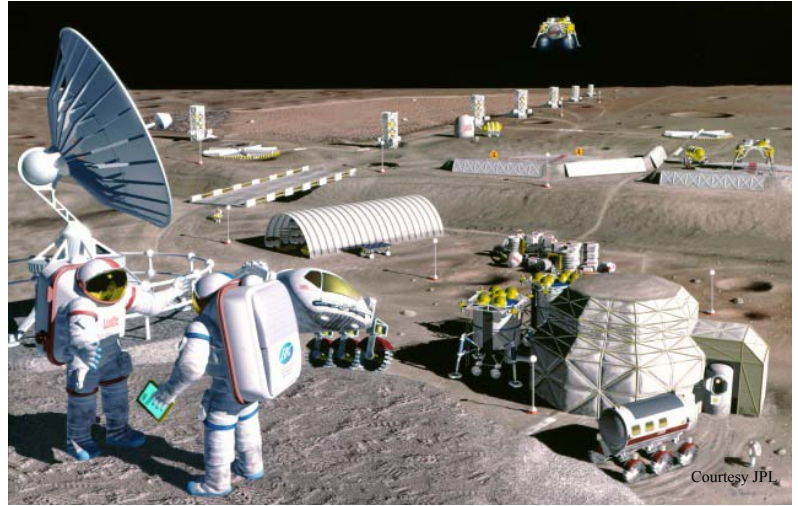


Asteroid Mining

Objectives

- Students will analyze an asteroid and develop a hypothesis on how best to mine the asteroid for minerals
- Students will develop and analyze a mining technique that will produce the most mineral with the least amount of damage to the asteroid
- Students will learn about and understand the risks and benefits of asteroid mining
- Students will compare and contrast risks and benefits of asteroid mining to mining on Earth
- Students will compare and contrast the damage caused by mining an asteroid to the damage mining does on Earth
- Students will develop an understanding of the difficulty of mining on Earth due to the variety of rocks and minerals in the Earth system



Courtesy JPL

Suggested Grade Level

4th-8th

Subject Area

Science

Timeline

One class period

Standards

Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Earth and Space Science

- Structure of the Earth system
- Earth's history
- Earth in the solar system

Science and Technology

- Abilities of technological design
- Understanding about science and technology

Science in Personal and Social Perspectives

- Natural hazards
- Risks and benefits
- Science and technology in society

History and Nature of Science

- Science as a human endeavor
- Nature of science
- History of science

Background

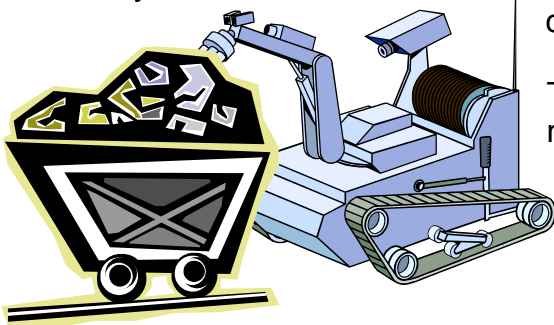
The year is 2050. The danger of Apophis colliding with Earth is a distant memory. In fact, while trying to stop Apophis scientists discovered ways in which to mine asteroids. It has become a very lucrative business. There are minerals that can be found on asteroids that can not be found on Earth. The minerals found on asteroids date back to the formation of the solar system billions of years ago. Luckily, several business owners with foresight, decided to mine asteroids and have become very wealthy.



Recently, a new mineral was found on several asteroids. It is one hundred times stronger than titanium and one thousand times more valuable than gold. The person that can mine this new mineral from the asteroid will become extremely wealthy. There is a catch, however. The mineral is embedded in the asteroid and must be mined with extreme caution. If the asteroid fractures it could become a problem. You would then have several pieces of asteroid with an unstable mass and trajectory. That could send the asteroid on a collision course with Earth! So, caution when mining is of the utmost importance.

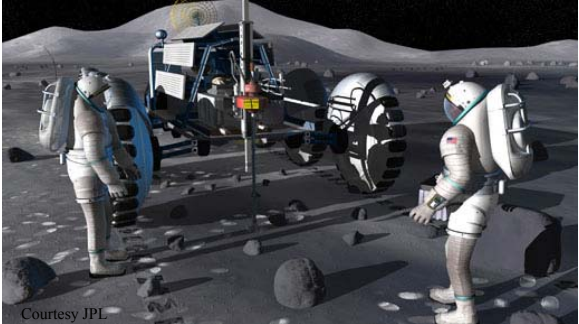
There is a trade-off. The more mineral that you can mine, the more money you will make. The more you destroy your asteroid, though, the bigger fine you will have to pay. Asteroid mining is governed by IAMA, the Intergalactic Asteroid Mining Authority. There is an IAMA officer at every mining operation. It is the job of the IAMA officer to determine how much mineral is mined, therefore, how much money is awarded to the company. The IAMA officer also judges how badly the asteroid has been

destroyed and hands out fines to the mining company. The teacher is the IAMA officer.



The mission for each student is to name their mining company, and name the mineral that they will be mining. They will then receive a

paper towel, their asteroid (chocolate chip cookie), and two toothpicks. There are three types of chocolate chip cookie. Each cookie has a different hardness, just like asteroids. Students will be given a type of cookie at random. They will then use the toothpicks to mine the mineral (chocolate chips).



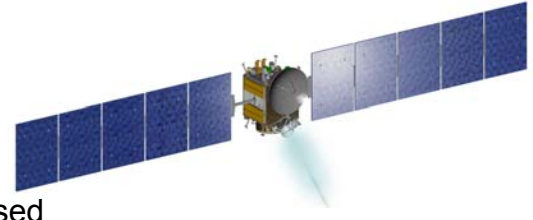
When the mineral has been mined, the IAMA officer will review their mining procedures and assess a mineral award and an asteroid destruction fine. Students must decide if mining more mineral is worth destroying the asteroid, which results in a bigger fine. They must analyze their asteroid and determine where the best place to

mine would be. Some students will mine very little to avoid huge fines. Others will totally destroy their asteroid to extract every piece of mineral. This will lead to a great class discussion after the activity.

After the activity, a class discussion may be started concerning the observations students made about their successes and failures in their mining attempts. They may notice that a certain hardness of cookie was better to have than another. They may also observe that a certain hardness of cookie crumbled easier than another. Students may notice that certain students totally demolished their cookie in order to maximize profits. They were not concerned with destroying the cookie, only making more money. They may also observe that other students mined very little because those particular students did not want to take the risk in disintegrating their cookie and therefore receiving an increased fine.

Call students' attention to what is happening on Earth with mining situations. Many times, mining companies will completely destroy an area in order to get to the wanted material. Open-pit mines excavate huge tracts of land in order to mine a specific mineral. Many times these pits are not filled in when mining is finished. Other areas, in mountain regions particularly, show scarring on mountainsides due to the excavation of minerals. Many times, when the mineral has been completely mined, the land is not reclaimed; but left as is. This is a good opportunity to get student reactions on this topic.

Students may also observe that a certain hardness of cookie allowed easier mining than another. This, too, can be associated with mining on Earth. On Earth, when a mining company has to mine through harder layers of rock the company will have to raise the price of the mineral due to increased work effort. Ask students which companies would have had to raise prices due to having to work harder. On Earth, the softer the rock layer at the location of the mine, the easier it is to dig when mining minerals.



Advancements in asteroid understanding have increased tremendously since 2000. The asteroid probe, NEAR Shoemaker, went into orbit around asteroid 433 Eros on April 30, 2000. After almost a year of orbiting and studying the asteroid, scientists attempted an unprecedented maneuver. They landed the probe on Eros. This was the first time this had ever been attempted, and what's more, the probe was not designed to accomplish that task.

Courtesy JPL

Based on the success of that mission, other probes have been sent to study asteroids. The Japanese launched the Hayabusa probe in 2005 that is studying asteroid 25143 Itokawa, and will bring samples of its surface back to Earth. The European Space Agency probe, Rosetta, will study the asteroids 2867 Steins and 21 Lutetia in 2008 and 2010. Finally, NASA will launch the Dawn probe in August of 2007. Dawn will study asteroid (dwarf planet) 1 Ceres, and asteroid 4 Vesta from 2011-2015.

Materials

Three different types of chocolate chip cookies (one per student)-a regular chocolate chip cookie works well for the M-type asteroids, shortbread chocolate chip cookies can be the S-type, and chewy chocolate chip cookies can be the C-type; paper towels; toothpicks; Asteroid Mining Analysis worksheet

Lesson

1. Do a brief pre-knowledge assessment of students' recall of asteroid facts. Remind students of the three classifications of asteroids C-type, S-type, and M-type. Each type of asteroid is made of different materials and formed in various ways; therefore, each has a different hardness.
2. Tell students that, in the future, we will be mining minerals from asteroids. In fact, today, they will create their own asteroid mining company and will be mining an asteroid for a new mineral that is 100 times stronger than titanium and 1000 times more precious than gold.
3. Give the students two to three minutes to come up with the name of their asteroid mining company, and the mineral that they will be mining.
4. Hand out the Asteroid Mining Analysis worksheet and review it with the students.
5. Have students write the name of their company and the mineral they will be mining, at the top of the paper.
6. Explain how the activity will proceed. Each student will be given a paper towel, two toothpicks and an asteroid (chocolate chip cookie). There are three types of asteroids. Each asteroid has a different hardness which will affect how you will mine your asteroid. The regular chocolate chip cookies are M-type asteroids because they are the hardest. The shortbread chocolate chip cookies are the S-type because they are not as hard as M-type, and are more brittle. Chewy chocolate chip cookies are the C-type because they are the most fragile. Have the students write down, on their Asteroid Mining Analysis worksheet, which type of asteroid they will be mining.

7. The objective is to mine the mineral (chocolate chips) out of the asteroid with the least amount of damage to the asteroid. If the asteroid breaks, you now have two asteroids that may impact the Earth.
8. Students can only use the toothpicks to mine for the mineral. They may NOT use your hands. It is OK to rotate the paper towel.
9. For every whole mineral crystal that is retrieved from the asteroid the student will get \$10,000. If two halves of a whole mineral crystal has been mined, that will count as one. If a student has several pieces of a mineral crystal, the pieces may be put together and counted as one mineral crystal. That determination will be done by the Intergalactic Asteroid Mining Authority (IAMU) Officer.
10. It will also be up to the discretion of the IAMU Officer to assess the amount of damage that has been done to each asteroid. If the student has very little or no damage to the asteroid the student will only be fined \$10,000. If the student has moderate damage done to the asteroid (asteroid broken into two pieces, or several crumbs lying around the asteroid), the student will be assessed a \$25,000 fine. If the student has extreme damage to the asteroid (asteroid is in several pieces or crumbs) the student will be assessed a \$50,000 fine.
11. It will be the student's determination, as president of the company, how much mineral he/she should mine and how much damage will be done to the asteroid to retrieve the mineral.
12. When the student finishes, have he/she raise their hand so their mining operation may be assessed by the IAMA Officer.
13. As the IAMA Officer finishes each assessment, have students fill in the rest of the worksheet. The officer will determine how many whole minerals were mined, and what the fine will be for each student. The student will complete the rest of the worksheet.
14. When the Analysis sheet is finished, the teacher may have students complete the Asteroid Mining Analysis Observations and Conclusions worksheet, or he/she may have a class discussion and then have them complete the worksheet.
15. The purpose of the last Observations and Conclusions page is to have students utilize their observation skills. The objective is to have the students draw conclusions from their observations. The teacher also wants the students to develop a hypothesis on how they could improve their mining techniques.

Extensions

Give each student all three types of asteroid. Students can compare and contrast which asteroids are the easiest to mine, and which asteroid produces the greatest profit.

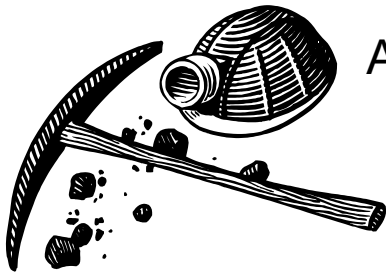
Have students analyze other students' mining techniques to determine if their techniques would be beneficial to them. Have students analyze and assess other student asteroid mining operations.

Evaluation/Assessment

Grade the Asteroid Mining worksheet.

Resources

National Science Standards: <http://www.nap.edu/readingroom/books/nses/>



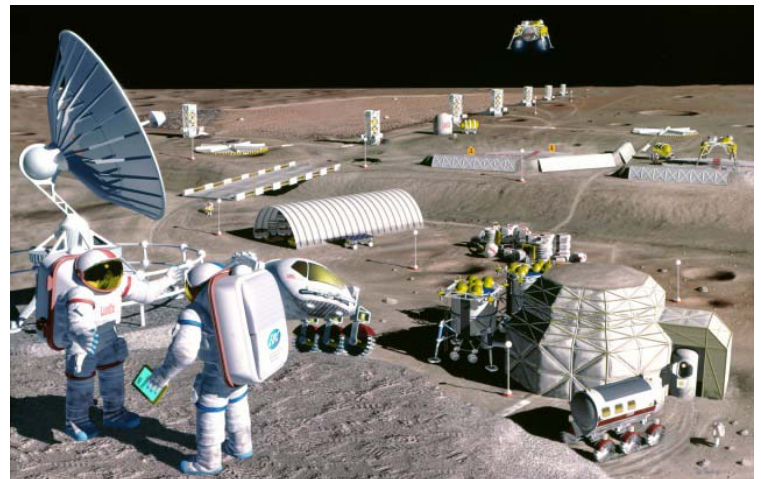
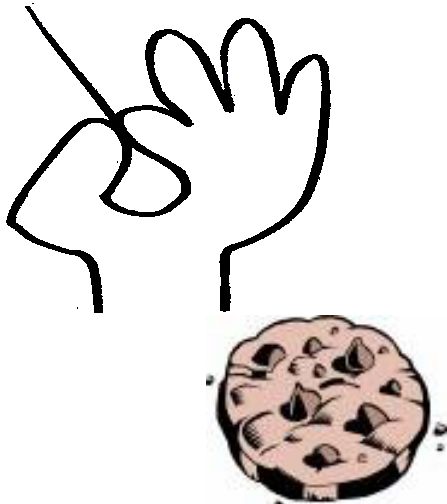
Asteroid Mining Analysis

Name _____

Date _____

Name of Asteroid Mining Company _____			
Name of Mineral Mined _____			
Type of Asteroid _____			
# of Whole Mineral Crystals Mined	_____	X \$10,000 =	\$ _____
Fine Assessed	\$ _____	(subtract from total above)	\$ _____
Total Profit			\$ _____

IAMA Officer Signature _____



Asteroid Mining Analysis

Observations and Conclusions

Name _____

Date _____

1. What type of asteroid did you mine? _____

2. How many whole mineral crystals did you mine? _____

3. How much were you fined? \$ _____

4. Draw a conclusion as to why you were fined that much.

5. What difficulties did you have during your mining?

6. What successes did you have during your mining?

7. What would you do differently next time to increase your chance of success? _____

8. Did you see a technique that was successful for someone else that you would want to use the next time you mine?

9. Are there any other observations or thoughts that you have on this activity? _____
