Key Terms
comet
asteroid
meteoroid
meteor
meteorite

7.5 Other Objects in the Solar System

The Moon and the planets are the most noticeable objects in the night sky. Comets, dwarf planets, meteoroids, and asteroids are other important objects in the solar system. **Comets** are composed of dust, ice, and rock. In 1994, the world watched as chunks of comet Shoemaker-Levy 9 hit Jupiter, as illustrated in **Figure 7.26**. Each impact left a mark the size of Earth in Jupiter's atmosphere. Canadian astronomer David Levy co-discovered this comet with Carolyn and Eugene Shoemaker, an American husband-and-wife astronomer team.

comet an object composed of rocky material, ice, and gas; comes from the Kuiper Belt and Oort Cloud

Trans-Neptunian Objects

Objects that circle the Sun beyond the orbit of Neptune are called *trans-Neptunian objects*. They are located in the Kuiper [pronounced KI-per] Belt, shown in **Figure 7.27**. The Kuiper Belt is a disc-shaped group of millions of small objects orbiting the Sun. Astronomers theorize that the Kuiper Belt is composed of fragments of material left over from the formation of the solar system (similar to the dust around the edges of a patio after it has been swept). Dutch astronomer Gerard Kuiper (1905–1973), after whom the Kuiper Belt is named, predicted that such an area might have existed when the solar system formed.

Figure 7.26 Comet Shoemaker-Levy 9 hit Jupiter in 1994 (artist's depiction).

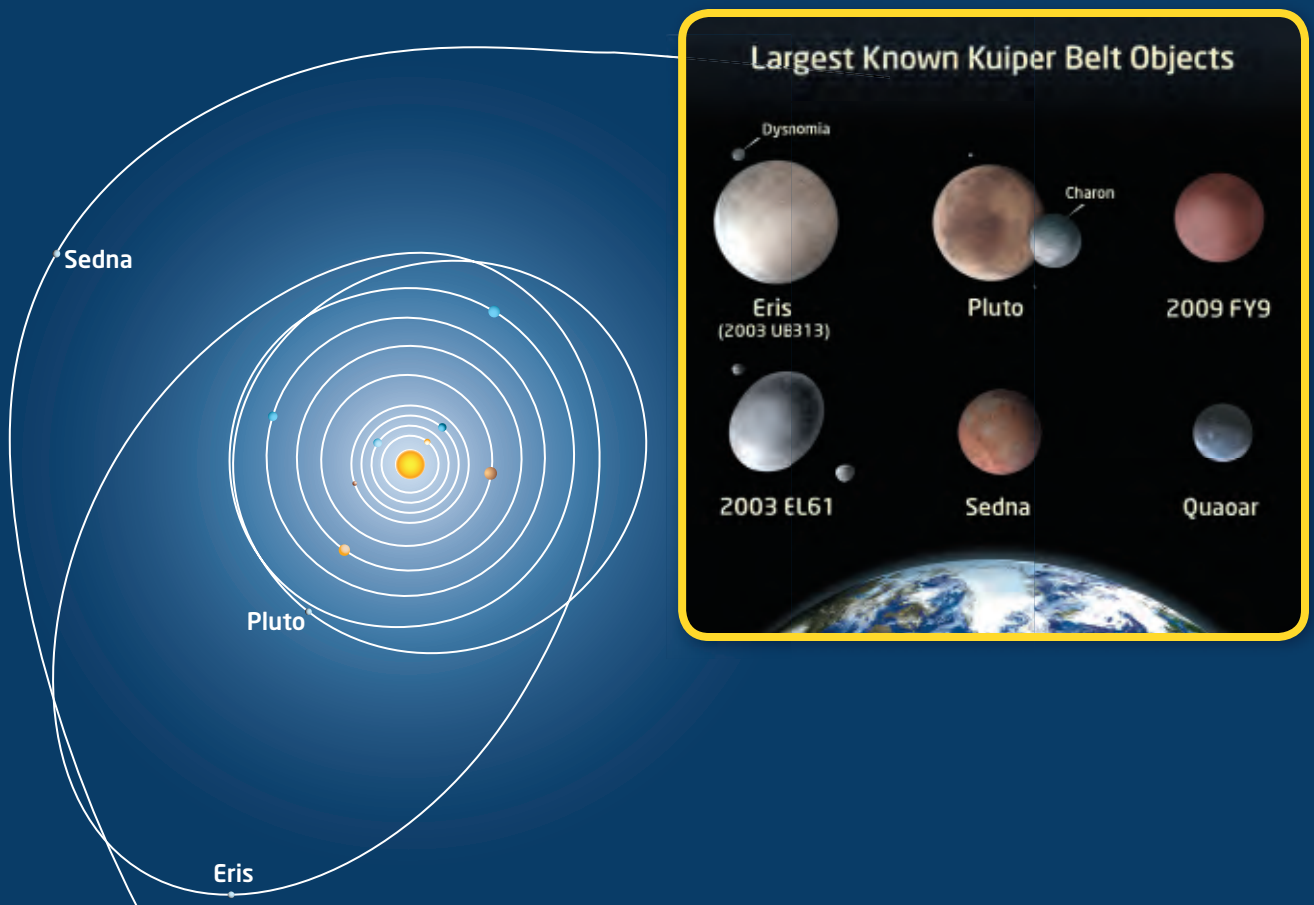
NATIONAL GEOGRAPHIC

VISUALIZING THE KUIPER BELT

Figure 7.27

Recent findings of objects beyond Pluto, in a vast disk called the Kuiper Belt, have forced scientists to rethink what features define a planet.

(Note: Buffy (XR190) is a nickname used by its discoverer. EL61 is an official number assigned to an unnamed body.)



Characteristic	Pluto	Sedna	Eris	EL61	Buffy
Distance, AU	30	67	97	52	58
Colour	red	red	white	bluish	?
Relative size	1	0.75	1.05	0.75	3
Moons	3	?	1	2	?
Orbital period (years)	248	10 500	560	285	440
Orbital tilt (°)	17	12	44	28	47
Orbital eccentricity	0.25	0.85	0.43	0.19	0

The Plight of Pluto

The Kuiper Belt contains the former planet Pluto and other small objects that are similar in composition and size. Astronomers think that Pluto is composed of rock and ice, and estimate its diameter to be 2300 km. Pluto has three known moons. Astronomers refer to Pluto and similar objects in the Kuiper Belt as *dwarf planets*. The largest Kuiper Belt object is Eris. It is almost 2700 km in diameter and has its own moon.

In 2006, the IAU promoted Eris to dwarf planet status. At the same time, Pluto was demoted to dwarf planet because its orbit sometimes crosses Neptune's orbit. That ended Pluto's 76-year history as the solar system's ninth planet.

The Oort Cloud

At the farthest reaches of the Sun's gravitational influence lies a spherical cloud of small icy fragments of debris called the Oort [pronounced ORT] Cloud. The Oort Cloud is between 50 000 AU and 100 000 AU from the Sun. It is roughly one quarter of the distance between the Sun and Proxima Centauri, the nearest star. In 1952, Dutch astronomer Jan Hendrik Oort (1900–1992) revived the theory of the Oort Cloud's existence, proposed in 1932 by Estonian astronomer Ernst Öpik (1893–1985).

Comets

Most comets originate in the Kuiper Belt and the Oort cloud. Every so often, a comet gets too close to Jupiter. Jupiter's gravitational force will either capture the comet, as you saw in **Figure 7.26**, or nudge the comet to change its orbit and enter the inner solar system. When a comet comes close to the Sun, the radiation from the Sun releases the gases and particles in the comet. The wind from the Sun pushes the gases and particles away, forming a tail, as seen in **Figure 7.28**.

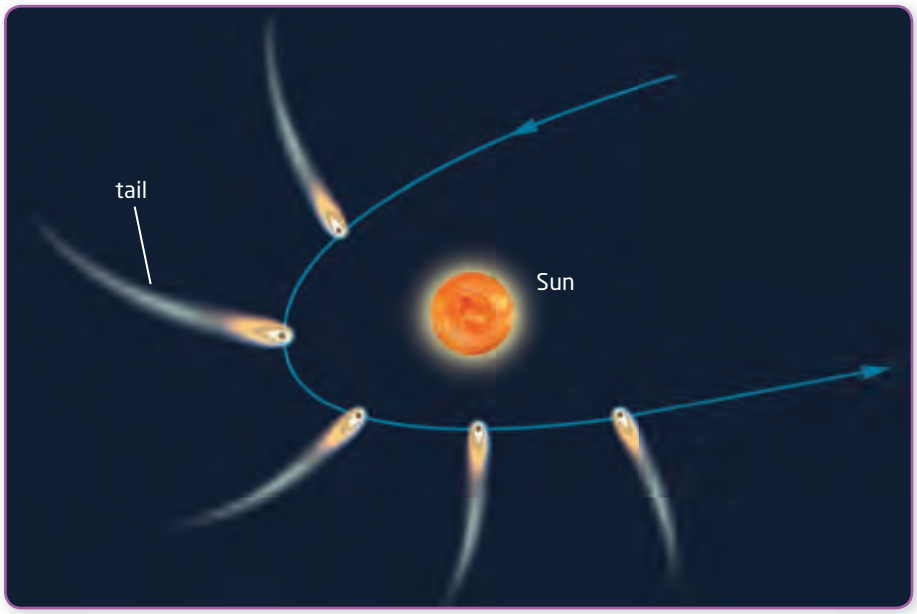


Figure 7.28 A comet's tail always points away from the Sun.

Study Toolkit

Making Connections to Prior Knowledge Think about what you already know about comets. Make some connections to your prior knowledge about this topic. Then draw a concept map, like the one on page 270, to show the connections.

Comet Tails

See the image of comet Hale-Bopp in **Figure 7.29**. The whitish tail is sunlight reflecting off the particles that have been released. These particles, generally called debris, stay in the comet's orbit. The blue tail is made of gases and is called the gas tail. The blue tail is also called the ion tail because the gases have been ionized by the Sun's radiation. It is perfectly safe to view a comet.

Table 7.3 Examples of Periodic Comets

Comet	Period (years)	Closest Approach to the Sun (AU)
Encke	3.30	0.34
Wild 2	6.41	1.59
Halley	76.1	0.59
Swift-Tuttle	133.28	0.96
Hale-Bopp	2533	0.91

Figure 7.29 Comets are named after their discoverers. Comet Hale-Bopp was discovered by two people at the same time: Thomas Bopp from Stanfield, Arizona, and Alan Hale from Cloudcroft, New Mexico.

Go to **scienceontario** to find out more

Some comets visit the Sun just once. Others orbit the Sun, and they are called periodic comets. See **Table 7.3**. In 1999, NASA (the National Aeronautics and Space Administration, in the United States) launched a spacecraft called *Stardust* to meet Comet Wild 2 [pronounced VILT 2]. *Stardust* collected samples from this comet using the aerogel mentioned at the beginning of Chapter 4, and returned the samples to Earth.

Asteroids

asteroid a small object that ranges in size from a tiny speck, like a grain of sand, to 500 km wide; most asteroids originate in the asteroid belt between Mars and Jupiter

Asteroids are small, non-spherical objects that are believed to be debris left over from the formation of the solar system. Most asteroids orbit the Sun in a band, called the asteroid belt, between Mars and Jupiter. See **Figure 7.30A**. Asteroids range in size from a tiny speck, like a grain of sand, to about 500 km wide. An object called Ceres, which is 1000 km wide, is in the asteroid belt. The IAU has promoted Ceres to the status of dwarf planet. Some asteroids even have their own moon, as seen in **Figure 7.30B**.

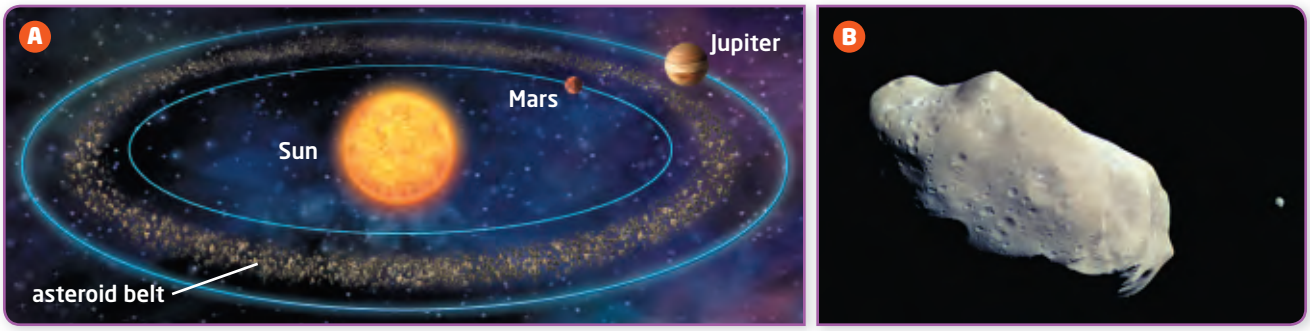


Figure 7.30 **A** Thousands of asteroids orbit in the asteroid belt. **B** The asteroid Ida has its own moon, named Dactyl. Dactyl is to the right of the potato-shaped Ida.

Meteoroids, Meteors, and Meteorites

Meteoroids are pieces of rock moving through space. Astronomers think that meteoroids are rocky chunks that have broken off asteroids and planets. When meteoroids collide with Earth's atmosphere, they burn up due to atmospheric friction, forming **meteors**. When Earth passes through an area where there is a lot of excess material, such as debris left over from a comet, a meteor shower results, such as the one shown in **Figure 7.31**.

meteoroid a piece of rock moving through space

meteor a meteoroid that hits Earth's atmosphere and burns up

Figure 7.31 Meteors in meteor showers seem to come from certain constellations, which is how meteor showers are named. This is an image of the Leonid meteor shower.

Study Toolkit

Word Origins The word *meteor* is from the Greek word *meteoron*, meaning "high in the air." Research the suffixes *oid* and *ite*. How does knowing the meaning of these suffixes help you remember the meaning of the words *meteoroid* and *meteorite*?

The most famous meteor shower is the Perseid meteor shower, which occurs around August 12 every year. In 1862, two American astronomers, Lewis Swift and Horace Tuttle, discovered a comet, which today bears their names: Comet Swift-Tuttle. In 1865, the Italian astronomer Giovanni Schiaparelli realized that the debris left along the orbital path of Comet Swift-Tuttle is responsible for the Perseid meteor shower.

Some people call meteors "shooting stars," but they are not stars. They are meteoroids that are colliding with Earth's atmosphere. Meteoroids that survive the impact with the atmosphere and reach the ground are called **meteorites**. Scientists estimate that about 100 000 metric tonnes of material from meteorites reaches Earth's surface annually.

meteorite a meteoroid that is large enough to pass through Earth's atmosphere and reach the ground, without being totally burned up

Learning Check

1. What are trans-Neptunian objects?
2. Why is the gas tail of a comet also called an ion tail?
3. What is an asteroid?
4. In 2004, NASA's *Stardust* spacecraft returned samples of Comet Wild 2 to Earth. Why do you think astronomers are so interested in learning about comets?

Asteroid and Meteorite Impacts

An asteroid about the size of a mountain struck Earth 65 million years ago. As a result, there were catastrophic changes to Earth's atmosphere. Some scientists think that these changes are responsible for global mass extinctions of thousands of species, including the dinosaurs. See **Figure 7.32**.

Figure 7.32 **A** About 65 million years ago, a large asteroid struck Earth. **B** So much debris must have been thrown into the atmosphere that Earth must have been dark for years. **C** Global mass extinctions likely resulted from the darkness.

There are several impact craters on Earth, and many are in North America. About 39 million years ago, an object about 2 km in diameter hit Devon Island, Nunavut. It left the crater, known as Haughton Crater, shown in **Figure 7.33A**. More recently, about 40 000 to 50 000 years ago, a huge impact produced the Barringer Meteorite Crater in Arizona, shown in **Figure 7.33B**. The impact produced an explosion with energy that was equivalent to about 1000 atomic bombs. This amount of energy probably generated hurricane-force winds up to 40 km from the impact site. Falling rock resulting from the impact would have destroyed everything within a 10 km radius.

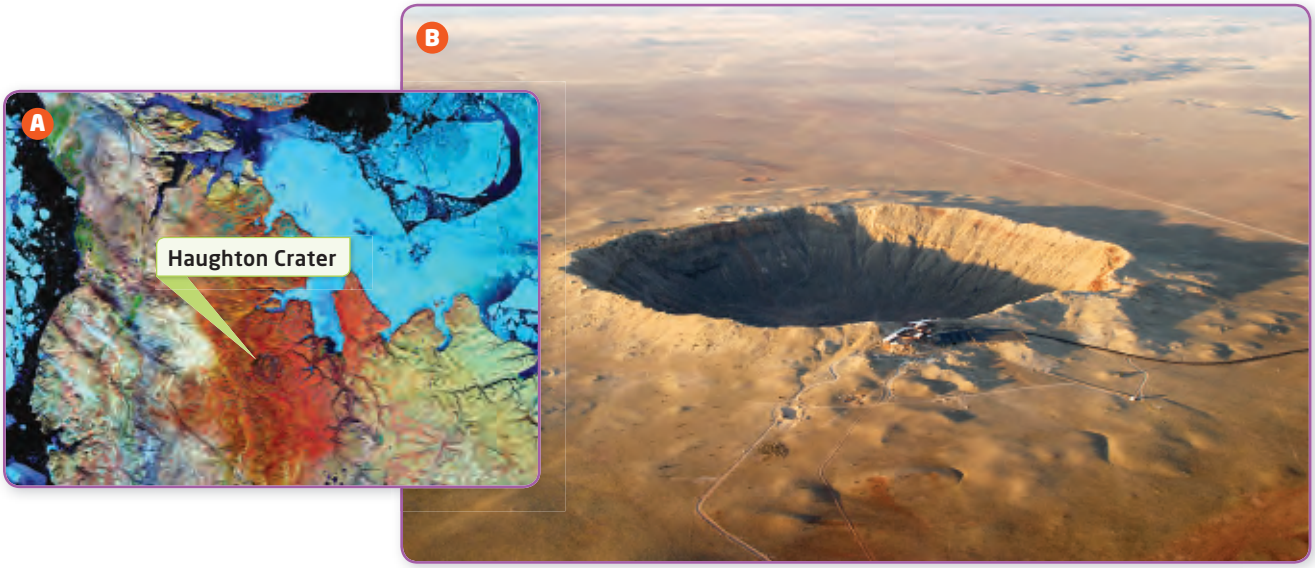


Figure 7.33 **A** The object that hit Devon Island, Nunavut, about 39 million years ago left this crater, 23 km in diameter. **B** About 40 000 to 50 000 years ago, a large meteorite struck the marshy swamps in the southwest region of North America. Today, visitors can see the crater in what is now the desert of Arizona in the United States.

Tunguska Devastation

Much more recently, on June 30, 1908, in Tunguska, Siberia, an object entered Earth's atmosphere and destroyed an area more than 2000 km^2. To put this in perspective, the city of Kingston, in Ontario, covers 1900 km^2. **Figure 7.34** shows an example of the devastation. The object flattened nearly 100 million trees and killed tens of thousands of forest mammals, including several large herds of reindeer. The explosion was probably caused by an object that was about 50 m in diameter. No remnants of the object have been recovered. Scientists speculate that some pieces may be at the bottom of Lake Cheko, in Siberia.

Figure 7.34 This photograph was taken after the Tunguska event. Such events happen about once every 200 to 1000 years.

Activity 7-4

Making Craters

How can you model a crater left by an object hitting Earth with flour and marbles? In this activity, you will demonstrate how an object can create a crater after hitting another object.

CAUTION: Clean up any flour spills immediately. Do not throw the marbles.

Materials

- newspaper
- shallow, rectangular pan
- sand
- flour
- cocoa powder
- 3 marbles, each a different size
- metric ruler

Procedure

1. Place the newspaper on the floor, and place the pan on the newspaper.
2. Half-fill the pan with sand, and then cover the sand with a layer of flour. Sprinkle a thin layer of cocoa powder over the layer of flour.
3. Hold out a large marble at shoulder level. Drop the marble into the mixture. Do not throw the marble. If any flour splashes onto the floor, clean it up immediately because it will make the floor slippery.
4. Observe and record what happens to the flour. Carefully remove the marble. Measure the width of the crater that was formed. Do not add more cocoa powder yet.
5. Repeat steps 3 and 4 with the other two marbles, but drop the marbles in a different area of the flour mixture.
6. Sprinkle another layer of cocoa powder on top of the flour. Repeat steps 3 to 5 but from knee height.
7. Sprinkle another layer of cocoa powder on top of the flour. Repeat steps 3 to 5. This time, drop the marbles from knee height, but angle them to give them some horizontal motion.

Questions

1. Why was it important to drop the three different marbles from the same height each time you completed steps 3 to 5?
2. What affected the size of a crater?
3. What did you notice when the marble hit with some horizontal motion?

Making craters

Looking Back

In this chapter, you learned that people have been observing the night sky and learning its patterns for thousands of years. In time, different cultures began building technologies, such as stepped pyramids and sundials, to predict motions of celestial objects. Understanding the motions of celestial objects allowed people to navigate and to predict the seasons and important events, such as flooding and the return of animal herds.

You also learned about the planets and other celestial objects. For example, each gas giant has dozens of moons. How do astronomers know this, when most of the moons are too small to be seen from Earth? How did scientists get an image of a small asteroid and its even smaller moon?

STSE Case Study

Can We Prevent the Next Big Impact?

In 1942, astronomers discovered a new group of asteroids. These near-Earth objects (NEOs) travel inside Earth's orbit. Many appear in the sky close to the Sun. Earth-based telescopes cannot see them because the NEOs set a few minutes after the Sun does, but before the sky gets dark. Scientists estimate that there are between 200 000 and 500 000 undiscovered NEOs larger than 100 m. These NEOs are large enough to cause a very bad day if one were to collide with Earth.

Finding NEOs

A Canadian project is underway to send a small satellite with a telescope into Earth orbit in 2010 to find NEOs. NEOSSat (Near-Earth Object Surveillance Satellite) will be the world's first space telescope to look for NEOs.

Many people and organizations are involved in the design, construction, launching, and use of NEOSSat. The Canadian Space Agency, university teams, and industry teams are all working together. Defence Research

NEOSSat Technology

- **Most satellites spend half of their time in Earth's shadow. NEOSSat will remain in sunlight, passing over the North and South Poles with every orbit. This will allow NEOSSat to get its power from sunlight and to look for NEOs without interruption.**
- **NEOSSat's telescope has to stay pointed toward the Sun. Usually, satellites use little rocket engines to do this. But NEOSSat is too small and light to carry fuel. A company called Dynacon Inc., in Mississauga, Ontario, solved this problem. They developed special small, spinning wheels that speed up or slow down to change the direction of the satellite.**

NEOSSat is about the size of a large suitcase. It will pass 700 km above Earth as its 15 cm telescope searches for NEOs. NEOSSat is expected to transmit hundreds of pictures a day to Earth for five years, starting in 2010.

Looking Forward

By the 1600s, theories and technologies had progressed extensively. Astronomers had a better understanding of the motions of some celestial bodies, and they had access to telescopes, thus opening the window to the universe even more. In just a few hundred years, technologies advanced from telescopes on the ground to sending astronauts to the Moon, putting telescopes and other technologies in space, and even planning a crewed mission to Mars. In Chapter 8, you will learn about some of these technologies and how they contribute to our understanding of space and the Sun and other stars, as well as some of the risks and hazards associated with space exploration. You will also learn how stars live and die.

Development Canada and the Canadian Space Agency are paying the $12 million bill. This sounds very expensive, but it is a lot cheaper than some modern ground-based telescopes. And NEOSSat will be able to do what those telescopes cannot–find hard-to-detect NEOs.

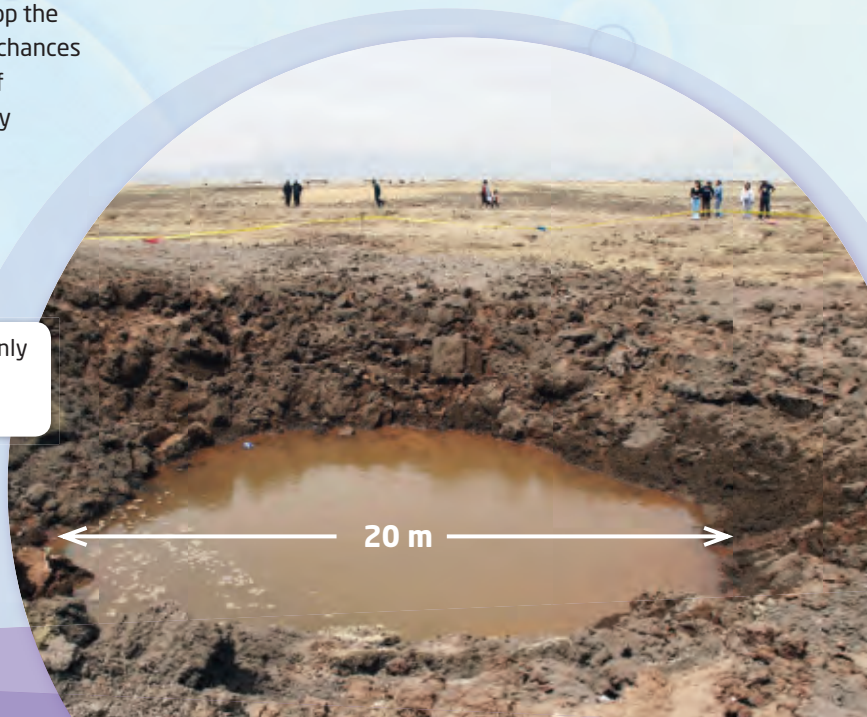
NEOSSat's Limitations

NEOSSat will only be able to detect objects that are 100 m in diameter or larger. This is larger than the objects thought to have caused the Tunguska and Barringer Meteorite Craters. Scientists think that these objects were about 50 m in diameter. As you can see in the photograph at the right, even much smaller asteroids can create large craters. So, even when NEOSSat has completed its mission, Earth will still be vulnerable to the impact of objects from space.

What happens if NEOSSat does detect a 1 km asteroid on a collision course for Earth? Unfortunately, the answer today is nothing. It may be decades before scientists develop the technology to deflect an oncoming asteroid. But the chances of a collision happening any time soon are slim. And if NEOSSat discovers an asteroid that passes harmlessly by Earth, scientists may be able to send a spacecraft to collect a sample and bring it back to Earth. Such a sample could be material left over from the birth of the solar system.

Your Turn

1. The design of NEOSSat is an example of technological problem solving.
   - **a.** Why will NEOSSat be able to look for NEOs, while Earth-based telescopes cannot?
   - **b.** Describe one technological challenge that designers of NEOSSat have faced and how they solved it.
2. Suppose that NEOSSat discovers an object, 1 km in diameter, that is likely to hit Earth off Canada's east coast in a few months. What steps could be taken to minimize loss of life?
3. "Funding for NEOSSat is a waste of money." Do you agree or disagree? List reasons to support your opinion. Then write a letter to your local MP to express your concern or support for NEOSSat funding.



In September 2007, an asteroid only 1 to 2 m in diameter created this 20 m crater near Carancas, Peru.

Section 7.5 Review

Section Summary

- In addition to planets, the solar system contains many different objects, such as dwarf planets, asteroids, comets, and meteors.
- There is a very real danger that an asteroid or a large meteor will hit Earth again.
- The Canadian Space Agency and Canadian businesses are building a satellite that will help to detect near-Earth objects that could be harmful if they hit Earth.

Review Questions

K/U **1.** What happens to a comet as it approaches the Sun?

K/U **2.** Why is Pluto no longer considered to be a planet?

C **3.** Write a convincing argument to support this statement: "Shooting stars are not really stars."

K/U **4.** Complete the following table.

Definition Table

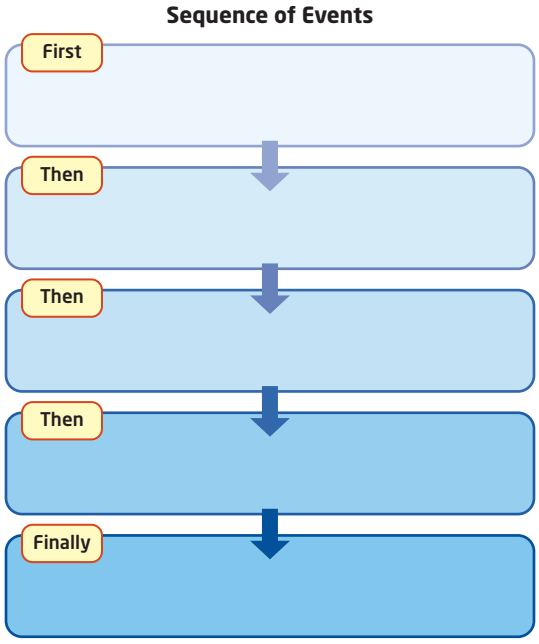
Object	Definition
asteroid	
meteoroid	
	a streak in the night sky
	the leftover matter when a meteoroid hits Earth's surface

K/U **5.** In terms of origin, what is the difference between a comet and most asteroids?

A **6.** Study **Figure 7.32** and its caption. Create a sequence of events graphic organizer like the one shown here. Complete your graphic organizer to describe the causes and effects that may have resulted in the destruction of several species, including the dinosaurs.

T/I **7.** How are comets related to meteor showers?

T/I **8.** Asteroids orbit the Sun like planets do. Why are asteroids not considered to be planets?



Sequence of events graphic organizer