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Frank Drake "The Father of SETI", May 28, 1930 to September 2, 2022

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Frank Drake was a hero, a legend, an icon. His eponymous Drake Equation was the catalyst for SETI—the search for extraterrestrial intelligence—and is often called the second most famous equation in physics, right up there with $E = mc^2$. His name is recognized by high school students—in a pantheon that includes luminaries such as Newton, Einstein, Gauss, Maxwell, Planck, Boltzmann . . .

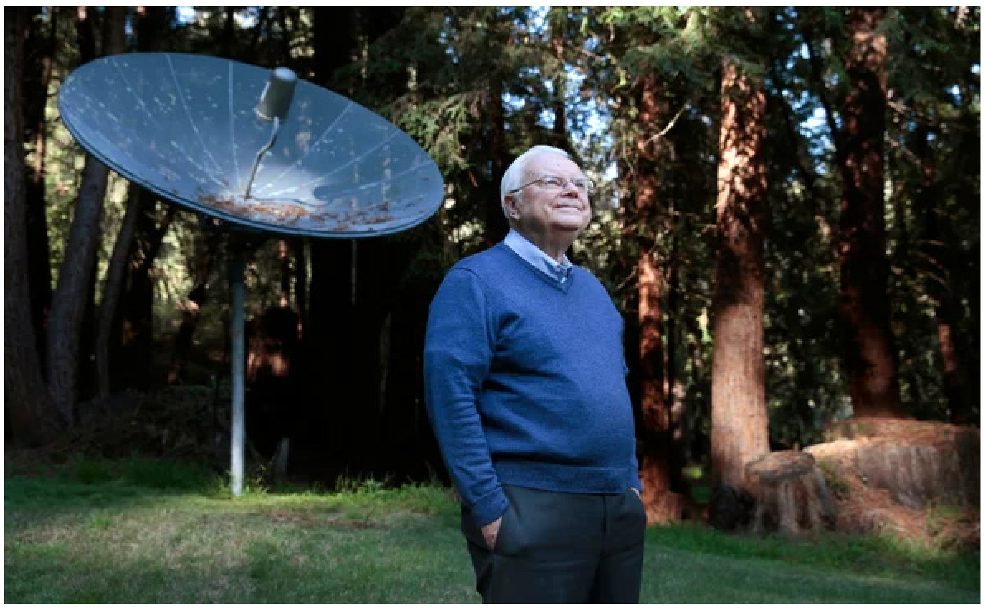

Figure 1. Frank Drake, founder of the search for extraterrestrial intelligence (SETI), poses for a portrait at his home in Aptos, Calif., on February 27, 2015. Photo credit: Ramin Rahimian for the *Washington Post* via Getty Images

I was, in fact, in high school when I first learned of the Drake Equation. "Are you any relation to . . . ?" No, I'm afraid not . . . "Drake" is not a very unusual name, but it's not so common either. Perhaps because of this, I have always felt some sort of tenuous connection with other Drakes. Being an astrophysicist myself, I felt this with Frank Drake even more so, though I never met him personally. The closest I got was an email exchange in the mid-1990s when I invited him to give a seminar at the University of California, Berkeley, where I was working at the time. He was a professor and dean at the University of California, Santa Cruz, and unfortunately too booked up to make it.

Drake came up with his equation in 1961 to serve as a loose agenda for a now-fabled meeting he hosted at the National Radio Astronomy Observatory (NRAO) in Greenbank, Virginia. The purpose of the meeting was to bring together top scientists in relevant fields of research, such as astrophysics, biochemistry, chemistry, and biology, to quantify the chances of SETI successfully detecting intelligent life beyond Earth. Among the dozen or so attendees were three Nobel Prize winners—Melvin Calvin was actually informed of his Nobel Prize in Chemistry during the meeting—and one young planetary scientist named Carl Sagan who would become a lifelong friend and colleague.

Drake, only three years on from his PhD, had brought SETI from a taboo subject prone to ridicule to one of serious scientific study.

Frank Donald Drake was born in Chicago in 1930 and was the oldest of three siblings. His mother was a music teacher, and his father a chemical engineer whom she met when they were students at the University of Illinois. The young Drake became interested in science while still a child, frequently cycling to Chicago's Museum of Science & Industry, and later dabbling with chemistry and making radios with friends. One of the exhibits at the museum that made an impression on the young Frank Drake was of our Milky Way galaxy, showing that our Sun is only an average star among billions. His interest in astronomy kindled, in his teens he constructed a telescope in the basement of the Drake residence.

At age 17, Drake took up a Naval Reserve Officer Training Corps scholarship to study at Cornell, earning a bachelor's degree in engineering physics in 1952. It was there that his interest in extraterrestrial life began after attending a lecture course on planetary system formation by renowned astronomer Otto Struve. Struve was one of the few professional astronomers of the time who promoted the idea that intelligent life was common in the Universe.

From 1952 to 1955, Drake was an electronics officer in the U.S. Navy, serving briefly on the Sixth Fleet's flagship heavy cruiser *USS Albany*. He then studied for a PhD at Harvard University under the supervision of the great Cecilia Payne-Gaposhkin, the pioneering spectroscopist who first worked out that stars—and the Universe—are primarily composed of hydrogen and helium. Drake graduated in 1958 with a thesis titled "Neutral Hydrogen in Galactic Clusters" looking at the 21 cm line of hydrogen that results from the spin flip of its electron to learn more about how star clusters form.

A PhD at Harvard in the newly emerging field of radio astronomy would have been a natural scientific choice for Drake. The 21 cm line had been predicted only 10 years earlier by Dutch astronomer and mathematician Hendrik van der Hulst and was first detected by Harvard scientists in 1951. Bart Bok, the astronomy department chairman at the time, was also keen to employ Drake's electrical skills for maintaining and developing equipment. Drake became one of the first PhDs in radio astronomy and in 1958 was well placed to take up a position of staff astronomer and head of telescope operations at the recently commissioned NRAO at Green Bank, West Virginia.

Drake would stay at NRAO for the next 5 years, publishing several important papers on the radio emission from planets. He was among the first to discover the radiation belts of Jupiter, and the high surface temperature of Venus—nearly 500 °C—and realize this was due to the atmospheric greenhouse effect. Drake summarized this work in a 1961 *Physics Today* article (Drake, 1961a, p. 30) and later wrote a review of planetary radio astronomy for the *Proceedings of the National Academy of Sciences* (Drake, 1963). This research was seminal in radio astronomy, but it was not this work for which Drake would become an almost household name.

Otto Struve had become the NRAO director in the summer of 1959 and enthusiastically endorsed an audacious proposal by Frank Drake to use a radio telescope to search for signals from intelligent life on planets around other stars. Drake named it Project Ozma, after the L. Frank Baum character Princess Ozma, ruler of the land of Oz. It used the newly built 85-ft. Howard E. Tatal Telescope that Drake tuned to observe in frequencies around 1420 MHz, close to the 21 cm line of hydrogen, reasoning that it would be an obvious choice for a civilization aiming to make radio contact with other technologically advanced worlds looking out into space. He spent a total of 150 hours over several weeks in the spring of 1960 pointing the telescope alternately at the two nearest northern hemisphere solar-type stars to us, τ Ceti and ε Eridani, but no signals were found. Drake described Project Ozma and the reasoning behind it in another *Physics Today* article in 1961 (Drake, 1961b, p. 40).

The subject of intelligent life beyond Earth was considered somewhat renegade by the astronomical community at the time, and Drake and Struve had originally intended to keep the project secret. Drake changed his mind when he became aware of a paper published in *Nature* by Cornell University scientists Giuseppe Cocconi and Philip Morrison titled "Searching for Interstellar Communications" (Cocconi & Morrison, 1959). Cocconi and Morrison reasoned that extraterrestrial intelligence would likely attempt to communicate with other planetary systems at radio wavelengths that can penetrate the gas and dust in the Milky Way—precisely what Drake had planned to look for. The publication prompted Drake to make Project Ozma known to the press and it subsequently garnered significant worldwide public attention. Peter Pearman, a biologist on the Space Science Board of the NAS, also took note. Despite the null result, Pearman was excited about Project Ozma and asked Drake to organize the now-famous meeting at Greenbank.

Figure 2. Frank Drake in front of the NRAO 85-foot Howard E. Tatel telescope that he used for Project Ozma. Image credit: NRAO/AUI/NSF.

Drake found he "could reduce the whole agenda for the meeting to a single line" (Drake & Sobel, 1992). That line was

$$N = R_{\star} f_p n_e f_l f_i f_c L.$$

Now widespread in popular culture, the Drake Equation can be found on T-shirts, mugs, the sides of boats, wall hangings, and countless other media. It is a simple multiplication of factors, but it cleanly encapsulates the relevant variables and splits the problem into its constituent parts. The point of the equation is to provide an estimate for N, the number of detectable civilizations in space. The answer is the product of $R_{\star}$, the star formation rate, f_p, the fraction of stars with planets, n_e, the average number of planets per stellar system with conditions suitable for life, f_l, the fraction of those planets on which life emerges, f_i, the fraction of life-hosting planets that develop intelligent civilizations, f_c, the fraction of intelligent civilizations that develop technology to generate signals or emission we can detect, and L, the length of time the civilization remains detectable.

During each session of the Greenbank meeting, a different factor of the equation was examined. Of these factors, $R_{\star}$, f_p, and n_e can, at least in principle, be measured. But at the time of the meeting only the star formation rate was known. That number for the Milky Way has been honed over the years and stands at about 2 solar masses per year. Thanks to the remarkable exoplanet discoveries in the last decade by missions such as *Kepler* and *TESS*, the fraction of Sun-like stars with habitable planets is known to be about 50%. This equates to approximately 4 potentially habitable planets around Sun-like stars within the nearest 30 light years and two billion or so in the Milky Way galaxy. Extending this to the lower mass M dwarf stars increases that number by an order of magnitude. Although they could not have been sure of their guesses, the values for $R_{\star}$, f_p, and n_e adopted by Drake and colleagues at the Greenbank meeting are within a factor of 2 or so of those estimated today.

It is the remaining factors that are more controversial and unconstrained. The Greenbank meeting consensus was that every habitable planet would develop intelligent life and that 10–20% of those would communicate, with the result that $N \approx L$, with L in years. Drake himself favored a value of 10,000 years, implying that there are approximately 10,000 civilizations in the Galaxy with detectable transmissions.

That was the birth of SETI. Drake was made president of the SETI Institute when it was finally founded in 1984 and would be an enthusiastic supporter and contributor for the rest of his life.

Drake eventually moved on from NRAO to become the chief of the Lunar and Planetary Science section of the Jet Propulsion Laboratory in California in 1963. Unhappy with the bureaucratic load, he soon relocated to Cornell University, taking up a faculty position in 1964. He would spend the next two decades at Cornell, gaining promotion to Goldwin Smith Professor of Astronomy in 1976. Between 1966 and 1968, Drake worked in Puerto Rico as director of Cornell's giant Arecibo radio telescope—the world's largest single-aperture telescope at the time. From 1971 to 1981, he was director of the National Astronomy and Ionosphere Center at Cornell, where he continued his oversight of Arecibo and supervised upgrades to the dish's surface and instrumentation.

The years 1972 and 1973 saw the launches of the NASA Pioneer 10 and 11 probes to study the asteroid belt, Jupiter, and Saturn. Each carried a special 9" x 6" plaque made of gold-anodized aluminium engraved to a design by Drake, Carl Sagan, and Linda Salzman Sagan. The design featured human male and female figures, together with various symbols depicting the 21 cm transition in hydrogen, the solar system, the position of the Sun relative to fourteen different radio pulsars and the Galactic Center, and an outline of the Pioneer spacecraft.

In 1974, Drake used the Arecibo telescope to make the first attempt at communicating with extraterrestrial civilizations. This became known as the "Arecibo message" and was beamed toward the M13 globular cluster 22,000 light years distant. It contained encoded data including the Earth's position in the Solar System, and information on the human race and DNA. This was followed in 1976 with design work to develop the "Voyager Golden Record" with a panel chaired by Carl Sagan. The Golden Record, made of gold-plated copper, was flown on both Voyager 1 and 2 missions to the outer Solar System and was the next step after the Pioneer plaque. It included audio recordings and analogue-encoded pictures that could be retrieved by playing the disc like a vinyl record. The record was encased in aluminium that included a sample of uranium-238. This isotope has a half-life of 4.5 billion years, and the idea was that its decay products could be used to determine the age of the spacecraft if it were ever found in the distant future.

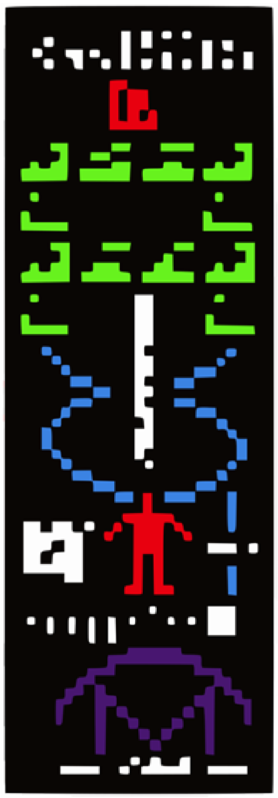

Figure 3. The binary code "Arecibo Message" beamed toward the globular cluster Messier 13 at a ceremony for the remodeling of the Puerto Rico Arecibo Telescope on November 16, 1974. Image credit: SETI Institute.

Frank Drake moved from Cornell in 1984 to become a professor of astronomy and Dean of the Division of Natural Sciences at the University of California, Santa Cruz. It was there he took up the position of President of the SETI Institute. When US Congress cut the funding for SETI in 1992, Drake worked tirelessly to help attract

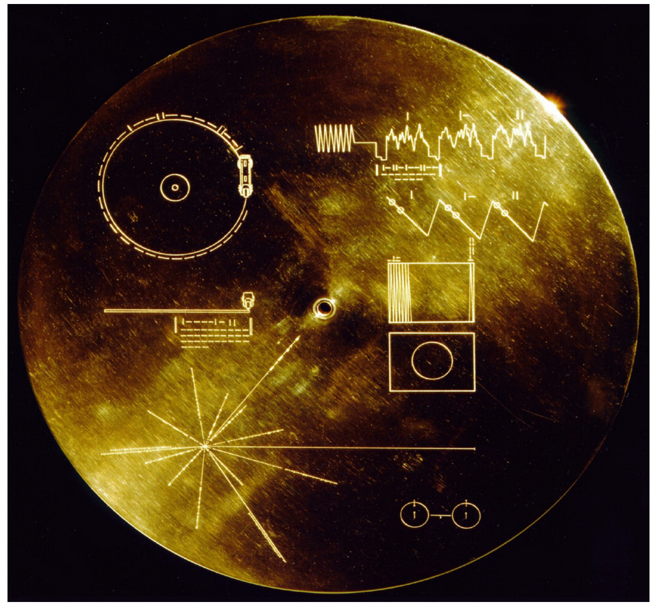

Figure 4. The Voyager "Golden Record" designed by a panel chaired by Carl Sagan that included Frank Drake. Image credit: NASA.

private funding that enabled work to continue. He retired from teaching duties in 1996, but continued working in astrophysics and on the Board of Trustees of the SETI Institute. He was on the advisory board as Chair Emeritus of the Breakthrough Listen project. Begun in 2016, Breakthrough Listen uses Green Bank and Parkes (in Australia) radio telescopes, together with laser detection at the University of California's Lick Observatory, to search for signals from one million nearby stars and one hundred galaxies—by far the most comprehensive search for alien signals to date.

In his spare time, Frank Drake enjoyed lapidary work, the cultivation of orchids, and making red wine. By all accounts, he was a very modest, kind, and patient man, much loved by his family, and always ready to listen and to lend help when needed. He was also very courageous. With great modesty, Drake said that he was too dumb to understand the huge career risk in pioneering SETI when the subject was tacitly proscribed by the community.

This, of course, cannot have been true, and he would have been well aware of the dangers. He carried through with it regardless, because he knew that it was the right thing to do.

He leaves behind three sons, Steve, Richard, and Paul, from his first marriage; his second wife, Amahl, and their two daughters, Nadia and Leila, and four grandchildren. One of his granddaughters, Grace Drake, is a budding astrophysicist who graduated this year from the University of Edinburgh. During the summer of 2021, I had the privilege of working with her on a research project that I think her grandfather would have approved of. We were looking at the energetic radiation environment of GJ9827, a K-dwarf at a distance of 97 lightyears with three known transiting planets that are prime targets for studying exoplanetary atmospheres.

The legacy Frank Drake leaves behind is immense and continues to inspire generations of scientists. In his 1961 *Physics Today* article on Project Ozma, he wrote:

> We are faced with a sound, highly important experiment that requires the use of very expensive equipment for a very long period of time. Those who feel that the goal justifies the great amount of effort required will continue to carry on this research, sustained by the possibility that sometime in the future, perhaps a hundred years from now, or perhaps next week, the search will be successful. (Drake, 1961b)

Frank Drake taught us the importance of that goal and made the search a reality.

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