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Bio-Cosmology: A New NASA Thrust*

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It is suggested herein that NASA should undertake a broad program of research to elucidate the origin of life in the universe, to assess its possible diversity and plenitude, and to seek evidence of such life including a search for extraterrestrial intelligent life (SETI). A short description of a rational SETI program is given. It is argued that such a program should concentrate on a targetted search, broadened to include an all sky survey only after a large scale high sensitivity system is available.

Today, the universe is believed to be about 15 billion years old. At birth, it was an enormous fireball of elementary particles and hard radiation that either flashed into existence for unknown (and perhaps unknowable) reasons, or else it represents the crushed remains of an earlier universe recycling itself. The fireball rapidly expanded and cooled into hydrogen, a little helium and a fading blaze of light. At 10 million years of age the gases had begun to clump into vast clouds that ultimately were to become galaxies, billions of them, each with hundreds of billions of stars, but as yet there were no stars and "darkness was everywhere on the face of the deep".

Then came the first massive stars and again there was light, not a uniform blaze now, but quadrillions of pinpoints arranged in gigantic pinwheels throughout space — a universe superficially much like the one we see today, but in reality very different. This early universe was composed only of hydrogen and helium. It could have no rocky planets on which life could evolve for it did not contain any of the heavier elements needed for rocks and for living things.

These heavy elements were manufactured in the cores of long-dead massive stars whose explosive deaths then hurled them back into space. The calcium in our bones, the carbon in our tissues, the iron in our blood, and the oxygen we breathe were all made by stars that blazed unseen in the early universe. We are indeed little bits of stardust. So is the earth itself, so indeed are countless quadrillions of rocky planets that circle later generations of stars—stars formed, along with their planets, from the interstellar gas enriched with dust from the earliest exploding stars. Earth-like planets are now thought to accrete out of stardust alone; nickel-iron meteorites, stony meteorites, and carbonaceous chondrites: tarry clumps of sand that may account for petroleum. The hydrogen and helium, so common on the outer giant

planets was probably swept away near the young sun leaving only small rocky planets devoid of atmospheres. The atmospheres of Venus, Earth, and Mars are the result of gases poured out of volcanoes: steam, carbon dioxide, methane, ammonia, and many others.

When a mixture of gases like those in the primitive atmosphere is exposed to sunlight the chemicals needed to produce DNA and organic matter are formed in great quantities. On earth we think these rained down into the early seas to make a "chicken soup" in which life began, and began quickly. Over the early aeons the blue-green algae kept extracting the carbon-dioxide from the atmosphere as fast as the volcanoes poured it forth, converted it to organic matter and freed oxygen. When enough oxygen had accumulated, animal life appeared.

On Venus, the temperature was too high for seas to form, life did not start, the carbon-dioxide accumulated into a crushing atmosphere that now suffocates the planet. The hundred fold heavier atmosphere of Venus is a blanket that lets sunlight in, but won't let the planet's radiation out. Venus is hot enough to melt lead. If it hadn't been for life—for all those blue-green algae—earth would be like Venus. We owe our blue skies and green hills to a living fossil that stubbornly refuses to be killed in our swimming pools.

The Miracle

But wait! How can we accept all this so calmly? Isn't science describing a miracle to us? If you were to witness the fireball of creation, would you ever believe that in only 15 billion short years, through the wonderful laws of physics and chemistry, some of the matter of that fiery chaos would have evolved itself into apple blossoms, into birds and eyes, and into minds? In 15 billion years, a small part of the universe now contemplates the whole of it. Man is always seeking the miraculous. What greater miracle could there be than the one spread before us?

But there is more to this miracle. We know of nothing unique about earth that might have restricted life to this planet. Indeed, we believe that there may be as many as 10 billion "good" earths circling "good" suns in our Galaxy. And there are billions of galaxies. If so, then intelligent life is a common phenomenon in the universe.

Advanced cultures probably besprinkle the Galaxy, but even if there are millions of them they will be so far from one another on the average that, with rare exceptions, none can afford to cross the gulfs of space to visit their nearest neighbors, even if they knew where those neighbors live. Decades of science fiction have beguiled the popular mind into accepting interstellar travel as a future reality for us, and a present reality for other races. Yet the hard facts are that, even with no technological limitations, interstellar flight is so costly in time, or energy, or both, as to be economically impossible, except *in extremis*.

Are these advanced cultures forever to exist in isolation? We think not, for *we already have the technology* with which to detect them and ultimately to communicate with them. Existing radio telescopes, if pointed in the right direction and tuned to the right frequency, could detect their counterparts clear across the Galaxy. Could, but never will, unless a rational search strategy is established and adhered to for an extended period of time. Such a program is SETI—The Search for Extra-Terrestrial Intelligence.

Bio-Cosmology

But SETI is only part of a broader program, which I am calling *bio-cosmology*. This encompasses all research aimed at explaining the origin of life, of predicting the frequency and location of highly evolved life, and of searching for that life by the most promising method or methods. Bio-cosmology could include something as apparently unrelated as searching for petroleum or methane in deep pre-organic formations for, if Thomas Gold is right and the earth is full of primodial hydrocarbons, it would mean that petroleum is not the result of some special geologic era on earth and that other habitable planets would have oil for their beginning technologies. It would incidentally mean that we have much more than we presently think.

From time-to-time, as new discoveries are made, new topics may appear as desirable additions to a bio-cosmology program while others may drop out. For the present, I would recommend that the program comprise the following subjects:

1. Extra-solar planetary detection.

Theory today suggests that planetary systems should accompany most stars. We

think they do, but we do not know. If we could determine the frequency of planetary systems and in particular, of earth-like planets, we would be more confident of our estimates of the number of advanced cultures that now exist. If we discovered that only certain classes of stars had suitable planetary systems, it would reduce the number of target stars to be searched.

Attempts have been made over many decades to infer the existence of planets around nearby stars from apparent wobble in their position, as the planet swings its heavier partner around their common center of gravity. It now appears that these observations are too full of instrumental errors to be significant.

Ames Research Center has conducted two workshops and one summer study on planetary detection and has concluded that more powerful approaches can be brought to bear. Two, in particular, require special instruments in space and would be excellent shuttle missions.

One scheme proposes to spin an infra-red interferometer around the line of sight to a star, causing any planet, in effect, to appear to orbit at high speed. As the planet passes in and out of the fringes of the interferometer, a modulation in the output signal will occur. Because the brightness of the planet compared with the star is much higher in the infra-red, the modulation should be detectable.

The other scheme involves a telescope so constructed that the light of the star image does not diffract and scatter into a disc large enough to drown the planet. The planet would then be visible as a very faint object. Three exposures taken over a period of 1/4 to 1/2 of its year would show it to be a planet in orbit and not a background star.

One advantage of direct imaging is that one might just possibly be able to do colorimetry on the planet and star. Only planets with oceans would be expected to be bluer than their star, only planets with chlorophyll or its equivalent would be expected to be greener. Thus it *could* happen that the first extraterrestrial life would be detected in an extra-solar planetary search program. Not intelligent life perhaps, but self-replicating organisms abundant enough to paint the planet as blue green algae once did here, as grass and trees do now. I recommend strong support of the Ames planetary detection program.

We probably will never be able to observe planets around any but the nearest 100 or 200 stars. We may be able to detect only giant planets. Good statistics on the frequency of good earths may have to come from theory rather than observation. Theoretical studies such as those of Cameron and others deserve continued support.

2. Studies of the Origin of Life.

The chemical precursors of life, the amino-acids, polypeptides, etc., can be formed in a variety of ways, some of them are even detected in interstellar space. But the bridge, or bridges, by which these precursors become DNA and by which DNA developed into the living cell, have not been discovered. We think the process occurred very rapidly on earth, perhaps in no more than a century, but our beliefs would be more convincing if we could demonstrate a likely route or even let life form again by the same route. *Then* we could say with confidence: see, it *will* happen everywhere! Archeo-biochemistry should be given further support.

3. Evolution of Intelligence

Intelligence is thought to have survival value and therefore to be favored in natural selection. The sentient organism withdraws from danger, the insensate organism does not, the intelligent animal uses better strategies to seek food, avoid danger and protect its young than the stupid animal. But are those factors sufficient to produce social beings with high probability, or are we rare exceptions? If they had not been mysteriously extinquished, would the dinosaurs have evolved into intelligent social species, or do only mammals do this? A number of unanswered questions make our estimates of the frequency of intelligent life uncertain. If sensible programs attacking those questions can be defined, they deserve support.

4. The Search for Extra-Terrestrial Intelligence (SETI)

It might be argued that SETI should be delayed until we find answers to all of the uncertainties in our estimates of the amount of extra-terrestrial intelligent life. Won't our technology continue to improve and make the job easier? Won't some totally new form of communication be discovered that would obsolete present ideas? The answer is no; we should begin now.

No matter how much study we give the problem, certain questions will remain and

the search will still be a gamble. We will probably never know the average longevity of advanced civilizations, for example, and the number around us depends directly on this factor. We can say that those who do search successfully probably increase their longevity enormously.

Our technology will improve, but not significantly. Our receivers are almost as sensitive as theory allows. Our data processing technology will improve a great deal, but it is already adequate and a small part of the cost. But most important, any improved technology will be useless if we delay too long. The microwave spectrum, where we must search, is filling up with interference. If we do not get busy and stake out certain appropriate bands for SETI (and search these and others while we can) we may forever close our only window on other life, dooming the human race to galactic isolation.

It is very *un*likely that any new and superior form of communication will be discovered, but one cannot guarantee this. However, it is irrational not to use existing means just because some day superior means *may* be found. This way one can forever rationalize doing nothing. Columbus did not wait for jet aircraft to be developed.

A Rational SETI Program

Since the central theme of this meeting is SETI in particular, and not so much the other aspects of bio-cosmology, let me describe at this point what I believe to be a rational SETI program. It is the culmination of two decades of thought on the subject by interested scientists and engineers.

First of all, to signal across the gulfs of space, something—some physical particle or form of energy—must be sent and received. Of all the various candidates for this task electromagnetic waves, which cover the wide spectrum from radio through light to x-rays turn out to be the best. And, out of all this wide spectrum, the portion known as the microwave region requires the least signalling energy. At lower frequencies, the Galaxy gets very noisy and more power is needed to override this noise. At higher frequencies, the noise increases because the signal itself gets "lumpy". Each photon has more energy so more power is required to receive a given number per second. In the microwave region both of these sources of noise become less than the cosmic radiation of the "big bang".

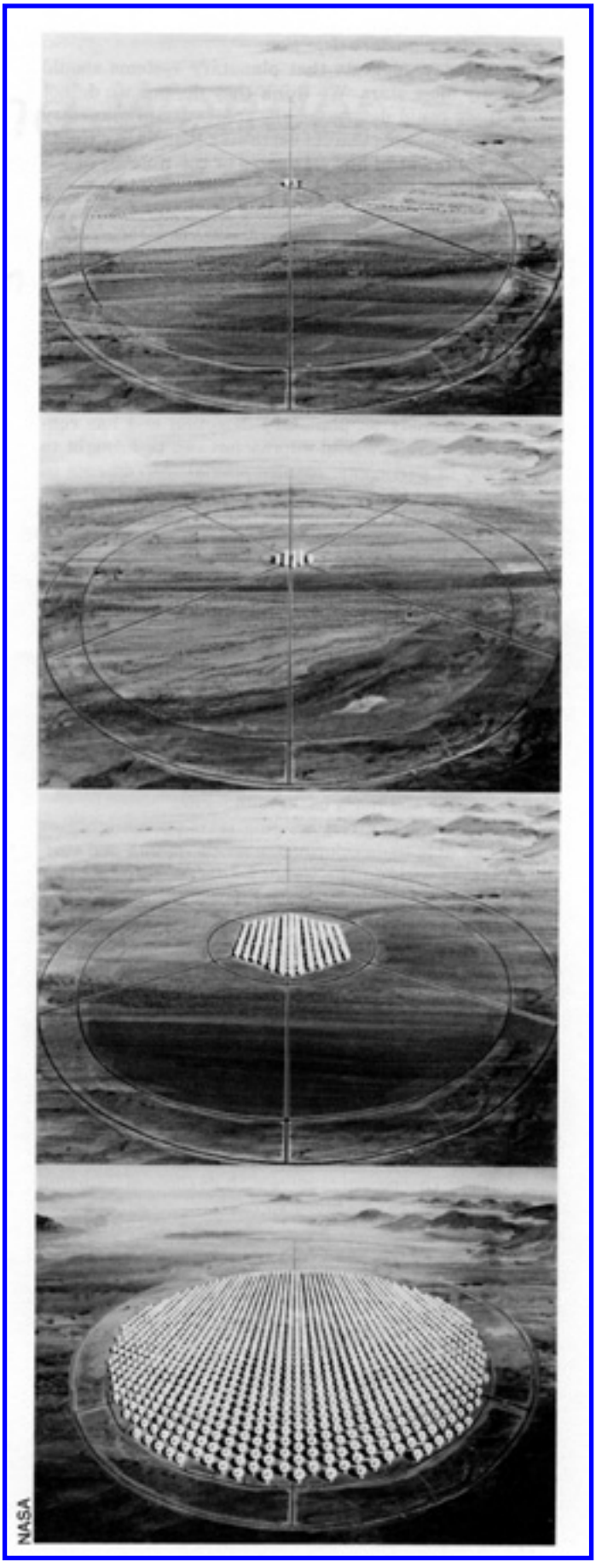
The more of the spectrum and the greater the number of directions we have to search in a given time, the less time we can spend on a given frequency channel and given direction. The signal must therefore have more power to deliver enough energy in this shorter time, which says our receiving sensitivity is less. The conventional wisdom of SETI is therefore to find ways of reducing the amount of spectrum to be searched and the number of directions in which we must look.

In the microwave region, certain cardinal frequencies have been identified. Cocconi and Morrison in 1959 pointed out that the hydrogen line at 1420 MHz was a naturally marked frequency in the best part of the spectrum. The Cyclops team in 1971 extended this concept, by observing that the hydrogen and hydroxyl lines define, between them, a relatively narrow frequency band in the best part of the spectrum. Because H and OH together form water and because water is a symbol of life, the team dubbed this band the "water hole" and suggested that this might be where different Galactic intelligent species meet. A rational SETI program would search this band thoroughly, *but not exclusively*.

It is hard to conceive of intelligent life evolving and existing anywhere except in the vicinity of certain middle class stars: isolated main sequence, F, G, and K stars, not too different from our own sun. A rational SETI program would concentrate its search in the direction of such stars, beginning with the closest and proceeding to greater and greater distances from the sun as the receiving sensitivity was increased.

"A rational SETI program begins with a single antenna and grows by stages only if necessary. This is the Cyclops concept."

The Cyclops study (1971) showed that it was technologically feasible, if it became necessary, to construct phased antenna arrays having collecting areas equivalent to a single antenna kilometers in diameter. Because we made artists renderings of such an array and showed these pictures widely, this huge array costing tens of billions of dollars, has become synonymous with SETI in people's minds. They think an antenna array of this size is needed to ensure success. This may be true, but it is also possible that SETI could succeed with only one antenna. If we must depend upon overhearing leakage signals —eavesdropping on signals not intended for us—and doing so out to 100 light years we'd need the full array. But suppose within that range another civilization has built a huge array of 2000 antennas. Having detected no signals during their initial search, they now use the array half of the time to beam signals at the 2000 good suns within 100 light years of them. Our sun would be one of those stars and half of the time a signal would fall on earth strong enough to hear with one antenna. Thus a rational SETI program begins with a single antenna and grows by stages only if necessary. This is the Cyclops concept.



As soon as the SETI array exceeded four 100 meter antennas, it would be the most powerful radio telescope on earth. A rational SETI program would share this facility with radio-astronomy some appropriate fraction of the time. Quite probably

the array would repay its debt to society on the basis of its radiondash;and radar–astronomy discoveries alone.

At the outset, with only a single antenna the sensitivity is low, even for a targeted search. Nevertheless, certain kinds of beamed signals would be detectable, as we said. For an all-sky survey covering about one-eighth of the microwave spectrum in the same time using one antenna, the sensitivity would be about one ten-thousandth as great. The sky survey is intended to receive signals from beyond 100 light years since anything closer would be picked up in the initial targeted search. But to be picked up on the all sky survey, a transmitter at 100 light years would have to beam 100 million watts at us with a 100 meter antenna. To do this for all the stars within 100 1ight years of them would take 200 billion watts, or roughly the electrical power consumption of the U.S. Beyond 300 1ight years, there would be so many stars to beam signals at that they'd give up beaming and radiate in all directions. The sky survey would then find them only if they radiated into space as microwaves the power of a *million* nuclear power stations. Thus it is difficult to imagine sources powerful enough to be discovered with a small scale sky survey that are not also close enough to be discovered with a small targeted search. Only when and if a very large facility has been constructed and targeted searches of long duration out to great distances are being conducted would a sky survey *using the same antennas at the same time* be cost effective. A rational SETI program would concentrate on a targeted search, piggybacking a sky survey using the same system.

Conclusion

I recommend the above programs in bio-cosmology as a *continuing mission* for NASA. I say *continuing* because one cannot say: In five years we will find other intelligent life, or in three years we will discover how life began. The program is a mixture of research and exploration. If we knew what we will find, we would not have to embark.

This discovery of other life is not only a legitimate mission for NASA, it is an *essential* one without which popular interest and support will fade. It is probably fair to say that NASA exists because it was felt that a space program might discover other life in the solar system. We now know that won't happen; we must look deeper into space.

In my opinion, bio-cosmology would enjoy great popular support. Even unscientific motion pictures and fraudulent books regarding extraterrestrial life enjoy unprecedented popularity. Surely a soundly based, scientific program would be accepted. In fact, most laymen *assume* that a SETI program is already going on. It is high time that NASA lived up to this popular belief.

Even if this committee and your senate counterpart endorse bio-cosmology and SETI, a significant program in this area will never become a reality unless your colleagues in the *appropriations* committee are convinced of its worth. It is a futile exercise to plan for years, to win your endorsement, to win the support of the President's Science Advisor and of the OMB, only to have the House and Senate appropriations committee strike the program from the budget. Of course, the budget must be controlled. But let us do this by eliminating large programs that are failures, not by practicing infanticide. If our penury prevents us from initiating new programs we are indeed lost. You prune a tree by sawing out old dead branches and balancing its shape, not by nipping off new buds. That's the way to kill a tree!

You must help to clear these political roadblocks or NASA will never be able to embark on this exciting electronic voyage of discovery. Help us convince our "Ferdinands and Isabellas", and we may show you completely new worlds, perhaps even a federation of new worlds comprising the mainstream of life in the Galaxy.

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From 1940 to 1952 he was employed at the Bell Telephone Laboratories in television and radar development and in 1952 he joined Hewlett-Packard. Dr. Oliver is the author of numerous technical articles and holds over 50 patents in the field of electronics. He is a member of the National Academy of Engineering and the National Academy of Sciences. He has served as president of the Institute of Electrical and Electronic Engineers and is the recipient of the Institute's Lamme Medal. Oliver's SETI activities span many years

and includes being Co-Director of the NASA-Ames Project Cyclops (1971). He is a member of the Editorial Board of **COSMIC SEARCH**, contributing an editorial in the March 1979 issue on "Let's Get SETI Through Congress".

HOME

Designed by Jerry Ehman.
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