BIOGRAPHICAL MEMOIRS

Frank D. Drake

May 28, 1930–September 2, 2022
Elected to the NAS, 1972

A Biographical Memoir by Kenneth Kellermann

Figure 1 Frank D. Drake. *Photo by Seth Shostak/SETI Institute.*

Although Frank Drake is probably best known for his career-long leadership in the search for extraterrestrial intelligent life (SETI), he was one of the first of a new generation of American radio astronomers. During a career that lasted for more than half a century, Drake made broad contributions to astronomy and astrophysics in fields ranging from planetary to galactic research as well as introducing new instruments and techniques for radio astronomy. He served on the important science policy bodies of the National Academy of Sciences (NAS), the National Aeronautics and Space Administration (NASA), and many other government and private organizations. Frank Drake was elected to the National Academy of Sciences in 1972 and at the time was only the third radio astronomer to be so honored.

Early Years

Frank Donald Drake was born on May 28, 1930, in Chicago and grew up in the South Shore section of the city. His father, Richard Carvel Drake, worked for the city of Chicago as a chemical engineer, and Frank proudly described his mother, Winifred Pearl Thompson, as a "housewife and a mother."[1] Like many young boys of that era, Frank developed an early interest in science, ranging from astronomy to chemistry and radio. He was a frequent visitor to the Chicago Museum of Science and Industry and as a teenager built several small optical telescopes. After receiving his bachelor's degree in engineering physics (with honors) from Cornell University in 1952 under an ROTC U.S. Navy scholarship, Frank spent three years in the Navy as an electronics officer on the heavy cruiser *U.S.S. Albany,* gaining important experience that would serve him well as a radio astronomer. Also during his tenure in the Navy, Frank received training in cryptography, which apparently inspired his later interest in decoding a message from some non-human civilization. He then enrolled in graduate school at Harvard University, where he was influenced by Bart Bok, Harold "Doc" Ewen, and Thomas Gold. Frank was immediately called upon to exploit his electronic skills to support the operation of the new 60-foot radio telescope at the Harvard College Observatory's Agassiz Station.

Frank received his Ph.D. from Harvard in 1958 using the new 60-foot radio telescope to search for 21-centimeter radio emissions from neutral hydrogen in galactic star clusters.[2] But he later lamented that the sensitivity was inadequate to make a significant detection of the hydrogen surrounding star clusters. He did succeed, however, in making the first radio images of the optically obscured galactic massive star-forming complex known as Cygnus X and showed that Cygnus X consisted of a number of discrete regions of ionized hydrogen.[3]

While still a graduate student, Frank went to work part time for Doc Ewen's fledging electronics firm as Head of the [one man!] Astronomical Research Group to help develop a radio sextant at a salary that he described as "an absolute fortune" compared with what he was being paid by Harvard as a graduate student. Drake and Ewen used the broadband traveling-wave tube 8 GHz radiometer that they had developed for the radio sextant to make the first detection of the thermal radio emission from the planet Saturn.[4]

In 1952, Frank married Elizabeth Proctor Bell, who was an accomplished musical composer. They had three sons, Paul, who became a photographer, Stephen, and Richard, who both became musicians. The couple divorced in 1976. In 1978, Frank married Amahl Shakhashiri, whom he had met when she was working at the NAS. Frank and Amahl had two daughters, Nadia, a science writer, and Leila, a ballet dancer. By age thirty, Frank's hair had turned white, and he delighted in pointing out that this made him look distinguished. Throughout his life, Frank enjoyed rock hunting and was a very knowledgeable gemologist and maker of fine jewelry, specializing in opals.

NRAO, JPL, and Cornell (Arecibo)

In 1958, Frank accepted the invitation of his former fellow Harvard graduate student David Heeschen to join the scientific staff of the new National Radio Astronomy Observatory (NRAO) in Green Bank, West Virginia. As Drake later related, "the only people there were Dave and John Findlay, one secretary, one technician and me."

As one of the first members of the NRAO scientific staff, Drake led the planning for the scientific programs on the 140-foot radio telescope then under construction in Green Bank. He quickly rose to be the NRAO Head of Telescope Operations and Scientific Services where he introduced the then-new concept of professional telescope operators to control the operation of the NRAO telescopes, allowing the scientists to concentrate on taking and interpreting the data. He also oversaw the development of what was probably the first digital computer system used in astronomy to record data output from the telescope.

Drake was also one of the first astronomers to appreciate the potential rewards of pushing radio astronomy to millimeter wavelengths. He hired Frank Low from Texas Instruments to come to Green Bank to develop bolometers for use at short-millimeter wavelengths. With only a few paragraphs of justification, he boldly added $600,000 dollars to the 1964 NRAO budget proposal to construct a millimeter wave radio telescope. This led to the construction of the 36-foot (later modified to 12-meter) radio telescope on Kitt Peak, Arizona, which played such an important role in the discovery of the rich population of interstellar molecules and the development of the new field of interstellar chemistry.

While at NRAO, Drake used the 85-foot Tatel radio telescope for his pioneering studies of planetary radio emission. These included his measurement of the extraordinarily high surface temperature of Venus, which he found surprisingly large, even on the nighttime side of the planet. His research provided the first evidence of the dense atmosphere of Venus that produced an atmospheric greenhouse effect. His radio observations also showed the retrograde rotation of Venus, later confirmed by planetary radar measurements.[5,6] Together with NRAO engineer Hein Hvatum, Drake also observed the anomalous strong nonthermal radio emission from the planet Jupiter, which he correctly interpreted as coming from radiation belts analogous to the recently discovered Earth's Van Allen belts.[7] In a separate investigation, Frank made the first high-resolution study of the radio emission from the optically obscured Galactic Center and showed that it was resolved into multiple thermal and nonthermal components.[8]

In 1963, Frank wrote an important review for the *Proceedings of the National Academy of Sciences* of the status of radio astronomy with some insightful reflections on the future development of this new field in the United States.[9] But with his family unhappy with the limited opportunities of living in rural West Virginia, in 1963 Frank accepted a position at the NASA Jet Propulsion Laboratory (JPL) in Pasadena as Chief of Lunar and Planetary Science and moved with his family to California.

Frustrated with the bureaucracy and lack of research opportunities at a NASA laboratory, in 1964 Frank accepted a position on the faculty at Cornell University, where he later became the Goldwin-Smith Professor of Astronomy and Head of the Cornell Astronomy Department. His captivating graduate course in radio astronomy attracted many students, several of whom went on to distinguished careers themselves in radio astronomy. Two years later, he became director of the Arecibo Observatory in Puerto Rico and, in 1971, the first director of Cornell's new National Astronomy and Ionospheric Center in Puerto Rico. While living in Puerto Rico, Frank enjoyed driving his Triumph sport car on the challenging dirt roads between his home and the observatory. As the giant 1,000-foot Arecibo dish had been designed primarily to operate at 430 MHz (68 centimeters) for ionospheric and

planetary radar, it had only limited capability for operation at the shorter wavelengths of interest to radio astronomy. Frank recognized the potential scientific impact of the Arecibo radio telescope if it could be made to work at shorter wavelengths and initiated a major upgrade of the facility to replace the wire mesh surface with 38,778 aluminum panels and to better stabilize the surface and feed platform. These improvements resulted in an order of magnitude increase in operating frequency.

Following the discovery of pulsars by Jocelyn Bell and Anthony Hewish in Cambridge in 1968,[10] Frank, together with a succession of students, began an intensive series of observational studies with the Arecibo radio telescope that led to a better understanding of these enigmatic rapidly rotating neutron stars. In particular, with the great sensitivity of the Arecibo telescope, they were able to resolve individual pulses into a set of shorter sub-pulses that they showed were related to periodic structures in the magnetospheres of the spinning neutron stars.[11]

Project Ozma and the Search for Extraterrestrial Intelligence (SETI)

Since childhood, Frank had been fascinated by the possibility of life on other worlds. While still a Cornell undergraduate, he took an elementary astronomy course and was enthralled by the lectures of visiting astronomer Otto Struve, later to be his boss at NRAO. Soon after Frank arrived at NRAO, he initiated the first "search for an extraterrestrial intelligence" (SETI) investigation in modern times and became the first person to search for radio signals from other civilizations. Frank named his investigation Project Ozma after the princess in L. Frank Baum's story *Ozma of Oz,* as Frank later related, because he "was dreaming of a land far away peopled by strange and exotic beings."[12]

Although his brief search for artificial radio transmissions from the nearby stars Tau Ceti and Epsilon Eridani was not successful, it set the stage for hundreds of (also unsuccessful) subsequent SETI programs made with ever increasing sensitivity. Soon after completing Project Ozma, Drake convened a small, invitation-only conference in Green Bank, co-sponsored by the NAS to discuss extraterrestrial intelligent life. In preparation for the conference, Frank developed his now famous Drake equation to estimate the number, N, of communicative extraterrestrial civilizations in the Milky Way Galaxy that might be detectable:

$$N = R_* f_p n_e f_l f_i f_c L,$$

where R_* is the mean rate of star formation over galactic history; f_p is the fraction of stars with planetary systems; n_e is the number of planets per planetary system with conditions

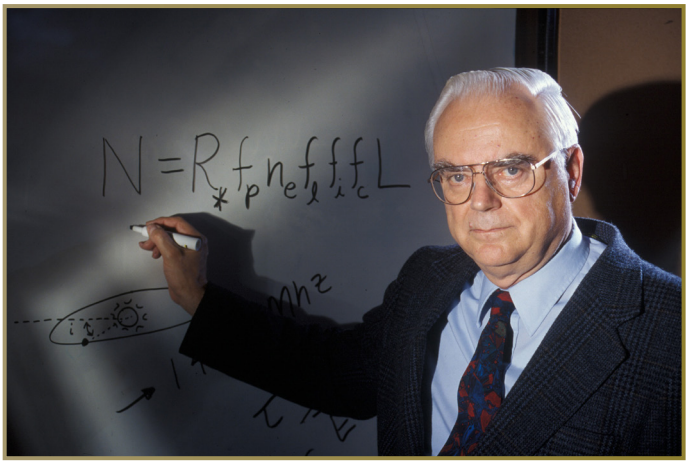

Figure 2 Frank Drake displaying his eponymous Drake Equation.

ecologically suitable for the origin and evolution of life; f_l is the fraction of suitable planets on which life originates and evolves to more complex forms; f_i is the fraction of life-bearing planets with intelligence possessed of manipulative capabilities; f_c is the fraction of planets with intelligence that develops a technological phase during which there is the capability for and interest in interstellar communication; and L is the mean lifetime of the technology.

For more than sixty years, the eponymous Drake Equation has served as the framework for nearly all discussions of the existence of extraterrestrial civilizations.[13] With the twenty-first-century discovery of the multitude of extrasolar planets, and the better understanding for the conditions necessary for the formation of life, there has been increased focus and concern about the factor L, the lifetime of the technological civilization. Some researchers have speculated whether the lack of success from more than half a century of sophisticated sensitive SETI investigations implies that L is short, owing possibly to nuclear or environmental self-destruction or to the ravages of pandemic disease. Frank, however, argued that that our galaxy probably contains thousands of advanced civilizations. For decades, he optimistically predicted that success was only twenty years away but never lost faith, arguing that we have not yet looked long enough or hard enough.

Over more than half century, Frank remained the acknowledged world leader in the quest to search for other intelligent civilizations. He published dozens of technical and popular articles on SETI, participated and chaired many studies and workshops aimed to define the optimum strategies for SETI, and was a sought-after lecturer who appeared in both national and international media and documentaries.

In 1971, together with Carl Sagan, Frank organized the First Joint Soviet-American Symposium on Communication with Extraterrestrial Intelligence held in Byurakan, Armenia.

Figure 3 Frank Drake (right) and the author (left) taken in July 2019 during an astrobiology conference held in Green Bank. The setting is the room, now known as the "Drake Lounge," where Drake first presented his 1961 Drake equation, shown on the memorial plaque in the background.

Co-sponsored by the NAS and the Soviet Academy of Science, the symposium brought together a unique collection of astrophysicists, radio astronomers, physicists, chemists, biologists, linguists, anthropologists, and historians to discuss the wide-ranging technical, scientific, social, legal, and moral implications of successful communication with an extraterrestrial civilization. In 1974, he initiated the first serious attempt to send a message from the Earth to another civilization. Using a half-megawatt transmitter on the 1,000-foot Arecibo dish, he beamed a crude 73x23 pixel image in the direction of the globular cluster M13 at a distance of 25,000 light years. Although what became known as the "Arecibo Message" would take at least 50,000 years to generate a return message, and, of course, much longer to have an actual extraterrestrial expedition visit the Earth, the initiative was not without criticism from those who feared that the extraterrestrials might come with aggressive intentions to the terrestrial civilization, or what might be left of our civilization at this distant time. Frank responded that "hostile tribes bent on war [would first] destroy themselves with their own weapons," and so only peaceful ones would survive.[14] Earlier, Drake and Sagan, together with Sagan's then wife, Linda Salzman, designed the plaques depicting life on Earth that were sent aboard the Pioneer 10 and 11 spacecraft beyond the Solar System to interstellar space. Frank's innovative map of the Milky Way, based on the position of fourteen pulsars, conveyed the location of the Earth within the Milky Way Galaxy.

In 1984, Frank moved to California to become dean of the Division of Natural Sciences and Professor of Astronomy and Astrophysics at the University of California, Santa Cruz, where he oversaw the science and engineering programs, continued to teach astronomy classes, and maintained his active involvement in the SETI program at NASA's Ames Research Center. He chaired the NASA SETI Working Group Report intended to formulate a national strategy for SETI research, and when NASA was no longer able to actively search for extraterrestrial intelligence, he became the president of the new non-profit SETI Institute's board of trustees and later the Institute's director of the Carl Sagan Center for Research. Drake died on September 2, 2022, at his home in Aptos, California, at the age of ninety-two.

Memberships and Other Activities

Over the course of his long and varied career, Drake served on many national science policy committees including as the chair of NAS/NRC Board on Physics and Astronomy, as well as on other NAS, NRC, National Science Foundation (NSF), and NASA committees. He was president of the Astronomical Society of the Pacific and a vice-president and chair of the Astronomy Section of the American Association for the Advancement of Science. He was also a member of the American Astronomical Society (AAS), which awarded him its 2001 Education Prize, and he served as the chair of the AAS Division of Planetary Astronomy. He was a member of the Institute of Radio Engineers and the Explorers Club and a fellow of the British Interplanetary Society and the American Academy of Arts and Sciences. He was active in the International Union of Radio Science (URSI) and served as president of the IAU's Commission 51 on Bioastronomy and the Search for Extraterrestrial Life. Early in his career, he was a member of the Pierce Committee convened by the NSF to study the needs of U.S. radio astronomy and later was a member of the first NAS decadal (Whitford) Committee and the NAS Greenstein and Field Committees and their panels to establish priorities for ground-based astronomy. Late in his life, he served on the advisory board of the Breakthrough Listen project, which uses essentially all of the world's large radio telescopes to search for radio signals from an intelligent extraterrestrial civilization. Drake also served on a number of editorial boards, including those of the *World Book Encyclopedia, Science Year*, and the *Astrophysical Journal.*

Acknowledgments

I thank Ellen Bouton, Don Campbell, Jim Cordes, Bill Diamond, Lindarae Polaha, Seth Shostack, Jill Tarter, and Virginia Trimble who all kindly provided valuable material used

to prepare this memoir. Additional information on Frank's life came from material housed at the NRAO/AUI Archives.[15,16]

References

1 Drake, F. D., and D. Sobel. 1992. *Is Anyone Out there?* New York: Delacorte Press, p. 3

2 Drake, F. D. 1958. *Neutral hydrogen in galactic clusters*. Ph.D. thesis, Harvard University, Cambridge, Massachusetts.

3 Drake, F. D. 1959a. On the nature of the composite radio source Cygnus X. In: *Paris Symposium on Radio Astronomy*, ed. R. Bracewell, pp. 339–346. Stanford, Calif.: Stanford University Press.

4 Drake, F. D., and H. I. Ewen. 1958. A broad-band microwave source comparison radiometer for advanced research in radio astronomy. *Proc. Inst. Radio Eng.* 46:53–66.

5 Drake, F. D. 1962. 10-cm observations of Venus near superior conjunction. *Nature* 195:894.

6 Drake, F. D. 1964. Microwave observations of Venus, 1962-1963. *Astron. J.* 69:62–64.

7 Drake, F. D., and S. (sic) [H] Hvatum. 1959. Non-thermal microwave radiation from Jupiter. *Astron. J.* 645:329–330.

8 Drake, F. D. 1959b. Radio resolution of the galactic nucleus. *Sky & Telescope* 18:428–429.

9 Drake, F. D. 1963. A review of the history, present status, and course of American radio astronomy. *Proc. Natl. Acad. Sci. U.S.A.* 49(6):759–766.

10 Hewish, A., et al. 1968. Observation of a rapidly pulsating radio source. *Nature* 217:709–713.

11 Drake, F. D., and H. D. Craft. 1968. Second periodic pulsation in pulsars. *Nature* 220:231–235.

12 Drake, F. D., and D. Sobel. 1992, p. 27.

13 Vakoch, D. A., and M. F. Dowd, eds. 2015. *The Drake Equation.* Cambridge, U.K.: Cambridge University Press.

14 Drake, F. D., and D. Sobel. 1992, p. 185.

15 F. Drake, interview by W. T. Sullivan at URSI Meeting, Helsinki, Finland, August 7, 1978, Papers of W. T. Sullivan III, NRAO/AUI Archives, Charlottesville, Virginia.

16 F. Drake, interview by W. T. Sullivan at Cornell University, New York, April 27, 1979, Papers of W. T. Sullivan III, NRAO/AUI Archives, Charlottesville, Virginia.

Selected Bibliography

1959 Radio resolution of the galactic nucleus. *Sky & Telescope* 18:428–429.

1959 With S. (sic) [H] Hvatum. Non-thermal microwave radiation from Jupiter. *Astron. J.* 645:329–330.

1962 With H. D. Craft. *Intelligent Life in Space.* New York: MacMillan.

1962 10-cm observations of Venus near superior conjunction. *Nature* 195:894.

1965 With A. Kliore et al. Occultation experiment: Results of the first direct measurement of Mars's atmosphere and ionosphere. *Science* 149:1243–1248.

1968 With H. D. Craft. Second periodic pulsation in pulsars. *Nature* 220:231–235.

1968 With H. D. Craft and J. M. Comella. Submillisecond radio intensity variations in pulsars. *Nature* 218:1122–1124.

1972 With C. Sagan and L. S. Sagan. A message from the Earth. *Science* 175:881–884.

1973 Interstellar radio communication and the frequency selection problem. *Nature* 245:257–258

1975 With C. Sagan. The search for extraterrestrial intelligence. *Sci. Am.* 232(5):80–89.

1992 With D. Sobel. *Is Anyone Out there?* New York: Delacorte Press.

2013 Reflections on the equation. *Int. J. Astrobiol*. 12(3):173–176.