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SEARCH FOR EXTRATERRESTRIAL INTELLIGENCE (SETI)

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The scientific community now considers that life, including intelligent life, is widespread in the universe. The big question we face is: To what degree are we now capable of conducting searches for that extraterrestrial life, especially intelligent life?

I would like to start with a little background. We all see the world in different ways. From about the year 200 A.D. for some 1200 years we believed that the sun and stars revolved around the Earth and the Earth was the center of everything. Then along came Copernicus (1473-1543), Tycho Brahe (1546-1601), and Galileo (1564-1642), and the great Copernican Revolution of the 1500's and 1600's when it was proved that the sun, not the Earth, is the center, and the planets revolve around the sun. We are now looking at the Earth and its relationship to the universe in yet another new way.

Our galaxy is called the Milky Way. The diameter of the galaxy is 125,000 light-years from edge to edge. In other words, if one shines a light at one edge, it will take 125,000 years to cross. There are about 400 billion stars in our own galaxy alone and an estimated 100 billion galaxies. We all know that the sun is one of the stars in our galaxy and that our galaxy is only one of billions of galaxies. How much thought have you given to the fact that there may be millions and perhaps even billions of other intelligent beings and civilizations scattered throughout these galaxies? This is the theory today.

Life is very old and the story of evolution is well known. Fifteen billion years ago there was the so-called "Big-Bang." Then the galaxies, stars, and planets were formed. All of the planets of our solar system were born at roughly the same time as our sun, which is a star. Then the process of chemical evolution began; small molecules, the building blocks of life, condensed to form polymers which turned into proteins and sugars and fats and all the other substances, including DNA, which make up life -- with the origin of life occurring some four billion years ago here in this solar system on this planet called Earth. We, of course, are the descendants of this process which began so long ago. During the two and one-half billion years of unicellular life through the

Precambrian era, the evolution of incredibly complex biochemical mechanisms continued within cells. Finally multicellular life developed, and then more recently intelligence, the great break, which is cultural evolution superimposed on biological. With this came the rise of civilizations, the appearance of science and technology and, finally, our ability to make in our heads models of this entire process to study the whole question of life in the universe. This is one of the things that makes us human and which, as far as we know, dolphins, elephants, whales and chimpanzees do not have -- the ability of humans to study life in the universe or anything else with abstract models of the type which allow us to create hypotheses to test.

Given that there are 100 billion galaxies and each galaxy has possibly 1,000 billion stars, the question is whether the occurrences described above have happened elsewhere -- are there extrasolar planets? We haven't seen any directly, but the answer seems to be yes. Over the next few years there will be announcements of increasing evidence for the existence of extrasolar planets. The current hypothesis is that the natural consequence of the birth of a star is a retinue of planets. Has the process of chemical evolution and origin of life on some planets, all the way to intelligent civilizations, taken place anywhere else in the universe? The current hypothesis is that it has. We do not know how often, but this is a natural process and, where there is another sun and another Earth far out in the galaxy or in other galaxies, the exobiology community considers it likely that life will begin. The belief is that this process has taken place countless times, is taking place today, and will take place in the future. So we believe that the universe is teeming with life, including intelligent life.

If this is the case, is there any way we can detect the existence of extraterrestrial life, including intelligent life? In 1975 and 1976, Project Viking attempted to detect microbial life on the planet Mars. While this was not successful, we know that Mars had an atmosphere and water four billion years ago, so it is still possible that microbial life might have begun on Mars at the same time that life began on Earth. When we go back to Mars we will dig up soil and look for evidence of ancient life which became extinct.

Are there other ways of detecting life? An idea first proposed by Philip Morrison in 1959 and Frank Drake in 1960 was that, if one wants to talk to other civilizations across the great distances between the stars, one should listen for radio signals they might be transmitting. Based on that idea, a plan was put together within NASA about 25 years ago to search for extraterrestrial intelligence. This plan was called the Search for

Extraterrestrial Intelligence (SETI). The plan was to see if one could detect radio signals emanating from transmitters of other civilizations in the galaxy and even the universe. That plan developed and evolved over the last 25 years and is now in being. The NASA version of SETI is called the High Resolution Microwave Survey (HRMS).

Twenty years ago we had to determine whether listening for radio signals from other civilizations was the right approach. We looked at many other approaches, including the possibility of detecting particles or gravity waves or neutrinos or spacecraft. We also investigated the possibility of interstellar travel. However, the distances involved are immense. The star nearest to us is 4.3 light-years away, which means that light traveling at 186,000 miles per second takes 4.3 years to get to us from the nearest star. We determined that the closest stars in significant numbers are at least ten light-years away. We calculated that with our current technology and traveling at the speed of an Apollo-type spacecraft, it would take such a spacecraft 40,000 years to get to the nearest group of stars. In the future, if we were to consider space travel using matter and antimatter annihilation, the spacecraft would scorch the Earth with gamma rays during launch and would present other major engineering problems. But if we could consider using such a launch, the enormous propulsion system would be accelerating all the way, going up to 3/10th of the speed of light; the spacecraft would then turn around and decelerate to the target star system. If it is estimated to take 200-300 years to reach another civilization, the amount of energy required for one round trip is estimated to be equivalent to about five hundred thousand years of total Earth energy consumption. This was discouraging, so we turned to Morrison's suggestion and Drake's early searches and developed the NASA SETI plan. NASA has a mandate for the exploration of space and was ideally suited for this. NASA-Ames already had an Exobiology group with a nucleus of people studying extraterrestrial life.

Twenty-five years ago we first considered where we should look in the spectrum, because the frequencies of extraterrestrial radio signals are unknown. We determined the spectrum to look at was between one and ten gigahertz (GHz). In all of the noise, including synchrotron radiation from the galaxy, the remains of the Big Bang, quantum noise, interference from the Earth's atmosphere, there was a window and at the bottom of the window was a trough which was quiet. It makes sense that if one hopes to pick up a faint whisper from far away, one should listen in the quiet region of the spectrum. This region is called the microwave window. SETI listens on frequencies between 1 and

10 gigahertz for radio signals of extraterrestrial intelligent origin, and is doing so even as we speak.

The NASA version of SETI, called the High Resolution Microwave Survey (HRMS), is a joint program of two NASA Centers; NASA-Ames and the Jet Propulsion Laboratory (JPL), and has a dual-mode search strategy. In the Targeted Search mode, the beam of the telescope is pointed at suitable target stars. The beam is held on the target star and integrated. We look at nearby stars that are like our sun because we know there is life on a planet (Earth) that is going around the star called the sun. Perhaps there is life on planets going around other stars that are like our sun; the F, G, and K type stars. We look for signals between 1 and 3 gigahertz in the microwave window and with high resolution and sensitivity. The HRMS system is sensitive to a wide variety of steady pulsed signals. We assume that all signals are narrow-band, perhaps 1 Hz wide, and likely to be drifting in frequency. It is more efficient to look for lighthouse-type signals and drifting signals that are always on, which is called continuous wave, and drifting because of Doppler drift due to the rotation of the planet on which the transmitter sits.

The Sky Survey mode looks at the whole sky because if we spent ten years looking at single stars, most of the sky would not have been examined at all. Supposing that very far away there is a very powerful signal; with the Targeted Search we would have missed it. The Sky Survey search strategy is to take another group of radiotelescopes and move the beams of the telescopes very slowly across the sky, backwards and forwards. When it reaches the end of a traverse, the beam is moved 1/2 beam width and brought all the way back. In this way the entire sky is covered. This takes three years in the northern hemisphere and three years in the southern hemisphere. These are two major complementary searches. The Targeted Search is being done at Ames, and the Sky Survey is being carried out at JPL.

SETI uses big radiotelescopes located all over the world. These telescopes are used primarily for communicating with our spacecraft out in the solar system on interplanetary missions. They will also be used for SETI. The largest radiotelescope, employing a 305 meter dish, is at Arecibo in Puerto Rico (Exhibit 1). The large radiotelescope at Parkes in Australia is 70 meters in diameter. Goldstone in California's Mojave Desert is part of NASA's Deep Space Network, run by JPL, and uses a 34 meter antenna (Exhibit 2).

Exhibit 1. Aerial View of the World's Largest (305 M) Radio Telescope at Arecibo, Puerto Rico

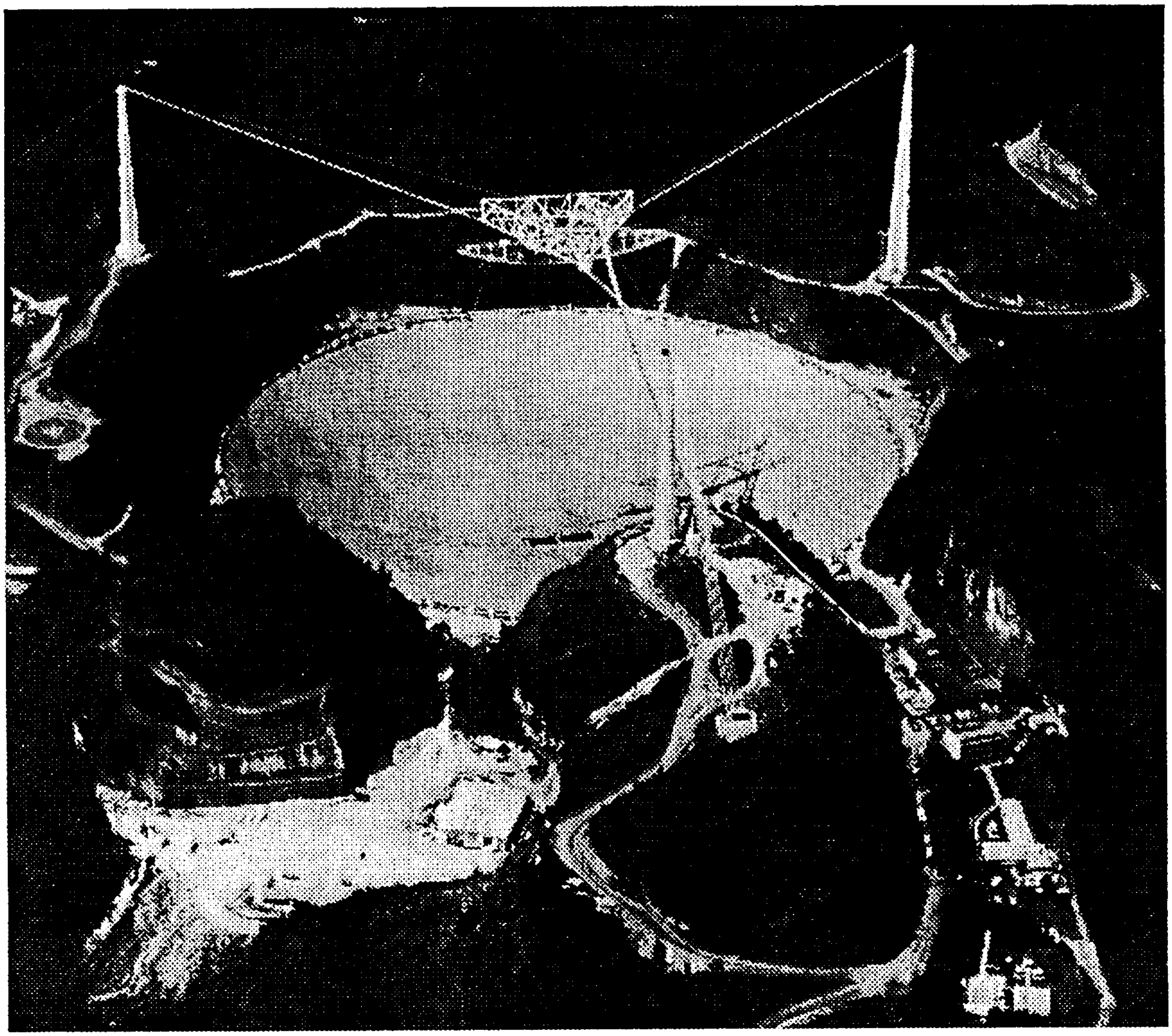
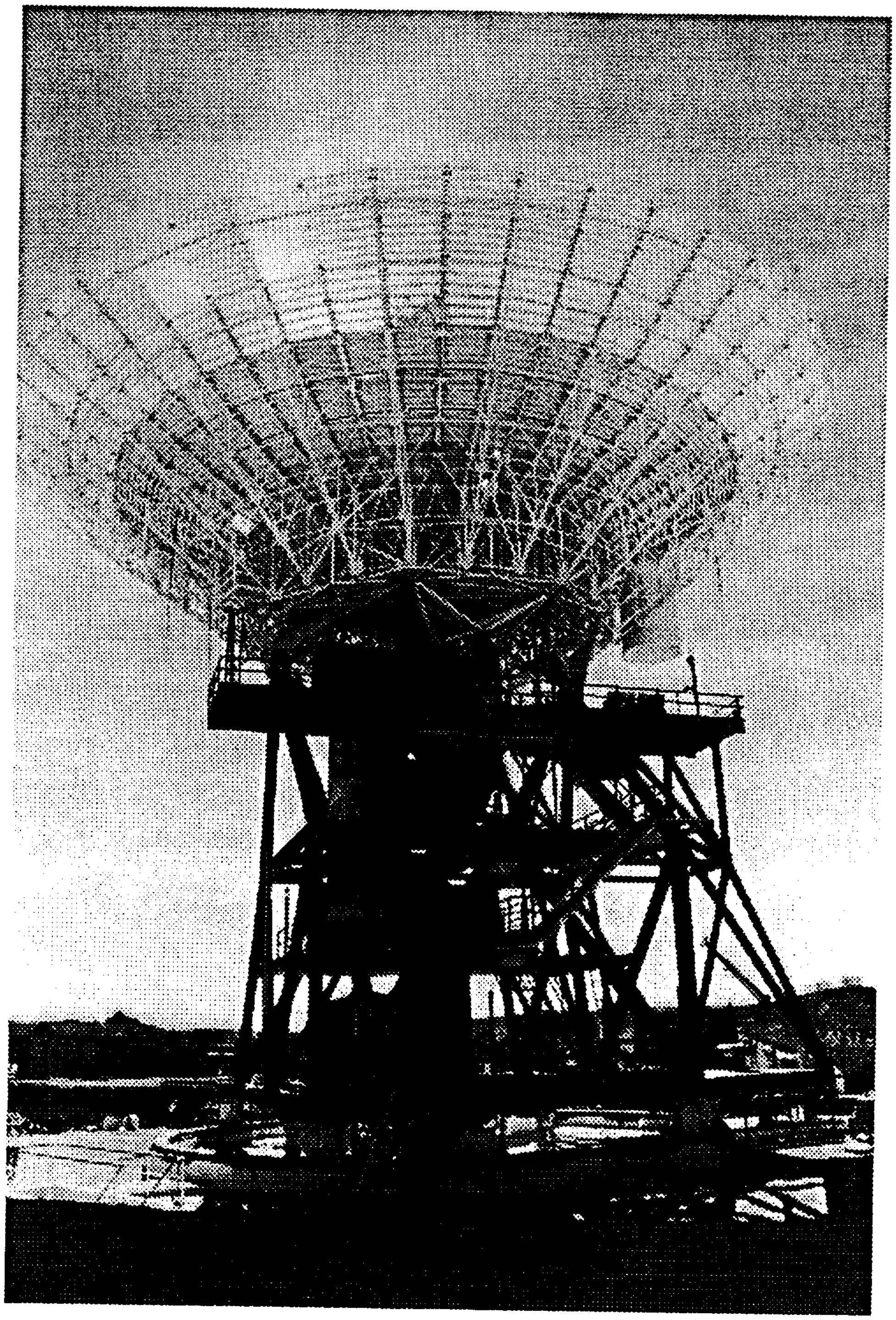
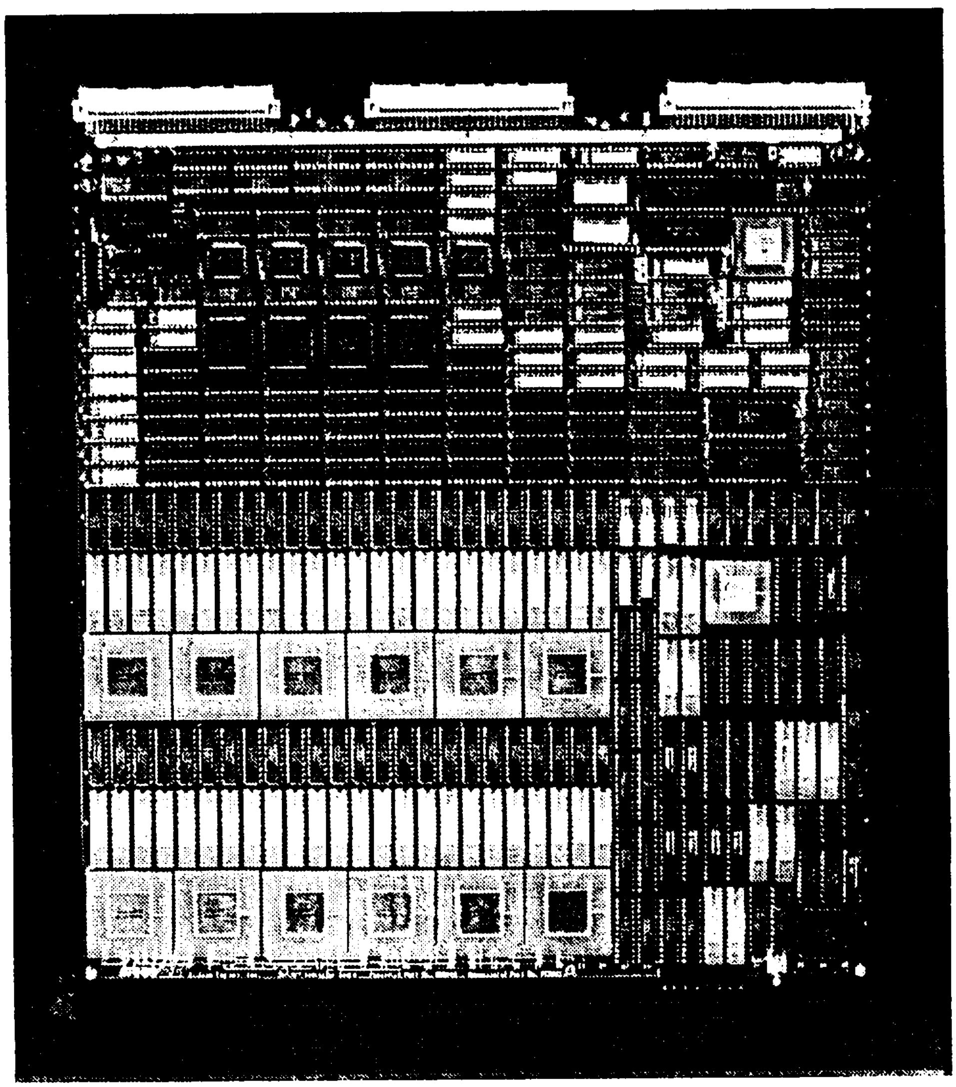


Exhibit 2. The High Efficiency Antenna at Goldstone, California, Operated for NASA by the Jet Propulsion Laboratory. The Antenna, 34 Meters in Diameter, Uses a Unique "Beam Waveguide" Design that Transfers and Focuses Radio Signals Into Ultra-Low-Noise Receivers.



The data stream is far too immense and difficult for humans to analyze, so we have an automated SETI system. This system includes the telescope where the signals are received and reflected back to a secondary focus, then into the telescope, and then into the SETI machine through the observatory computer. The radio frequency input goes to a receiver, is split into right circular polarization and left circular polarization, and then to two multichannel spectrum analyzers (Exhibit 3).

Exhibit 3. Discrete Fourier Transform PC Board Used in the Multi-Channel Spectrum Analyzer. This Board Contains 12 Custom VLSI Digital Signal Processing Chips for Computing Fast Fourier Transforms.



The multichannel spectrum analyzer splits the spectrum into 14 million individual channels which we listen to all at once because we do not know where the signal is in the microwave window. The signal then goes to a pattern detection machine which tries to determine if there is any significant artifact in the stream of analyzed data; in other words, a real extraterrestrial signal. This is all controlled by a computer; a control subsystem which links everything together and makes it work.

The analyzed signals go into the signal detection subsystem, which looks for patterns. The continuous wave stream goes through a data buffer and path sieve. Anything that survives the sieve is significantly different from the background noise and goes to the signal detection control subsystem as a candidate extraterrestrial intelligence signal.

If a signal looks promising, it goes through a yes/no logic tree to see how real it is. We are constantly bothered by interference because we on Earth generate a colossal number of signals. The problem is to separate all of our own signals from a real ETI signal. This is the purpose of the logic tree. If a signal passes all of the automatic tests, a scientist conducts more tests, the most important of which is to contact another observatory 3,000 miles away for verification. The scientist explains that we have a candidate ETI signal and gives the sky coordinates, sensitivity, polarization and drift. If the second observatory can verify, then the evidence is very good that this is a real signal.

We have made progress on SETI but much remains to be done. Significant advances have been made in our computerization. For example, in the early years we had large circuit boards, but we designed our own chip, the HRMS chip, which makes the system more portable. The HRMS system now can be built to fit in a trailer and taken anywhere.

So far, $50 million has been spent on the SETI system. The 10-year HRMS Project will probably cost another $130 million until completed at the beginning of the year 2003.

One of the most difficult things about this project is that so far we have not been able to verify any signals as extraterrestrial, and we do not know when we might have an authentic signal. It is possible that we may not detect a signal within the next ten years. Perhaps our systems are not sensitive enough. But the next phase of SETI in the next century will have bigger and better machines. It would also be better if we could operate the system from space rather than Earth because the Earth is a source of heavy radio frequency interference. If we built a new telescope which would float free in space, the signals could be reflected to receivers on station-keeping spacecraft. The signals would go to the relay satellite and back to Earth for interpretation. The dish could be large and could be shielded from radio frequency interference from the Earth.

Another interesting possibility for the future is to utilize the far side of the moon. The far side of the moon is always quiet. The moon is locked in tidal rotation with the Earth, so it always faces away, and of course the bulk of the moon shields the far side from all radio frequency interference from Earth. Thus, it would be a very good place to place microwave or radio observatories.

As we continue the development of the SETI Program, both through the incorporation of more advanced technologies and possible use of more suitable receiving sites, our chances for success will improve. Whether we will identify signals from life elsewhere in the universe remains to be seen. However, we will have made a sincere and scientifically valid attempt to determine if such signals do in fact exist.