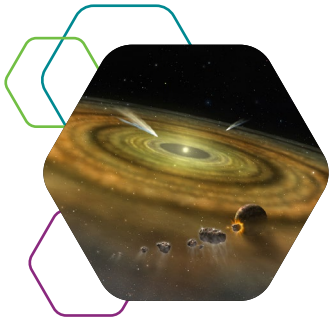

# FACILITATOR GUIDE
# Asteroid Mining

## Learning objectives

- Asteroids are small, rocky objects—some contain precious metals or water ice.
- It's exciting to imagine what our lives might be like in a future filled with more space exploration—and it's also important.
- NASA missions are helping researchers learn more about asteroids and the resources they might contain.

## Materials

- Asteroid drawing worksheets
- Markers
- Challenge cards
- Campo del Cielo meteorite sample
- Activity and facilitator guides
- Information sheets
- *Tips for Leading Hands-on Activities*

**The Explore Science toolkit comes complete with all necessary materials for this activity.** Most materials are also readily available online or at local retail stores to create or restock activity kits. Graphic files can be downloaded from *www.nisenet.org.*

## Notes to the presenter

Start this activity by using the Campo del Cielo meteorite sample to invite participants to engage in observation and discussion. Participants, especially younger visitors, may not be familiar with the concept of mining, asteroids, or asteroid mining. You can use the meteorite sample as the "hook" to introduce the topic by talking about where meteorites come from. Ask the participant if they'd like to hold a real meteorite! To move into thinking about asteroid mining, start with some of the questions in the guide.

This activity is designed as an open-ended, conversational experience. Working together, you can encourage participants to think about future technologies related to mining resources found on asteroids. While some participants may find the drawing component of the activity especially helpful and fun, some visitors (particularly adults) may prefer to just talk about their ideas rather than draw them.

It is important to remember that these technologies **do not yet exist**, although current missions exploring and studying asteroids may lay the groundwork for future asteroid mining operations. Before scientists and engineers can begin building the machines used to mine asteroids, they need to imagine what this technology will look like. They also need to consider questions such as: Who will own these resources? How will the mining technology work? How will the machines even get to the asteroids? And what will we do with the materials once we know how to extract them?

Younger children will probably only participate in the drawing portion of the activity, and that's ok. Try to engage the child's caregiver to talk about mining and encourage them to draw their own mining machine. They might be more receptive to the challenge cards. Younger children also won't be familiar with mining for minerals on Earth, so give some additional explanation about how mining works and what the purposes of mining are by referencing the information sheet provided.

**Conversational prompts**

Besides using the meteorite sample to encourage visitors to participate in the activity, try asking some introductory questions to get started.

- Did you know scientists and engineers are thinking about going to space to mine asteroids?
- This is a future technology. Scientists and engineers are imagining how they will mine asteroids. If you were a scientist or engineer, how would you design a machine that can mine materials on an asteroid?

As visitors imagine, talk about, and/or draw, you can engage them in conversation about what they are drawing (or just imagining) and ask them to expand on their ideas. Here are some example prompts, but you'll also want to follow the lead of your guests:

- How did your machine travel to the asteroid?
- Where do the mined materials go in your machine and how much can it hold?
- How does your machine break apart the surface of the asteroid?
- Digging material out of an asteroid might just be the first step of a mining operation. What do you think happens next? Would you move it to a space station? Back to Earth? Why?

Visitors may also need some encouragement to talk about how their creations and asteroid mining in general might be connected with potential future scenarios. Once again, follow the interests of your visitors. Here are some suggested prompts:

- What might we be able to do with the resources mined from asteroids? How might they help us explore further?
- Who should have access to asteroids to mine? Who should get to keep and use the resources? Individuals? Corporations? Governments?

- How might mining on Earth change after asteroid mining starts? Who might be affected? How might the environment change?
- Should we protect or preserve some asteroids and not allow mining there?

**Difficult Concepts**

Although the concept of asteroid mining seems like it belongs in science fiction, scientists, engineers, and even corporations are thinking about how it might happen one day. However, it is good to remind visitors that asteroid mining is not something going on in our solar system today. While NASA and various space agencies have visited—and even landed on—asteroids, we are still many years away from any large-scale mining projects.

Visitors might have heard about other objects in the solar system. It would be helpful to discuss the differences between them if questions come up on the nature of these space objects.

**ASTEROIDS** are space objects mostly composed of rock left over from the solar system's formation over 4 billion years ago. There are lots of asteroids in the solar system, but the mass of all of them added together is still less than that of the Earth's moon. Most of our solar system's asteroids are orbiting the Sun in the "asteroid belt" between Mars and Jupiter.

**COMETS** are icy bodies made of frozen gases, rock, and dust. Most comets orbit the Sun in very large orbits, meaning they spend most of their time in the far reaches of space where it's very cold. When a comet's orbit brings it close to the Sun, it heats up and spews dust and gases, creating a glowing head and sometimes a long tail that stretches away from the Sun.

**METEOROIDS** are space objects of mostly rock, but they're generally much smaller than asteroids. When one of these objects enters Earth's atmosphere and starts to burn up, it's called a meteor. (A "shooting star" is a meteor.) A meteor that falls to Earth's surface is called a meteorite.

Although asteroids are smaller than Earth's Moon, many are quite large compared with spacecraft. For example, the asteroid Bennu is just a bit taller than the Empire State Building (443m/1453ft), and the spacecraft that visited it—NASA's OSIRIS-REx—is only 6.2m/20.4ft in length with its solar panels deployed.

Mining is a complex, multistep process. Once materials are extracted from the ground or from an asteroid, they still must be crushed, smelted, refined, and transported to transform them from raw ore into a useful product.

With this activity, it is important to remind participants that we haven't found life or signs of life anywhere else in the whole universe. Some people have had experiences, heard about events, or seen popular media that suggest extraterrestrial creatures exist and have even visited Earth. Scientists have not validated any of these accounts, so the current scientific opinion is that no "aliens" have been found or have been in contact with people or planet Earth.

However, scientists do expect that life exists beyond Earth and that one day we may encounter it. There are many research programs looking for evidence of life in other parts of the universe. If we find living organisms on other planets, they are likely to look very different from people, or the little green creatures of popular culture.

If participants bring up things they've experienced or have heard of, you might say something like, "Yes, we hear lots of stories and see movies about aliens, and that makes them seem real to us. But right now, scientists haven't been able to verify any alien encounters, so we're still looking for good evidence of life beyond Earth." Or, "Yes, sometimes we experience things we can't explain, and we wonder if extraterrestrials could be involved. But right now, scientists haven't been able to verify any alien encounters, so we're still looking for good evidence of life beyond Earth."

**Extensions**

Many participants may be satisfied with just the drawing component of this activity. As an extension, the challenge cards are designed to invite participants to pretend they are the person on the card. Will they think differently about mining asteroids in their new role? What new ideas do they come up with? You can use the challenge cards in different ways. You can wait to introduce the cards as an extension after the participants have drawn their machine. Or, you can start by inviting the participants to select a challenge card before they begin to draw. You can either provide participants with a card or have them choose one.

Another extension to this activity could be an invitation to think about what happens 10, 20, or even 50 years after the asteroid has been mined and its resources depleted. After thinking about this prompt, participants can either modify their current drawing or turn their paper over and make a new drawing. This also might be a great prompt for participants to write a story about the asteroid.

For larger groups, such as classes or camps, participants can work collaboratively on a large sheet of butcher paper. You can even create teams using the characters on the challenge cards and invite them to plan a mission to travel to space in search of precious resources on asteroids!

Although not included in the toolkit, you can incorporate a magnet wand and magnifier to enhance visitors' observations of the meteorite sample.

## Background Information

Asteroid mining involves collecting raw materials from asteroids and other objects in space. Depending on their type, asteroids can contain everything from water (useful for long-term space exploration missions because water can be split into hydrogen and oxygen to make rocket fuel) to nickel and cobalt or even valuable metals like gold or platinum. These resources can be more concentrated on asteroids than they are on Earth. Asteroid mining is not currently happening, so it's still largely hypothetical. A lot of the same mining technologies used on Earth could possibly be used for extracting materials on asteroids.

Examples of NASA missions exploring asteroids:

NASA's asteroid sample return mission OSIRIS-REx (Origins, Spectral Interpretation, Resource Identification, Security, and Regolith Explorer)
*https://www.nasa.gov/content/goddard/new-nasa-mission-to-help-us-learn-how-to-mine-asteroids*

The Psyche mission is a journey to a unique metal asteroid orbiting the Sun between Mars and Jupiter.
*https://www.jpl.nasa.gov/missions/psyche/*

The meteorite sample included in the physical toolkit was collected from a group of meteorites referred to as *Campo del Cielo,* which translates to "Field of Heaven." These meteorites were first discovered in 1571 about 500 miles northwest of Buenos Aires, Argentina. They are mostly composed of iron and nickel, with small quantities of many other elements.

## Staff training resources

Refer to the *Tips for Leading Hands-on Activities* sheet in your activity materials.

- Content Training Video: *https://vimeo.com/366777714*
- Activity Training Video: *https://vimeo.com/366777451*
- Edu-cathalon Facilitation Strategies Video: *https://vimeo.com/304241578*

The NISE Network has a curated list of programs, media, and professional development resources that directly relate to the toolkit. These resources can be viewed and downloaded from: *www.nisenet.org/earthspacekitextensions*

## Credits and rights

Artist's depiction of potential lunar robots courtesy NASA.

Artist's depiction of OSIRIS-REx TAGing Bennu courtesy NASA's Goddard Space Flight Center.

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Developed and distributed by the National Informal STEM Education Network.



This material is based on work supported by NASA under cooperative agreement award number NNX16AC67A and 80NSSC18M0061. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the view of the National Aeronautics and Space Administration (NASA).