North American AstroPhysical Observatory

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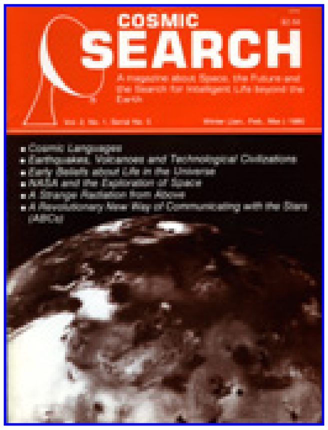

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The SEnTInel

By: Robert S. Dixon

Highlights of the Conference on Life in the Universe

On June 19-20 of this year, the largest SETI conference to date was held at the NASA Ames Research Center near Mountain View, California (the complete program appeared in the Fall 1979 issue of **COSMIC SEARCH**). The many expert speakers wove a fascinating and richly eventful tapestry of cosmic evolution, each one presenting a chapter in the thread of events beginning with the primordial big bang and leading up to intelligence.

NASA-Ames Research Center, Moffett Field, California. The "Life in the Universe" conference was held in the main auditorium, located in the building inside the circle in the foreground.

Cosmic History in a Nutshell

Eric Chaisson of Harvard University began the conference by compressing 18 billion years of cosmic history into a 30-minute overview, tantalizing his audience with a number of insights and observations. The 3 degree background radiation is the oldest fossil. We will never see the birth of a galaxy because they stopped forming 10 billion years ago. Stars are still being born in spiral galaxies like ours, but in elliptical and other kinds of galaxies the maternity ward has been dismantled; no new stars will ever be born. Cosmic evolution has followed the sequence

Galactic→Stellar→Elemental→Chemical→Biological→Cultural

in which complexity arises from simplicity at each step. Man has created proteinoids in the laboratory that behave like simple cells; they have walls and permeable membranes, grow, bud and link together into chains. No known process exists to combine simple substances and create the large organic molecules found by radio astronomers in space; perhaps these molecules are but fragments of an all-pervasive super-molecule that lives in space. In the beginning the universe was dominated by radiation; eventually the radiation gave way to matter; matter will eventually give way to life. Thus, the entire history and future of the universe can be summarized by the sequence

Radiation Era→Matter Era→Life Era

Man and his neighbors will ultimately restructure the universe to suit their own ends, and thereby achieve immortality.

The Role of Carbon

Sherwood Chang of NASA-Ames pointed out that Earth actually has very little of the elements that are most abundant in the universe and are necessary for life—hydrogen, helium and carbon. Half the mass of our galaxy is contained in the invisible clouds of matter between the stars and these same clouds contain large organic molecules. Comets contain organic molecules, have nuclei from 1 to 10 km in diameter, and give up about 0.1 percent of their mass to the inner solar system on each close approach to the sun. Meteorites have a total carbon content of 21/2 percent. These are all examples of how organic molecules could have arrived on Earth from elsewhere. Chang summarized the prospects for life in the solar system by noting that organic molecules may be responsible for the colors in Jupiter's atmosphere, that Venus is too hot for organic chemistry, and that Mars may be promising for remnants of past life.

Importance of Sulfur

Benton Clark of the Martin Marietta Aerospace Co., Denver, Colorado, described how sulfur-based life can exist without energy from any nearby star. For example, there are sulfur-based microscopic organisms that exist on Earth in the vicinity of natural steam vents, which ignore the sun and take all their energy from the hot steam. Sulfur is required by *all* life forms, and is known to exist on the Sun, Venus, Earth, Mars and Io. Many of the large organic molecules observed in space contain sulfur. Clark suggests that sulfur-based life may exist in areas where heat is generated from non-stellar causes, such as from tidal effects on a satellite like Io.

Geologic Evolution

Karl Turekian of Yale University discussed the evolution of continents and oceans on the Earth, pointing out that among all the planets of our solar system only the Earth has all three phases of matter (gas, liquid, and solid) present at its surface. All continents would erode out to sea in a geologically short time, if continuous upwelling of new rock from below did not keep replenishing them.

Climatic Evolution

Donald Hunten of the University of Arizona summarized our understanding of planetary climate evolution by saying that "the various causes are only beginning to be disentangled." These causes include the varying heat output of the sun, changes in the orbit and tilt of the planet, and formation of ice, water and clouds on the planet. It is known that long ago rain fell on Mars for a very long time, gradually carving out the well-formed system of rivers and tributaries that are now dry. There is also evidence of sudden water flow on Mars, perhaps due to catastrophic failure of a natural dam. The heat output of the Sun changes appreciably only over time periods of about 100,000 years, so it cannot directly cause rapid climate changes.

Planetary Orbits

Robert Harrington of the U.S. Naval Observatory discussed planetary orbits that might exist in multiple star systems. He has calculated that stable planetary orbits can exist in a wide variety of circumstances. It turns out that the orientation and direction of the planetary orbit does not matter, and the only necessary criterion is that the separation ratio be greater than 4. This means, for example, that a planet could exist in a double star system in one of two ways. The planet could orbit both stars at a distance greater than 4 times the spacing of the two stars, or it could orbit one of the stars at a distance less than one-quarter the spacing of the stars. In either case, the planet could be in a reasonable temperature zone. A more fundamental question which remains to be answered is—would the planets ever form at all in such a system? This question is more difficult to answer since we do not yet understand completely how planets and multiple star systems are formed.

Our Dependence on Microorganisms

Lynn Margulis of Boston University gave a very lively presentation of the profound interrelationships and interdependence between life forms and the planetary environment. Microorganisms are the unsung heroes of environmental evolution. They are responsible for converting Earth's original atmosphere of ammonia and methane to the current nitrogen and oxygen composition, and for replenishing the oxygen and other gases that leak off into space. Microbes caused concentrations of minerals like gold and iron in the Earth's crust, as well as organic deposits like coal and oil. All the animals and plants (including man) taken together have less influence on Earth than do the microbes. Ten percent of human body weight is essentially micro-organisms. We are not really individuals, but rather live in symbiosis with our internal microbes.

Life Zones around Stars

Stephen Schneider of the National Center for Atmospheric Research in Boulder, Colorado, pointed out the uncertainties of predicting likely life zones around stars from climate models. Atmospheric response to changes in external effects such as solar heat is so complicated that predictions cannot be made with any certainty. For example, if the sun's output were to increase, there would be greater evaporation of water from the oceans, which would cause more clouds, which would reflect more sunlight, which would reduce the temperature increase of the earth. This and other feedback effects may tend to stabilize or even reverse the effects of external influences. He mentioned that the predictions of Michael Hart are thus subject to considerable inherent uncertainty.

Detecting Planets around Other Stars

David Black of NASA-Ames reviewed the current status of efforts under way to detect planets associated with stars other than the sun. The discovery of such planets would help us understand how stars and planets are formed, and provide improved estimates of the probability of other life in the universe. Classical astrometric techniques (see "Detection of Planets Near Distant Stars," on p. 26 of the Summer 1979 issue of **COSMIC SEARCH**) can measure to one ten-thousandth of an arc second, which is sufficient to detect planets around the nearest 20 to 30 stars. Speckle interferometry techniques can reach one hundred-thousandth of an arc second, or the nearest 60 stars. Specially designed space-based telescopes could reach one millionth of an arc second, bringing 1000 to 2000 stars within range. Radial velocity techniques (see "Another Search for Extrasolar Planets" on p. 38 of the Fall 1979 issue of **COSMIC SEARCH**) can measure velocities to an accuracy of 1 meter per second, enabling planets to be detected around the nearest 50 to 100 stars. The radial velocity approach has the added advantage that the Earth's atmosphere has much less of a harmful effect on the measurements. The space telescopes now planned are not designed for this problem and hence will not be as good as ground-based ones. In addition to merely showing the existence of planets, the techniques being investigated could also measure their mass, orbit, temperature and atmospheric composition. Black made a point of the fact that man has the technology to answer this question within the next decade. Unlike searching for extraterrestrial radio signals, no assumptions are necessary and "All we have to do is interrogate nature."

Evolution May Proceed at an Uneven Rate

James Valentine of the University of California at Santa Barbara presented evidence that evolution does not create new kinds of life at a uniform rate. There are certain short periods in Earth's past when many new kinds of creatures appeared very rapidly, separated by much longer periods of little evolutionary advancement. Valentine pointed out that all of the major divisions of life forms appeared rather suddenly 700 million years ago, followed by lower sub-divisions again rather suddenly again at 580 million years ago. More recently, the various mammals sprang up about 80 million years ago. He believes that this non-uniform evolution is not due to external influences (nearby supernovae, etc.) but rather is a natural process. As life becomes more and more complex, it reaches a threshold at which it can suddenly occupy a whole new class of ecological niches. New types of life then evolve very quickly to occupy all those niches. Once all the niches are filled, evolution proceeds slowly again until another threshold is reached.

The Evolution of the Brain

Dale Russell of the National Museum of Canada in Ottawa, discussed possible future evolution of the brain. The brain performs two main functions, controlling the motion of the body and planning purposeful action. The control function requires a brain weight proportional to body weight to the two-thirds power. Thus, a whale needs a larger brain than man, merely to control its body. If the control part of the brain is neglected, the remaining brain weight is proportional to the intelligence of the creature involved. Sea creatures are in general not as intelligent as land creatures; the most intelligent sea animals are those that were originally birds and land animals that returned to the sea (such as dolphins). Animals with passive defense systems such as horns, armor or poison are generally less intelligent than others. The human brain requires 20 percent of the total energy intake of the body for support. Reptiles cannot spare such a large fraction of their energy intake, and hence cannot develop a larger brain. Future human brain weight could increase by a factor of 6.5, before being limited by the ability of the human body to supply sufficient energy. This would require a shorter pregnancy period, to allow the larger head to pass through the birth canal. Russell ended by cautioning his audience that Life is much more common than Intelligence.

The Use of Tools by Animals

Bernard Campbell of the Leakey Foundation in Pasadena, California, gave a number of examples where animals have learned to use and improve mechanical tools, implying that Man is not unique in having technological potential even though only Man has made technology the major part of his recent development. Birds use twigs to prod insects out of holes in trees, and modify notches to hold pine cones securely while they peck at them. Some insects use tiny stones to hammer down the tops of their egg burrows. Otters use stones to smash abalone shells. Chimpanzees sharpen sticks with their teeth to use as prods, and crunch up leaves to use as a sponge for washing their bodies. Tool manufacture is, however, the sole province of Man. Early man made sharp cutting edges because the skin of prey animals was over an inch thick and otherwise impenetrable. Fire allowed man to live in colder climates, and to compete with bears in occupying cave dwellings. Campbell noted that since technology has eliminated Man's natural enemies, there may be no need for his brain to grow any larger.

Cosmic Catastrophies and Threats to Life

Wallace Tucker of Harvard-Smithsonian and the U.S. International University in Bonsall, California, discussed the other end of the evolutionary trail — how life is ended. Despite all the problems that have befallen life on Earth, it is still abundant. The vast interstellar distances protect us from astrophysical crises, but also imprison us. The red giant phase of a star would wipe out all life on its inner planets (such as Earth), but would not affect any other nearby planetary systems. Even in binary star systems, the red giant phase of one star might not affect the planets of the other star. A quasar at the center of our galaxy would not hurt us. Supernovas could, however, be dangerous if they were nearby. If one were 30 light-years away, its exploded shell would reach us in about 1000 years, and would spend several thousand years in passing us. During those millenia, cosmic radiation would be a factor of 1000 greater than it is now. This would not kill all life forms outright, but would make life very difficult. Ninety percent of the ozone layer would be depleted, allowing the sun's ultraviolet light intensity reaching the Earth's surface to increase by a factor of 10. Nitrogen dioxide would become an important constituent of the atmosphere, causing world-wide cooling and drought. A supernova significantly closer than 30 light years would extinguish all life. Gigantic explosions are believed to occur in the centers of galaxies about every 500 million years. An example of a currently observable exploding galaxy is Centaurus A. These explosions extinguish all life within 1000 light years of the galactic center, but would not harm us since most of the explosion takes place perpendicular to the plane of the galaxy. Tucker gave his audience and our planet some sage advice by warning them to "stay away from hot young heavenly bodies."

We Need to Know More About Our Stellar Neighborhood

Kenneth Janes of Boston University criticized the current state of Man's knowledge of our stellar neighborhood. There are about 250,000 stars brighter than 14th magnitude within 300 light-years of the sun, but we have only identified and cataloged 15,000 of them. These catalogs were prepared in the early part of this century, using very laborious manual procedures. Since then, astronomers have not been willing to spend the time and effort necessary to make the catalogs more complete. In this era of computers and automation, astronomical catalogs seem to have been left behind. Janes described ways in which this situation might be remedied. Technology is available to use Charge-Coupled Devices (CCDs) to directly record the output of a telescope, avoiding photographic film completely. This would be analogous to a super-sensitive television camera. The electronic sky picture could then be examined by a computer to find all the stars and classify them as to spectral type. He estimates that such a system could measure star positions to one hundredth of an arc second and catalog 15 million stars in a 10 year period of operation. From all these, about 90,000 stars closer than 300 light years and likely to harbor life (F, G and K types) could be selected for detailed SETI studies. A large problem that remains unsolved is determining the age of a star. This would be helpful in eliminating those stars from the search that are not old enough to have formed stable planets and evolve higher life forms.

The Many Methods of Interstellar Communication

Ronald Bracewell of Stanford University provided an entertaining discussion of "exotic" methods of interstellar communication, along with their advantages and (more often) disadvantages. According to some theories you could fly into a black hole and instantaneously fly out of another one somewhere else; unfortunately the cosmic radiation intensity would be dangerous. Mental telepathy has no known distance effect or limit; thus, it must have a poor signal-to-noise ratio since all thoughts would be present in all minds, causing interference. Tachyons move fast enough (see p. 37 of Fall 1979 **COSMIC SEARCH**) but cannot interact with slower life forms. Gamma rays, cosmic rays, and x-rays have quanta so large that a great deal of energy is necessary to send very much information. Radio waves below a frequency of 1 megahertz are severely refracted in the interstellar medium, making them arrive at the receiver from an inconveniently wrong direction. Below 10 kilohertz, the interstellar medium is opaque, but if you got some good cosmic engineers to apply a magnetic field in just the right way, the signal might still get through. Gravitational waves are too hard to detect. Shock waves and Alfven waves are mixtures of magnetic and material waves. They travel slowly, and might be created by cosmic engineering projects. They would arrive here from random directions, and could be detected by looking for unusual changes in the interplanetary magnetic field out beyond Jupiter. The changes would not be detectable inside Jupiter's orbit because the sun's magnetic field and particle output would mask them. Interstellar matter transfer is possible by depositing things (like panspermia) on comets and letting them ride along. Interstellar probes (a favorite topic of Bracewell) have an advantage in that they are not restricted to making round trips in a human lifetime. They could be sent out to all stars within a 100 light year range, and could be made durable and inexpensive. Bracewell proposes a scheme requiring "equi-partitioning of effort," whereby a civilization sends out very cheap probes that are not capable of decelerating and going into orbit when they reach their target planetary system. It would be up to the target civilization to detect the presence of the probe as it flew past them.

Interstellar Travel versus Interstellar Communication

Bernard Oliver of Hewlett-Packard Co., Palo Alto, California, compared the energy required for interstellar travel to that needed for interstellar communications. The most efficient rocket that we can imagine works by combining matter with anti-matter, resulting in total annihilation of all the matter and the liberation of vast amounts of energy that could in principle be used for propulsion. If we could build such a rocket, a manned round trip to the nearest star would require as much energy as the entire United States' electrical power output for 500,000 years, or 3 trillion trillion (3×10^{24}) joules. (A joule is the energy content of a power of one watt flowing for one second). An unmanned one-way interstellar probe would require less energy, about 300 billion billion (3×10^{20}) joules. In contrast, a ten megawatt omni-directional radio beacon could operate for 10,000 years and use up only 2 billion billion (2×10^{18}) joules, and a thousand beamed transmitters of 10 kilowatts each could operate for 1,000 years and use only 3 million billion (3×10^{15}) joules. Oliver believes the most efficient way to operate an interstellar beacon is to rotate a fan beam, analogous to a lighthouse. This implies that we should search for pulsed signals.

Inadvertent or Leakage Radiation

Woodruff Sullivan of the University of Washington advocated searching for the "leakage" signals from other technical civilizations. These signals might be radar, television and other transmissions intended for the internal use of the sending civilization, but which inevitably also radiate out into space. To learn how the Earth might sound to distant listeners, he has collected data about all the Earth's transmitters and found that the most likely signals to be heard are our television broadcasts. The programs would not be detectable, but the presence of the narrowband picture transmitter carrier signal would be. The Arecibo telescope could detect Earth television out to two light-years distance, and a full-sized Cyclops array could detect Earth at 50 light-years. Our sun poses no interference problem to distant listeners, since the TV signals would be 1,000 times stronger than the natural radio signals radiated by the sun.

The NASA SETI Program

John Wolfe of NASA-Ames and **Robert Edelson** of the Jet Propulsion Laboratory outlined the NASA SETI program now in the planning stages. Existing radio telescopes at Arecibo, Puerto Rico; Green Bank, West Virginia; Ohio State University and various NASA tracking stations around the world will be equipped with the most sensitive receivers that Man can build, and with multi-million channel spectrum analyzers. High sensitivity searches will be made in the water hole frequency range, toward nearby stars, star clusters, galaxies and our own galactic plane. Lower sensitivity searches will be made over a much wider frequency range and over the entire sky. The total cost of the NASA SETI program is comparable to the production costs of the movie "Close Encounters of the Third Kind."

Some Philosophical Reflections

Phillip Morrison of the Massachusetts Institute of Technology ended the conference with some philosophical reflections. You can travel back and forth between any two points an infinite number of times, and yet never traverse exactly the same path twice. This illustrates the principle of convergent evolution, by which life eventually evolves creatures that are adapted to almost any environment, regardless of the evolutionary path taken to get there. The path may have had many branches and blind alleys, and the ultimately successful path may be very tortuous, indirect and unlikely. The point is that sooner or later some pathway will be found, so one cannot argue that Man, for example, is so unlikely that a similar creature would not evolve elsewhere in a similar environment. The sign language used by the deaf has song, poetry and expression, demonstrating that complex communications need not be vocal in any sense, and could use methods as yet unimagined. The Malthusian view that if anything (like population) is plotted as a function of time it will eventually go to infinity is true only in the short term. Unexpected and unpredictable events always occur that turn off the increase. Morrison decried those who say that since their calculations indicate the galaxy is unoccupied, we should not search. We must search, since our knowledge is so meager.

On-The-Air SETI Programs

Many people believe that radio observatories spend all their time searching for signals from other civilizations. It would be much closer to the truth to say that radio observatories never search for such signals. The actual situation is that most observatories never search at all, a few search for a tiny fraction of their time, and only one searches all the time. This can be seen from the summary of past and present on-the-air SETI programs shown in the accompanying table.

To place these programs in perspective, one must keep in mind several things. There are about 20 million stars in our galaxy that are considered good candidates for harboring life; we have searched less than a thousand of them. Signals could be on almost any frequency; we have searched only a miniscule fraction of the available frequency range. The signals could come at any time; we have searched each star for only a few minutes. Man has only scratched the surface of what he is capable of doing right now, not to mention what he could do with a concentrated effort.

On-the-Air SETI Programs*

Date	Observers	Location	Telescope Size (meters)	Frequency (MHz)	Objects Searched	Total Time
1960	Drake	West Virginia	26	1420	2 stars	2 weeks
1968–69	Troitskii, Gershtein, Starodubtsev, Rakhlin	USSR	15	927 and 1420	12 stars	½ day
1970 to Present	Troitskii, Bondar, Starodubstev	USSR	¼	600, 927 and 1863	All-sky, pulses	4½ years
1971–72	Verschuur	West Virginia	91	1420	9 stars	½ day
1972–76	Palmer, Zuckerman	West Virginia	91	1420	600 stars	3 weeks
1972 to Present	Kardashev	USSR	1/10	1337–1863	All-sky, pulses	Unknown
1973 to Present	Dixon, Ehman, Arnold, Kraus	Ohio	110	1420	All-sky	6 years
1974 to Present	Bridle, Feldman	Canada	46	22,000	500 stars	1 week
1975–76	Drake, Sagan	Puerto Rico	305	1420, 1653 and 2380	4 galaxies	4 days
1975–79	Israel, DeRuiter	Netherlands	100	1415	250 stars	2 weeks
1976 to Present	Bowyer, Welch, Tarter	California	26	1420 and 1670	All-sky	3 months
1976	Clark, Black, Cuzzi, Tarter	West Virginia	43	8500	4 stars	⅓ day
1977	Black, Clark, Cuzzi, Tarter	West Virginia	91	1666	200 stars	4 days
1977	Drake, Stull	Puerto Rico	305	1666	6 stars	½ day
1977 to Present	Wielebinski, Sieradakis	Germany	100	1666	6 stars, pulses	2 hours
1978	Horowitz	Puerto Rico	305	1420	185 Stars	3 days
1978	Cohen, Malkan	Puerto Rico, Massachusetts, Australia	305 36 63	1666 22,000 1612	25 star Clusters	3 days

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1978	Cohen, Malkan	Puerto Rico, Massachusetts, Australia	305 36 63	1666 22,000 1612	25 star Clusters	3 days

*Based on information provided by Dr. Jill Tarter of NASA-Ames

HOME

Designed by Jerry Ehman.
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