Bibliography

Gatland, Kenneth. *Illustrated Encyclopedia of Space Technology.* New York: Harmony Books, 1981.

Plant, Malcolm. *Dictionary of Space.* New York: Longman Publishers, 1986.

Internet Resources

NASA Ames Research Center. <http://www.arc.nasa.gov/>.

SETI

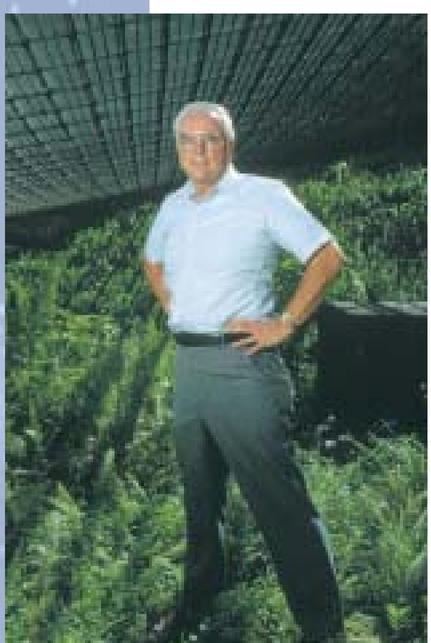
Of all the scientific efforts to find life in space, none has potential consequences as profound as SETI, the Search for Extraterrestrial Intelligence. SETI researchers are trying to uncover other civilizations whose technical sophistication is at a human level or higher.

While science fiction routinely describes face-to-face encounters with intelligent aliens, it may be that we will never actually meet extraterrestrials. Building fast rockets capable of carrying living cargo to the stars is a formidable, perhaps even impossible, challenge. The amount of energy required to hurl a craft the size of the space shuttle at even half the speed of light is enormous—equivalent to the energy required to keep New York City running for 10,000 years.✶ This is a problem of physics, not technology.

✶At half the speed of light, travel time to Alpha Centauri, the nearest star system, would take nine years.

On the other hand, there are ways to reach other civilizations without **interstellar** travel. In 1959 Philip Morrison and Giuseppe Cocconi, two physicists at Cornell University, made a simple calculation to determine how far away a good radio receiver and a large antenna could detect our most powerful military radar transmitters. To their surprise, the answer turned out to be light-years—typical of the distances to the stars. Morrison and Cocconi realized that while interstellar rocketry was hard, interstellar communication by radio was easy. They suggested that other galactic civilizations might be discovered by simply eavesdropping on their radio traffic.

interstellar between the stars



Frank Drake stands under the Arecibo radio telescope on October 12, 1992. Drake is one of the leaders in the Search for Extraterrestrial Intelligence (SETI).

The Search for Extraterrestrial Intelligence

Within months, Frank Drake, a young radio astronomer at the National Radio Astronomy Observatory in Green Bank, West Virginia, tried to do just that. He was unaware of the work of the two Cornell physicists but had independently thought of the same idea. For several weeks in the spring of 1960, Drake pointed an 85-foot antenna (a radio telescope) at two Sun-like stars, Tau Ceti and Epsilon Eridani, tuning his receiver up and down the dial near 1,420 megahertz (MHz). This particular frequency was chosen because it is truly a universal radio channel. Hydrogen gas, which drifts and swirls through the immense spaces between the stars, naturally emits some radio noise at 1,420 MHz. Drake believed that every sophisticated society in the cosmos would know of this hydrogen hiss, and consequently it would make sense to broadcast interstellar hailing signals near this sweet spot on the dial.

Drake's Project Ozma was the first modern SETI search. By the early twenty-first century, about seventy others were undertaken. One of the most ambitious was the NASA SETI program, which ultimately became known as the High Resolution Microwave Survey. NASA got into SETI slowly, beginning in the 1970s with a technical study of the equipment and strat-

egy required for a serious search. In the fall of 1992, sufficient equipment had been built to start the listening. However, very shortly thereafter, the U.S. Congress stopped all NASA SETI efforts. The rationale for canceling this research was to reduce federal spending during an era of large budget deficits.

The receiver for the Arecibo Radio Telescope in Puerto Rico requires three large poles to support its weight above the 305 meter (1,000 foot) dish. Scientists monitoring this telescope, which scrutinizes about 1,000 Sun-like stars less than 150 light-years distant, hope to find signs of intelligent extraterrestrial life.

SETI work continued, however, funded in the United States by private donations. Most of these projects have been radio experiments, of the type pioneered by Drake. The SETI Institute, in California, runs the most sensitive search, known as Project Phoenix. Various large radio telescopes, including the king-sized 305-meter (1,000-foot) antenna at Arecibo, Puerto Rico, have been used by Project Phoenix to carefully examine the neighborhoods of nearby, Sun-like stars. Other projects, such as the University of California, Berkeley's SERENDIP experiment, sweep the sky in an attempt to survey greater amounts of cosmic real estate. While more of the heavens are examined, the sensitivity in any given direction is lower. Some of the SERENDIP data have been distributed on the Web for processing at home with a screen saver program known as SETI@home.

Additional radio SETI experiments are being carried out in Australia (Southern SERENDIP), Argentina (META II), and Italy. Starting in the late twentieth century, another approach to SETI has gained a number of adherents: so-called optical SETI. Rather than tuning the dial in search of persistent, artificial signals, ordinary telescopes (with mirrors and lens) are outfitted with special detectors designed to find very short (less than a billionth of a second) laser pulses from distant worlds.

The Probability of Success

So far, no confirmed extraterrestrial signals—either radio or optical—have been found by SETI scientists. What are the chances that the aliens will *ever* be found? In 1961 Drake summarized the problem with a simple formula that predicts the number of galactic civilizations that are broadcasting now. Known as the Drake Equation, the computation is simply a product of factors bearing on the existence of intelligence. These factors include the number of galactic stars capable of supporting life, the fraction of such stars with planets, the number of planets in a solar system on which life evolves, the fraction of inhabited worlds where intelligence appears, and the lifetime of a broadcasting society. While we still do not know many of these factors, some scientists contend that the recent evidence for **extrasolar planets** and the growing suspicion that biology might be a common phenomenon have increased the chances for finding intelligence among the stars.

extrasolar planets planets orbiting stars other than the Sun

SETI scientists have made plans to greatly expand their search during the first two decades of the twenty-first century. The SETI Institute will build the Allen Telescope Array, a large grouping of small antennas that will be used for full-time searching. A world consortium of radio astronomers is considering the construction of a radio telescope a kilometer in size, a gargantuan instrument that could also be used for SETI. Optical SETI experiments are already increasing in number and sophistication.

In light of this rapid improvement in experimental technique, some scientists are optimistic that a signal will be found in the early decades of the twenty-first century. If so, the consequences would be dramatic. If we can ever successfully find and decode any message accompanying the signal, we might learn something of the knowledge and culture of other galactic beings, most likely from a society technologically far more advanced than our own. Even if we never understand or reply to an interstellar message, simply knowing that we are not the only "game" in town—let alone the most interesting game—would give us new and valuable perspective. SEE ALSO Extrasolar Planets (volume 2); Life in the Universe, Search for (volume 2); Why Human Exploration? (volume 3).

Seth Shostak

Bibliography

Cocconi, Giuseppe, and Philip Morrison. "Searching for Interstellar Communications." *Nature* 84 (1959):844.

Davies, Paul. *Are We Alone? Philosophical Implications of the Discovery of Extraterrestrial Life.* New York: Basic Books, 1996.

Dick, Steven. J. *Life on Other Worlds.* Cambridge, UK: Cambridge University Press, 1998.

Drake, Frank D., and Dava Sobel. *Is Anyone out There?* New York: Delacorte Press, 1992.

Goldsmith, Donald, and Tobias C. Owen. *The Search for Life in the Universe.* Reading, MA: Addison-Wesley, 1992.

Harrison, Albert. *After Contact: The Response to Extraterrestrial Life.* New York: Plenum, 1997.

Regis, Edward, Jr., ed. *Extraterrestrials: Science and Alien Intelligence.* Cambridge, UK: Cambridge University Press, 1985.

Shostak, Seth. *Sharing the Universe: Perspectives on Extraterrestrial Life.* Berkeley, CA: Berkeley Hills Books, 1998.

Shapley, Harlow

Astronomer
1885–1972

Harlow Shapley discovered that the solar system does not rest in the center of the Milky Way, but is actually located in the outer regions of the galaxy.

Cepheid variables a class of variable stars whose luminosity is related to their period; their periods can range from a few hours to about 100 days—the longer the period, the brighter the star

globular clusters roughly spherical collections of hundreds of thousands of old stars found in galactic haloes

Harlow Shapley was born on November 2, 1885, in Nashville, Missouri. He worked for a newspaper in Kansas and later attended the University of Missouri, intending to study journalism, but taking up astronomy instead. In 1911 Shapley went to Princeton University, where he worked with Henry Norris Russell on eclipsing binary stars. After completing his doctoral thesis, Shapley began work at Mt. Wilson Observatory in California in 1914, where he studied **Cepheid variables**. Brighter Cepheids have longer periods, and Shapley was able to determine the distances to faint Cepheids and show that the Milky Way galaxy was far larger than previously believed.

Shapley's most important contribution to astronomy was to note that the **globular clusters** were concentrated toward the constellation Sagittarius, and he made the correct assumption that the center of this concentration marked the center of the Milky Way. He thus moved the universe from a Copernican Sun-centered system to a Sun located far from the galactic center in one of the spiral arms.

On April 20, 1920, a famous debate was held between Shapley and fellow astronomer Heber Curtis on the subject of "The Scale of the Universe." Curtis was correct in arguing that spiral nebulae were galaxies like our own but incorrect in placing the Sun at the center of the Milky Way. Shapley was correct in placing the Sun far from the center of the Milky Way but incorrect in saying the spiral nebulae were nearby gas clouds.

In 1920 Shapley was offered the directorship of the Harvard College Observatory, where he stayed for the rest of his career. He died in Boulder, Colorado, on October 20, 1972. Shapley's legacy as a popularizer of astronomy is maintained by the American Astronomical Society's Harlow Shapley Visiting Lectureships Program, which sends astronomers on two-day visits to universities and colleges in the United States, Canada, and Mexico. SEE ALSO Astronomy, History of (volume 2); Copernicus, Nicholas (volume 2); Galaxies (volume 2); Stars (volume 2).

A. G. Davis Philip

Bibliography

Grindlay, Jonathan E. and A. G. Davis Philip, eds. *The Harlow Shapley Symposium on Globular Cluster Systems*, IAU Symposium No. 126. London, UK: Kluwer, 1988.

Shapley, Harlow. *The View from a Distant Star.* New York: Basic Books, 1963.

Shoemaker, Eugene

American Astrogeologist
1928–1997

Eugene Merle Shoemaker was instrumental in establishing the discipline of planetary geology. He founded the U.S. Geological Survey's Branch of