then the spacecraft travels an additional three years to reach Ceres. The tremendous capability of the ion propulsion allows Dawn great flexibility in its launch date, with the scenario shown above as an example.

The Dawn mission marks the first time that a spacecraft will orbit a main belt asteroid, enabling a detailed and intensive study of it. That this mission orbits two asteroids, both large and massive with contrasting properties (Vesta–Dry), (Ceres–Hydrated), has potential for tremendous scientific return.

At each asteroid, Dawn will

- compile a global color map,
- compile a topographic map,
- map the elemental composition,
- map the mineralogical composition,
- map the gravity field, and
- search for moons.

Slide Seven: *Innovative Propulsion System Aboard***:** Dawn's journey to the asteroid belt, spanning nine years from launch to completion of data return, is made possible by ion propulsion. Initially tested and proven successful on NASA's Deep Space 1 mission, this innovative technology is now applied for the first time in the design and implementation of a dedicated scientific space flight with the Dawn mission. Ion propulsion allows Dawn to undertake a bold and important mission that would be unaffordable—or perhaps even impossible—with a more conventional propulsion system.

Note to Teacher: See the Ion Propulsion Module for more information and activities about Dawn's propulsion system.

Slide Eight: NASA invites you to come along and share in the exciting journey through the asteroid belt with Dawn. Through education and public outreach, NASA provides opportunities to learn about the science of the Dawn mission, to meet the team, and to chart the Dawn spacecraft's progress throughout its nearly decade-long exploration. Educational activities for space enthusiasts of all ages are available at the Dawn mission Web site. For more information visit: http://dawn.jpl.nasa.gov

Slide Nine: Dawn is the ninth Discovery mission in NASA's Science Mission Directorate and is a collaborative partnership made up of the University of California, Los Angeles; Jet Propulsion Laboratory (JPL); Orbital Sciences Corporation; Los Alamos National Laboratory; German Aerospace Center; Max Planck Institute for Solar System Research; Italian Space Agency, and Italian National Institute of Astrophysics. Dawn outreach materials are developed under contract by Mid-continent Research for Education and Learning (McREL), Denver, CO.

Part 3: News Flash!

1. Explain to students that they will be reading about the launch of the Dawn spacecraft.

2. Distribute copies of the news story, "Dawn Spacecraft Poised for Flight to Asteroid Belt." This news story mentions some technology with which students may be unfamiliar. It may be helpful to read this final text aloud to guide the reading.

3. In the next section of this module, students will be reading "flashbacks" that offer a snapshot of significant moments in asteroid history. Students will become experts on one flashback, and in the synthesis section they will be responsible for communicating what they have learned and determining how their piece of evidence (history) fits into the whole in the form of a physical timeline of asteroid discovery and exploration.

Teacher Guide Appendices for Briefing Section

APPENDIX A—Main Ideas and Leading Questions

News Story Main Ideas—"Dawn Spacecraft Poised for Flight to Asteroid Belt"

- The purpose of the Dawn mission is to study two very different asteroids, Vesta and Ceres. By studying these two asteroids, scientists hope to determine the role that water and size played in planetary evolution.
- Dawn is the first science mission to use ion propulsion technology, which will allow us to study each asteroid for extended periods of time and at low altitudes.
- Ground-based telescopes and Earth-orbiting telescopes like the Hubble Space Telescope have provided much of the known information about Ceres and Vesta. In order to learn more about these asteroids, scientists have to use instruments that go beyond Earth-bound technology.
- More is known about Vesta than about Ceres. Vesta appears to be dry and **differentiated** and to have surface features such as **basaltic** lava flows and a large, deep impact basin. Ceres appears to have some evidence of water content, and the surface may be covered with a dry clay. Astronomers believe that some meteorites found on Earth are from Vesta. None have been found from Ceres.
- The Dawn spacecraft will be equipped with cameras and two different spectrometers to capture "close-up" images of surface features, more accurate measurements, and information about the compositions of Vesta and Ceres.
- Dawn is a part of NASA's Discovery program of robotic missions designed to learn more about the solar system.

Questions relating to—"Dawn Spacecraft Poised for Flight to Asteroid Belt"

1. Where and when was the Dawn spacecraft launch? How long will it take the Dawn spacecraft to reach Vesta? [Dawn launched on September 27, 2007 from the Cape Canaveral in Florida. It will take about four years to reach Vesta.]
2. The Dawn mission marks a few historic breakthroughs. What are two historic "firsts" that Dawn will contribute to space exploration? [It is the first purely scientific mission to use an **ion propulsion** system. It is the first mission to orbit two different solar system bodies in one journey.]
3. What are Ceres and Vesta? Why are they important to study? What do scientists hope to find out? [They are asteroids that are thought to be intact since their formation. They may give us some information about the early solar system. Vesta is a comparison object for the rocky inner solar system, whereas Ceres may reflect the transition to the icy outer solar system.]
4. What instruments will be onboard the Dawn spacecraft? What kind of data will these instruments be able to gather? [The spacecraft will be equipped with a framing camera, a mapping spectrometer, and a gamma ray/neutron spectrometer. The instruments will be able to capture images of Ceres and Vesta's surface features; obtain more accurate measurements of the asteroids' mass, shape, volume and rotation rate; determine the size of the internal cores; piece together the asteroids' thermal history; and search for water-bearing minerals.]
5. How are Ceres and Vesta thought to be different? [They have different sizes, masses, and rotation rates. Ceres is larger than Vesta, but we know more about Vesta than Ceres. Vesta appears to be dry and differentiated and to have surface features such as basaltic lava flows and a large, deep impact basin. Astronomers believe that some meteorites found on Earth are from Vesta. Ceres is farther from the sun than Vesta. It appears to have some evidence of water content, and the surface may be covered with dry clay.]
6. Why do we need to send a spacecraft to the asteroid belt to study these asteroids? [We have learned all we can about Vesta and Ceres from Earth-bound telescopes and Hubble.]

Teacher Guide Appendices
For Briefing Section

APPENDIX B—STANDARDS ADDRESSED

National Science Education Standards addressed:

Science As Inquiry
Understandings about Scientific Inquiry
The newspaper article "**Dawn Spacecraft Poised for Flight to Asteroid Belt**" provides students with a bridge from the asteroid results of Hubble during the 1990's to the launch of the Dawn spacecraft in 2007 to the asteroid belt to study Vesta and Ceres. In this article, students learn that there is still much to discover about these asteroids and what they can tell us about the early solar system. Vesta and Ceres should provide clues about the role that water content and size played in the early solar system. The instruments on board the spacecraft will be used to investigate the internal structure, density, and homogeneity of these two very different asteroids.

History and Nature of Science
Nature of Science
In the newspaper article, **"Dawn Spacecraft Poised for Flight to Asteroid Belt**," students will read about how scientists will formulate explanations of the nature of the solar system by studying the transition from objects that are more like inner planets to bodies in the outer solar system possibly similar to icy bodies such as the moons of Jupiter.