WEIRD CAREERS IN SCIENCE

SETI Scientist

Mary Firestone

WEIRD CAREERS IN SCIENCE

SETI Scientist

WEIRD CAREERS IN SCIENCE

Animal Therapist
Astrobiologist
Computer Game Developer
Pyrotechnician
SETI Scientist
Virus Hunter
Volcanologist

WEIRD CAREERS in SCIENCE

SETI Scientist

Mary Firestone

CHELSEA HOUSE PUBLISHERS
A Haights Cross Communications Company ®
Philadelphia

CHELSEA HOUSE PUBLISHERS

VP, NEW PRODUCT DEVELOPMENT Sally Cheney
DIRECTOR OF PRODUCTION Kim Shinners
CREATIVE MANAGER Takeshi Takahashi
MANUFACTURING MANAGER Diann Grasse
SERIES DESIGNER Takeshi Takahashi
COVER DESIGNER Takeshi Takahashi

STAFF FOR SETI SCIENTIST

PROJECT MANAGEMENT Ladybug Editorial and Design
DEVELOPMENT EDITOR Tara Koellhoffer
LAYOUT Gary Koellhoffer

A Haights Cross Communications Company®

www.chelseahouse.com

First Printing

9 8 7 6 5 4 3 2 1

Library of Congress Cataloging-in-Publication Data

Firestone, Mary.
SETI scientists / Mary Firestone.
p. cm. — (Weird careers in science)
Includes bibliographical references and index.
ISBN 0-7910-8701-8
1. Life on other planets—Study and teaching—Juvenile literature. 2. Interstellar communication—Juvenile literature. 3. Radio astronomy—Research—United States. I. Title. II. Series.
QB54.F45 2005
576.8'39—dc22

2005012076

TABLE OF CONTENTS

Chapter 1

Introduction

AN UNUSUAL SIGNAL

IT WAS AUGUST 15, 1977, and a typical night at Ohio State University's Big Ear telescope. SETI (search for **extraterrestrial** intelligence) volunteer Jerry Ehman was going over Big Ear's computer printouts, as he always did, when he came across a strange signal. There, on paper, was evidence of a radio signal 30 times stronger than the usual noise from outer space. The night would not be so typical, after all. Dr. Ehman tore the paper from the printer and wrote "Wow!" next to the signal. He showed it to other scientists the next day. That week, the Big Ear telescope was turned in the direction of the strong

signal, and kept that way for a full month. Everyone waited, hoping the signal would repeat itself.

It did not. If it had, it might have been evidence of extraterrestrials (ETs) trying to make contact with Earth. The August 15, 1977, signal, known today as the Wow signal, remains famous in the field of SETI research. "We still don't know what it was, and we probably never will," Ehman says. The mysterious Wow signal was one of the strongest ever received from outer space. But it was also one of several strong signals received by telescopes over the years. According to scientists, none of these signals was a sign of life in outer space. For a signal to be considered a genuine sign from ETs, scientists believe it must occur more than once. So far, no repeat signals have arrived.

SETI scientists today are still seeking the real thing, but in the meantime, they devote their days to studying other wonders of the universe.

SEARCHING THE STARS

Have you ever looked up at the night sky and wondered if there was life out there beyond Earth? SETI scientists have a passionate curiosity about life on other planets (Figure 1.1). Are we alone in the universe? How did life begin on Earth? How many planets revolve around stars? Do any of these planets support life? These questions, in addition to seeking contact with actual ETs, are what SETI scientists are always thinking about.

WHY LOOK FOR ETI?

Interest in extraterrestrial intelligence (ETI) is almost as old as civilization. Greek philosopher Democritus (b. 460 B.C.) was among the first to declare his belief in inhabited

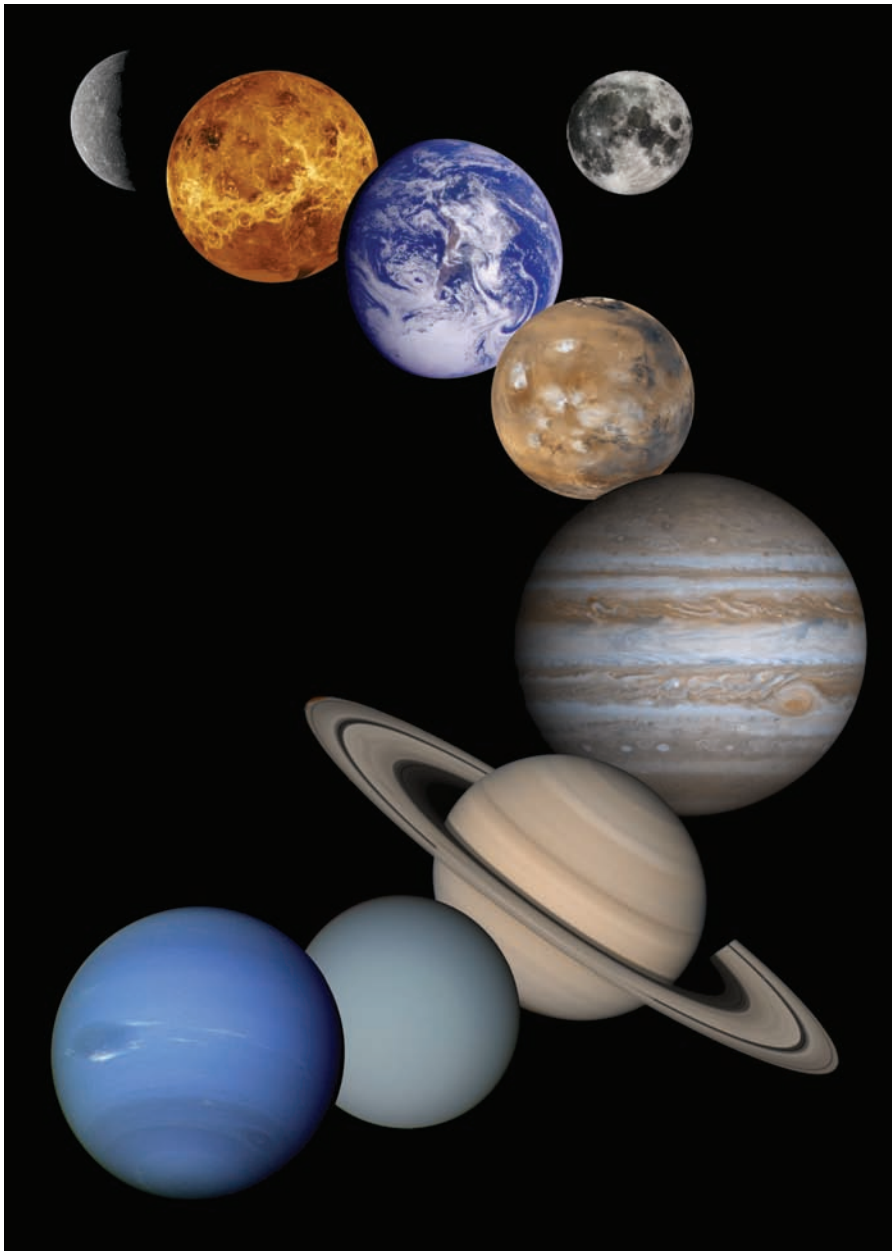

Figure 1.1 This is an artist's depiction of our solar system.

worlds other than our own. Just about everyone has pondered the topic, at least at some point.

Today, SETI science benefits from advances in technology. Scientists search for extraterrestrial life because powerful telescopes, computers, and spacecraft that travel between planets have proven that other **solar systems** and planets really do exist (Figure 1.2). They have another good reason to believe there might be life elsewhere in our galaxy. Actually, make that 400 billion reasons, since that's how many stars are in the **Milky Way**. If a star of the right size and age is the right distance from a planet, the chance for life on that planet is a very real possibility. Why? Because our sun is a star, and we know that Earth's precise distance from it is a foundation for the development of life.

What is "Space Weather"?

Scientists have discovered that "weather" occurs in space. The sun is responsible for disturbances in our space environment, because it gives off a stream of plasma called solar wind. It also periodically expels billions of tons of matter. When directed toward Earth, these huge clouds of material can cause large magnetic storms in the magnetosphere and the upper atmosphere.

According to the National Aeronautics and Space Administration (NASA), magnetic storms produce many noticeable effects on and near Earth, such as the aurora borealis (northern lights) and aurora australis (southern lights), communication disruptions, radiation hazards to orbiting astronauts and spacecraft, surges in current through power lines, and corrosion in oil pipelines.

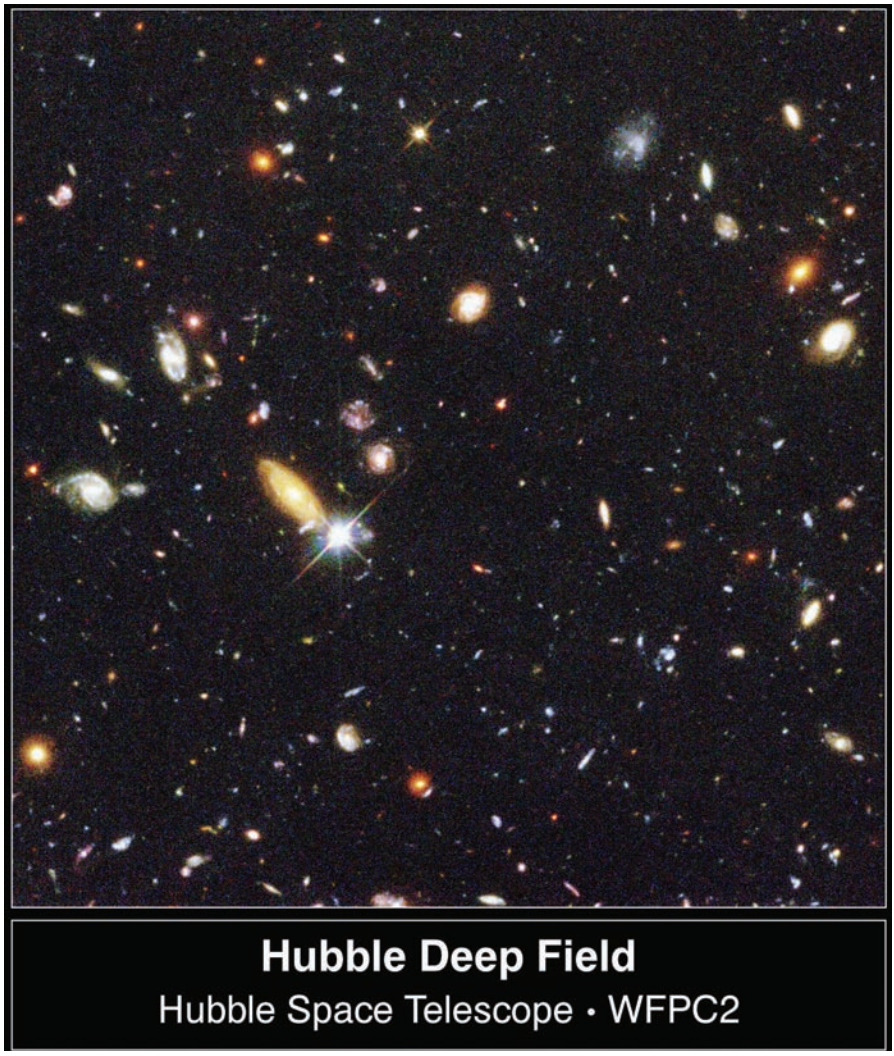

Figure 1.2 **The Hubble Space Telescope records images of galaxies in deep space.**

DISCOVERING OTHER PLANETS

Scientists have now discovered more than 100 planets outside our solar system. There is clearly much more to know. In fact, new planets and stars are forming right now. SETI has searched only one-billionth of the galaxy so far.

Other discoveries within our own solar system, such as the fact that water that once flowed on the surface of Mars and the possibility that there was an ocean beneath the ice of Jupiter's moon Europa, have caused a lot of excitement about extraterrestrial life, even if it's just **microorganisms** and ancient fossils. The discovery of a **magnetosphere** around Jupiter's moon Ganymede and an **ionosphere** around Io have surprised scientists, since these are usually only found around planets, not moons. What do these discoveries mean? Might Jupiter's moons Ganymede and Io have once been covered with oceans, lakes, and grass? SETI scientists are doing everything they can to find out.

Scientists look for extraterrestrial life because they want to understand the universe. They begin by deepening their understanding of Earth, and how life formed here. Discoveries on Earth, such as the existence of life-forms in deep ocean areas, where there is no light or warmth, have led experts to believe that life can exist in some uncomfortable places, including outer space. They can't help but wonder what the potential is for life to exist elsewhere. Life on Earth is about 3.8 billion years old, and despite some intense periods of extreme temperatures and **asteroid** bombardments, it has continued to thrive.

Chapter 2

What Is a SETI Scientist?

A SETI (PRONOUNCED SEH-TEE) scientist searches for life in the universe, especially on planets other than Earth. *Extraterrestrial* means "beyond Earth." A SETI scientist may be an astronomer, an astrophysicist, or a biochemist. SETI scientists use advanced technology, such as telescopes and satellite dishes that receive flashes of light or radio waves from outer space. They collect and analyze this information, looking for strong, repeated pulses of energy from "way out there."

WHAT ARE SETI SCIENTISTS LOOKING FOR?

If you close your eyes, and think of extraterrestrial life, what

Figure 2.1 For many people, the first thing that comes to mind when they hear the term *extraterrestrial* is the lovable creature from Steven Spielberg's film, *E.T.*

comes to mind (Figure 2.1)? You probably don't imagine bits of **bacteria** and ice. But these things are very important to SETI science. SETI science looks for intelligent life in outer space, but it is also a branch of **astrobiology**.

Astrobiology studies **extrasolar** water, ice, rocks, plants, bacteria, and microorganisms to detect life-forms. It's true

that SETI is trying to make contact with technologically advanced types of life that can talk back, read, and send signals around the universe. But SETI is also very involved in looking for signs of life (such as bacteria and ice) anywhere in the universe, no matter how smart that life might be. Even so, SETI science's greatest dream is for another technically advanced world somewhere in outer space to contact Earth.

WAYS OF LOOKING

Most SETI searches are conducted in our own galaxy, the Milky Way, which has 100 billion (100,000,000,000) stars. Powerful optical and radio telescopes scan the skies with two different search strategies: a **Full Sky Survey** search that looks at the whole sky, or a **Targeted Search**, which focuses on a particular section of sky, or a star—whatever the scientist chooses. There is ongoing debate among SETI scientists about which is the best way to receive signals from life in outer space.

Radio telescopes are the more effective tool, according to most scientists, because radio waves can pass through thick layers of **interstellar gases** and clouds, while the visible light waves of **optical SETI** cannot.

Scientists estimate that less than 1% of the sun-like stars in our region of the galaxy have Earth-sized planets in their orbit. In August 2004, NASA reported that astronomers found a new class of planets beyond our solar system. These ". . . Neptune-sized planets—about 10 to 20 times the size of Earth—are far smaller than any of the previously detected extrasolar gas giants [**gas-giant planets**]. It's even possible that the new class of planets is rocky, like Earth and Mars," NASA's Website says.

Scientists have determined that the newly discovered

planets are smaller than Jupiter, and think they might be made of rock, or rock and ice, rather than gas, but add that they aren't sure what they're made of at this point.

WHAT HAPPENS IF WE HEAR FROM ETS?

The surprise of contact from an ET would capture worldwide interest, so SETI scientists are extremely cautious about signals. If telescopes actually do receive a signal that might be from ETs, they are programmed to immediately confirm their findings by double-checking the signal. SETI uses radio telescopes with tens of millions of channels, and the world's largest antennas, so signals of all kinds are very frequent.

If an unusual, artificial (not produced by planets or other natural objects) signal is detected in the narrow **bandwidth** range, then scientists will contact a second radio telescope elsewhere in the world, to see if it has detected the signal, too. If the artificial signal is genuine, then an announcement would be made, worldwide.

World space organizations have come to an agreement about what should be done in case of contact from alien beings. The agreement is called the Declaration of Principles Concerning Activities Following Detection of Extraterrestrial Intelligence. There would be no secrecy. A

Check It Out

You don't have to be a scientist to listen to the universe. Tune your television to a channel that has no station on it and observe the "snow" and listen to the scratchy sounds. Some of this is cosmic microwave background noise, being detected by your television's antennas. Scientists believe this static is the cooled-off part of the very hot Big Bang.

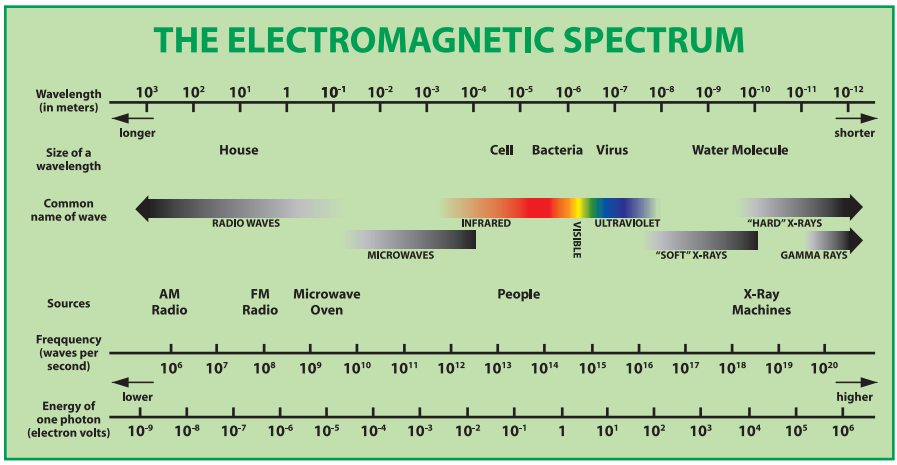

Figure 2.2 **This diagram shows the wide range of the electromagnetic spectrum, demonstrating the size of wavelengths produced at different frequencies.**

portion of it reads: "A confirmed detection of extraterrestrial intelligence should be disseminated promptly, openly, and widely through scientific channels and public media, observing the procedures in this declaration. The discoverer should have the privilege of making the first public announcement."

SETI scientists using radio telescopes will know when they've picked up a signal, because they believe it will occur only in the narrow band width of the **electromagnetic spectrum** (Figure 2.2), at 300 Hz. There are many **satellites** in Earth's orbit (for telecommunications and military surveillance) that produce such signals, so scientists continuously have to sort out these unwanted signals. Any repeated, strong signal would stand out easily in this range.

Chapter 3

History of SETI Science

A LOT CAN HAPPEN when a couple of physicists kick back and think out loud about the universe.

In 1959, Cornell University physicists Giuseppi Cocconi and Phillip Morrison had been doing just that. After chatting a lot about **gamma rays** and how these rays could travel between stars, their discussion expanded into how the entire electromagnetic spectrum, including radio waves and microwaves, could travel at the speed of light through the universe (Figure 3.1). They wondered what would happen if scientists searched these signals for something unusual, or changed the focus of a telescope, just to see what they would find. Cocconi and Morrison

then wrote a two-page paper called "Searching for Interstellar Communications" for the September 1959 issue of *Nature*, a British science journal, and waited to see how scientists in their field would respond. Other scientists around the world found no problems with their theories.

EXPERIMENTS WITH RADIO TELESCOPES

Around the same time, other scientists began to experiment with radio telescopes. One of these scientists was a young radio astronomer named Frank Drake, whose studies were fueled heavily by his fascination with searching for alien civilizations. His calculations told him that if a strong signal were sent from Earth, with Earth technology, it could be detected by a world 10 light years away from us, if that world had an 85-foot (26-meter) dish. The reverse, then,

Figure 3.1 SETI science officially began after two Cornell scientists pondered what might happen if people studied radio signals for unusual activity from other places in the universe, such as the Andromeda galaxy (seen here).

would also be true: We could hear signals from 10 light years away with an 85-foot dish.

In 1960, Frank Drake got the chance to try out his theories. He developed a project, called Project Ozma, which was the first microwave radio search for artificial signals from space. Using the 85-foot radio telescope at the National Radio Astronomy Observatory in Green Bank, West Virginia, he set his sights on two of the nearest sun-like stars, called Epsilon Eridani and Tau Ceti. Sun-like stars, it was hoped, would also have planets in their orbit, just as the planets in our own solar system orbit the sun. These planets might have also produced life.

Drake thought his steady, single focus would bring some information. The telescope was tuned to these stars for six hours each day, for nearly a year, but nothing happened. Still, Frank Drake's experiment got other scientists thinking, especially the Russians, who invested huge sums of government money in new radio telescopes and research, although their experiments brought no significant results.

Radio Telescopes

Radio telescopes are used for radio astronomy, planetary radar, and terrestrial aeronomy. Radio telescopes can detect signals transmitted from the *Pioneer 10* spacecraft, which was launched from Earth in 1972, now more than 6 billion miles (9.7 billion km) away. Its signal has only the power of a flashlight, but it can still be detected. It takes the signal more than 10 hours to reach Earth at the speed of light. According to Christopher Chyba at the SETI Institute, *Pioneer 10* has itself become an "extraterrestrial source, it provides an excellent test for our system—it comes in loud and clear."

MEETING OF THE MINDS

In 1960, a group of distinguished scientists met in secret in Green Bank, West Virginia, home of the National Radio Astronomy Observatory, to discuss establishing contact with other worlds. The meeting was important to the field of SETI, because it was the first time communication with alien civilizations was seriously considered by the world's most prominent scientists, officially. The meeting was held secretly because the scientists who took part worried that their interest in ETs would make them objects of ridicule in the scientific community.

Carl Sagan, a famous astronomer, was there. He said, "these good scientists [were] all saying that it wasn't nonsense to think about the subject. . . . it was like this 180 degree flip of this dark secret, this embarrassment. It suddenly became respectable."

Rocket science and the "space age" was peaking around this time. Astronauts were circling the Earth in space capsules and walking on the moon. It was a time when scientists had begun to wonder just how far their skills could take them, and whether they might actually be able to find life on other planets.

PROJECT CYCLOPS

In the early 1970s, NASA hired a team of experts to research and analyze SETI science and technology. They called it Project Cyclops. It became the foundation for further research and established SETI as a genuine scientific field. Through NASA-supported studies and workshops, two main search strategies emerged: the Targeted Search and the Full Sky Survey (see Chapter 2). NASA decided to use both strategies in its overall SETI plan. NASA

named these searches High Resolution Microwave Survey (HRMS).

VOYAGER

In 1977, *Voyager* spacecrafts carried information about Earth, in case ETs came in contact with them. NASA experts and scientists, government officials, business executives, science educators, and many others produced a gold-covered, copper record that contained photographs, music, greetings in 62 languages, and sounds from the planet Earth. One copy of the record (plus a cartridge, stylus, and pictorial instructions for playing it) was sent into space on each of the *Voyager* spacecrafts. Carl Sagan said the most difficult part of making the record was selecting just the right material to help others learn what life on Earth is like. Typical questions for the group may have been: Which photos, songs, or sounds best represent the diversity of life on Earth? How would you identify universal themes so they can be understood by alien life-forms?

THE MICROWAVE OBSERVING PROGRAM

In the late 1970s, NASA gave Ames Research Center the task of examining 1,000 nearby sun-like stars in its Targeted Search. At the Jet Propulsion Laboratory (JPL), scientists would sweep all directions in the Full Sky Survey. NASA called the project the Microwave Observing Program. In 1988, NASA headquarters formally adopted these strategies, and gave them more funds for continued searching. Four years later, the observations began (again), but in 1993, Congress suddenly voted to end the flow of money from NASA to SETI. Senator Richard Bryan of Nevada convinced the government that spending tax dollars on SETI

was wrong. He called SETI "the Great Martian Chase." The cancellation of funds was a major blow to SETI.

Without NASA money and support, scientists began to lose hope. They saw their dreams of finding ETI in their lifetime going down the drain. Money is critical to research.

NASA had devoted $60 million and 23 years to the study of SETI when it was forced to stop its involvement. But its investment was not entirely wasted. NASA-supported research had led to new technologies, which SETI would use on future projects. Also, NASA's long involvement in SETI had elevated the scientific quality of its research, which had previously been done largely by amateurs.

PRIVATE ORGANIZATIONS

However, SETI science was never entirely dependent on NASA for its survival. The SETI Institute and the Planetary Society, both private organizations, stepped in to preserve the ongoing scientific search for ETI, in 1993. SETI Institute took on the Targeted Search, and became its sponsor.

In 1995, SETI launched Project Phoenix, using the Targeted Search technology. For the Targeted Search, scientists at the SETI Institute compiled a list of 1,000 stars, and searched for signals in the 1,000–3,000 MHz range.

The Planetary Society, founded in 1980, had always had an interest in the Full Sky Survey approach to searching for ETI. Bruce Murray, chairman of the board for the Planetary Society, always believed SETI should not limit its search to particular areas, but should search with a variety of techniques in all areas of the sky. The Full Sky Survey project was suitable for this way of doing things.

In 1995, with funds from the Planetary Society, Paul

Horowitz of Harvard University launched Project BETA, a Full Sky Survey project. BETA (Billion-channel Extra-Terrestrial Assay) is based at the Harvard-Smithsonian Observatory in Cambridge, Massachusetts.

Around 1998, optical SETI was beginning to gain new interest in the SETI community. New technology was making it possible to accurately detect pulses of light from light years away. The University of California at Berkeley and Harvard launched several optical SETI projects, both Targeted Searches and Full Sky Surveys.

You Can Discover a New Planet

PlanetQuest's Collaboratory can turn your computer into an astronomical observatory and resource library if you download the free Collaboratory software, available on the PlanetQuest Website. PlanetQuest telescopes are focused on extremely dense star regions, such as the center of the galaxy in Sagittarius, and "when an observing run ends and thousands of images have been collected, data is downloaded" to your home computer, your Collaboratory software will begin to analyze it.

"In less than a month," the PlanetQuest Website says, "you should know whether you have a planet candidate. But even if you don't yet, you will have discovered important new information about that star—information that will contribute to our overall understanding of the universe. With our telescopes and your computer, you'll make real discoveries at the frontiers of knowledge."

"Most exciting of all," one writer for PlanetQuest says, "you could discover a new planet—a never-before-seen world beyond our solar system! You will be credited for your discovery, and your find will be entered into the PlanetQuest catalog."

Optical SETI is continuing to gain momentum. In 2001, scientists at the University of California's Lick Observatory, the SETI Institute, and the University of California at Berkeley joined together to support a project using a new pulse-detection system, which can find laser beacons from civilizations many light years away from Earth.

PROJECT SERENDIP AND SETI@HOME

Project SERENDIP, which began in 1979, has greatly expanded. In 2005, SERENDIP IV is operating at the Arecibo Observatory in Puerto Rico. This is a radio astronomy project, with equipment piggybacked onto Arecibo's giant dish. This allows SERENDIP to run continuously.

SETI@home began in 1999, as part of Project SERENDIP. SETI@home is a unique project that uses screensavers on the personal computers (PCs) of volunteers around the nation, to process SERENDIP's data. PC users then send the data back to the laboratory for more number-crunching. Without the help of these volunteers, the data would take much longer to process.

Chapter 4

What Do SETI Scientists Do?

BESIDES TRAVELING TO EXOTIC telescope sites around the world, making television and radio appearances, and writing articles about their work, SETI scientists type reports, answer e-mail, write grants, and surf the Internet for new information.

Depending on their skills, SETI scientists may also perform administrative duties. They may become research team leaders, program managers, or planetarium directors. They can be science journalists or editors of scientific journals. If they are professors, they teach college classes, plan lectures, write scientific papers, and supervise student projects.

When SETI scientists work in laboratories, they analyze data from research and telescope searches, write down their conclusions and observations, and sometimes even develop new scientific theories and laws.

Most scientists in SETI work in collaboration with others to conduct studies or to design and develop new procedures. Teamwork is a common approach to large-scale projects.

MATH RULES

Math is a big part of SETI science. SETI astronomers and astrophysicists develop mathematical tables to get a better understanding of the positions of the sun, moon, and stars, and to analyze the **wavelengths** of their **radiation**. They calculate **orbits** and determine the size, shape, brightness, and motion of different **celestial bodies**.

They use their extensive training in math, physics, and astronomy to think about stars, planets, moons, solar systems, and galaxies (such as our own, the Milky Way galaxy). They also study the galaxies' chemical makeup, and the effects of those compositions on planetary atmospheres and biology. SETI scientists sometimes work closely with computer programmers, designing sensitive equipment for "listening" to the stars. SETI scientists think of radio telescopes as "ears" that "listen," since they detect what we cannot see with our eyes.

No matter what job they have, SETI scientists spend a lot of time at their computers. They use computer software to calculate planetary orbits, to determine the size and shape of stars, and to find out their brightness and movements. They process their calculations by typing in numbers and letters. They use critical thinking and problem-solving skills on a regular basis.

SETI scientists analyze wavelengths of radiation from celestial bodies in our solar system and beyond, and make notes of their findings. SETI scientists often consult with other scientists and experts. They are often consulted by the media to report on new SETI projects, and they make public speeches about the field of SETI science. They also travel around the world to attend workshops with other scientists, engineers, and technologists.

AREAS OF RESEARCH

SETI scientists receive education and skills that are in demand. Technology is a big industry, and space technology is an expanding field, both scientifically and commercially.

SETI scientists may also work as astrobiologists, physicists, electrical engineers, or chemists. As lead investigators, researchers, or technology experts, SETI scientists may work in government jobs, institutes, and universities, studying one or more of the following topics:

- interstellar **organic chemistry**
- the formation of planets
- extrasolar planets
- life's origins
- life in extreme environments
- **planetary climatology**
- Mars
- how asteroids and comets have affected life on Earth.

TARGET MISSIONS AND FOCUS GROUPS

The universe is bigger than we can imagine, so scientists pick certain parts of it, trying to understand it just a little at

a time. At NASA and the Ames Research Center (ARC), SETI scientists frequently work in focus groups, and missions where they use a new instrument, technology, or approach and apply it to new or existing facts about life in outer space. Focus groups and missions consist of teams of scientists, which are formed to "focus" their studies on a particular area of space research. Some projects currently under way include the following:

Mars Focus Group

The Mars Focus Group considers past or present Martian life, and **prebiotic** (pre-life) chemistry. This focus group makes recommendations and gives advice about astrobiology missions.

Mission to Early Earth Focus Group

The search for life beyond Earth requires a **concept** of the conditions in which life begins and develops. This focus group is based on Earth, the only planet where life is known to exist. This project believes the study of life and the environment on early Earth is a critical part of making plans for future space missions.

Impacts Focus Group

The Impacts Focus Group examines how asteroids, comets, and other materials that have physically impacted the Earth have influenced the origin, evolution, and extinction of life.

TARGET MISSIONS: PLANETS, MOONS, AND COMETS

Mars

The Mars Global Surveyor is now in orbit, gathering information about Martian surface features, atmosphere, and

magnetic properties. Another probe currently in orbit is the Mars *Odyssey*, which can determine the planet's surface composition, including the presence of water and ice.

"By comparing Earth to Mars, scientists will better understand Earth's history and perhaps its future. The data will also help in planning future missions," says one writer for the Ames Research Center Website.

Each of NASA's Mars exploration rovers carries a set of instruments designed to search for evidence of life in the planet's past. Future projects on Mars include searching for water, studies of environmental changes, and testing for fossils. A new scientific report from NASA says primitive life-forms may once have existed on Mars, perhaps a form of bacteria. Scientists have found magnetite crystals in a Martian meteorite. Bacteria on Earth use magnetite crystals to find food and energy.

Europa

The discovery of an ocean beneath the icy surface of Europa (Figure 4.1) has created new goals for astrobiology. Goals are set to determine the moon's prebiotic organic history and search for life on Europa.

Future missions to Europa will be the testing ground for "**hydrobots**"—remote-controlled submarines that could melt through the ice and explore the undersea realm.

Titan—Saturn's Largest Moon

Titan is the only moon in our solar system with a dense atmosphere and a sophisticated organic chemistry. The *Cassini* orbiter sent the **Huygens Space Probe** into the atmosphere of Titan to take measurements. For many years, biochemists will closely study the chemistry of this unusual

Figure 4.1 **Jupiter is seen here with its four moons (Europa is the one at the far right).**

moon, to determine whether it has the ability to support life.

Comets

Comets may have had an impact on life on early Earth, according to scientific studies. There are theories that suggest that the water and ice from comets could have formed the world's oceans, and may also have "seeded" the early Earth with organic material—the stuff needed for life to begin.

Muses

The interplanetary space probe *Muses* (and its **rover**) is on its way to Asteroid 1998SF36. It was launched in May

2003, to arrive at the asteroid in September 2005. Its rover, Muses-CN, will collect up to three samples from the asteroid and return them to Earth in 2007. This is a joint mission with the Japanese Space Agency, the Institute of Space and Astronautical Science (ISAS; also of Japan), and NASA. The tiny NASA rover for this mission is the smallest rover ever to fly in space. Muses-CN is a 2.2-pound (1-kg), hopping-and-rolling nanorover, which works like a robot.

Planets Outside Our Solar System

The Spitzer Space Telescope (an **infrared telescope**) is a new, highly sensitive telescope that will use the infrared spectrum for astrobiology studies such as **protoplanetary** and **planetary debris** and surveys of the early universe.

JOB DESCRIPTIONS

Astronomers and Astrophysicists

Astronomers and astrophysicists try to understand the physical nature and origin of stars and other celestial bodies. Some of the main questions they ask are: How are stars born? What happens when a star dies? How did the universe begin? What is the rotation of planets, moons, and stars? (Rotation is how fast a planet spins on its axis.) What causes **quasars**, pulsars, and **nebulae**? Scientists have been able to form some ideas about these space phenomena. For example, they've learned that when a star dies, depending on its size, it may end in a **supernova**, eventually becoming a **neutron star** or a **black hole**. Smaller stars get smaller in size over thousands of years. As they run out of fuel, they later become **red giants**, and eventually, **white dwarfs**. Scientists

gather information by directly observing the skies and by looking at the research of other scientists, including amateur astronomers.

Space Physicists

Space physicists investigate charged particles, magnetic fields, and other invisible parts of outer space. They check out the sun's composition, its outer atmospheres, and solar winds. They also study the sun's effect on Earth and the other planets in our solar system. Space physicists ask questions such as: What is space weather? What is interplanetary space (the space between the planets) made of?

SETI Chemists and Biochemists

SETI chemists study the Earth's chemistry to help them understand how life might develop elsewhere in the universe. For example, at NASA's Ames Research Center in Moffet Field, California, scientists created freezing conditions similar to those in gigantic interstellar clouds of dust, gas, and ice that are the birthplaces of new stars and planets, and then exposed these conditions and matter to **ultraviolet** (**UV**) **light**. Their experiment resulted in the formation of a group of amino acids similar to those found on Earth. Amino acids are essential ingredients for life to begin.

Gas Giants

U.S. astronomers have recently discovered five gas-giant planets outside our solar system. This makes 139 known planets orbiting stars other than the sun. The findings were based on observations made at the Keck Observatory.

SETI biochemists study Earth microbes and plants, to understand the chemistry and structure of living organisms that might exist in space.

Paleontologists

Paleontologists in SETI investigate fossils of microorganisms, rates of **evolution**, and changes in prehistoric lands and planets in our solar system. Paleontologists are currently studying fossils here on Earth, to help them understand ancient life-forms on other planets. By studying ancient fossil evidence found at the hot springs in Yellowstone Park, for example, paleontologists might draw conclusions about how early life developed on Earth.

Astrobiologists

An astrobiologist studies the earliest life-forms on Earth and compares the conditions in which they lived to the **surface geology** of planets and moons. Recently, astrobiologists have begun to study the ocean chemistry of Jupiter's moon Europa. They want to know: How does life begin and evolve? What is the future of life on Earth and beyond? Astrobiologists try to answer these questions, and also try to figure out how life can survive in extreme environments, such as Mars.

Computer Software Engineers

Software engineers in SETI develop software programs that tell computers what to look for during radio telescope searches (this is called "application software"). They design systems that make research more efficient and accurate. They work closely with the research team, since computers are the main communication device between scientists and the telescopes that receive information.

The field of SETI is broadening into the area of astrobiology. NASA has a recently established division of Astrobiology Research, which includes SETI-related missions, creating new employment possibilities for scientists.

Job descriptions of SETI scientists and astrobiologists vary widely, ranging from involvement in the movie industry to scientific study of deep space. Refer to the Appendix for job listings related to SETI and astrobiology at NASA.

Chapter 5

Astronomical Tools

RADIO TELESCOPES

CAN YOU IMAGINE a satellite dish as big as a football field? How about 20 football fields? That's the size of the Arecibo Observatory Telescope dish in Puerto Rico: 1,000 feet (305 meters) in diameter. The Arecibo dish is the largest single-dish radio telescope in the world (Figure 5.1). Scientists use the Arecibo dish and several other radio telescopes to conduct their research.

Placing radio telescopes in the right spots on Earth (such as Arecibo's location near the equator) allows astronomers and scientists to see the largest sections of sky. Radio telescope

Figure 5.1 **The Arecibo radio telescope in Puerto Rico is the largest single-dish telescope in the world.**

sites are where SETI scientists and astronomers do most of their field work, and are perhaps the most important tool of SETI science.

When SETI scientists look for evidence of advanced life on other planets, they listen for radio and microwave signals. They've decided that any advanced civilization that might exist would know that radio waves are the clearest path through **interstellar space**, and, like Earth, would use that path to contact other worlds. Radio waves travel at the speed of light, and penetrate clouds of dust, interstellar clouds, and even some solid materials, making them a logical tool.

Most of what we know about stars and planets has been brought to us by light waves, also known as the visible light spectrum. However, this is the smallest part of the electromagnetic spectrum.

Infrared and radio waves have brought scientists a lot more information about the universe, because they carry information that can't be obtained visually, such as the existence of distant sun-like stars and planets. Radio telescopes were the first nonvisual tool (optical telescopes came first) for exploring the universe.

Radio telescopes, which were first used in the 1940s, scan the skies for radio wave signals. They collect the data that would be missed if visible light were the only form that possible messages from life in space could take. Many previously hidden planets have been detected because of radio telescopes.

Cosmic microwave background noise was first found with radio telescopes, by U.S. radio engineer Karl Jansky in 1932. This background noise is present everywhere in the universe, and contains remnants of the Big Bang, which many scientists believe is the origin of the universe itself.

Waves

The electromagnetic spectrum is made of radio waves, microwaves, infrared waves, visible light waves, ultraviolet, X rays, and gamma rays. All waves in the electromagnetic spectrum are made up of photons, which are particles of light. Wave frequencies are also called oscillations. Oscillations describe how often a wave completes a cycle, over time. Radio waves have the longest wavelengths in the spectrum, some of them as long as a football field (100 yards [91 meters]). Radio waves bring music to your radio, images to your television, and conversations over your cellular phone. Antennas receive radio wave signals, which are broadcast from television, radio, or cellular towers.

How Radio Telescopes Work

Radio telescopes of all types use a reflecting dish, somewhat like a satellite dish for televisions, but much larger. Radio telescopes are big, because radio waves are big. If scientists hope to create clear images from the radio waves, they must have equipment large enough to receive them.

Objects in space give off radio wave signals (all objects in space give off electromagnetic waves—even you). These signals strike the reflecting surface of the dish, which is made of metal. These reflected waves are concentrated and focused through receivers, which use "**wave guides**" that are specially tuned to the radio or microwave frequencies.

Signal processors in the telescope are extremely sensitive to the distances and **amplitude** of the radio waves, which reveal plains, mountains, valleys, and the quality of the atmosphere of distant planets.

Years ago, scientists were able to learn that the moon's surface was covered in sand, long before astronauts ever walked on it, because radio waves that the moon gave off revealed its grain-like surface. Flares and spots on the sun send strong radio waves that told scientists how high and wide they are.

Arecibo

Arecibo Observatory in Puerto Rico has the greatest electromagnetic-wave-gathering capacity of any radio telescope in the world. Its 1,000-foot-diameter dish is set inside an ancient limestone crater, creating a convenient natural setting. Astronomers, astrobiologists, and SETI scientists from all over the globe compete for time at the Arecibo dish. Visiting scientists make proposals to the staff at the site, who assign time according to the merits of the research proposals.

The Arecibo dish can detect asteroids, meteors, distant galaxies, quasars, and pulsars. SETI scientists visit the dish at Arecibo several times a year, to take advantage of its location near the equator, which is ideal for observing all planets in the solar system, and the outermost layer of the Earth's atmosphere, the ionosphere.

Green Bank Radio Telescope

The Green Bank radio telescope is part of the National Radio Astronomy Observatory (NRAO), an institution set up by the U.S. government, which designs and builds its own telescopes for scientific uses around the world. The Green Bank telescope is located in Green Bank, West Virginia. It's the world's largest fully mobile (steerable) radio telescope. It can be aimed at any part of the sky.

Very Large Array

The Very Large Array in Socorro, New Mexico, is a collection of 27 individual 25-meter, 230-ton **parabolic** dishes, spread over an area in a way that lets it receive the most radio and microwave signals possible (Figure 5.2). Like the Green Bank Radio Telescope, the Very Large Array is part of the National Radio Astronomy Observatory.

Allen Telescope Array

The Allen Telescope Array is the world's largest radio telescope. It consists of several hundred small satellite dishes. (See Chapter 6 for more information.)

OPTICAL SETI TELESCOPES

Optical SETI (OSETI) is another choice for searching the skies. OSETI seeks pulses of light in the visible or infrared

Figure 5.2 The Very Large Array in New Mexico consists of 27 large dish telescopes.

range of the electromagnetic spectrum. With optical telescopes, SETI scientists look for brief, powerful pulses of light from other planets. They use light detectors called **photomultipliers** to look for short laser pulses that last for less than one-billionth of a second. These short pulses of light can be easily distinguished from naturally occurring light, because they are so brief. Scientists have determined that receiving these signals would indicate contact with extraterrestrial intelligence.

In 2003, scientists at the University of California's Lick Observatory, the SETI Institute, and the University of California at Berkeley joined together to support a project that uses a new pulse-detection system. It can find **laser beacons** from civilizations that might exist many light years away from Earth.

Past optical SETI searches have had problems with false alarms, because of Earth-based light that looked like pulses from outer space. In a press release, SETI Institute chairman Frank Drake said the Lick optical SETI project is "perhaps the most sensitive Optical SETI search yet undertaken."

Stuart Kingsley is a well-known optical SETI scientist who has been conducting his own experiments for many years. Recently, his research has been embraced by others in the SETI field. He has convinced some scientists that optical SETI is an effective tool because powerful lenses can receive pulsed laser beacons. Any type of signal, whether light flashes or radio waves, if repeated, might be an indication of ETI.

Keck Interferometer

The Keck Interferometer is a system that links two 10-meter optical telescopes to create the world's most powerful optical telescope system. The Keck Interferometer is used to search for planets around nearby stars. It combines light from the two telescopes to measure **emissions** from dust orbiting stars.

INFRARED TELESCOPES

Spitzer Telescope

Infrared telescopes collect information about planetary surfaces. Telescope sensors record the information with infrared images, which are beyond visible wavelengths. Colors are then assigned to the different wavelengths, and these variations in color make the image visible. These colors can show climate changes and surface biology. The NASA Infrared Telescope Facility at the Institute for Astronomy at the University of Hawaii has recently been able to determine the

presence of methane on Mars by a close reading of infrared images. Methane gas is a by-product of microscopic life-forms, and is associated with the presence of life, which is useful information to SETI.

COMPUTERS

After telescopes, the next most important tool of SETI science is computers. SETI scientists use **supercomputers** for processing large chunks of data, and smaller computers for graphic displays, calculations, and software programming. Without computers, understanding the chemistry and signals coming from the universe would be impossible. Astronomy and physics are intimately connected, because the universe is based on the laws of physics. Attempting to understand billions of **frequencies** that arrive continuously requires lots of calculations.

At Arecibo, Project Phoenix computers are uniquely designed to analyze microwave signals sent by receivers within the dish. Teams of scientists program the computers so they'll recognize which stars to search, or to have the computer search more than one star at a time. "The computers swallow a big chunk of radio information," says the SETI Institute's Jill Tarter. "They slice it up into tiny little channels, kind of like slicing a salami. They carefully analyze every single piece to see if there's a pattern."

SEARCH STRATEGIES ARE TOOLS, TOO

In a universe with billions of stars to choose from, SETI scientists face a challenge to find the best method for searching for radio signals. They must decide where and how to look. Two types of search strategies are used by both optical and radio SETI science, to make the most of

their efforts. They are called Targeted Search and the Full Sky Survey.

Targeted Search

Targeted Search surveys the sky for stars closest to Earth, and most similar in size to our sun. Scientists pick older stars for the Targeted Search, since it can take billions of years for life to develop on planets. They can estimate the age of a star by the amount of activity in the radio signals. Young stars are more active.

The Targeted Search allows for more detailed investigations, since more can be seen and heard when objects are nearer. Most scientists think water is needed for life to develop. If a planet were too close to a star, water would boil and evaporate, and the planet would not be a good candidate for further study. If a planet were too far away from a star, then the lack of light and warmth would likely prevent life from developing there. Scientists look for evidence of conditions favorable to all kinds of life, however. Extreme conditions do not necessarily eliminate a planet, but conditions must fall within certain limits. The Targeted Search looks for signals from 1,000 to 2,000 stars at a time. The major limitation of the Targeted Search is that it leaves out large portions of the sky. Project Phoenix is a large-scale Targeted Sky project.

Full Sky Survey

The Full Sky Survey search strategy doesn't leave out any part of the sky. Its aim is to check for unusual signals from as many stars as possible. It has many different names, including Full Sky, All Sky, Sky Survey, and Wide-Field, but they all refer to the same basic method in which large

areas of sky are surveyed. Project Argus is a Full Sky Survey Project.

Scientists believe these two types of searches work together. Targeted Searches have the ability to focus on likely candidates for ETI, but if all searches were focused this way, scientists might miss candidate stars that are farther away.

For both search strategies, if telescopes detect an unusual signal from a particular section of the sky, they tell a second telescope somewhere else in the world to scan the same section of sky. If the signal is false (accidental, or coming from Earth-based background noise), it will not be detected by the second telescope.

LABORATORIES

SETI scientists use microscopes, **particle accelerators**, test tubes, and a collection of chemicals for freezing and heating up matter in laboratories, to test their theories about life on Earth and other planets.

NASA Astrobiology scientists study salt-loving and UV-resistant microorganisms in the lab, to learn about the survival and biological evolution of life in space. SETI scientists also use signal-processing labs, which are equipped with computers and electronics equipment to study incoming signals from radio telescope searches.

OTHER TOOLS

SETI scientists gather information from the tools of NASA and the **European Space Agency**. **Space probes** from these programs, such as the **Hubble Space Telescope** (**HST**) (Figure 5.3), are helpful to SETI, because scientists can check the galaxy and its celestial bodies without inter-

Figure 5.3 The Hubble Space Telescope has been an extremely valuable tool for scientists involved in SETI research.

ference from the Earth's atmosphere. HST was the first to find evidence that there were planets around other stars, a major discovery for SETI in 1995. Swiss astronomers Michael Mayor and Didier Queloz discovered the planet's orbit around the star 51 Pegasi.

Huygens Space Probe, which landed on Saturn's Titan moon in January 2005, has analyzed Titan's atmosphere and sent photographs back to Earth. It has revealed an atmosphere made up of nitrogen and methane, which tells us that life may have existed there at some point. SETI uses

all of this data to draw conclusions about life on planets elsewhere in the universe.

Space vehicles, such as the twin Mars rovers, *Spirit* and *Opportunity*, send both visible and infrared images back to Earth. These are analyzed for signs of life by SETI scientists.

Satellites and optical telescopes fitted with **photometers** check for the presence of Earth-sized planets by focusing on certain stars, and looking for changes in that particular star's light emissions. A slight dimming in light indicates that a planet is revolving around the star.

It's important to note that SETI scientists do not investigate reports of aliens or UFOs, since these do not involve systematic scientific observation.

Chapter 6

Where Do SETI Scientists Work?

NASA

Many SETI scientists work as astrobiologists for NASA's Astrobiology Institute (NAI), with its base operations at the Ames Research Center in Moffet Field, California. NAI is a **virtual** institute, made up of 15 teams, each engaged in astrobiology research under the direction of NASA. Each team works from its own facility, mainly from universities, located all over the United States.

For scientists with revolutionary ideas about aeronautics and space concepts, there is the NASA Institute for Advanced Concepts (NIAC). This organization "encourages scientists to think

decades into the future, in pursuit of concepts that will leapfrog the evolution of current aerospace systems," says the NIAC Website. The projects currently under way at these centers of SETI and astrobiology study space exploration with a broad range of scientific disciplines and technologies to find answers about life in the universe.

In addition to NASA's National Astrobiology Institute, the Jet Propulsion Laboratory (whose missions include Mars exploration rovers and the Spitzer Space Telescope) and Johnson Space Center (the lead center for space shuttle activities), many universities, such as the University of California at Berkeley, Harvard University, and Princeton University, are involved in astrobiology and SETI projects.

SETI INSTITUTE

The SETI Institute mission statement says its purpose is "to explore, understand and explain the origin, nature and prevalence of life in the Universe." The SETI Institute is a private organization. That means it receives its money for research from individuals' donations, and not from the government. Most American SETI scientists spend part of the year working at the SETI Institute in Mountain View, California, teaching and doing research. The SETI Institute collaborates with NASA and other organizations on a variety of topics, employing SETI scientists from many walks of life.

CURRENT SETI INSTITUTE PROJECTS

The Allen Telescope Array (ATA)

Two executives from the Microsoft Corporation have made a big investment in SETI. Paul Allen (a cofounder of Microsoft) and Nathan Myhrvold (the former chief tech-

nology officer for the company) are fascinated by SETI research. In fact, they've given the SETI Institute $12.5 million to develop a radio telescope dedicated entirely to SETI and radio astronomy. It's called the Allen Telescope Array, after Paul Allen.

The Allen Telescope Array consists of 350 individual satellite dishes. The project is located at the Hat Creek Radio Observatory near the University of California at Berkeley. With its 350 satellite dishes, the ATA is able to study many areas of the sky at once, using more **channels**. It is in operation 24 hours a day, 7 days a week. The combination of these features will make it possible to study 100,000, or maybe even a million, nearby stars.

Project Phoenix

Project Phoenix was developed from NASA's Targeted Search Project. SETI Institute took over the program after NASA lost its government funding for SETI in 1994. Project Phoenix uses the world's largest radio telescopes to study the nearest sun-like stars, one by one. Project Phoenix workers search for artificially produced signals (signals made by technological devices) in the **microwave spectrum**. According to the SETI Institute, Project Phoenix's ability to detect and analyze slowly drifting signals is the most comprehensive in the world today.

Twice a year, SETI Institute scientists visit the world's largest radio telescope, located in Arecibo, Puerto Rico, as part of Project Phoenix. At Arecibo, there are cabins set up for the scientists to live in during their stay. They work around the clock in shifts, taking turns at the computer, analyzing radio signals, and observing the sky.

Observatories

Observatories are places where astronomy is put into action. They are designed for visual observation of the universe, and are usually associated with university programs in astronomy and OSETI (optical SETI). Some examples are the Hat Creek Observatory at the University of California at Berkeley; the FitzRandolph Observatory at Princeton University in Princeton, New Jersey; the Harvard Telescope, located on the Harvard campus in Cambridge, Massachusetts; and the Lick Observatory at Mount Hamilton above San Jose, California.

NASA's Jet Propulsion Laboratory

PlanetQuest is the astrobiology center for JPL. Its mission is "the search for another Earth." Current projects under way at PlanetQuest are the Space Interferometry Mission (SIM) and the Terrestrial Planet Finder (TPF). The SIM project involves a spacecraft, to be launched in 2011, which will be sent into an Earth-following solar orbit. Its onboard **interferometers** are designed to detect the precise dis-

Lick Observatory

Lick Observatory at University of California, built in 1887, was the world's first mountaintop observatory. It uses the Nickel 40-inch (102-cm) reflector, and specially designed hardware and software for its light detector system. Lick optical SETI continuously examine star systems and star clusters. Each star is observed for ten minutes, checked for brief light pulses, and then scientists move on to the next star. Lick Observatory is located at the summit of Mount Hamilton, near San Jose.

tances of stars from Earth in the Milky Way galaxy, with an accuracy that is hundreds of times greater than before. The TPF project consists of two separate outer-space observatories. One will be launched in 2014 and the other in 2020. The TPF will study all aspects of planets outside our solar system: their formation from spinning disks of dust and gas around newly forming stars, planets orbiting nearby stars, the various sizes, and suitability for supporting life.

PlanetQuest's scientific mission is to discover not just a few but thousands of new planets in our galaxy within the next five years. Some 150 planets with nearby stars have been found since 1995, but many are too small and faint to be seen directly. PlanetQuest scientists determine their presence indirectly through a process that requires careful analysis of very large amounts of astronomical data.

Chapter 7

Profiles of SETI Scientists

JILL TARTER

AS A YOUNG CHILD, SETI scientist Jill Tarter (Figure 7.1), born on January 16, 1944, loved to go fishing and camping in the Catskills with her father, who eventually told her that she should spend more time learning about domestic life in the home. "I thought that was the most unreasonable thing that anyone had ever said to me," Tarter recalls. In *Looking for Life in the Universe*, Tarter describes how she later told her father that she wanted to become an engineer, aware that this was considered a field for men. This time, he encouraged her, telling her that hard work would get her wherever she wanted to go.

Figure 7.1 SETI scientist Jill Tarter poses for the camera while she takes a break from working on the Arecibo telescope.

Tarter had more stereotypes to break through in high school. She wanted to take shop (a carpentry class usually reserved for boys at the time), but was told she had to take home economics, so she could learn how to cook and take care of a household. She ended up taking both classes. She credits her mother for being supportive of her choices. She adds, "I learned early on that the way to get what you want is to do the extra work. And then people can't say no." She excelled in high school physics, and earned a scholarship to Cornell University, where she was the only woman in her class of 300 male engineering students. It wasn't easy. She ended up doing her homework alone. However, she felt that the experience actually gave her a better education. She finished a five-year engineering program in four years, and

decided that astronomy interested her more than engineering. After a few years, she focused on SETI research. She has been active at the SETI Institute in a range of leadership and scientific roles since 1984. She is happily married to Jack Welch, who is in charge of SETI at the University of California at Berkeley.

CARL SAGAN: A STAR IN SETI

As a child growing up in Brooklyn, New York, Carl Sagan (Figure 7.2) loved science fiction and became fascinated with astronomy when he learned that every star in the universe was actually a sun. His parents always encouraged him to research his own answers to the many science questions he asked. He earned three degrees—bachelor's and master's degrees in physics, and a Ph.D. in both astronomy and astrophysics—all from the University of Chicago.

Figure 7.2 **Carl Sagan, one of the most respected scientists of the 20th century, helped bring SETI science to the attention of the general public.**

Sagan was among the first scientists to determine that life had once existed on Mars. In 1968, Sagan began teaching at Cornell, where he also became the director of the Laboratory for Planetary Studies. He became a visiting scientist at the Jet Propulsion Laboratory in Pasadena, California, and helped design and manage the *Mariner 2* mission to Venus, *Mariner 9* and *Viking* trips to Mars, the *Voyager* mission to the outer solar system, and the *Galileo* mission to Jupiter. Sagan was famous for being a pioneer in the field of astrobiology and the search for extraterrestrial life. He achieved fame by appearing on television programs to discuss astronomy and by creating the popular PBS series *Cosmos*, in 1977. He also wrote a novel that was made into a movie, called *Contact*, in 1997, starring Jodie Foster (Figure 7.3). The lead character was based on Jill Tarter, the astronomer at the SETI Institute, and a pioneer in her own

Figure 7.3 **In this scene from the movie *Contact*, Jodie Foster listens to radio signals, hoping to hear a pattern that would indicate a signal from extraterrestrials.**

right, as one of the first women in the field of SETI. Carl Sagan was a cofounder of the Planetary Society, which is involved in several SETI projects. His 1977 book, *The Dragons of Eden*, won the Pulitzer Prize.

FRANK DRAKE

Frank Drake (Figure 7.4) was born in Chicago on May 28, 1930. Like others in the field of SETI, he showed an early interest in science. He spent hours with radio experiments and chemistry sets, and as his interest in astronomy grew, he became fascinated with the size of the universe. He also began to wonder about life on other planets. Because of his parents' religious beliefs, however, he didn't pursue the topic of extraterrestrial life until after he graduated from high school.

While he was a student at Cornell University, Drake attended a lecture by Otto Struve, a world-renowned astrophysicist. In the lecture, Struve explained evidence for **planetary systems** (planets revolving around sun-like stars) beyond our own, in the Milky Way galaxy. Struve also believed that life could exist on some of these far-away planets. Frank Drake was inspired that a scientist of this stature shared ideas similar to his own.

Drake received his degree in electronics from Cornell and entered the U.S. Navy as an electronics officer in 1956. In the navy, he gained valuable experience with the most advanced electronics technologies of the day.

When his navy tour of duty ended, Drake attended Harvard, initially hoping to study optical astronomy, but the summer positions he wanted were taken. There was room in the school's summer program in radio astronomy, however, and he eventually became hooked on the science of

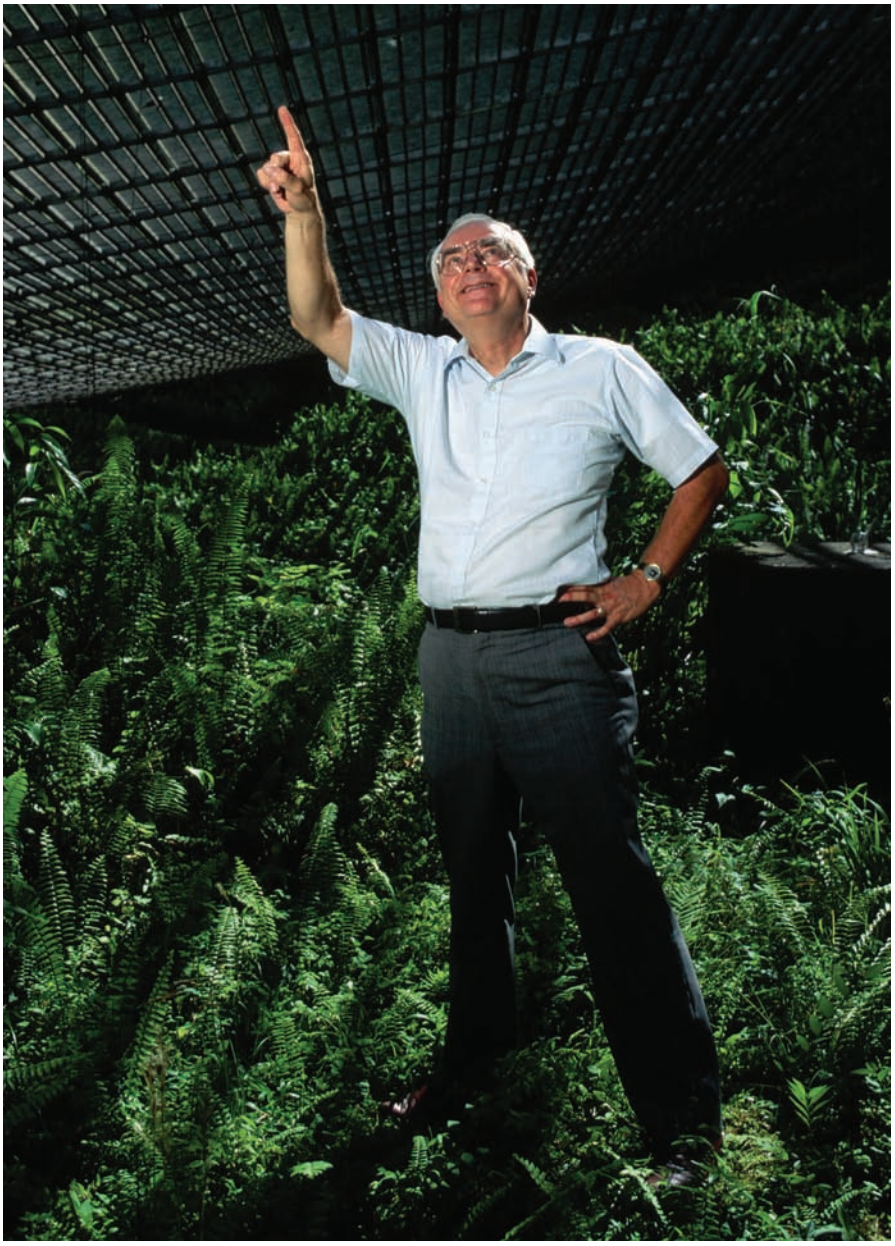

Figure 7.4 Frank Drake, the founder of the SETI Institute, points to the sky.

radio astronomy. When he finished graduate school at Harvard, he got a job at the National Radio Astronomy Observatory (NRAO) in Green Bank, West Virginia. The first official radio astronomy search took place there, in 1960, under his direction, observing the stars Tau Ceti and Epsilon Eridani.

In 1961, Drake and J. Peter Pearman from the National Academy of Sciences organized the first SETI conference. In preparation for the conference, Drake devised an equation to help the other scientists focus on the key questions of whether life can exist on other planets. The equation considers astronomical, biological, and social factors in its estimates of the probability of life in a galaxy or planetary system.

KEVIN HAND

Kevin Hand is one of the younger astrobiologists at the SETI Institute, born in 1977. His passion for astronomy began during his childhood in Vermont, where he camped outdoors under star-filled skies. He greatly admired his older brother, whose deep interest in the world of science had an impact on Hand. These experiences helped shape Hand's future. He was also influenced by Carl Sagan, the astrophysicist whose book and television series *Cosmos*, Hand says, in an interview for the SETI Institute's *Voices*, "connected his direct experience of the natural world with the science that explained it."

Hand deepened his knowledge in high school, when he wrote a paper for a biology class about life on other planets: "I wrote about life on Mars, Europa, the solar system, and searching for planets around other stars." He was not aware of the field of astrobiology at the time, nor that it

would become his career. To prepare for his high school project, he'd read the work of Jill Tarter and Frank Drake, who are now his fellow scientists at the SETI Institute.

By the time Hand entered college, he knew that astrobiology would be his career. "There was never a decision," he states, about his desire to use science to explore life on other worlds. "It just always had to be."

Hand went on to Stanford University for his Ph.D., and currently participates in a NASA internship through the SETI Institute, where he works at SETI Institute's Center for the Study of Life in the Universe.

While on Catalina Island (off the coast of California) for a field-study program, Hand met James Cameron, a famous Hollywood film producer, who was looking for an astrobiologist to join his film project about an exploration to the **mid-Atlantic ridge**, and the **East Pacific Rise** of **hydrothermal vents**. Hydrothermal vents, found deep below the ocean's surface, are of major interest to SETI. Scientists think the vents are important to the origins of life, and perhaps the basis for the existence of life on other planets. The film, called *Aliens of the Deep*, explores the microorganisms that thrive in near-impossible conditions, in complete darkness, with almost no food.

Hand's advice to young science enthusiasts who are trying to find their career path is: "We tell people to let their teachers know when they need them to slow down," so the students have enough time to understand. "And we tell them to ask questions, no matter how intimidating it might seem. The exciting side of science really resides in the questions."

Chapter 8

Do You Want a Career in SETI Science?

ARE MATH AND SCIENCE your favorite subjects in school? If you often wonder about life in the universe, you may someday find yourself at a powerful telescope, searching for ETs.

A SETI scientist is a lot like a detective, looking at clues to find answers about ETI and life in space. They spend a lot of time thinking. This might sound a little boring, but if you're a SETI scientist, thinking, wondering, and trying to figure out where there might be life in the universe is about as exciting as it gets.

In many ways, SETI science is similar to the pursuits of the early explorers and discoverers. Like Christopher Columbus,

SETI scientists have an intense curiosity and a belief that there are new worlds out there, despite the lack of hard evidence. If you love the unknown, you can apply this to a search for life in the universe.

CHECK OUT THE UNIVERSE

Scientists estimate that the universe began with the Big Bang, around 14 billion years ago. But the truth is no one knows for sure how the universe came into being. We do know that it's a big place. Astronomers now estimate there are 70 sextillion stars in the universe—that's 70 thousand million million million, or 7 with 22 zeroes behind it.

There are at least several billion galaxies in the universe. The nearest galaxy is the Andromeda, which is 2 million light years away. The visible universe is roughly 28 billion light years in diameter. Where is the boundary of the universe, and what lies beyond it? This is what scientists want to know. Many objects in the night sky are planets, reflecting sunlight. Other objects may be comets. You might think you see a star, but are actually seeing a whole galaxy. These objects appear to be close to each other but are actually huge distances apart.

THE RIGHT STUFF

Curiosity, determination, and imagination are important qualities in a SETI scientist. Determination is necessary because no signs of ETI have yet been found, and still the scientists do not give up the search. Research projects often take years, so you need to be self-motivated and able to stay focused on your goals. Successful SETI scientists are enthusiastic, honest, and creative. They are passionate about their work.

GET A GOOD START

If you take plenty of math and science in high school, and even in middle school, you will be giving yourself a good start for a SETI career. You should be good enough at these subjects so you don't get left behind when you take college math and science classes. If you want a career in SETI and do not start college with a solid foundation in high school math, it will be hard to catch up.

COLLEGE IS NECESSARY

All SETI scientists go to college and receive at least undergraduate degrees in mathematics, biology, physics, chemistry, or engineering. This builds the foundation for later studies in astronomy and astrophysics. SETI scientists use their mathematics and physics knowledge to give them a deeper understanding of astronomy and the workings of the universe.

SETI scientists can also receive training through student fellowships, internships, and by volunteering at observatories and **planetariums**.

Math, science studies, and internships are not the only things needed for a career in SETI. Successful SETI scientists must be able to communicate effectively both in speech and in writing. SETI research is eventually described mostly in words, and SETI scientists often present the results of their studies to the science community by giving talks on a variety of topics. Scientists need to study English and writing at the college level, so they can handle this important aspect of SETI work.

After SETI scientists receive their undergraduate degrees, most of them go to graduate school for a Ph.D. in astronomy, astrobiology, astrophysics, engineering physics,

or software engineering. Without a Ph.D., it might be hard to find a job in SETI science.

TRAINING TO BE A SETI SCIENTIST

NASA Astrobiology Academy

The NASA Astrobiology Academy is a unique summer institute of higher learning that helps guide future leaders of the U.S. space program by giving them a glimpse of how the whole system works. The goal is also to train students in fields related to astrobiology early in their careers and provide them with hands-on experience in this exciting field.

Arizona State University, Tempe

Astrobiology programs include meteorite studies; research on the evolution of **photosynthesis**; fossilization processes in microbial ecosystems; snail-fish ecosystems in springs; and life on Mars and Europa.

University of Colorado, Boulder

The Center for Astrobiology at the University of Colorado has focused on the formation of stars and planets; planetary atmospheres, clouds, and hazes; the origin of life; and hydrothermal systems and weathering.

Harvard University

Studies in SETI science at Harvard include the evolution of the early **biosphere**, **micropaleontology**, **geochemistry** of organics and trace elements, and **tectonics**.

Pennsylvania State University

Penn State Astrobiology Research Center studies include

the early environment of Earth, including the atmosphere and oceans, as well as the atmospheres of other planets.

YOU CAN PARTICIPATE IN SETI SCIENCE

Home computers have the ability to analyze information. Scientists at the University of California at Berkeley created software for home computers so that people (anyone—not just scientists—can take part) can download SETI@home software from the Internet and place it in a screensaver program. When these home computers are not in use, SETI@home software goes into action, and uses that time to analyze SERENDIP data. When millions of home computers are participating in SETI@home, they act as one very large supercomputer.

The process works like this:

1. Data is collected from the Arecibo dish in Puerto Rico.
2. Data is stored on a disk with notes such as time, date, and **sky coordinates**.
3. The data is divided into small chunks of information, so that home computers can process it.
4. The SETI@home program on home computers downloads the information from computer servers at the University of California at Berkeley.
5. When the home computer is not in use, it switches to the SETI@home screensaver program and analyzes the information. This takes anywhere from 10 to 20 hours, depending on the size of the home computer's **microprocessor**.
6. Home computers upload the results to the University of California at Berkeley, and make note of any "hits" (hits are signs of possible ETs).

In 2005, 2 million people were participating in SETI@home.

List of Current Job Titles and Occupations on file at NASA

A background in physics, biology, mechanical and electrical engineering, math, software engineering, or astrobiology qualifies applicants for many of these positions.

Advanced Projects Design Team Leader
Aeroacoustics Engineer
Aerodynamics Engineer
Aeromechanics Engineer
Aeronautical Engineer
Aeronautics and Aerospace Technologist
Aerospace Engineer
Aerospace Engineer Technician
Aerospace Optical Engineer
Aerospace Research Engineer
Aerospace Systems Safety Research Assistant
Aerospace Technologist
Airborne Telescope Operator
Analytical Chemist
Applied Meteorology
Assistant Astronomer
Assistant Branch Chief
Assistant Science Coordinator
Assistant Superintendent
Associate Producer
Associate Staff Scientist
Astrobiologist
Astronaut
Astronomer
Astronomy Educator
Astrophysicist
Atmospheric Physicist
Atmospheric Structure Investigator
Biocomputation Center Deputy Director
Bioengineer
Biological Engineer
Biologist
Biomedical Engineer
Biomedical Technician
Branch Chief
Center Controller
Chemical Engineer
Chemist
Chief of Biological & Chemical Analysis Laboratories
Chief of Guidance and Propulsion Systems
Chief of Life Sciences Division
Chief Project Engineer
Chief Toxicologist
Cinematographer
Civil Engineer
Cognizant Engineer
College Intern
Commander
Computational Fluid Dynamicist
Computational Fluid Dynamics Engineer
Computer Engineer
Computer Programmer
Computer Scientist
Computer Systems Engineer
Computer Systems Technician

Computer Technician
Conceptual Aircraft Designer
Congressional Staff Member
Crew Chief
Crew Coordinator
Crew Training
Crew Training Coordinator
Curriculum Specialist
Data Communications Engineer
Data Management Team
Data Systems Specialist
Deep Space Tracking Network Operations Project Engineer (NOPE)
Deputy Chief of Propulsion and Fluid Systems Branch
Deputy Chief, Systems Division Mission Operations Directorate
Deputy Director of Aeronautics
Deputy Director of Operations, Research and Development Services
Deputy Manager of Payloads Office
Deputy Navigation Team Chief
Deputy Uplink Systems Engineer
Design Engineer
Design Lead
Development Group Leader
Director of Development, Space Center Houston
Director of Flight Operations
Director of Public Relations
Director, Astrobiology and Space Research
Director, California Air & Space Center Teacher Institute
Director, Counseling and Psychological Services Center
Director, NASA Life Sciences Division
Dive Specialist, Neutral Buoyancy Lab (NBL)
Division Chief
Education Specialist
Electrical Designs Engineer
Electrical Engineer
Electrical Operations Engineer
Electrical Power System/Thermal
Electrical Supervisor
Electronics Engineer
Engineer
Engineering Analyst
Engineering Assistant, NASA's SHARP Program
Engineering Manager
Engineering Technician
Engineering Test Pilot
Environment Control and Life Support Systems Engineer
Environmental Physiologist
Environmental Protection Specialist
Environmental Specialist
Environmentalist
Exercise Physiologist
Exobiologist
Experiment Integration Engineer
Experiment Processing Engineer
Experiment Support Scientist/ Microbiology Coordinator
Experiment Systems Manager
Geophysicist
Hardware Engineer
Hardware Project Engineer
Hazardous Robotics Specialist
High-Energy Astrophysicist

HST Astronomer

Journalist

K–12 Outreach Support Personnel

Knowledge Engineer

Laboratory Manager

Lander Camera Support Personnel

Launch Site Support Office Personnel

Launch to Activation Procedures Lead

Lead Altimetry Analyst

Lead Mechanical Engineer

Lead Mechanical Technician

Lead Ops planner, Mission Operations Directorate

Lead Robotics and Avionics Engineer

Lead Schedule Integration Engineer

Lead Shuttle Systems Inspector

Lead, Space Station Power Resource Management Team

Leader of the Test Engineering Group

Life Science Space Experiment Ground Lab Logistics Coordinator

Life Science Specialist

Life Sciences Division Deputy Chief

Life Sciences Education Programs Coordinator

Life Sciences Outreach Office Personnel

Life Sciences Program Manager

Local Controller

Logistics Operations Manager

Magnetometer (MAG) Science Coordinator

Manager Mars Exploration Program Education

Manager of Mars Exploration Program

Manager, Galileo Administrative Office

Manager, Mars Sample Return Lander

Manager, Space Shuttle Office

Mars Atmosphere Interdisciplinary Scientist

Mars Exploration Program Architect

MARS Outreach Program Project Coordinator

Material Research Engineer

Materials Engineer

Materials Scientist

Mathematical Researcher

Mechanical Design Engineer

Mechanical Engineer

Mechanical Instrumentation Tech

Mechanical Systems Engineer

Mechanical Technician, Shuttle Systems

Microbial Ecologist

Mission Commander

Multimedia Education Specialist

Multimedia Specialist

National Research Council Post-Doctoral Fellow

National Science Foundation Representative, Palmer Station

Navigation Team Leader

Navigator

Network Engineer

Neurobiologist

Neuroscience Researcher

New Space Transportation Developer

NTSB/FAA Investigator

Numerical Software Engineer

Nutritionist

Observational Infrared Astronomer

Observing Assistant
Oceanographer
Operations Lead
Operations Management
Operations Servicing Mission
Operations, Rover
Optical Engineer, Rover
Orbital Debris Scientist
Orbital Engineering Team
Orbiter Operations Group Lead
Orbiter Processor
Orbiter Test Conductor
Ornithologist
Outreach Program Manager for Life Sciences
Outreach Specialist
Payload Project Manager
Payload Project Scientist
Photopolarimeter Radiometer Instrument Engineer
Photopolarimeter Radiometer Science Coordinator
Physicist
Physics Research Associate
Physiologist
Pictures/Remote Sensing Specialist
Pilot
Planetary Geologist
Planetary Scientist
Plasma Wave Assistant Science Coordinator
Power, Heating, Articulation, Lighting and Controls Officer
Principal Investigator
Principal Scientist
Probe Deputy Manager
Professor, Adventure Education
Program Manager
Program Planning Specialist
Program Scientist
Project Engineer
Project Engineer, Hardware Development
Project Engineer, Thermal Control
Project Manager
Project Scientist
Project Teacher
Propulsion Engineer
Psychophysiologist
Radio Astronomer
Real-Time Operations Lead
Research Instrument Maker
Research Assistant
Research Associate
Research Astrophysicist
Research Engineer
Research Engineer, Mechanical Systems
Research Nutritionist
Research Physicist
Research Pilot
Research Scientist
Science Instruments Specialist
Science Planning Coordinator
Sciences Requirements Manager
Scientific Director
Scientist
Senior Scientist
Senior Software Engineer
Senior Specialist Engineer
Senior Technical Trainer
Sequence Integration Engineer
Shuttle Project Engineering

Shuttle Structures and Transporters Engineer

Shuttle Test Director

Simulation Supervisor

Software Development Lead

Software Engineer

Software Operations Engineer

Software Safety and Mission Assurance Engineer

Solar Physicist

Solar Scientist

Space Farming Engineer

Space Flight Technician

Space Flight Training Specialist

Space Physicist

Space Physicist, Space Radiation Analysis

Space Physiology

Space Plasma Physicist

Space Scientist

Space Shuttle Crew

Space Shuttle Remote Manipulator System Training Instructor

Space Station Robotics Instructor

Space Station Utilization Division

Space Suit Project Engineer

Spacecraft Design Engineer

Spacecraft Systems Engineer

System Design Engineer

System Engineer/Integrator

System Safety Engineer

System Safety, Reliability & Quality Assurance Lead

Systems Engineer

Systems Management

Systems Verification

Teacher

Team Manager, ISS Mission Evaluation

Technical Advisor, Earth: Final Conflict Television Series

Technical Integration Engineer with Space Station

Technical Leader for Space Station Outreach Group

Technical Writer

Technician

Technology Transfer Specialist

Test Engineer

Test Project Engineer

Thermal Protection System/Shuttle Upgrades Specialist

Trajectory and Aerobraking Design Analyst

Trajectory Optimization Engineer

GLOSSARY

Amplitude: The strength of a signal.

Asteroid: A small rocky celestial body found between the orbits of Mars and Jupiter.

Astrobiology: The search for and study of life in space.

Bacteria: Single-celled or noncellular organisms that can only be seen with a microscope.

Bandwidth: The numerical difference between the upper and lower frequencies of a band of electromagnetic radiation, especially an assigned range of radio frequencies.

Big Bang: A theory about the origins of the universe.

Biosphere: Living things and their environment.

Black hole: A celestial object with such a strong gravitational field that even light cannot escape.

Celestial bodies: Planets, stars, comets, and moons.

Channels: Bands of frequency used for communication.

Concept: A scheme or plan.

Cosmic microwave background noise: Microwave radiation from outer-space, related to the Big Bang, stars, and planets.

East Pacific Rise: Mid-ocean ridge system extending from New Zealand to the coast of Mexico; a site of much volcanic and hydrothermal activity.

Electromagnetic spectrum: The entire range of wavelengths or frequencies of electromagnetic radiation, extending from gamma rays to the longest radio waves and including visible light.

Emission: Electromagnetic waves radiated by an antenna or a celestial body.

European Space Agency: Europe's space exploration program, which includes 16 European nations.

Evolution: A gradual process in which something changes into a different and usually more complex form.

Extrasolar: Outside the solar system.

Extraterrestrial: Originating, located, or occurring outside Earth or its atmosphere.

Frequencies: How often a wavelength completes a cycle over time.

Full Sky Survey: Telescope searches that include the full sky.

Gamma Rays: High energy, very short wavelength electromagnetic radiation that can be generated by nuclear reactions.

Gas-giant planets: Jupiter, Saturn, Uranus, and Neptune; gas giants are large planets made mostly of hydrogen and helium gas.

Geochemistry: Study of the chemical changes of the Earth.

Hubble Space Telescope (HST): Launched in 1990, HST was the first space-based optical telescope.

Huygens Space Probe: A spacecraft consisting of an orbiter and a probe, launched in 1997 and arrived at Saturn in 2004.

Hydrobots: Remote-controlled submarines that burrow into the ground to explore underground oceans on other planets.

Hydrothermal vents: Openings in a planet's surface where geothermally (heated underground) heated water emerges.

Infrared telescope: A telescope designed to detect radiation in the infrared range of the electromagnetic spectrum.

Interferometers: Devices that use interruptions in waves to determine distance or wavelength.

Interstellar gases: Gases that exist between or among the stars consisting mostly of helium and hydrogen.

Interstellar space: Space between the stars.

Ionosphere: Region of Earth's atmosphere at 50 to 300 miles (81–483 km) above the surface, dominated by electrically charged or ionized atoms.

Laser beacon: An instrument used in optical SETI; it emits a single powerful laser beam.

Magnetosphere: The magnetic field around a planet, located above the planet's top layer of atmosphere.

Microorganisms: Also called microbes; organisms too small to be seen without a microscope.

Micropaleontology: The study of microscopic fossils.

Microprocessor: A chip that carries the main logic programs of a computer; the central processing unit (CPU).

Microwave spectrum: Microwave part of electromagnetic spectrum, not visible to the human eye.

Mid-Atlantic ridge: A part of the mid-ocean ridge system that extends from north to south through the center of the Atlantic Ocean.

Milky Way: The galaxy in which our solar system is located.

Nebulae: Interstellar clouds of dust and gases.

Neutron star: A celestial object made up of tightly packed neutrons.

Optical SETI: The branch of extraterrestrial search that uses optical telescopes and laser beacons.

Orbit: The path taken by a celestial body during its revolution around another body.

Organic chemistry: The chemistry of carbon compounds, the basis of life on Earth.

Oscillation: Process of something swinging or moving regularly back and forth.

Parabolic: Bowl-shaped.

Particle accelerator: A device used by particle physicists to speed up particles.

Photometers: An instrument used for measuring the intensity of light.

Photomultipliers: A photoelectric instrument that amplifies electrons.

Photons: An amount of electromagnetic energy.

Photosynthesis: Process of plant respiration in which carbon dioxide is taken in and oxygen is released.

Planetariums: A building with a revolving projector that simulates the sun, moon, and stars.

Planetary climatology: The science dealing with climate on other planets.

Planetary debris: Small pieces of planetary material, broken into pieces by collisions.

Planetary radar: A process of detecting planets by using reflected radio waves.

Planetary systems: Planet or planets orbiting a star.

Plasma: A collection of charged particles that has about equal numbers of positive ions and electrons.

Prebiotic: The conditions before life began to form.

Protoplanetary: Early formation of a planet.

Pulsar: Celestial objects, thought to be rotating neutron stars, which emit electromagnetic radiation.

Quasars: Celestial objects that emit immense quantities of light and radio waves; thought to be ancient, exploding origins of new galaxies and possibly the most distant and oldest objects in the universe, which can be observed.

Radiation: Energy in the form of waves sent out through space.

Radio astronomy: The study of the universe with radio telescopes.

Red giants: Stars that have low surface temperatures and large diameters relative to the sun.

Rovers: Space vehicles equipped with sensitive instruments for scientific observation of planets and asteroids.

Satellites: A man-made object or moon revolving around a planet.

Signal processors: Instruments used for converting signals into other forms.

Sky coordinates: The system of keeping track of planets and stars in relation to Earth.

Solar system: Group of planets that orbit a star.

Space probes: An unmanned research space craft.

Star clusters: Groups of stars.

Star systems: Multiple stars orbiting around each other.

Supercomputers: Computers that operate many times faster than conventional systems, achieving the highest speeds of calculative work.

Supernova: The explosion of a star.

Surface geology: The study of a planetary surface.

Targeted Search: The search for extraterrestrial life technique that focuses on a few stars.

Tectonics: Branch of geology that studies the structure of the crust of the planet.

Terrestrial aeronomy: The science that deals with the physics and chemistry of the upper atmosphere.

Ultraviolet light (UV): a band of light in the electromagnetic spectrum.

Virtual: Existing in effect, but not in reality.

Wave guides: Devices used to direct the motion of electromagnetic waves.

Wavelength: The distance a light wave travels over time.

White dwarfs: Small hot stars of a mass about equal to that of the sun, but much denser.

X rays: Bands of electromagnetic radiation with wavelengths between gamma rays and ultraviolet rays.

BIBLIOGRAPHY

Echaore-McDavid, Susan. *Career Opportunities in Science*. New York: Checkmark Books, 2003.

Jackson, Ellen. *Looking for Life in the Universe: The Search for Extraterrestrial Intelligence*. New York: Houghton Mifflin, 2002.

Sagan, Carl. *Cosmos*. New York: Random House, 1980.

Spangenburg, Ray. *Artificial Satellites*. New York: Franklin Watts (Grolier Publishing), 2001.

U.S. Department of Labor and Bureau of Statistics. *Occupational Outlook Handbook.*

Websites

Astrobiology Now
www.astrobiology.com

Harvard SETI Home Page
http://seti.harvard.edu/seti/

NASA: Astrobiology
nai.arc.nasa.gov
astrobiology.arc.nasa.gov

NOVA: Hunt for Alien Worlds
www.pbs.org/wgbh/nova/worlds/

Physicists and Astronomers
www.bls.gov

The Planetary Society
www.planetary.org

The Search for Extraterrestrial Intelligence at UC Berkeley
http://seti.ssl.berkeley.edu/

SETI Institute Online
www.seti.org

The SETI League
www.setileague.org/

Sign up for SETI@home
www.pbs.org/wgbh/nova/sciencenow/involved/distrib.html

Jackson, Ellen. *Looking for Life in the Universe: The Search for Extraterrestrial Intelligence*. New York: Houghton Mifflin, 2002.

Jedicke, Peter. *SETI: The Search for Alien Intelligence*. Mankato, MN: Smart Apple Media, 2003.

Phillips, Cynthia. *The Everything Astronomy Book: Discover the Mysteries of the Universe*. Avon, MA: Adams Media Corporation, 2002.

Shostak, Seth. *Sharing the Universe*. Albany, CA: Berkeley Hills Books, 1998.

Websites

Astrobiology Now
www.astrobiology.com

NASA: Astrobiology
nai.arc.nasa.gov
astrobiology.arc.nasa.gov

The Search for Extraterrestrial Intelligence at UC Berkeley
http://seti.ssl.berkeley.edu/

SETI Institute Online
www.seti.org

The SETI League
www.setileague.org/

Sign up for SETI@home
www.pbs.org/wgbh/nova/sciencenow/involved/distrib.html

PICTURE CREDITS

page:

9: © Courtesy of NASA
11: © CORBIS
14: © Haruyoshi Yamaguchi/CORBIS
17: © Gary Koellhoffer
19: © Roger Ressmeyer/CORBIS
31: © CORBIS
37: © Roger Ressmeyer/CORBIS
41: © Lester Lefkowitz/CORBIS
46: © 1996 CORBIS; Original image courtesy of NASA/CORBIS
54: © Roger Ressmeyer/CORBIS
55: © Bettmann/CORBIS
56: © CORBIS/SYGMA
58: © Roger Ressmeyer/CORBIS

Cover: © Lester Lefkowitz/CORBIS

ABOUT THE AUTHOR

MARY FIRESTONE grew up in North Dakota. She lives in St. Paul, Minnesota, with her 11-year-old son, Adam, their pet beagle, Charlie, and cat, Rigley. She has a bachelor's degree in music from the University of Colorado at Boulder, and a master's degree in writing from Hamline University. When she isn't writing articles for magazines and newspapers and books for children, she enjoys gardening and spending time with her son.