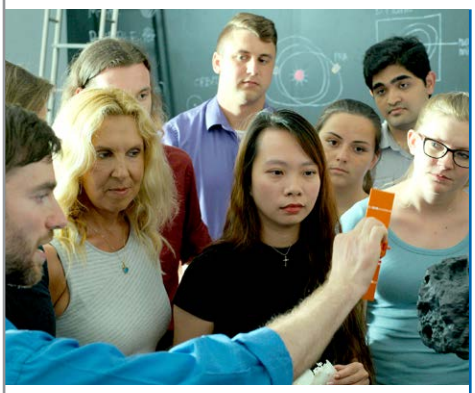


ABOUT ASTEROID HUNTERS

Asteroid Hunters is a spectacular new IMAX experience film that travels into orbit from the asteroid belt and back, showing us how remnants from the formation of the Solar System hold the keys to both our past and our future. Scientists believe that an asteroid impact is one of the greatest dangers facing Earth, but as we see in the film, they have embarked on incredible efforts to protect against such an event.

Target Audience:
These activities are designed for students in grades 9-12, as a supplement to environmental, Earth, and physics science curricula.

Objectives:
- *To introduce the space environment as part of the history of Earth*
- *To explore the opportunities and risks posed by asteroids orbiting near Earth*
- *To highlight some of the programs NASA and its partner agencies are conducting to study asteroids*

Program Components:
- *This two-page teacher's guide*
- *Two reproducible activity sheets*
- *A standards alignment chart on page 20*
- *An online feedback form available at* **ymiclassroom.com/feedback-asteroid**

How to Use These Activities:
Make copies of the two activity sheets for students. Review the material and web resources before scheduling the activities. The first lesson should take approximately one class period. The second activity can be extended into a longer unit. While students do not have to see ***Asteroid Hunters*** *to complete the activities, the activities are designed to enhance your students' viewing experience. Students can also complete the activities before viewing the film.*

National Standards:
These activities align with Next Generation Science Standards and Social Studies standards for grades 9-12. For standards correlation, see page 20.

TRACING THE PAST
Instructions for Educator

In this activity, students will learn how scientists study asteroids and why. Start the lesson by explaining that asteroids and other space objects can provide us with valuable information about the history of the Solar System and that scientists consider an asteroid hitting Earth to be one of the biggest dangers to our planet. Distribute the activity sheet and provide time for students to read the article and answer the questions in Part 1, then discuss their answers as a class. If students don't have access to the Internet in class, print out copies of the article: **nasa.gov/feature/jpl/cosmic-detective-work-why-we-care-about-space-rocks**.

For Part 2, explain that scientists also study existing impact craters to unlock important parts of Earth's history, such as the extinction of dinosaurs. Give students time to research impact craters and write up their findings. Then have them share their discoveries with the class.

Answers:
Part 1: Exact wording will vary.

1) Particles of dust, rock, ice, and metal avoided falling into the Sun or being flung out of the Solar System, and now orbit the Sun just like planets. Scientists believe that Jupiter's gravity prevented these particles from combining into a planet.
2) Study of asteroids and comets can help us understand how planets including Earth formed, locate hazards from incoming objects, and think about the future of exploration. It can tell us about the growth of planets from smaller objects, and if small planets may have provided Earth with ingredients for life.
3) It is thought that up to 80 percent of Earth's water may have come from small bodies like Bennu. Learning about the presence of water can help scientists better understand the kinds of objects that helped bring life to Earth and form theories about the formation of the Solar System.
4) Learning about the composition of asteroids can help us better understand the potential hazards of asteroids to Earth and what it would take to deflect them.
5) Asteroids may serve as future fueling stations for spacecraft and possible sites for mining.

Part 2: Answers will vary.

Extension:
Have students plot each of the impact sites they study on a globe or world map, and then discuss the similarities and differences between the locations. Impact sites are random, but are there similarities between the ways the land has eroded or the ecology has grown since the impact?

DEFENDING THE FUTURE

Instructions for Educator

This lesson gives students an opportunity to synthesize the information they researched in Activity 1, along with what they may have learned from watching the film. It will also help them develop group planning and organizational skills. (Students who are unable to see the movie can review some of the web resources listed below on asteroid deflection and mitigation.) Introduce the activity by talking about the efforts of NASA and other organizations to prevent asteroid collisions. Provide time for students to complete the short question section based on the film. Then divide them into groups.

Lead a discussion about what might happen if there were an asteroid impact in various places: a major city like New York City or Tokyo; a small, rural village in South America or West Africa; or the ocean, along the coastline or far out to sea. Ask students where they think an impact would be the easiest and hardest to manage. Ask each group to choose a location for further examination—make sure they choose locations where people live and work to assure a full scope for each project. Provide time in class over several days for groups to meet and discuss their projects. Encourage them to research similar disasters and how they were handled in the past. Once they have outlined their plan, extend the activity by having them put together a visual presentation to share with the class.

Answers:

Part 1: Exact wording will vary:

- *Observer Probe*: A spacecraft that travels to an asteroid to record its movements, including changes in its surface after a deflection attempt.
- *Nuclear Probe*: A spacecraft designed to explode the outer layers of an asteroid in an attempt to shift its trajectory and increase its potential for missing Earth. In the film, this is the method scientists choose to deflect the fictional asteroid Ficta A3D, but there are several other ways to cause an asteroid to miss Earth.
- *Computer Simulation*: Scientists use complex algorithms to estimate what would happen in an asteroid collision based on mathematical data about the asteroid and its trajectory.
- *Additional technologies include*: NEOWISE, Pan-STARRs, Goldstone radar imaging, and OSIRIS-REx.

Part 2: Projects will vary.

Extensions:

- Asteroid Day (June 30), sponsored by the Asteroid Foundation, is a program helmed by astronauts and scientists from around the world, seeking to bring attention to the risks posed by asteroids in the near future. Using what they've learned, have students create a poster or handout to raise awareness about asteroids and the organization.
- Direct students to research asteroid tracking efforts outside the scope of NASA and the European Space Agency (ESA), such as the Asteroid Decision Analysis and Mapping (ADAM) Project, and the Large Synoptic Survey Telescope (LSST) and summarize why they think asteroid detection and mitigation should involve private industry as well as government organizations.

STEAM FOCUS

Add an arts component to this program:

- Before they view the film, ask students what they think it would sound and feel like to be orbiting in the asteroid belt or riding an NEO (Near-Earth Object) as it enters Earth's atmosphere and during an asteroid collision. Have students create a relevant soundtrack for the experience as they imagine it. The soundtrack can be a musical score using real or homemade instruments, or series of sound effects. After students see the film, ask them how the movie's soundtrack enhanced their sensory experience.
- Have students create an original artwork depicting the asteroid belt, Solar System, or an asteroid impact using charcoal pencils, gouache, or collage.

RESOURCES

- Cosmic Detective Work: Why We Care About Space Rocks **nasa.gov/feature/jpl/cosmic-detective-work-why-we-care-about-space-rocks**
- Terrestrial Impact Craters **lpi.usra.edu/publications/slidesets/craters/index.shtml**
- OSIRIS-REx **nasa.gov/osiris-rex**
- Solar System Exploration: Dawn **solarsystem.nasa.gov/missions/dawn/overview/**
- How NASA Studies and Tracks Asteroids Near and Far **jpl.nasa.gov/edu/news/2017/4/18/how-nasa-studies-and-tracks-asteroids-near-and-far/**
- Planetary Defense: Near-Earth Object Observations Program **nasa.gov/planetarydefense/neoo**
- Asteroid Impact & Deflection Assessment (AIDA) Collaboration **www.esa.int/Safety_Security/Hera/Asteroid_Impact_Deflection_Assessment_AIDA_collaboration**
- OSIRIS-REx Captures Laser 3D View of Bennu **nasa.gov/image-feature/goddard/2019/osiris-rex-captures-laser-3d-view-of-bennu**
- Pan-STARRS1 Data Archive **panstarrs.stsci.edu/**
- Mission to Asteroids and Comets: NEOWISE **jpl.nasa.gov/missions/neowise/**
- B612 Asteroid Institute's Asteroid Decision Analysis and Mapping (ADAM) Project **b612foundation.org/asteroid-decision-analysis-mapping-adam-project-update/**
- Large Synoptic Survey Telescope **lsst.org**
- NASA/JPL NEO Deflection App **cneos.jpl.nasa.gov/nda**

TRACING THE PAST

In a spectacular new IMAX experience, ***Asteroid Hunters***, the origins of our Solar System will feel closer than you've ever imagined. You'll travel to the outer reaches of space and back to discover what scientists believe is the biggest threat to our planet—and what they're doing to try to stop it.

PART 1 SEARCHING THE SKIES

As you'll discover in ***Asteroid Hunters***, there are hundreds of thousands of rocky, airless objects orbiting the Sun, fragments remaining from the creation of our Solar System 4.6 billion years ago—asteroids. They range in size from grains of dirt to mountains, and can be made of any variety of rock, clay, minerals, and metals. Some even contain water and carbon molecules—the building blocks of life.

Asteroids that orbit within 18.6 million miles of Earth's orbit are called Near-Earth Objects (NEOs). Potentially Hazardous Asteroids (PHAs) are a sub-class of NEOs that pass within 4.65 million miles of Earth or closer, and are large enough to cause considerable damage if they fell through our atmosphere. Although asteroids just 50 meters in diameter can form a crater, PHAs are generally 500 meters or more in diameter. So far, scientists have identified more than 20,000 asteroids close enough to endanger Earth, and that number is growing. NASA estimates that there are almost 5,000 PHAs, but only about 2,000 have been found.

Teams of scientists around the world study asteroids to learn more about Earth's past—and our future. Read the following article from NASA's Jet Propulsion Laboratory to learn more, and use it to answer the questions below: **nasa.gov/feature/jpl/cosmic-detective-work-why-we-care-about-space-rocks**.

1. How did gravity help to form the asteroid belt?
2. What can asteroids tell us about the history of our Solar System?
3. What can scientists learn from the presence of water on some asteroids like Ceres and Bennu?
4. Why is it important to learn about the composition of asteroids, particularly the ones classified as Near-Earth Objects (NEOs)?
5. What opportunities do asteroids present for the future?

PART 2 EVIDENCE ON EARTH

The surfaces of the Moon and Mars are battered with craters from asteroid impacts occurring over millions of years. Scientists have discovered that Earth's surface is battered too—but these craters have been hidden or altered by erosion, plate tectonics, and other shifts in our planet's surface. The discovery of one such crater, in Chicxulub, Mexico, changed the understanding of the dinosaur's extinction.

By studying impact craters on Earth, scientists can learn about Earth's past, and, perhaps more importantly, about what to expect if we were to get hit by an asteroid again. For example, in the Tunguska event in 1908, only very tiny fragments of the asteroid were ever found—scientists know, therefore, that the energy and heat were likely caused by an explosion miles above the ground rather than the asteroid actually crashing into the ground.

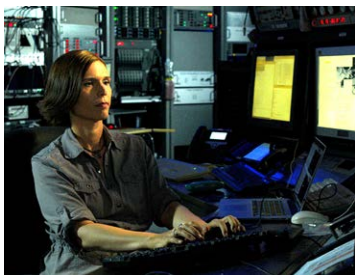
Choose one historic crater or impact site to research. Describe how scientists discovered it was a crater and any challenges they faced identifying it. Then use the back of this sheet to write down two to three facts that the impact site can tell us about Earth's history or about what might happen in a future asteroid impact. Here is a link to get you started: **lpi.usra.edu/publications/slidesets/craters/index.shtml**.

ASTEROID HUNTERS
AN IMAX ORIGINAL FILM

DEFENDING THE FUTURE

Scientists believe that it's not a matter of IF an asteroid will hit Earth again; it's a matter of WHEN and WHERE.

As we see in ***Asteroid Hunters***, even a small meteor would crash with enough energy to permanently change our world—not only would people need to be evacuated for hundreds of miles from the impact zone, but in today's global economy, the impact would be felt around the world.



PART 1 CURRENT PROJECTS

Asteroid Hunters gives us a glimpse at some of the work scientists and space agencies are doing to deflect future asteroid impacts and/or reduce their damage. For example, we meet Marina Brozović, a scientist at NASA's Jet Propulsion Laboratory who uses radar beams to study asteroids from the Mojave Desert.

What other technologies do you see in the film? Start with the three examples below. Record some details you learned about each one, and then add two of your own.

- Observer Probe:
- Nuclear Probe:
- Computer Simulation:
-
-

PART 2 PLANNING COMMITTEE

Now, it's your turn. Get together with a group of classmates and imagine that you are a coalition of scientists, engineers, emergency managers, and political leaders. There is an asteroid headed for Earth that is expected to hit in 6 months. A computer simulation estimates that after burning through our atmosphere, the asteroid will be approximately 150 feet in diameter when it approaches the surface, about double the 2013 Chelyabinsk meteor seen in the film. Your teacher will work with you to select a location to study. Use this sheet to outline your planning.

Location

- *What are the unique hazards presented at this location?*
- *What advantages does this location have in terms of harm reduction?*
- *Besides safety of residents, what might be the ecological or economic effect of an impact in this location?*

Deflection

- *What method will you use to try to deflect or eliminate the asteroid? You can choose one discussed in the film or devise your own strategy.*
- *Why do you think this is the best option?*

Evacuation

- *If impact is inevitable, how will you keep people safe?*
- *Where will you send people, assuming you need to evacuate for hundreds of miles?*
- *How will you get food and water to displaced residents?*
- *How will you handle communications and electricity, if at all?*
- *What systems will you implement for keeping as much of the economy as possible intact?*

Present Your Plan!

Once you've outlined a plan with your group, put together a presentation or model of your strategy for deflection and harm reduction to share with the class.