Cambridge Core Science Series: Space Science

IS ANYBODY OUT THERE?

Cambridge Educational

Teacher's Guide

Introduction

This Teacher's Guide provides information to help you get the most out of *Is Anybody Out There?,* the eighth title in Cambridge Educational's eight-part *Space Science* series. The guide will allow you to prepare your students before viewing the program and to present follow-up activities to reinforce the program's key learning points.

Is Anybody Out There? examines the possibility of the existence of life elsewhere in the galaxy. The program considers UFOs, the discovery of extrasolar planets, and the Drake Equation, a method for estimating the probability that detectable, intelligent life exists in our galaxy. The program briefly explores the history of humankind's search for extraterrestrial intelligence (SETI). Scientists involved with SETI and the search for extrasolar planets comment on these topics.

The *Space Science* video program series consists of eight titles:

- The Planets
- The Sun and Stars
- Just How Big Is Space?
- The Invisible Universe
- Black Holes, Pulsars, and Other Odd Bodies
- Yesterday the Moon, Tomorrow Mars?
- Living in Space
- Is Anybody Out There?

Learning Objectives

After viewing the program, students will be able to:

- Provide logical arguments as to why most scientists believe there have been no visits to Earth from extraterrestrials.
- Relate some of the history of the search for extraterrestrial intelligence.
- Describe the scientific methods used in the search for intelligent extraterrestrial life (SETI).
- Name and explain several past and future SETI projects.
- Describe the Drake Equation—what it is, how it's used, and why it was developed.
- Describe the first extrasolar planets that have been discovered.
- Explain two different methods used to detect extrasolar planets.
- Describe some current and proposed missions designed to find Earth-like extrasolar planets.

Educational Standards

This program series correlates with the National Science Education Standards for grades 9-12. The content of this program has been aligned with the following educational standards from this publication:

Science as Inquiry Standards

CONTENT STANDARD A: As a result of activities in grades 9-12, all students should:

- Develop an understanding of scientific concepts
- Understand and appreciate "how we know" what we know in science
- Understand the nature of science

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- Develop the skills necessary to become independent inquirers about the natural world
- Develop the dispositions to use the skills, abilities, and attitudes associated with science

History and the Nature of Science Standards
CONTENT STANDARD G: As a result of activities in grades 9-12, all students should:
- Develop understanding of science as a human endeavor
- Develop understanding of the history of science
- Develop an understanding of the nature of scientific knowledge

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English Language Arts Standards
The activities in this Teacher's Guide were created in compliance with the National Standards for the English Language Arts from the National Council of Teachers of English.

- Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences for a variety of purposes.
- Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g., print and non-print texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience.
- Students use a variety of technological and information resources (e.g., libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.

Standards for the English Language Arts, by the International Reading Association and the National Council of Teachers of English, Copyright 1996 by the International Reading Association and the National Council of Teachers of English. Reprinted with permission.

This program series also coordinates with the following *Benchmarks for Science Literacy* by the American Association for the Advancement of Science for grades 9 through 12:

The Scientific World View
By the end of the 12th grade, students should know that:
- Scientists assume that the universe is a vast single system in which the basic rules are the same everywhere. The rules may range from very simple to extremely complex, but scientists operate on the belief that the rules can be discovered by careful, systematic study.
- From time to time, major shifts occur in the scientific view of how the world works. More often, however, the changes that take place in the body of scientific knowledge are small modifications of prior knowledge. Change and continuity are persistent features of science.
- No matter how well one theory fits observations, a new theory might fit them just as well or better, or might fit a wider range of observations. In science, the testing, revising, and occasional discarding of theories, new and old, never ends. This ongoing process leads to an increasingly better understanding of how things work in the world but not to absolute truth. Evidence for the value of this approach is given by the improving ability of scientists to offer reliable explanations and make accurate predictions.

Scientific Inquiry
By the end of the 12th grade, students should know that:
- Investigations are conducted for different reasons, including to explore new phenomena, to check on previous results, to test how well a theory predicts, and to compare different theories.

- Hypotheses are widely used in science for choosing what data to pay attention to and what additional data to seek, and for guiding the interpretation of the data (both new and previously available).
- Sometimes, scientists can control conditions in order to obtain evidence. When that is not possible for practical or ethical reasons, they try to observe as wide a range of natural occurrences as possible to be able to discern patterns.
- There are different traditions in science about what is investigated and how, but they all have in common certain basic beliefs about the value of evidence, logic, and good arguments. And there is agreement that progress in all fields of science depends on intelligence, hard work, imagination, and even chance.
- Scientists in any one research group tend to see things alike, so even groups of scientists may have trouble being entirely objective about their methods and findings. For that reason, scientific teams are expected to seek out the possible sources of bias in the design of their investigations and in their data analysis. Checking each other's results and explanations helps, but that is no guarantee against bias.
- In the short run, new ideas that do not mesh well with mainstream ideas in science often encounter vigorous criticism. In the long run, theories are judged by how they fit with other theories, the range of observations they explain, how well they explain observations, and how effective they are in predicting new findings.
- New ideas in science are limited by the context in which they are conceived; are often rejected by the scientific establishment; sometimes spring from unexpected findings; and usually grow slowly, through contributions from many investigators.

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Program Overview

The program begins by examining the question of whether our planet has been visited by extraterrestrials. A scientist involved in the search for extraterrestrial intelligence provides arguments as to why most scientists do not believe extraterrestrials have visited the Earth. Project Blue Book, the US Air Force's investigation of UFOs, is profiled. The program then takes a look at projects that have conducted legitimate scientific searches for signs of intelligent extraterrestrial life.

The Drake Equation, a way to estimate the probability that detectable intelligent life exists in our galaxy, is presented. Frank Drake, the author of the equation that bears his name, comments.

Deborah Fischer, one of the team of scientists that has discovered many of the first extrasolar planets, talks about the characteristics of the giant extrasolar planets discovered thus far, and the missions that will search for Earth-like planets.

The program describes two methods scientists use to discover extrasolar planets. It also explains current and future efforts to find extrasolar planets that are the size of Earth and that have the conditions necessary for life.

Main Topics

Topic 1: Have They Already Been Here?
Surveys indicate that up to half of American adults think it's possible that the Earth has been visited by technically advanced extraterrestrials. This section of the program takes a look at government investigations of UFOs. A scientist from the SETI Institute discusses why he and other space scientists do not believe the Earth has been visited by extraterrestrials.

Topic 2: The Search for Extraterrestrial Intelligence
The Search for Extraterrestrial Intelligence, or SETI, is a field of inquiry that seeks evidence of intelligent life elsewhere in the universe, not by going there, or waiting for them to come here, but by looking for some signature of their technology such as a radio signal. The emphasis is not just on finding life, but finding intelligent life. This program explores the history of the search for intelligent extraterrestrials. The SETI Institute's current and future work in this area is presented. The basic requirements for the development of life on other planets are reviewed.

Topic 3: The Odds
During the 1960s, radio astronomer Dr. Frank Drake was interested in quantifying the probability that intelligent extraterrestrial life exists in our galaxy. The Drake Equation was developed to assess the practicality of looking for signals sent by alien societies. Dr. Drake comments on the factors that make up his equation.

Topic 4: Extrasolar Planets
For many years extrasolar planets were thought to exist, but astronomers didn't have the technology to detect them. Finally, on October 6, 1995, the first extrasolar planet around an ordinary star was discovered. This section examines what we know about these extrasolar planets, techniques used for detecting them, and what missions are planned to look for Earth-like planets circling other suns in our galaxy. A leading scientist in the discovery of extrasolar planets comments.

Fast Facts

- Surveys indicate that up to half of American adults think it's possible that the Earth has been visited by technically advanced extraterrestrials.
- Most mainstream scientists don't think there is evidence to support the claim that intelligent extraterrestrial beings have visited the Earth.
- The US Air Force and NASA have both been involved in independent investigations of UFOs and the possibility of alien life on other planets. After studying all of the available facts, it was determined that there was an absence of tangible evidence that any of the UFOs could be definitively linked to extraterrestrials.
- The Search for Extraterrestrial Intelligence, or SETI, is a legitimate scientific field of inquiry that seeks evidence of intelligent life elsewhere in the universe, not by going there, or waiting for them to come here, but by looking for some signature of their technology. The emphasis is not just on finding life, but finding intelligent life.
- Programs to search for signs of intelligent extraterrestrial life were established at NASA's Ames Research Center as well as the Jet Propulsion Laboratory by the late 1970s. By 1993 all government funding of these efforts ceased.

- In 1995 the SETI Institute, using private funding, took over much of the NASA equipment and continued the search for signs of intelligent extraterrestrial civilization under the name Project Phoenix. During its nine years of operation, Project Phoenix observed and processed thousands of signals, but found no evidence of another technological civilization in our galactic neighborhood.

- The presence of carbon and other chemical building blocks, liquid water, and a sun-like star that can provide a stable and long-term source of energy are the minimum requirements for life as we know it.

- The Drake Equation is a tool developed by astronomer Frank Drake to estimate the number of civilizations with the technological capability of broadcasting their presence that might exist in our galaxy. It was developed by Drake primarily to assess the practicality of looking for signals sent by alien societies.

- In discovering extrasolar planets, scientists make use of the fact that as a planet orbits a star the planet's gravitational pull causes the star to wobble. This is called the Doppler method.

- The planet 51 Peg b is the first confirmed extrasolar planet found using Doppler spectroscopy—a way of using changes in the wavelengths of light to detect movement.

- The Kepler Mission will look for Earth-size planets using the transit method. The transit method relies on being able to detect extremely small changes in a star's brightness when a planet crosses (transits) across the face of the star. The transit method can only detect extrasolar planets that are directly aligned between the star and the Earth.

- Future efforts to search for Earth-like worlds (e.g., the Terrestrial Planet Finder mission) will focus attention on the habitable zones around sun-like stars. A habitable zone is the distance from a star where liquid water can exist on a planet's surface—a necessary condition for the evolution of life.

Vocabulary Terms

Allen Telescope Array: A collection of small, inexpensive radio dishes that will function as one giant radio antenna but can be constructed for about half the cost. The Allen Telescope Array is the site for the next major search for extraterrestrial intelligence.

Area 51: An airbase in southern Nevada that has long been the testing site for America's most advanced aircraft.

Doppler method: A method of detecting extrasolar planets by measuring the amount a star wobbles as a planet orbits it.

Drake Equation: A formula for estimating the probability of intelligent, detectable extraterrestrial civilizations in the galaxy. The product of its seven terms yields the number of potentially detectable galactic civilizations that are broadcasting signals.

habitable zone: The distance from a star where liquid water can exist on a planet's surface—a necessary condition for the evolution of life

Project Blue Book: One of the projects under which the U.S. Air Force actively investigated reports and sightings of unidentified flying objects, or UFOs.

Project Phoenix: From 1995 to 2004, scientists and engineers from the SETI Institute conducted the world's most sensitive and comprehensive SETI program, called Project Phoenix. Thousands of radio frequency signals were observed and processed to determine if any were generated by an extraterrestrial civilization, but scientists found no evidence of another technological civilization in our galactic neighborhood.

SETI: The Search for Extraterrestrial Intelligence, or SETI, is a field of inquiry that seeks evidence of intelligent life elsewhere in the universe, not by going there, or waiting for them to come here, but by looking for some signature of their technology. The SETI Institute is involved in this field by seeking to "explore, understand and explain the origin, nature and prevalence of life in the universe."

transit method: A way of detecting extrasolar planets that measures miniscule changes in a star's brightness when a planet crosses in front of it. Extrasolar planets can only be detected with this method if the planet lies in the direct line of sight between Earth and the star.

UFOs: Unidentified flying objects. Many people believe that UFOs are alien spaceships visiting Earth. Surveys indicate that up to half of American adults think it's possible that the Earth has been visited by technically advanced extraterrestrials.

Pre-Program Discussion Questions

1. Up to half of American adults believe it's possible that technically advanced extraterrestrials have visited the Earth, but most scientists do not. Why do you think scientists are not convinced of extraterrestrial visits?

2. If UFOs are not alien spacecraft, what are they?

3. Some scientists believe that intelligent life exists in our galaxy, and we can detect it. How do we go about making contact, and how would we communicate?

4. In the last decade scientists have discovered a number of extrasolar planets. What are they, and what are they like?

5. Life is abundant on the Earth, but if we were to search for signs of life somewhere else in our galaxy, what would we look for?

6. Is there a way to estimate the probability that civilizations capable of signaling their presence exist elsewhere in the galaxy?

Post-Program Discussion Questions

1. What are some explanations for UFOs that have been found in investigations? Just because a logical, Earth-based explanation cannot be found for a UFO, does that mean it's an extraterrestrial spacecraft? Explain the rationale for your answer.

2. For several decades, radio astronomers and engineers have been searching the sky for a sign of an intelligent presence somewhere in the galaxy. So far none of the signals observed and analyzed indicates an alien presence. What are some of the reasons why it may be difficult to detect alien signals even if there are broadcasting alien civilizations?

3. What is the Drake Equation? Explain why it is a useful tool in the search for extraterrestrial intelligence.

4. The first extrasolar planets to be detected were giant planets, the size of Jupiter or larger. What method did scientists use to detect them? Can that method be used to detect smaller Earth-sized planets? Explain your answer.

5. Scientists have developed the concept of a "habitable zone" to help direct our search for Earth-like planets. What defines the "habitable zone," and why is it more likely we will find planets like Earth within its boundaries?

6. What is the Kepler Mission, and how will it operate?

Group Activities

Does Intelligent Life Exist Beyond Earth?

Divide the class into groups and have each group research evidence to support or refute the thesis that intelligent life exists beyond Earth. Students will need to objectively evaluate data, separate fact from opinion, and form an opinion based on available information. To begin:

- Pose the following question to students: Does intelligent life exist elsewhere in the universe?
- Ask students to choose a position on the issue.
- Organize students into small groups. Each group should include a roughly equal number of students holding pro and con positions on the issue.
- Ask each group to research and stage a debate on the issue.
- After all the groups have debated, vote on the most persuasive position.
- Students can begin their research at www.seti.org and http://astrobiology.arc.nasa.gov.

Planet Quest

Over the next 15 years, NASA is embarking on a bold series of missions to find and characterize new worlds. These missions will incorporate some of the most sensitive instruments ever built, instruments capable of reaching beyond the bounds of our solar system.

Divide the class into groups and assign each group to research and report to the class on one or more of the following missions and projects. The reports should include both science and technology goals: What do the missions hope to accomplish? How are they going to do it? What are the biggest technological challenges?

<u>Space-based</u>

- The Spitzer Space Telescope
- The Kepler Mission
- SIM PlanetQuest
- Terrestrial Planet Finders (TPFs)

<u>Ground-based</u>

- Keck Interferometer
- Large Binocular Telescope Interferometer
- Palomar Observatory
- Michelson Science Center

Use the following links to get started: http://planetquest.jpl.nasa.gov/index.cfm and http://planetquest.jpl.nasa.gov/missions/missions_index.cfm

Individual Student Projects

Ancient Space Travelers
Do centuries-old legends of gods and heroes tell of space travelers who came to earth from distant parts of the cosmos? Are some of the ruins of antiquity remnants of great airfields, the favored landing sites of extraterrestrial craft?

Have students investigate the thesis that ancient space travelers have visited the Earth and left physical signs of their visits, for example, the enormous Nazca line drawings of Peru, the giant stone figures on Easter Island, or the pyramids of Egypt. Have them take one or more of the ancient sites supposedly of alien origin, research the history of the local civilizations, and develop an argument for why those sites could have been constructed by local people, not space travelers. Here are a few places to start:

www.debunker.com/texts/vondanik.html
www.answers.com/topic/easter-island
www.nationalgeographic.com/pyramids/pyramids.html

Art Imitates Life
On Earth, life has evolved into a myriad of forms. Which form it takes depends largely on the environment it's in. Using an extreme Earth environment (e.g. the Atacama Desert in Chile and Peru or a volcanic vent deep on the ocean floor) as your guide, describe the characteristics of an alien species that might have evolved in that environment. Draw a picture of your creature and present your alien to the class. In your report be sure to describe how every characteristic of your creature helps it survive in the environment you have chosen.

UFOs and Interstellar Travel
Most scientists do not believe that the Earth has been visited by intelligent extraterrestrials. There are no proven artifacts from UFOs or any tangible evidence to confirm alien visitation. In addition, the laws of physics, as we currently understand them, make it highly unlikely that extraterrestrials could transit the vast distances from their home star to ours and back in any reasonable time frame. Take the position of a scientist denying the possibility of visits by alien spacecraft and develop arguments to support your position. The following links will take you to sites which look at the evidence for UFOs:

www.ufoevidence.org
www.ufoevidence.org/topics/science.htm

Internet Activities

SETI@home
SETI@home is a scientific experiment that uses individual Internet-connected computers in the search for extraterrestrial intelligence. You can participate by running a free program that downloads and analyzes radio telescope data. Follow this link to SETI@home: http://setiathome.ssl.berkeley.edu. After you have participated in SETI@home, write up your experience and present it to the class. Was it interesting, or boring? Would you do it again? Would you recommend it to your friends?

Project Blue Book
When Project Blue Book was closed down in January 1970, the original files were transferred to Maxwell Air Force Base, where they were made available on request for public viewing until 1975. In 1975 these documents were microfilmed by the Air Force for internal use and then transferred to the National Archives for public release. These files are now available online at the following URL: http://bluebookarchive.org

Divide the class into groups. Have each group access and review Project Blue Book case files from a single year (1947 to 1952). Students can then analyze the investigation and evidence from the cases they select. In their reports they can agree or disagree with the conclusions of the original investigators and present a detailed explanation for their position.

Assessment Questions

Q1: True or False: Project Phoenix was the first SETI project to detect signals from an extraterrestrial civilization in our galaxy.
A: False
Note: Thousands of radio signals were observed and analyzed during Project Phoenix, but none was found to be generated by an extraterrestrial civilization.

Q2: Surveys indicate that up to _____ of the adult American population believes that Earth has been visited by technically advanced extraterrestrials.
a) one-fourth
b) one-half
c) two-thirds
d) three-fourths
A: b.
Note: Surveys indicate that up to half of American adults believe we have been visited by extraterrestrials, although most mainstream scientists don't think there is evidence to support that claim.

Q3: Which of the following are true of UFO sightings?
a) NASA does not have the funds available to investigate them.
b) They have been investigated by the U.S. Air Force and NASA; many turned out to be experimental aircraft.
c) Some were identified as alien spacecraft.
d) They are sometimes accompanied by tangible evidence.
A: b.
Note: At times both NASA and the U.S. Air Force have actively investigated UFO sightings. Most have been explained as experimental aircraft, weather balloons, natural weather phenomena, or hoaxes. No tangible evidence of an extraterrestrial presence has ever been discovered.

Q4: Scientists believe the most important ingredient for the evolution of life is _____.
a) silicone
b) oxygen
c) liquid water
d) hot gas
A: c.
Note: Chemical building blocks such as oxygen, carbon, nitrogen, and hydrogen are important for the evolution of life, as are a source of energy and a protective atmosphere. But the one ingredient essential to the development of life as we know it is liquid water.

Q5: True or False: Project Blue Book was the first organized scientific search for evidence of extraterrestrial intelligence.

A: False

Note: Project Blue Book, conducted by the Air Force in the 1950s and '60s, was an investigation of UFO sightings.

Q6: True or False: The Doppler method is an extrasolar planet-finding technique which uses minute changes in the brightness of a star to detect a planet orbiting around it.

A: False

Note: The Doppler or "wobble" method is used to find extrasolar planets by monitoring changes in the light spectrum emitted by a star. A planet in orbit around the star will cause the star to wobble very slightly. If the star wobbles toward Earth, its spectrum is blue-shifted; if it wobbles away, its spectrum is red-shifted. The transit method uses minute changes in a star's brightness to detect planets crossing the face of the star.

Q7: Which one of the following is a factor in the Drake Equation?

a) Habitable zone
b) Cool hydrogen gas
c) Detectable technology
d) Planet temperature

A: c.

Note: The Drake Equation is a formula designed to estimate the probability that intelligent life with the ability and willingness to communicate its existence exists in our galaxy. Detectable technology is one of the seven factors in the equation. Although a planet located in the habitable zone (the distance from a star where water can exist in a liquid state) is more likely to develop life, the habitable zone is not a factor in the Drake Equation. Neither is cool hydrogen gas or planet temperature.

Q8: True or False: The Kepler Mission will use the transit method to detect Earth-size extrasolar planets.

A: True

Note: The extremely sensitive instruments on the space-based Kepler satellite are able to detect infinitesimal changes in the brightness of a star, when a small, Earth-sized planet "transits" across its disk.

Q9: Which one of the following will serve as the site for the sequel to Project Phoenix?

a) Arecibo Radio Observatory
b) The Allen Telescope Array
c) The Green Bank Radio Telescope
d) The Keck Observatory

A: b. The Allen Telescope Array

Note: Project Phoenix was the first comprehensive search for signs of extraterrestrial intelligence. The SETI Institute will conduct the sequel to that project using the Allen Telescope Array at the Hat Creek Observatory. The Allen Telescope Array is a collection of many smaller, less-expensive radio dishes that will work together to function as one giant radio telescope.

Q10: True or False: The search for extraterrestrial intelligence looks for signs of technology such as a laser or radio signal that is powerful enough to cross the distances between the stars.

A: True

Note: Distances between the stars are too great and we lack the technology to go there to look for intelligent life. We must stay close to Earth and search the heavens for signs of broadcasting civi-

lizations. However, if an intelligent extraterrestrial species hasn't developed technology that signals their existence or is unwilling to release signs of their technology, we cannot detect its presence.

Additional Resources

NASA Space Science Education Resource Directory
http://teachspacescience.org/cgi-bin/ssrtop.plex

Science Teacher Lesson Plans
www.ncsu.edu/sciencejunction/terminal/imse/lowres/4/lessons.htm

The International Space Station
www.shuttlepresskit.com/ISS_OVR

SETI Institute
www.seti.org

BBC: Science & Nature: Space and the Solar System
www.bbc.co.uk/science/space/solarsystem

The Nine Planets: A Multimedia Tour of the Solar System
www.nineplanets.org

NASA Hubble Site
http://hubblesite.org

The European Homepage for the NASA/ESA Hubble Space Telescope
www.spacetelescope.org

Additional Resources at www.filmsmediagroup.com

Available from Films Media Group • www.filmsmediagroup.com • 1-800-257-5126

Space Science Video Library

- **DVD #30964**
- **Correlates to National Science Education Standards**
- **User's Guide included**

The *Space Science Video Library* contains 19 video clips on the structure of the universe, star formation and destruction, the solar system, and space exploration. It is part of the complete Discovery Channel/Films for the Humanities & Sciences *Science Video Library*. A User's Guide is included, containing an overview; a numbered index of clips, with brief descriptions and lengths; suggested instructional strategies; and a list of additional resources. A Discovery Channel/FFH&S Production. © 2003.

How Scientists Look at the Sun

- **VHS/DVD-R #34120**
- **Correlates to National Science Education Standards**
- **Produced in association with the Accreditation Board for Engineering and Technology and the Junior Engineering Technical Society**
- **Viewable/printable Teacher's Guide included**

This *Science Screen Report* explores the Sun's multilayered structure, the forces at work inside it, and the methods by which scientists study it. Detailing the activities of the SOHO spacecraft, the video also explains various solar phenomena: nuclear fusion, the release of neutrinos, oscillation of the photosphere, and the processes by which the Sun may have formed as well as those that will eventually cause its collapse. A viewable/printable teacher's guide is available at www.cambridgeeducational.com. (19 minutes) © 2004.

The Complete Cosmos

- **13-part series**
- **VHS/DVD-R #8622**
- **Preview clip online at www.films.com (Search on 8622)**
- **"Best Educational Program," Radio & Television Golden Laurels, French Senate, 1999**
- **"Special Award," Jules Verne Film Festival, France, 1999**

This unique series is a visual encyclopedia of the planets, the galaxy, and the universe. Rich in awe-inspiring images and meticulous research, it presents information on everything from the reason for seasons, to the Hale-Bopp comet and black holes. A definitive introduction to the study of space and astronomy. The series includes *From Stonehenge to Hubble: Looking to the Stars; Home Star: The Sun and the Planets; Venus and Mars: Earth's Sisters; The Blue Planet and Pale Moon Above; Jupiter and Saturn: Probing the Planets; Uranus, Neptune, and the Milky Way: Dark, Deep Space; Impact! Comets and Asteroids; Celestial Wonders: Eclipses, Auroras, and Light Fantastic; Black Holes, Dark Matter; Space Explorers: A History of the Last Frontier; The Next Step: Of Robots and Space Stations; The Expanding Universe: From Big Bang to Big Crunch?; Spaceship Earth and the Search for Intelligent Life.* (20 minutes each) © 1998.

Space Frontier: The Future of Space Exploration

- **VHS/DVD-R #8622**

By 2019, a colony on the Red Planet—the stuff of science fiction—is expected to become scientific fact. Using computer simulations and interviews with scientists, robotics experts, and officials from NASA and the National Space Society, this program investigates the four main challenges to initiating a self-sustaining colony on Mars. An economical, single-stage, reusable spacecraft must be developed, such as the proposed Venture Star. The effects of long-term low- and zero-gravity living must be studied and counteracted, on the Moon and at the multi-national Alpha space station. The Moon must be developed as a launch platform. And robots must be sent to Mars to prepare for human habitation and create stores of fuel. Once established, a Mars colony will become the jumping-off point for exploring the rest of the solar system and the cosmos beyond. (54 minutes) © 1997.

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Visit our Website at
www.cambridgeeducational.com

2572 Brunswick Pike, Lawrenceville, NJ 08648

Toll Free: 1 800/468-4227
Fax: 1 800/FAX ON US

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