K-12 Educator's Guide

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This K-12 Educator's Guide includes supplemental information and activities to help extend the learning experience associated with watching *Space Junk*. The film tells the story of a growing ring of orbiting debris located 22,000 miles above Earth—a troubling legacy of 50 years of launching our dreams into space. That debris field casts a shadow over the future of space exploration. This Educator's Guide presents a historical timeline of satellite launches and the background science to help learners understand the physics of space junk.

Space Junk also challenges students to imagine solutions to the problems we now face in space. While the film's message is a cautionary tale, it also seeks to inspire a new age of innovation. Today's K-12 students are tomorrow's scientists and engineers who will forge the future of space exploration and discovery.

This Guide also includes hands-on activities and a complete presentation of how the film can be used to support classroom learning in context with the National Science Education Standards.

Learning Goals for K-12 Students:

- The basic physical principles of orbital mechanics have enabled a half-century of rapid innovation in satellite technology, impacting our daily lives.
- Actions have consequences. The benefits of satellite technology have been great, but the orbital debris field has grown to become a new and pressing challenge.
- Scientists and engineers work steadily to improve society by imagining and testing new technologies.

GLOSSARY

asteroid belt – the region of space between the orbits of Mars and Jupiter in which most asteroids are located.

constellation – a group or configuration of objects. In this case, a grouping of satellites, spread out in a set of orbital rings.

debris – the remains of anything broken down or destroyed.

Geosynchronous Earth Orbit (GEO) – a circular orbit around the Earth having a period of twenty-four hours, enabling a satellite to remain in a fixed position above the Earth.

hypervelocity – extremely high velocity, up to 15,000 miles per hour.

Low Earth Orbit (LEO) – an orbit that is not more than 2000 km above the Earth's surface.

meteors – small solid objects passing from space into the Earth's atmosphere.

Meteor Crater – a site near Winslow, Arizona formed when a meteor crashed into the ground, causing an explosive reaction.

meteorite – a mass of stone or metal that has reached the Earth from space.

orbit – the curved path, usually elliptical, of an object's movement around a celestial body.

satellite – an object, whether natural or manmade, that orbits a celestial body.

Fast Facts!

- Planet Earth has just one natural satellite orbiting it—the Moon!
- Planet Earth has thousands of artificial satellites orbiting it.
- The largest artificial satellite is the International Space Station.
- The smallest artificial satellites are debris—paint chips, fuel drops, bolts, spare parts, and other junk.

Satellite History

Artificial Earth satellites serve many purposes and are launched into orbit for many reasons. They may be used for scientific experimentation, exploration, and communication —enabling technological innovations that impact our daily lives. There is no reason to stop launching satellites, but we do need to find a way to control the clutter. Today, there are voluntary international guidelines for new satellites to have a twenty-five-year operating plan, including ways to reserve the resources that will be needed to remove the satellite safely from orbit once it is no longer operational. These guidelines will do a lot to improve the situation for the future. Of course, they do not help to resolve the problems we face with the orbiting debris that already exists. This timeline shows some significant satellite launches and events over the past half-century, including their fate.

1957

October 4
Sputnik 1

The world's first artificial satellite, about the size of a beach ball. Remained in orbit until it re-entered Earth's atmosphere on January 4, 1958. Launched by the Soviet Union.

November 3
Sputnik 2

Carried a dog named Laika, the first living creature to orbit the Earth. Remained in orbit for 162 days before re-entering Earth's atmosphere. Launched by the Soviet Union.

1958

January 31
Explorer 1

Discovered the Van Allen Belts, magnetic radiation fields around the Earth that can be dangerous to satellite technologies. Re-entered Earth's atmosphere after 111 days in orbit. Launched by the United States of America.

1960

April 1
TIROS-1

First successful weather satellite placed into orbit to provide television images of weather patterns. It only worked for 78 days, but it proved the value of satellites for weather forecasting. It remains in orbit. Launched by the United States of America.

1961

April 12
Vostok 1

Carried Cosmonaut Yuri Gagarin into space for 89 minutes, making him the first human being to orbit the Earth.

1962

February 20
Friendship 7

Carried Astronaut John Glenn into space, placing him into Earth orbit for 4 hours and 56 minutes before re-entering the atmosphere and splashing down safely into the Atlantic Ocean. Launched by the United States of America.

July 10
Telstar 1

First satellite used to relay television signals, enabling the first live transatlantic television broadcast. It stopped working on February 21, 1963. It remains in orbit. Launched by an alliance of American, British, and French companies.

1963

May 15
Faith 7

Carried Astronaut Gordon Cooper into space and safely returned him to Earth 25 hours and 19 minutes later, making him the first human being to spend more than a day in space. Launched by the United States of America.

1973

May 14
Skylab

An orbiting space station used for scientific research and experimentation by a crew of three people. Abandoned in 1974. Fell out of orbit and re-entered Earth's atmosphere on July 11, 1979. Launched by the United States of America.

1986

Feburary 19
Mir

An orbiting space station used for scientific research and experimentation by a crew of three people. Decommissioning began in 2000 with re-entry into Earth's atmosphere completed on March 23, 2001. Launched by the Soviet Union.

1990

April 24
Hubble Space Telescope

First satellite placed in orbit for scientific observation of the universe beyond the Earth's atmosphere. It remains in orbit. Launched by the United States of America.

1993

June 16

Cosmos 2251

A satellite used for military purposes.
It stopped working in 1995, but remained intact in orbit until 2009. Launched by Russia.

1997

September 14

Iridium 33

One of many communication satellites that orbit the Earth in order to relay voice and data signal transmissions. It remained in orbit until 2009. Launched by Iridium Satellite LLC, an American company.

1998

November 20

International Space Station

Construction began with the orbital placement of the first module. The first three-person crew arrived on October 31, 2000. Construction continued over the next decade as new modules are added, eventually becoming the largest artificial satellite ever placed in Earth orbit. It remains in orbit, with additional component placements still anticipated. Launched by an international alliance of space agencies.

2009

February 10

Destruction of Cosmos 2251 & Iridium 33

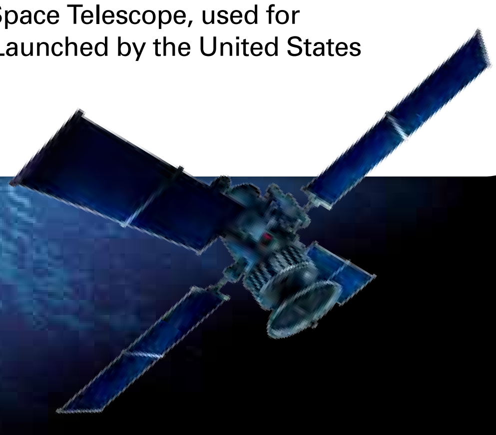
First major collision of two satellites in Earth orbit. The operational Iridium satellite was destroyed, as was the non-working Cosmos. More than 100,000 pieces of debris resulted from the collision, all left to crowd Low Earth Orbit.

2009

March 7

Kepler Space Telescope

Designed to improve upon the aging Hubble Space Telescope, used for astronomical observation. It remains in orbit. Launched by the United States of America.



Scientists

Don Kessler has had a lifelong love of astronomy.

After earning his bachelor's degree in physics from the University of Houston, Kessler studied orbital debris, meteoroids, and interplanetary dust for over thirty years. His dedication earned him a special nickname: "The Father of Space Junk." He worked as a senior scientist for NASA at the Johnson Space Center in Texas before he retired and moved to North Carolina.

His nickname makes sense when you know that he was the first to predict that the clutter of satellites in orbit would lead to random collisions that would create smaller and smaller pieces that would become more and more hazardous to other satellites and spacecraft. The process became known as "The Kessler Syndrome." Even if we never launch another satellite, the syndrome will continue, causing pieces to get smaller and smaller and, eventually, might even cause the formation of stable "rings" around the Earth, like those we see around Saturn.

"Growing up, it was my fantasy that I would get to see humanity spread off of the Earth and throughout the solar system. So, do I think this snowballing event will actually happen? I can't imagine, after dreaming and working towards spaceflight, and after fifty years of having achieved it, that we would ever cut ourselves off from space. That goes against everything that humanity has ever strived for. My legacy will probably always include being known as the Father of Space Junk. What I hope that means is that we continue to maintain access to space and learn more about life and the environment."

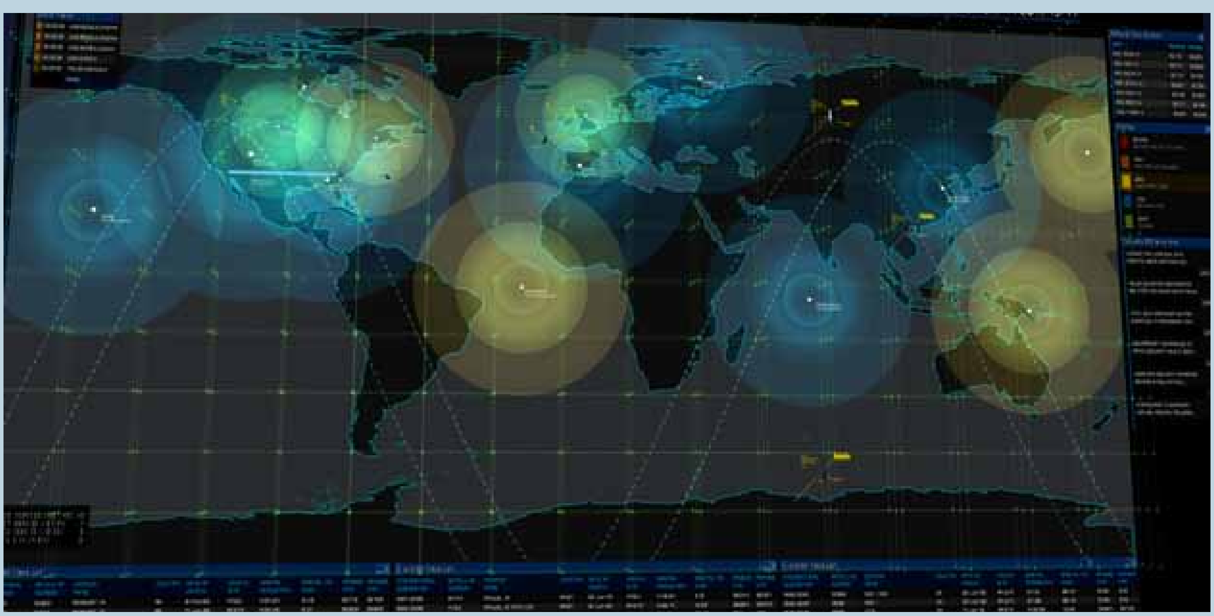
Analysts & Satellite Operators

Space Situational Awareness

Space Situational Awareness is the ability to know what is in space, where it is, and where it is going in relation to everything else in space. In *Space Junk*, analysts work at the Space Surveillance Network's (SSN) Command Center to catalog the debris that is large enough to track and monitor a satellite's orbital path. While SSN Analysts cannot entirely prevent collisions, they can make predictions and issue warnings, called conjunction assessments, when two objects appear to be on the same path. The warnings allow satellite operators to move the spacecraft to a clearer path. These men and women are like the air traffic controllers of Low Earth Orbit.

Satellite operators conduct station-keeping maneuvers to keep satellites in their assigned orbit and also move satellites out of the way of potential collisions with debris.

The future of space awareness is data-driven and collaborative. In order to reduce collisions in space, we need better debris tracking. In order to track objects more accurately in space, satellite owners need to share the exact positions of their satellites with one another. For example, three major commercial satellite managers have already recognized the need to share data and work together to reveal exact locations of where their satellites are positioned, maintaining "cooperative situational awareness" so that everyone can prosper.

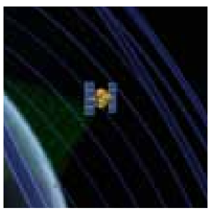


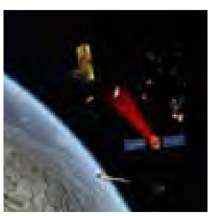
Engineers, Innovators, & Entrepreneurs

In *Space Junk*, we see that cleaning up debris and reusing our resources in space will be critical to addressing the Kessler Syndrome. In order to clean up space, a solution needs to catch up to the object that is traveling at hypervelocity (7km/second) speeds. Then, then it must “grab” the object and, finally, de-orbit the object. Many different scientists, innovators, and engineers will need to be part of each phase of cleaning up space. Of course, this is expensive work—so we will need new businesses that invest in recycling resources in space.

Like Don Kessler and the engineers who work at the Space Surveillance Network’s Command Center, scientists of the future will need curiosity, dedication, and strong observation skills. They will need to become experts at interpreting data—massive amounts of data. While scientists and engineers have always needed mathematical and analytical skills, today’s technological innovations are changing the nature of scientific investigation. The future of scientific discovery and innovation is going to be dependent on human abilities to analyze and interpret huge sets of data collected by instruments and computers. And, that work is too big for any one person. So, the future of science is also certain to be collaborative.

Try This! Space Junk Clean-Up





In *Space Junk*, we see several ideas that are currently being considered for how to clean up junk in space.

One idea is to use an electrodynamic tether, which would de-orbit a spacecraft by generating drag through interactions between currents in the tether and the Earth's magnetic field. This increased drag would lower the spacecraft out of orbit until it re-enters the Earth's atmosphere.

Another idea involves capturing debris with a net. Japan's space agency has been working with a fishing net manufacturer to design a space net, which, like the tether, could be powered using the Earth's magnetosphere.

Lasers could one day "sweep space," striking smaller objects, slowing them down, and causing them to tumble into the atmosphere.

Solar sails could someday be a part of new satellites we launch, a resource held in reserve, ready to help the satellites de-orbit once their work in space is done.

DESIGN CHALLENGE FOR K-6

Have students draw pictures of their favorite of the four proposed ideas: the tether, the net, the laser sweeper, or the sail. Have them explain why they chose that idea. Challenge them to think of other possible ideas for "cleaning up" space junk.

DESIGN CHALLENGE FOR 7-12

Divide students into five teams, one for each of the five proposed ideas. Have them develop a proposal for why that idea is the best and how they might develop it. Have each team present its proposal and then collectively decide which idea should be implemented, based upon the strength of the proposal.

Alternatively, older students could brainstorm and propose an entirely original idea for space junk clean-up instead. Challenge them to be creative and imaginative. Have students construct working models to accompany their original designs.

Try This! Orbital Fun:

This simple activity illustrates the principle of centripetal force. Students will place an object into orbit around themselves. We recommend doing this outside or, if indoors, on a water-resistant, non-slip surface.

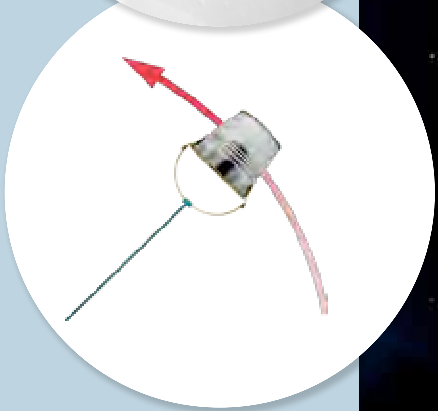
For K-4 classes, use the foam cup and string option. For 9-12 classes, use the bucket and rope option. For 5-8, use your judgment based on average student strength. At all grade levels, consider grouping students into small teams so that fewer objects are in motion at once. Make sure to leave plenty of space between teams.

MATERIALS

- Foam cup or bucket with handle
- String or rope, 3 feet long
- Water

PROCEDURE

1. If using a cup, punch holes in the sides of the cup, opposite each other. Thread one end of the length of string through one hole and tie a knot inside. Thread the other end through the opposite hole and knot it so that you have a long "handle" over the cup.
2. If using a bucket, tie the rope securely to the middle of the handle.
3. Fill the cup or bucket halfway with water.
4. Hold onto the end of the rope and carefully, but confidently, begin swinging in a circular movement. What happens to the water? What do we call the path that the cup/bucket is moving in?
5. To stop, slow down your swing as the bucket approaches the ground.
6. Predict what would happen if the string/rope were shorter. Wrap the end of the rope around your hand a couple times and try again. How does the path of the cup/bucket change?
7. Think of other variables that might affect the motion. Make a hypothesis about what will happen and then test it!



WHAT'S HAPPENING?

The circular path of the cup/bucket is like an orbit. The cup/bucket (and water) is held in orbit by the string/rope. The force that you apply to the cup/bucket through the string/rope when you swing it is called centripetal force. In the case of a rocket or other satellite, the force of gravity provides the centripetal force. The Earth pulls on the satellite just as you pull on the string/rope to keep the cup/bucket in orbit. You must constantly apply force to the string/rope to keep the cup/bucket from flying off in a straight line. If the string/rope is shorter, then the orbit is smaller and so the speed of the cup/bucket increases.

Try This! Satellite Tracking:

The International Space Station is often visible in the sky. Consider planning a viewing event at your school for students and their families when the world's largest artificial satellite is passing overhead. Or, encourage students to go outside at home and track its passage.

PLAN AHEAD

Find out when the International Space Station will be visible over your location.
Go to: spaceflight.nasa.gov/realdata/sightings

Select your country from the list and then continue selecting locations until you find your town. If you do not see your exact location listed, select a nearby town. The sighting opportunities will be the same, or vary by just a second or two. The listings will be for the next week or two, depending on your location. The best opportunities, of course, are those with the longest durations. Those that say < 1 minute will be the most challenging.

Note: You will also need to pay attention to the weather forecasts in your area. Cloud cover will prevent you from seeing the satellite.

WHAT TO DO

When you know that the satellite will be passing overhead and the sky will be clear, go outside and be ready to look to the sky.

Note: No special equipment is needed. You will be able to see the International Space Station just by looking. Of course, binoculars will enhance your view. Telescopes are actually not practical because of the satellite's speed.

WHERE TO LOOK

Younger students will need an adult to point to the satellite's position in the sky.
Older students can be challenged to "read" the sky for themselves. The satellite tracking data for your location will include the local date/time, duration, maximum elevation, approach, and departure. For example, your result might look like this:

This means that the International Space Station will be visible overhead on Tuesday, November 14 from 6:22AM to 6:26AM. It will come into view from the southwestern sky and pass out of view from the northeastern sky. The maximum elevation means that the satellite will never be higher than 66 degrees above the horizon. (90 degrees is directly overhead.) When it first comes into view, it will appear low in the sky, just 10 degrees above the horizon. It will climb as high as 66 degrees and then descend to 31 degrees before passing from view.

EXTENSION IDEAS

If you are going to track the International Space Station in the sky, you may want to use an Astrolabe to help locate it. On the following page, you will find instructions to make your own Astrolabe.

Older students can access live tracking data for the International Space Station online. Challenge them to read the map and name the location currently below.
Go to: www.isstracker.com

The crew's view is also available online. See what the astronauts are looking down on right now.
Go to: external.jsc.nasa.gov/events/ISSPhotos

This is particularly fun to do while students are waiting to go outside and see the satellite pass overhead. They will see it coming into range over your continent and then get to go outside and see it in the sky.

SATELLITE	LOCAL DATE/TIME	DURATION (minutes)	MAX ELEV (degrees)	APPROACH (degrees/direction)	DEPARTURE (degrees/direction)
ISS	Tue Nov 14 06:22 AM	4	66	10 above WSW	31 above NE

Try This! Make Your Own Astrolabe:

An Astrolabe is a classical instrument used to locate and predict the position of objects in the sky.

In this simple activity, students will construct their own Astrolabe. The activity can be used at almost any grade level by increasing the complexity of the observation challenges. For K-6 students, simply having them record one angle of elevation in sunlight is sufficient. For 7-12 students, identification of objects in the night sky is appropriate.

Depending on your classroom circumstances, it may be acceptable to have students share the Astrolabes in which case you would need fewer supplies. However, if you want to challenge your students to use their Astrolabes to observe the nighttime sky at home, they will each need their own. For young children, consider using brightly colored string or thread which will be easier for them to manipulate.

Note: The materials for this activity are inexpensive and readily available in your local discount store's school supply and hardware aisles.

MATERIALS

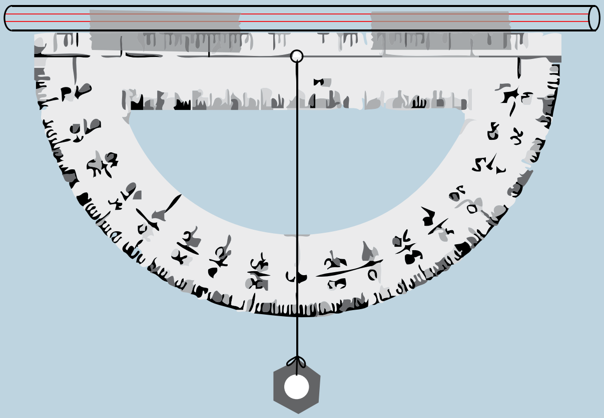
- One straight plastic straw (not the flexible kind)
- One protractor
- Fine string or thick thread cut to 12 inch length
- One weight such as a bolt or fishing sinker
- Scotch tape
- Notebooks/pencils for recording observations

PROCEDURE

Locate the hole at the center of the protractor's straight edge. Loop one end of the thread through the hole and tie it securely, using as little of the thread as possible. There should be about 10 inches left hanging.

At the other end of the string, attach the weight, again being careful not to waste too much length.

When you hold the protractor level, the weight should hang down with the string passing along side of the 90 degree mark on the arc of the protractor.



Using scotch tape, carefully attach the plastic straw to the straight edge of the protractor. Be sure that the string is not caught in the tape. The string needs to move freely.

Now, look through the straw to observe a tall object like a tree or rooftop. As you tilt the Astrolabe up, the weight will move to measure the degree of your angle of observation. Work with a partner and take turns reading each other's angles. Record your data.

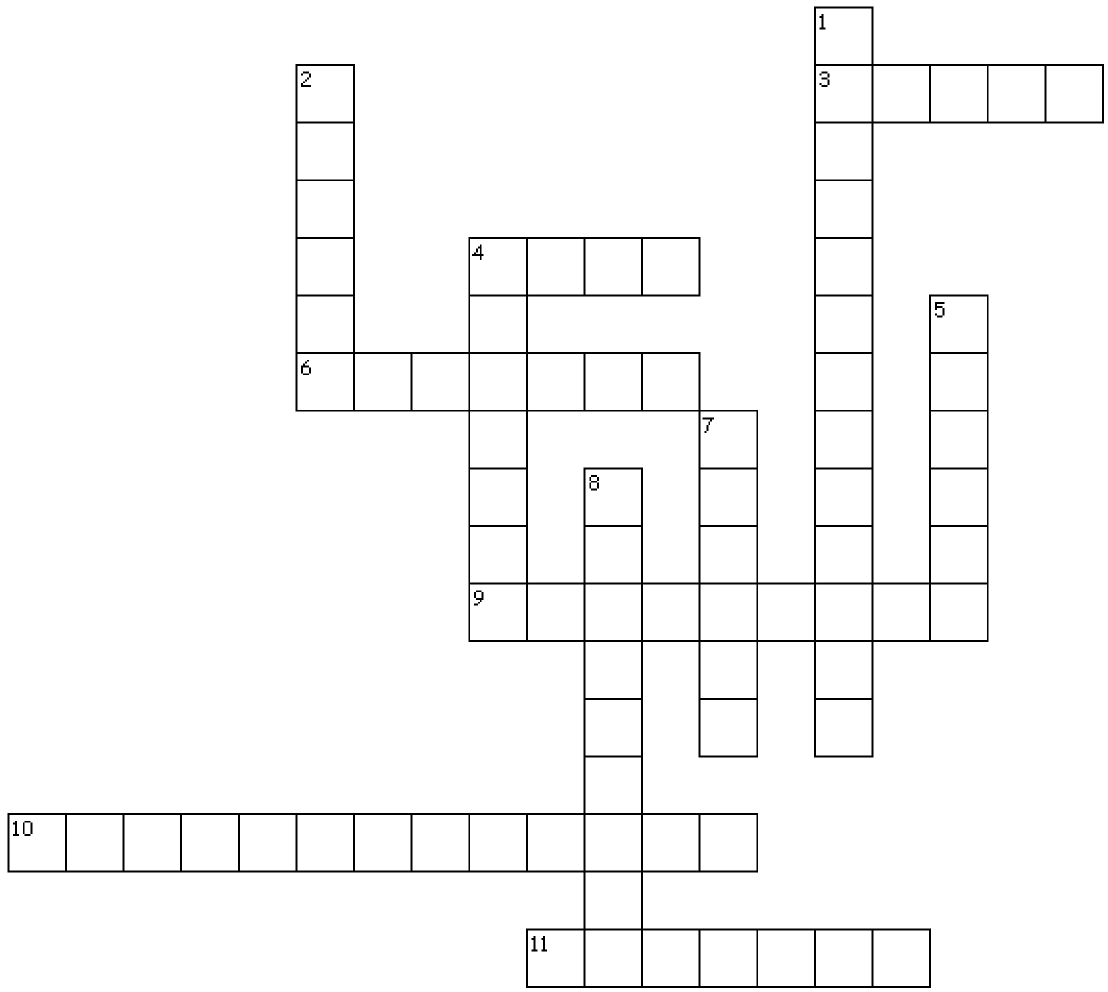
Once students know how to use the Astrolabe, they can use it to locate and track satellites based on their predicted elevation.

EXTENSION IDEAS

Challenge older students to use their Astrolabe at home to observe planets and stars in the nighttime sky. You can make your own observation the night before and challenge them the next night to tell you what they see at certain angles of elevation. Or, you can use one of the many online stargazing information websites to identify what they should be able to see in your town on a certain night. Don't forget, though, that cloud cover will interfe re with this activity, so make sure the weather forecast calls for clear skies.

Here are two websites that offer daily sky charts by zip code.
Weather Underground:
www.wunderground.com/sky/index.asp
Sky and Telescope:
www.skyandtelescope.com/observing/skychart

Crossword Puzzle



ACROSS

3. The curved path, usually elliptical, of an object's movement around a celestial body.
4. Earth's only natural satellite.
6. The world's first artificial satellite, about the size of a beach ball.
9. An object, whether natural or manmade, that orbits a celestial body.
10. Extremely high velocity, up to 15,000 miles per hour.
11. First communications satellite.

DOWN

1. A grouping of satellites, spread out in a set of orbital rings.
2. The remains of anything broken down or destroyed.
4. Small solid objects passing from space into the Earth's atmosphere.
5. Space telescope launched into orbit in 1990.

Word Search

R	S	R	S	R	V	S	O	M	A	V	J	T	S	Y
E	P	A	H	E	M	I	R	U	J	N	I	U	S	T
T	A	T	K	L	O	R	B	A	J	B	O	N	P	I
A	C	S	I	P	O	B	I	P	R	N	A	O	A	C
R	E	L	N	E	N	E	T	O	O	E	S	I	C	O
C	J	E	T	K	J	D	H	R	R	T	T	T	E	L
R	U	T	U	F	V	T	H	O	B	I	E	A	T	E
O	N	N	P	W	R	C	E	A	R	L	R	L	E	V
E	K	V	S	A	N	T	L	S	I	L	O	L	L	R
T	W	D	E	Y	E	Y	K	Z	M	E	I	E	E	E
E	A	W	S	M	K	Z	I	G	N	T	D	T	S	P
M	O	O	U	S	E	E	S	P	R	A	B	S	C	Y
L	E	D	E	L	B	B	U	H	R	S	E	N	O	H
G	M	E	T	E	O	R	I	T	E	K	L	O	P	P
J	D	U	D	X	G	R	I	F	V	K	T	C	E	V

ASTEROID BELT
CONSTELLATION
DEBRIS
GEOSYNCHRONOUS
HUBBLE
HYPERVELOCITY
KEPLER
LOW EARTH ORBIT
METEOR
METEOR CRATER
METEORITE
MIR
MOON
ORBIT
SATELLITE
SKYLAB
SPACE JUNK
SPACE TELESCOPE

Recommended Resources for Teachers

WEBSITES

Space Data Association's Space Data Center
www.space-data.org/sda/space-data-center
Includes video presentation of number of objects in space, 1957 to present.

NASA Orbital Debris Photo Gallery
orbitaldebris.jsc.nasa.gov/photogallery/photogallery.html
Helpful photos, provided by NASA.

NASA Orbital Debris FAQ
orbitaldebris.jsc.nasa.gov/faqs.html
Basic questions, answered by NASA scientists.

NASA Space Operations Learning Center
solc.gsfc.nasa.gov
Kids Zones 1 and 3 feature satellite information for K-6. Advanced Space Communications features activities for 7-12.

U.S. Strategic Command's Space Control and Space Surveillance
www.stratcom.mil/factsheets/USSTRATCOM_Space_Control_and_Space_Surveillance
Facts about the Space Surveillance Network which monitors and tracks objects in Earth orbit.

U.S. Space Objects Registry
www.usspaceobjectsregistry.state.gov
Searchable database of space objects.

Recommended Reading for Children and Young Adults

Grades K-3

Newton and Me
by Lynne Mayer.
ISBN 1607180677

I Fall Down
by Vicki Cobb.
ISBN 0688178421

Sputnik: The First Satellite
by Heather Feldman.
ISBN 082396244X

Grades 9-12

Close Encounters: Exploring the Universe with the Hubble Space Telescope
by Elaine Scott. ISBN 0786821205

Something New Under the Sun: Satellites and the Beginning of the Space Age
by Helen Gavaghan. ISBN 0387949143

The Seven Secrets of How to Think like a Rocket Scientist
by James Longuski. ISBN 1441921591

Sputnik: The Shock of the Century
by Paul Dickson. ISBN 0802779514

Grades 4-8

The International Space Station
by Franklyn M. Branley.
ISBN 0060287020

Space Station Science: Life in Free Fall
by Marianne J. Dyson.
ISBN 0590058894

How the Future Began: Communications
by Anthony Wilson.
ISBN 0753451794

Exploring Dangers in Space: Asteroids, Space Junk, and More
by Buffy Silverman.
ISBN 0761378820

Space Junk
by Isaac Asimov.
ISBN 0836839838

Crossword Answer Key:

Across

3. Orbit
4. Moon
6. Sputnik
9. Satellite
10. Hypervelocity
11. Telstar

Down

1. Constellation
2. Debris
4. Meteors
5. Hubble
7. Skylab
8. Meteorite

National Science Education Standards

The film and the accompanying activities suggested in this guide can be used to support student learning as called for by the National Science Education Standards.

UNIFYING CONCEPTS AND PROCESSES – K-12

As a result of activities in grades K-12, all students should develop understanding and abilities aligned with the following concepts and processes:

Systems, Order and Organization

The natural and designed world is complex; it is too large and complicated to investigate and comprehend all at once. Scientists and students learn to define small portions for the convenience of investigation. The units of investigation can be referred to as ''systems.'' A system is an organized group of related objects or components that form a whole.

Evidence, Models and Explanation

Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems. Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work.

Constancy, Change and Measurement

Although most things are in the process of becoming different—changing—some properties of objects and processes are characterized by constancy, including the speed of light, the charge of an electron, and the total mass plus energy in the universe. Changes might occur, for example, in properties of materials, position of objects, motion, and form and function of systems. Interactions within and among systems result in change. Changes vary in rate, scale, and pattern, including trends and cycles.

Evolution and Equilibrium

Evolution is a series of changes, some gradual and some sporadic, that accounts for the present form and function of objects, organisms, and natural and designed systems. The general idea of evolution is that the present arises from materials and forms of the past. Although evolution is most commonly associated with the biological theory explaining the process of descent with modification of organisms from common ancestors, evolution also describes changes in the universe.

CONTENT STANDARD B – PHYSICAL SCIENCE

GRADES K-4

Position of Motion and Objects

- The position of an object can be described by locating it relative to another object or the background.
- An object's motion can be described by tracing and measuring its position over time.
- The position and motion of objects can be changed by pushing or pulling. The size of the change is related to the strength of the push or pull.

GRADES 5-8

Motion and Forces

- The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.

GRADES 9-12

Motion and Forces

- Objects change their motion only when a net force is applied. Laws of motion are used to calculate precisely the effects of forces on the motion of objects.
- Gravitation is a universal force that each mass exerts on any other mass.

CONTENT STANDARD D – EARTH AND SPACE SCIENCE

GRADES K-4

Objects in the Sky

- The sun, moon, stars, clouds, birds, and airplanes all have properties, locations, and movements that can be observed and described.

Changes in the Earth and Sky

- Objects in the sky have patterns of movement.

GRADES 5-8

Earth in the Solar System

- Most objects in the solar system are in regular and predictable motion.
- Gravity is the force that keeps planets in orbit around the sun and governs the rest of the motion in the solar system.

CONTENT STANDARD E – SCIENCE AND TECHNOLOGY

GRADES K-4

Understanding About Science and Technology

- People have always had questions about their world. Science is one way of answering questions and explaining the natural world.
- People have always had problems and invented tools and techniques (ways of doing something) to solve problems. Trying to determine the effects of solutions helps people avoid some new problems.
- Scientists and engineers often work in teams with different individuals doing different things that contribute to the results. This understanding focuses primarily on teams working together and secondarily, on the combination of scientist and engineer teams.
- Women and men of all ages, backgrounds, and groups engage in a variety of scientific and technological work.
- Tools help scientists make better observations, measurements, and equipment for investigations. They help scientists see, measure, and do things that they could not otherwise see, measure, and do.

GRADES 5-8

Understanding About Science and Technology

- Many different people in different cultures have made and continue to make contributions to science and technology.
- Science and technology are reciprocal. Science helps drive technology, as it addresses questions that demand more sophisticated instruments and provides principles for better instrumentation and technique. Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable due to factors such as quantity, distance, location, size, and speed. Technology also provides tools for investigations, inquiry, and analysis.
- Perfectly designed solutions do not exist. All technological solutions have trade-offs, such as safety, cost, efficiency, and appearance. Engineers often build in back-up systems to provide safety. Risk is part of living in a highly technological world. Reducing risk often results in new technology.
- Technological solutions have intended benefits and unintended consequences. Some consequences can be predicted, others cannot.

GRADES 9-12

Understanding About Science and Technology

- Science often advances with the introduction of new technologies. Solving technological problems often results in new scientific knowledge. New technologies often extend the current levels of scientific understanding and introduce new areas of research.
- Creativity, imagination, and a good knowledge base are all required in the work of science and engineering.
- Science and technology are pursued for different purposes. Scientific inquiry is driven by the desire to understand the natural world, and technological design is driven by the need to meet human needs and solve human problems. Technology, by its nature, has a more direct effect on society than science because its purpose is to solve human problems, help humans adapt, and fulfill human aspirations. Technological solutions may create new problems. Science, by its nature, answers questions that may or may not directly influence humans. Sometimes scientific advances challenge people's beliefs and practical explanations concerning various aspects of the world.

CONTENT STANDARD F – SCIENCE IN PERSONAL AND SOCIAL PERSPECTIVES

GRADES K-4

Science and Technology in Local Challenges

- People continue inventing new ways of doing things, solving problems, and getting work done. New ideas and inventions often affect other people; sometimes the effects are good and sometimes they are bad. It is helpful to try to determine in advance how ideas and inventions will affect other people.

GRADES 5-8

Risks and Benefits

- Risk analysis considers the type of hazard and estimates the number of people that might be exposed and the number likely to suffer consequences. The results are used to determine the options for reducing or eliminating risks.
- Individuals can use a systematic approach to thinking critically about risks and benefits. Examples include applying probability estimates to risks and comparing them to estimated personal and social benefits.

Science and Technology in Society

- Technology influences society through its products and processes. Technology influences the quality of life and the ways people act and interact.
- Scientists and engineers work in many different settings, including colleges and universities, businesses and industries, specific research institutes, and government agencies.

GRADES 9-12

Natural and Human-Induced Hazards

- Human activities can enhance potential for hazards.
- Natural and human-induced hazards present the need for humans to assess potential danger and risk. The scale of events and the accuracy with which scientists and engineers can (and cannot) predict events are important considerations.

CONTENT STANDARD G – HISTORY AND NATURE OF SCIENCE

GRADES K-4

Science as a Human Endeavor

- Although men and women using scientific inquiry have learned much about the objects, events, and phenomena in nature, much more remains to be understood. Science will never be finished.
- Many people choose science as a career and devote their entire lives to studying it. Many people derive great pleasure from doing science.

GRADES 5-8

Science as a Human Endeavor

- Women and men of various social and ethnic backgrounds—and with diverse interests, talents, qualities, and motivations—engage in the activities of science, engineering, and related fields such as the health professions. Some scientists work in teams, and some work alone, but all communicate extensively with others.
- Science requires different abilities, depending on such factors as the field of study and type of inquiry. Science is very much a human endeavor, and the work of science relies on basic human qualities, such as reasoning, insight, energy, skill, and creativity—as well as on scientific habits of mind, such as intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas.

GRADES 9-12

Science as a Human Endeavor

- Individuals and teams have contributed and will continue to contribute to the scientific enterprise. Doing science or engineering can be as simple as an individual conducting field studies or as complex as hundreds of people working on a major scientific question or technological problem. Pursuing science as a career or as a hobby can be both fascinating and intellectually rewarding.

National Science Education Standards

	K - 4	5 - 8	9 - 12
UNIFYING CONCEPTS & PROCESSES	*Systems, order, and organization. Evidence, models, and explanation. Constancy, change, and measurement. Evolution and equilibrium.*		
PHYSICAL SCIENCE	**POSITION & MOTION OF OBJECTS** *Relative positions, motion over time, change*	**MOTIONS & FORCES** *Object motion, direction, speed*	**MOTIONS & FORCES** *Net force, laws of motion, gravity*
EARTH & SPACE SCIENCE	**OBJECTS IN THE SKY** *Patterns of movement* **CHANGES IN THE EARTH & SKY** *Locations, movements*	**EARTH IN THE SOLAR SYSTEM** *Predictable motion, gravity*	
SCIENCE & TECHNOLOGY	*Questions about the world, tools to help answer questions, scientists work in teams.*	*Reciprocity between science and technology unintended consequences, constraints*	*Process of research, motivations, risk & reward*
SCIENCE IN PERSONAL & SOCIAL PERSPECTIVE	**LOCAL CHALLENGES** *Inventing new ways to address challenges*	**RISKS & BENEFITS** *Risk analysis* **SCIENCE & TECHNOLOGY IN SOCIETY** *Technology influences society*	**NATURAL & HUMAN INDUCED HAZARDS** *Potential for hazards, risk analysis*
HISTORY & NATURE OF SCIENCE	**SCIENCE AS A HUMAN ENDEAVOR** *Men & women, never be finished, great pleasure*	**SCIENCE AS A HUMAN ENDEAVOR** *Diversity, collaboration, intellectual honesty, tolerance, skepticism*	**SCIENCE AS A HUMAN ENDEAVOR** *Individuals & teams, ethical traditions*

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